RESEARCH REPORT

Transportation Association of Canada

Management of Road Construction and Maintenance Wastes

October 1994

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La mission de l'Association des transports du Canada (ATC) est de promouvoir la sécurité, l'efficience, l'efficacité et le respect de l'environnement dans la prestation de services de transport, en vue d'appuyer les objectifs sociaux et économiques du pays. cette fin, l'ATC offre une tribune neutre pour la discussion des enjeux et des problèmes liés aux transports, sert de centre d'études techniques dans le domaine des transports routiers, encourage les activités de R-D et diffuse l'information sur le secteur des transports qu'elle-même et d'autres organismes réunissent. Le rôle du Conseil de la recherche et du développement de l'ATC est de contribuer à l'essor du secteur canadien des transports en favorisant la mise en oeuvre de projets de recherche innovateurs, efficients et efficaces ainsi que le transfert de la technologie issue de ces derniers. Le présent projet a été exécuté à la faveur du programme de recherche collaborative du Conseil, programme financé par les ministères fédéral, provinciaux et territoriaux des Transports.

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Abstract

There are concerns worldwide over the management and disposal of excess materials produced during the construction, reconstruction and maintenance of transportation facilities. These materials often find their way to land disposal, where they are wasted and lost to future use, or worse, create environmental problems.

Sometimes these materials are wastes that need to be managed according to legislated procedures. More often, they are useful products that have become excess to the needs of the current owner. These materials usually have value and can be reused or recycled by road agencies or others. Through the application of innovative approaches to reducing, reusing, or recycling these materials, cost savings and environmental protection can be achieved.

This report: outlines methods for encouraging transportation agencies to be more proactive in managing their materials in the most environmentally acceptable manner; lists some of the materials that are produced from the construction and maintenance of roads, and how these materials are currently being handled; indentifies options for reducing, reusing, or recycling excess materials; discusses these options according to the environmental impacts, cost effectivess, operational efficiency and/or changes to policies or standards that are needed.

A four-phased approach is described for managing excess materials: from assigning the necessary personnel and resources, to scanning, identifying and prioritizing specific problem areas, to team-building and preparing specific strategies, and finally to implementing the new management strategy.

The report also discusses in detail specific materials: abrasive blasting medium, asphalt concrete, catchbasin material, concrete, earth materials, wood, metals, and road sweepings.

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Executive Summary in English and French

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Résumé

Partout dans le monde, la gestion et l'élimination des matériaux excédentaires provenant des activités de construction, de reconstruction et d'entretien de l'infrastructure des transports soulèvent des préoccupations. Ces matériaux aboutissent bien souvent dans des dépotoirs où, d'emblée, ils sont considérés comme rebuts et perdent donc toute valeur de réutilisation, lorsqu'ils n'engendrent pas de problèmes d'ordre environnemental.

Parfois, il s'agit de matériaux de rebut qui doivent être traités selon des méthodes prévues par la loi. Plus souvent, il s'agit de matériaux utiles qui, simplement, sont devenus excédentaires aux besoins de leur propriétaire. Ces matériaux conservent habituellement une certaine valeur et peuvent être réutilisés sinon recyclés par les administrations routières ou d'autres organismes. À la faveur du recours à des méthodes innovatrices de réutilisation ou de recyclage de ces matériaux et de réduction de leurs quantités, il devient possible de réaliser des économies de coûts et de mieux protéger l'environnement.

Le présent rapport décrit des méthodes destinées à encourager les organismes responsables des transports à adopter des stratégies plus proactives de gestion de leurs matériaux excédentaires tout en se montrant aussi respectueux de l'environnement que possible. Il traite notamment de certains des matériaux issus des activités de construction et d'entretien des routes et des méthodes actuelles de gestion de ces derniers, cerne les possibilités de réduction des quantités de matériaux excédentaires ainsi que de réutilisation ou de recyclage de ceux-ci et expose les possibilités qui s'offrent à leur endroit au regard de leurs incidences sur l'environnement, du rapport coûts-efficacité de ces méthodes, de leur efficience opérationnelle et des propriétés techniques des matériaux en question. Enfin, le document cerne les obstacles éventuels à la mise en oeuvre de telles méthodes et décrit les besoins en recherches sinon les changements qu'il conviendrait d'apporter aux politiques ou aux normes en la matière.

Ce rapport préconise une méthodologie en quatre étapes de gestion des matériaux excédentaires, à savoir : l'importance d'affecter dans ce contexte le personnel et les ressources nécessaires; la surveillance et la détermination des domaines problématiques spécifiques et l'attribution d'une priorité à chacun d'eux; la constitution d'équipes chargées de définir des stratégies de mise en oeuvre et, enfin, l'application de nouvelles stratégies de gestion des matériaux excédentaires.

Le rapport traite également en détail de matériaux spécifiques, dont les résidus de sablage par jet, le béton bitumineux, les boues de bassins collecteurs, le béton de ciment, les géomatériaux, le bois, les métaux et les rebuts de nettoyage des routes.

Mots-clés

3665 Construction routière
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0145 Administration (gestion)
2455 Environnement
5911 Efficacité
0165 Économie
4563 Résidu industriel
4506 Bois
4755 Béton hydraulique
4955 Produits hydrocarbones
5188 Sautage
4156 Sol
4543 Métal

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Renseignements supplémentaires

Sommaire en français et en anglais

Foreword

Transportation authorities are increasingly looking for ways of managing excess construction and maintenance materials through their reduction, re-use and recycling. In certain cases these materials are in fact wastes which are managed according to existing regulations and legislations. More typically, however, they represent useful materials which have simply become excess to the needs of the current owner.

The value of such materials becomes particularly apparent when re-use and recycling approaches and methods are employed. In turn, cost savings as well as improved environmental protection is achieved by those transportation agencies that choose to support and implement such strategies.

This report represents a comprehensive discussion on how transportation agencies should approach the management of road construction and maintenance wastes. In addition, the report provides extensive details on key construction and maintenance waste materials.

This study was initiated in July 1992 and was conducted by G.M. Sernas & Associates Limited of Mississauga and Clifton Associates Limited of Saskatoon.

Avant-propos

Les administrations responsables des transports sont de plus en plus à la recherche de méthodes de gestion des matériaux excédentaires provenant des activités de construction et d'entretien des routes, des méthodes qui leur permettraient de réduire les quantités de ces derniers, de les réutiliser et de les recycler. Dans certains cas, ces matériaux sont de fait des rebuts et sont dès lors traités en conformité avec les règlements et les lois en vigueur. Toutefois, d'un point de vue plus pragmatique, ces matériaux n'en conservent pas moins une certaine valeur même s'ils sont simplement devenus excédentaires aux besoins de leur propriétaire.

La valeur de tels matériaux devient particulièrement évidente lorsqu'ils sont réutilisés et recyclés aux termes de différentes méthodes et pratiques. Aussi, les organismes responsables des transports qui choisissent d'appuyer sinon de recourir à de telles stratégies de réutilisation s'offrent du même coup la possibilité de réaliser des économies de coûts en même temps qu'ils contribuent à mieux protéger l'environnement.

Le présent rapport offre aux lecteurs un exposé approfondi de la philosophie que devraient poursuivre les organismes responsables des transports au titre de la gestion des matériaux excédentaires provenant de la construction et de l'entretien des routes. De plus, ce rapport fournit des renseignements détaillés sur les principaux matériaux de rebut provenant de telles activités.

L'étude dont il est ici rendu compte a été amorcée en juillet 1992 par les cabinets d'experts-conseils G.M. Sernas & Associates Limited, de Mississauga, et Clifton Associates Limited, de Saskatoon.

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The authors would like to express their appreciation for the assistance provided by the members of the Project Steering Committee. As well, those individuals who provided advice and input to this study are thanked.

TAC wishes to thank all those who contributed input to the study and hopes that it will help transportation professionals to improve the way in which they manage their excess materials.

Management of Road Construction and Maintenance Wastes
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Executive Summary

The number and volume of excess materials produced by transportation agencies during the construction, reconstruction and maintenance of their facilities is extensive. Often these materials are wasted either through disposal at landfill sites, or through dumping on vacant property, old quarries or low lying areas. Most of the materials generated in the field by road agencies are relatively inert, and do not require disposal at landfill sites. As well, these materials usually have value and can be reused or recycled for use by road agencies or others. As both non-renewable natural resources and financial resources become increasingly scarce, it will be everyone's responsibility to eliminate wasteful practices.

This report challenges those responsible for managing excess materials to be creative in finding new ways to use these materials in productive and environmentally acceptable ways. The report provides insights into the barriers that stand in the way of innovation. These barriers include changing social values, economic constraints, regulatory impediments, information and technological shortages, and organizational inertia. However, despite what may seem as insurmountable barriers, transportation professionals across Canada are finding ways to reduce, reuse and recycle their excess materials.

To help those who have not yet left the comfort of their traditional ways, to venture forth and try new management options, the report outlines a four phased materials management approach.

Phase I involves setting the philosophical and organizational context in which new options will be developed. It is important that senior management within transportation agencies assign responsibility for developing new material management options, and provide the necessary support and resources to ensure success.

Phase II is the problem identification stage. Organizations must have an environmental scanning system in place that will ensure that emerging issues are identified early enough that timely and cost-effective responses can be developed. A key step in efficiently focusing your efforts is the development of data on the nature of excess materials currently being generated and how they are being managed. Armed with this data, and a clear understanding of emerging issues and regulatory trends, an organization can prioritize the materials requiring attention in the short and longer term.

Phase III (Planning) involves the organization of specific teams to define and assess new management practices, and prepare and implementation strategy for the preferred option.

Finally, **Phase IV** involves the implementation of the new management strategy, including obtaining the necessary approvals and resources; recruiting, equipping and training staff; modifying the necessary internal documents; and monitoring and reporting on the new procedures.

The later part of the report discusses the following 9 specific materials:

1. Abrasive Blasting Medium
2. Asphalt Concrete
3. Catchbasin Material
4. Concrete
5. Excess Earth Materials
6. Manufactured/Treated Wood
7. Metals
8. Natural Wood/Stumps
9. Street/Road Sweepings

Excess abrasive blasting media is generated from the paint removal operation that prepares steel bridges for recoating. This material consists of the abrasive blasting medium contaminated with the paint and rust removed from the structure. Because the old paints contained lead, the contaminated material may exceed local standards for leachable lead and have to be disposed of at special landfill sites. This report explores some options for using the material in other industries, as well as treating the material to either remove or bind the contaminants so that less costly management options are available.

Knowledge and experience in Canada with managing asphalt concrete is extensive. There are few reasons why excess asphalt concrete cannot be reused or recycled. The various methods available for using excess asphalt concrete are not universally understood and applied. This can be due to the lack of local knowledge about various practices, the lack of experienced and properly equipped contractors, or the shortage of available material to make certain options commercially viable. Most of the management options for asphalt concrete discussed in this report are already being applied somewhere in Canada. They are reported here to help those who are not using particular options to know what can be done and to encourage transportation professionals to lead the way in bringing proven practices from other jurisdictions to their locale.

The excess material generated from cleaning out catchbasins in storm sewers is difficult to manage because it is a slurry. Although it is not considered to be contaminated to the point where it must be taken to a special waste disposal facility, it does contain oil, grease and heavy metals. Therefore this material requires some special handling. Generally, the water is separated from the solids and decanted back to a stormsewer, a sanitary sewer, or a sewage treatment plant. The solids are usually taken to a landfill site. Some experimentation has been done to wash the

contaminants from the sand, and then use the cleaned sand for various applications.

Like asphalt concrete, there is considerable experience with the management of excess Portland cement concrete. These methods are not understood and applied to the same extent across Canada. With the proper infrastructure established, there is little reason why excess concrete could not be fully and productively used. The report discusses many options for reducing, reusing and recycling excess concrete.

There are many different kinds of earth materials that become excess to road construction and maintenance operations. These range from mineral soils; to wet clay, silt or organic soils; to high organic content soils. Soils that are contaminated through chemical spills require special handling, and have not been addressed in this report. There are few environmental problems associated with earth materials themselves. Adverse environmental impacts usually arise from improper management of these materials. Earth materials are a resource that can used either as engineered fill (mineral soils) or top dressing (organic soils). Creative management of these materials must begin at the planning phase of the project, so that earthworks can be balanced to the fullest extent and outlets for the excess materials can be planned.

Manufactured/treated wood often contains chemicals that limit their management options. Treatments such as fast pyrolysis and bioremediation are used to separate the chemical preservatives from the wood, allowing the cleaned wood to be reused, and the chemicals to be reused of sent to disposal. Careful planning and management of treated wood elements removed from service may permit them to be reused.

Natural wood is more easily managed. These include the above ground portion of trees (i.e. trunk, branches, leaves) and the stump. Apart from using trunks for firewood or lumber, recycling options usually require chipping or shredding of the tree and stump. The resultant chip/shred can be used for landscaping mulch, energy from wood fuel, manufacturing of paper or composite boards, or as an input to composting operations. Stumps pose special problems because they are tougher to crush and chip, and the product is dirty, making it less attractive to chip users.

Metal products such as culverts, sign posts and guiderails are easily recycled by scrap metal dealers. These dealers exist in most areas of Canada. Reuse of these materials could be improved if care was exercised when they are removed, and road agencies established a process for collecting the materials, and making them available to others.

Street sweepings are the product of the spring cleanup of winter sand placed to control skidding on roads during the winter. This sand contains some heavy metals, oil and grease, and litter. In rural areas, the sand is swept to the road shoulder. In urban areas, where sweeping to the shoulder is not viable, the sand is collected and used as fill. Because of the contaminants, fill options are limited. One suggested reuse option is to take the sand from urban areas and reuse it as winter sand in rural areas the following year. Then it can be swept to the shoulder in the second spring.

There is a lot of excellent work being done across Canada to develop and evaluate new management options for excess materials. A first step to promoting more universal application of proven methods is to improve the information exchange between those areas where the practices are being applied and those where they are not. As well, there are barriers that need to be overcome. Many of the barriers are market driven and need provincial transportation agencies to develop partnerships with municipalities and the private sector to create a positive economic climate that will foster the development of necessary infrastructure to support new management options. Some of these are institutional, and require people to show leadership and take some risks. One of the largest barriers is complacency. Unless people are willing to challenge the status quo, change will not occur. Consider this, many people complain that their jobs have become routine, free from new challenges. Finding more environmentally acceptable and cost effective new management options presents new challenges awaiting someone to take the initiative.

Sommaire

Les travaux de construction, de reconstruction et d'entretien de l'infrastructure routière qu'exécutent les organismes responsables des transports sont sources d'importantes quantités de matériaux excédentaires. Bien souvent, on dispose de ces matériaux en les déversant à des sites d'enfouissement sinon sur des propriétés vacantes, dans d'anciennes carrières ou sur des terres basses. La majorité des matériaux excédentaires issus des activités exercées par les administrations routières sont relativement inertes et n'exigent aucunement leur enfouissement à des sites désignés. De plus, ces matériaux, bien qu'excédentaires, conservent habituellement une certaine valeur et peuvent être réutilisés sinon recyclés par les administrations routières ou d'autres organisations, d'autant plus qu'en raison de la rareté croissante des ressources naturelles non renouvelables et même des ressources financières, il appartient dorénavant à tout un chacun de faire en sorte de mettre un terme aux pratiques de gaspillage.

Le présent rapport a pour but d'inviter les responsables de la gestion des matériaux excédentaires à faire preuve de créativité et à trouver de nouveaux moyens d'utiliser ces derniers de façon productive et non préjudiciable pour l'environnement. De fait, ce rapport fournit dans ce contexte un aperçu des obstacles à l'innovation, obstacles qui tiennent non seulement aux valeurs sociales changeantes, aux contraintes économiques actuelles et aux entraves réglementaires, mais encore au manque d'information sur le sujet, à l'absence de techniques appropriées, voire à certaines inerties institutionnelles. Et pourtant, si ces obstacles peuvent sembler insurmontables pour d'aucuns, le fait demeure que les professionnels canadiens du secteur des transports parviennent malgré tout à trouver des moyens de réutiliser et de recycler leurs matériaux excédentaires sinon d'en réduire la quantité.

Dans le but d'aider ceux qui hésiteraient encore à abandonner leurs modes traditionnels de gestion des matériaux en question à opter pour de nouvelles lignes de conduite en la matière, le présent rapport propose une méthodologie en quatre phases.

> La **phase I** traite de l'instauration du cadre philosophique et organisationnel à la faveur duquel seront élaborées de nouvelles méthodes de gestion des matériaux excédentaires. Cette première phase du processus vise à souligner l'importance, pour la haute direction de toute administration des transports, de désigner des responsables de l'élaboration de nouvelles options de gestion des matériaux visés et de leur accorder le soutien et les ressources nécessaires au succès de leurs démarches.
>
> La **phase II** porte sur la détermination des problèmes à résoudre. Les organisations ici visées doivent se doter d'un système d'évaluation environnementale qui leur permettra de cerner les questions ou problèmes nouveaux suffisamment à temps pour mettre au point des mécanismes

d'intervention opportuns et rentables. L'une des étapes clés à cet égard demeure certes l'établissement de données sur la nature des matériaux excédentaires actuellement produits et leur gestion. En ayant ces données en mains de même qu'une vision claire des problèmes qui se posent et des tendances réglementaires qui se dessinent, toute organisation sera en mesure de déterminer ses priorités à court et à long termes de gestion des matériaux excédentaires.

La **phase III** (planification) concerne la mise en place d'équipes chargées spécifiquement de définir et d'évaluer de nouvelles pratiques de gestion ainsi que de préparer une stratégie de mise en oeuvre des solutions retenues.

Enfin, la **phase IV** a pour sa part trait à la mise en oeuvre de nouvelles stratégies de gestion des matériaux excédentaires ou de rebut, y compris l'obtention des autorisations et des ressources nécessaires à cette fin, le recrutement et la formation du personnel approprié, l'acquisition des équipements voulus, la modification des documents visés de procédure interne ainsi que la surveillance de la mise en oeuvre des nouvelles méthodes, rapports à l'appui.

La dernière partie du présent rapport vise plus précisément les 9 types ci-après de matériaux excédentaires :

1. résidus de sablage par jet,
2. béton bitumineux,
3. boues de bassins collecteurs,
4. béton de ciment,
5. matériaux de remblai excédentaires,
6. bois usiné/traité,
7. métaux,
8. bois non usiné/souches,
9. rebuts de nettoyage des routes.

La préparation des ponts en acier en vue de l'application d'un nouveau revêtement protecteur exige généralement un sablage par jet de ces derniers aux fins d'enlever la peinture existante. Cette opération produit des résidus de sablage qui sont contaminés par l'ancienne peinture et la rouille qui recouvrent ces ouvrages d'art. Du fait que les vieilles peintures contiennent du plomb, il peut arriver que le degré de contamination des résidus de sablage par jet dépasse les normes locales de lixiviation et qu'on doive en disposer à des sites d'enfouissement désignés. Ce rapport propose un certain nombre de solutions quant à l'utilisation de tels résidus par d'autres industries ou encore à leur traitement aux fins d'en éliminer les matières contaminantes sinon de fixer celles-ci de manière à permettre l'application de méthodes de gestion moins coûteuses.

Au Canada, les administrations routières possèdent des connaissances et une expérience approfondies de la gestion des rebuts de béton bitumineux. Qui plus est,

rares sont les circonstances où ces rebuts ne peuvent être réutilisés ou recyclés, mais il faut toutefois ajouter que les différentes méthodes qui s'offrent à ce titre ne sont pas universellement connues ni appliquées. Cette situation est peut-être attribuable au manque de connaissances, au plan local, des diverses pratiques auxquelles il serait possible d'avoir recours, au manque d'expérience des entrepreneurs, à l'absence d'équipements appropriés, voire à l'insuffisance des approvisionnements en rebuts de béton bitumineux ce qui, bien sûr, ne peut que compromettre la rentabilité des solutions envisagées dans ce contexte. La majorité des options de gestion des rebuts de béton bitumineux dont il est question dans ce rapport sont déjà appliquées dans une région ou une autre du Canada. Il en est fait état aux présentes par souci de renseigner ceux qui ne privilégient aucune méthode en particulier et d'encourager les professionnels des transports à employer des méthodes éprouvées par d'autres administrations.

Les résidus provenant du nettoyage des bassins collecteurs d'égouts pluviaux posent des difficultés de gestion du fait qu'ils se présentent sous forme de boues. Bien qu'elles ne soient pas jugées contaminées au point d'exiger leur élimination à une installation spéciale, le fait demeure que ces boues contiennent des huiles, des graisses et des métaux lourds. Dès lors, elles nécessitent un traitement particulier, à savoir que l'eau qu'elles contiennent est en général séparée des matières solides puis décantée de nouveau dans un égout pluvial, un égout sanitaire ou à une usine de traitement des eaux usées. Pour leur part, les matières solides sont habituellement envoyées à un site d'enfouissement. Certaines expériences ont été pratiquées en vue d'éliminer, par lessivage, les contaminants du sable contenu dans ces boues et de réutiliser ensuite ce dernier, une fois nettoyé, à diverses fins.

Tout comme dans le cas du béton bitumineux, les constructeurs routiers du pays possèdent une vaste expérience de la gestion des rebuts de béton de ciment Portland. Ces méthodes ne sont cependant pas connues ni appliquées de la même façon à l'échelle du Canada. En présumant de la mise en place de l'infrastructure appropriée de gestion des rebuts de cette nature, rares seraient les circonstances où ceux-ci ne pourraient être entièrement réutilisés de façon productive. Ce rapport expose plusieurs options visant à réduire les quantités de rebuts de béton de ciment Portland sinon à réutiliser ou à recycler ces derniers.

On dénombre plusieurs types de géomatériaux excédentaires provenant des activités de construction et d'entretien des routes. La nature de ces matériaux peut varier considérablement : sols minéraux et matières pierreuses, argile humide, limon, terre à faible ou forte teneur en matières organiques. Ceux de ces sols qui sont contaminés par des produits chimiques exigent un traitement spécial, ce dont ne traite cependant pas le présent rapport. En soi, les géomatériaux utilisés aux fins de la construction ou de l'entretien des routes posent peu de problèmes environnementaux. De fait, les préjudices causés à l'environnement dans ce contexte tiennent davantage à une mauvaise gestion des matériaux en question. Les géomatériaux constituent globalement autant de ressources naturelles qui peuvent être utilisées comme remblais d'appoint (sols minéraux) ou comme

revêtements de sol (matières organiques). La gestion innovatrice des géomatériaux s'inscrit à l'étape de la planification de tout projet de construction. En effet, c'est à l'étape de la planification des travaux de terrassement que doit être déterminée de façon aussi poussée que possible la façon de coordonner les diverses utilisations de ces matériaux de même que les méthodes de disposition des excédents.

Le bois usiné/traité contient bien souvent des produits chimiques qui limitent le nombre des méthodes de gestion des rebuts de cette nature. Divers procédés tels la pyrolyse rapide et la biorestauration sont utilisés pour éliminer les agents chimiques de préservation des matériaux de bois usiné ou traité, ce qui permet ensuite de réutiliser ceux-ci à d'autres fins. Le cas échéant, les produits chimiques ainsi extraits de ces matériaux peuvent être eux aussi réutilisés sinon éliminés. Une planification et une gestion attentives des rebuts de bois traité permet bien souvent de réutiliser ces derniers.

Le bois non usiné pose moins de problèmes au plan de la gestion des rebuts, ceux-ci s'entendant des parties aériennes des arbres (troncs, branches, feuilles) et des souches. Outre l'emploi des troncs comme bois de chauffage ou bois d'oeuvre, il est habituellement possible de recycler de telles ressources naturelles en les transformant en copeaux ou en les déchiquetant. Les copeaux ainsi obtenus peuvent ensuite être utilisés comme paillis d'aménagement paysager, comme combustible, pour la fabrication de papier ou de panneaux composites ou encore comme agent de compostage. En revanche, les souches posent des problèmes particuliers du fait qu'elles sont plus difficiles à broyer ou à transformer en copeaux, sans compter les saletés qui les recouvrent, ce qui les rend moins attrayantes aux yeux des utilisateurs de copeaux de bois.

Les produits métalliques tels les tuyaux de drainage pour ponceaux, les poteaux de panneaux de signalisation et les glissières de sécurité sont facilement recyclés par les ferrailleurs. On trouve des ferrailleurs dans la plupart des régions du Canada. La réutilisation des rebuts métalliques pourrait donner de bien meilleurs résultats si toute l'attention voulue était accordée au moment de leur enlèvement et si les administrations routières établissaient une procédure appropriée de collecte et de disposition de ces matériaux.

Les rebuts de nettoyage des rues sont principalement constitués de sable épandu pendant l'hiver, comme antidérapant, et récupéré au printemps. Ce sable contient certains métaux lourds, des huiles, des graisses et autres débris. En milieu rural, ce sable est balayé sur les accotements routiers. En milieu urbain, où une telle méthode d'élimination saurait difficilement être appliquée, le sable est recueilli et utilisé comme remblai. En raison des contaminants qu'il contient, sa réutilisation comme remblai se heurte toutefois à certaines limites. L'une des solutions suggérées aux présentes consiste à récupérer le sable épandu en milieu urbain pour le réutiliser comme antidérapant en milieu rural, l'hiver suivant. Ensuite, au printemps, il pourrait être simplement balayé sur les accotements routiers.

Un peu partout au Canada, bon nombre d'excellents projets se poursuivent en vue de mettre au point et d'évaluer de nouvelles méthodes de gestion des matériaux excédentaires issus de la construction ou de l'entretien des routes. Dans le but de promouvoir l'application plus universelle de méthodes éprouvées de gestion de ces matériaux, le présent rapport préconise, en guise de première étape, d'améliorer l'échange d'information entre les régions où de telles méthodes sont employées et celles où elles ne le sont pas. Par ailleurs, d'autres obstacles devront être surmontés. Nombre de ces obstacles sont de nature économique, d'où le besoin pour les administrations provinciales des transports de créer des partenariats avec les municipalités et le secteur privé aux fins d'instaurer un climat favorisant la mise en place de l'infrastructure nécessaire à l'emploi de nouvelles méthodes de gestion. Certains de ces obstacles sont de nature institutionnelle et exigent donc de la part des principaux intervenants qu'ils fassent preuve de leadership et qu'ils consentent à prendre certains risques. Ceci dit, le principal obstacle en cette matière demeure avant tout l'inertie des principaux intéressés. En effet, à moins que ceux-ci ne se décident à relever les défis qui se posent, il ne faudra pas escompter de changements majeurs de la situation. Et pourtant, bien des gens se plaignent de l'aspect routinier de leur travail et de l'absence de défis à relever. Il suffirait donc que ces personnes fassent preuve d'initiative et se lancent dans la recherche de nouvelles solutions de gestion des matériaux excédentaires qui soient plus rentables et plus acceptables du point de vue de l'environnement.

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1.0 INTRODUCTION

1.1 AUTHORIZATION

In the interest of helping the transportation sector to show leadership in dealing with excess materials, **The Transportation Association of Canada** (TAC), through its Research and Development Council, sponsored a project to investigate and report on the management of excess materials from the construction and maintenance of roads.

On the basis of a proposal submitted on October 23, 1992, and a presentation on November 3, 1993, TAC authorized **G.M. Sernas & Associates Ltd.** of Mississauga, Ontario, in association with **Clifton Associates Ltd.** of Saskatoon, Saskatchewan, to carry out this study.

1.2 BACKGROUND

There are concerns worldwide over the management and disposal of materials that no longer are needed. These materials often find their way to land disposal, where they are lost for future use, or worse, create environmental problems.

Sometimes these materials are regulated wastes and need to be managed according to specified legislated procedures. However, often they are useful products that have become excess to the needs of the current owner. Through the application of innovative approaches to reducing, reusing, or recycling (3Rs) these materials, cost savings and environmental protection can be achieved.

Transportation authorities, like other organizations, are wrestling with the question of how to deal with those materials that are excess to their needs, in a cost-effective and environmentally acceptable ways. Some of these transportation-related excess materials are listed in Table 1.

TABLE 1

LIST OF TYPICAL EXCESS MATERIALS FROM ROAD CONSTRUCTION AND MAINTENANCE

CONSTRUCTION	MAINTENANCE
Asphalt Concrete Concrete Granular Material Topsoil Earth Material Stumps and Trees Swamp Material Rock Metal/Wood Culverts	Abrasive Blasting Media Catchbasin Material Road Sweepings Treated Wood Utility Poles Note: Only field materials are listed.

The Transportation Association of Canada has a long standing history of helping Canada's transportation sector to deal with new issues. In addition TAC's recently endorsed Environmental Policy and Environmental Code of Ethics state a commitment, among other things,

> "*to promoting environmentally sustainable transportation services, and to continually reducing discharges of wastes (including excess materials) through the development and application of 3R programs and technologies*".

See **Appendix A** for the full text of TAC's Environmental Policy and Code of Ethics.

1.3 STUDY OBJECTIVES

The objective of the study was to produce a practical, concise, and easy to follow report on the potential options for managing excess materials arising out of the construction and maintenance of local roads and streets across Canada.

This report is intended to help road agency staff to begin or enhance their handling of these materials by more environmentally appropriate methods. This report:

- identifies methods for encouraging transportation agencies to be more proactive in managing their materials in the most environmentally acceptable manner.
- identifies some of the materials that are produced from the construction and maintenance of roads;
- lists how these materials are currently being handled;
- identifies existing, as well as new options for reducing, reusing, or recycling excess materials;
- discusses these management options according to their environmental impacts, cost effectiveness, operational efficiency and/or engineering properties. Note: This was done on the basis of existing information, and expert knowledge. No laboratory analysis or testing of the materials was done;
- identifies possible barriers to the implementation of new options;
- identifies research, and/or changes to policies or standards that are needed to implement the options; and

1.4 BASIS OF THE STUDY

In conducting this study several guiding concepts were followed. Throughout the study, and this report, the materials have been referred to as "**Excess Materials**" and not as "wastes". The label "waste" affects the way the public, property owners, lenders, insurers and municipalities perceive these materials, and their willingness to accept them as useful products rather than as harmful wastes.

This distinction is also important because in many jurisdictions, waste management legislation defines the term "waste" and places management restrictions on these wastes. These regulatory and perceptional barriers interfere with efforts to develop 3R options for materials that may no longer have obvious economic value, but are still useful. The underlying premise of this report is that although these materials are perceived to be excess to the needs of the current owner (e.g. contractor or road authority), they could be useful to either the current owner, or someone else. The term "Excess Material" recognizes this distinction and the fact that, provided the material has not become contaminated, it is not a waste, but rather is a useful commodity.

This study is intended to be relevant to those in the transportation sector across Canada. Not all regions of the country have the same problems, nor are they at the same stage in managing their materials. This is due to many factors, including differences in:

- The volume of materials generated;
- The regulatory requirements;
- The evolutionary stage of the road building, and waste management sectors, with respect to understanding of the issues, development and/or availability of technology, and availability of markets; and
- The regional economic conditions.

In addition, in conducting this study, higher priority was placed on finding ways of managing the materials so that they are being reused or recycled in an environmentally acceptable way.

Other guiding concepts included:

- The study, and report should be consistent with TAC's Environmental Code of Ethics;

- The recommendations should support the concept of environmentally sustainable transportation;

- The recognition that many existing practices and products are illegal, or about to be made illegal, and that there is a need to find replacement practices and processes;

- Preference should be given to obtaining the greatest value from excess road materials (i.e. the highest and best use);
- The degree of concern over any one material or practice is context sensitive. An action that is of concern in one part of Canada, may not be a concern in another location;
- The recognition that engineering practices, regulations and social values with respect to the environment are in a transition. This creates uncertainty and confusion. It is intended that this study will help to reduce the confusion;
- The quality of the materials being used should not be compromised;
- Some materials are likely to be contaminated, and will have limited management options; and
- The study will have to focus on a limited number of materials in order to be detailed enough to be useful.

1.5 CAUTIONARY REMARKS

This report is based on information and opinions obtained from other studies and conversations with people from the transportation and industrial sectors across North America. The validity of all of the information was not tested, but has been presented to help stimulate thought and discussion.

In addition, the management options (both past, and proposed) presented in this report are not represented by the authors as being acceptable for any or all regions of Canada. It was not the intent of this report to document the regulatory requirements, or to comment on the legality of a particular management option in each jurisdiction. The reader is cautioned that there are some practices that are currently being carried on in some areas of Canada that are questionable, and would be illegal in other areas.

It is the intent of this report to open the prospects of new options and to encourage those responsible for managing excess materials to pursue some of them in their jurisdictions in the interest of finding more environmentally acceptable and cost effective management options. In all cases, one should start with determining if local legislation will permit a given option.

This report does not cover all management possibilities. We have assumed that the materials being managed are typical in chemical composition for that material. For example, when addressing management options for asphalt concrete, we have assumed that standard mix designs have been used, and that no unusual contaminants are present. If the chemical or physical properties of the material being managed are not typical, management options may be limited.

1.6 STUDY METHODOLOGY

A detailed description of the methodology is contained in Appendix B. The study consisted of the following 6 Phases:

I	-	Project Start-up
II	-	Identification of Excess Construction and Maintenance Materials and Current Practices
III	-	Prioritization of the Materials for Further Study
IV	-	Identification and Evaluation of New Management Options
V	-	Identification of Research Needs, and Changes to Operational Standards and Policies
VI	-	Identification of How to Encourage Road Authorities to be More Proactive in Using Environmentally Responsible Management Practices.

The materials that were selected for more detailed study and are discussed in Chapter 4 of this report are set out in Table 2. Appendix E describes some previously reported management practices for materials that were not selected for detailed study.

TABLE 2

LIST OF PRIORITY MATERIALS

1.	Asphalt Concrete
2.	Abrasive Blasting Medium
3.	Natural Wood/Stumps
4.	Concrete
5.	Excess Earth Materials
6.	Metals
7.	Manufactured/Treated Wood
8.	Street/Road Sweepings
9.	Catchbasin Material

1.7 STRUCTURE OF THIS REPORT

The report consists of two parts. The first part is process oriented and consists of Chapters 2 & 3. Chapter 2 discusses:

- how issues evolve, and why you should be proactive in managing excess materials;
- key concepts that apply to the development of proactive management practices;
- barriers to implementing new practices; and
- how you should go about developing new management options.

Chapter 3 presents a new materials management approach to guide road agencies.

The second part consists of Chapter 4 which describes:

- the priority materials;
- current management practices for each material;
- new management options;
- barriers to implementing these options; and
- research and policy changes that may be needed to assist in making these options viable.

The level of detail for each material varies depending on the priority the material was given, and the availability of information.

A bibliography is provided for each material discussed in Chapter 4. In addition, a comprehensive bibliography is provided in Appendix F.

2.0 PROACTIVE MANAGEMENT CONSIDERATIONS

2.1 THE ANATOMY OF AN ISSUE

An understanding of issues and how they emerge is important to developing proper issue management skills. Issues tend to fall into four categories, each having its own characteristics. These four categories are discussed below.

2.1.1 Category of Issues

Universal Issues
These are issues that affect large numbers of people from many walks of life, and that the public feels need to be handled by the government. Examples of Universal Issues include global warming and the management of hazardous wastes.

Heightened public concern over water quality, air quality, and waste management is driving government action and the development of stiffer regulations, which are affecting transportation agencies. There is little that one agency can do to halt the development of Universal Issues. However, road agencies, along with their associations, can influence the specific way in which governments respond to these issues.

Advocacy Issues
An advocacy issue is one where the issue does not emerge spontaneously, but rather is championed by a specific interest group. Without a champion, these kinds of issues would not emerge. An advocacy issue that could affect the transportation sector is the recent attention environmental activist groups are giving to automobile emissions.

Selective Issues
Selective issues are those that are of specific interest to a selected group of people. The NIMBY (Not In My Back Yard) concern falls into this category. These are usually local concerns over a specific activity and require local attention. The burning of wood at a construction site falls into this category. Another term used for this type of concern is LULU (Locally Undesirable Land Use).

Technical Issues
These issues relate to such aspects as standards, technology, processes, and design. Technical issues are usually of little interest to the public, and generally are left to the experts to resolve. In the transportation sector, these issues include the satisfaction of product design standards (e.g. mix designs), and technical requirements of the local Ministry of the Environment. Although these issues are of little interest to the general public, their resolution will help in satisfying public concerns, and preventing advocacy issues and selective issues from evolving.

2.1.2 Issue Life-Cycle

All issues have a life-cycle. They often begin as a series of localized concerns that may be short lived. It is only when public concern reaches a sufficient level, that governments become concerned enough to initiate policy action. Often a champion for the issue will emerge. This champion usually comes from local, provincial or national activist groups. The necessary support to cause government action often comes with the help of the media.

Once public opinion about the need for change is large enough, and the concern has been picked up by a political champion, public policy development begins. Although this process can be drawn out, as long as public pressure is maintained, it will ultimately lead to the establishment of public policy. The pace at which an issue unfolds can speed up significantly with a single trigger event such as a spill.

Once the policy framework has been established at the political level, the activity moves more to the bureaucratic level to work out the operational details. At this stage the policy life-cycle flattens out. If one hopes to influence the development of public policy, contact with the regulatory agencies at both the political and bureaucratic levels is important.

It is important to understand that issues are often related to perceptions rather than reality. Effective issue management therefore is dependant upon effective management of people's perceptions. A public concern that is dismissed because there is no scientific basis for the concern, can escalate into a major issue if it gets the attention of the media or a political champion.

Therefore an issue's position in the policy life-cycle, will affect a stakeholder's ability to influence the outcome. The greatest opportunity for road authorities to affect the policy response to an emerging issue is at the formative stages, before the issue catches the attention of the interest groups, or the politicians.

2.2 THE WORLD IS CHANGING

The context in which we must carry on business is undergoing continuous change, and increasing in complexity. In the past 10 years the rate of change has been accelerating. The need for new and innovative practices for managing excess materials from road construction and maintenance activities may be caused by events or regulations that are beyond the control of road agencies. Some of these events are:

- Changes in environmental regulations or standards which ban current practices;
- Changes in landfill tipping fees which make landfill disposal costly;
- Changes in landfills policies that mean that some excess road materials may no longer be accepted. Longer hauls to other disposal sites further adds to the cost of disposal; and
- Changes in practices or equipment make innovative uses of excess materials economically attractive.

Road agencies will be required to react to these external changes, either for legal or economic reasons. When a road agency is forced to react to external events, much of the control or management of the situation is taken out of its hands. Road agencies may be forced to use new material management practices, whether or not the agency has had sufficient time to find and confirm the most appropriate new practice.

Social values on environmental issues can change rapidly. Governments often react quickly to these changing values with new laws or regulations putting organizations into a reactionary mode with little or no control over the situation.

This reactionary response to an issue can lead to the adoption of costly and inefficient processes. It is better to anticipate changes and develop responses to these changes before they become a requirement. In this way, there is time to develop and implement well thought out solutions to emerging issues.

2.3 WHY SHOULD YOU BE INNOVATIVE OR PROACTIVE?

Changing social values will lead to changes in public policy and the requirement placed on road agencies. An agency can either take a proactive or a reactive approach to dealing with these changes. By taking a reactive approach, road agencies are leaving it to others to develop requirements that they will have to live with in the future. Often these requirements are difficult and costly to implement. On the other hand, a proactive approach has greater likelihood of ensuring that new requirements will be environmentally appropriate, operationally practical, effective and economical.

To be proactive, road agencies must be forward thinking - watching the trends, and leading in the development of new and environmentally responsible materials management practices.

Operational staff and technical specialists within road agencies are in the best position to identify, test and implement new materials management practices. They should work closely with regulatory agencies to help them to understand the needs of the road industry, so that these needs can be properly accounted for in the development of new requirements.

By adopting proactive materials management practices, road agencies can avoid unacceptable practices becoming an issue that catches the eye of policy makers, and can influence how the public and regulatory agencies perceive the agencies' activities.

The enactment of the United States Intermodal Surface Transportation Efficiency Act (ISTEA), 1991, Section 1038 pertaining to the use of crumb rubber in hot mix asphalt concrete is an excellent example of road agency and construction industry reaction to a mandated change. This new legislation requires road agencies to include an increasing amounts of crumb rubber from used tires, in hot mix asphalt concrete over a four year period in order to qualify for United States Federal Government shared funding.

The crumb rubber industry effectively influenced the U. S. Senate to add the requirement for crumb rubber in hot mix asphalt concrete to the ISTEA legislation. State road agencies had to scramble to find acceptable crumb rubber asphalt concrete processes that would be technically and economically suited for their local conditions. Anxiety levels over this mandated use of crumb rubber in hot mix asphalt concrete is high within road agencies and the pavement construction industry. The pavement construction industry has lobbied for and achieved a one year delay on the program implementation. In the meantime large sums of money are being spent on research and test sections as agencies search for the best systems for their area.

This example illustrates that the implementation of this technology in a crisis environment appears less than desirable. A better approach would have been a cooperative effort amongst the paving construction industry, the crumb rubber industry, and the regulatory agencies to develop acceptable approaches before it became a legislated requirement.

A cooperative, proactive approach to addressing issues always leads to better solutions than a confrontational, reactive approach. It is better to guide your own future, than to let someone who does not understand your business, do it for you.

2.4 BARRIERS TO INNOVATIVE MANAGEMENT PRACTICES

Anyone who has tried to implement new management practices soon realizes that there are many barriers standing in the way of innovation. Some of these barriers are more easily addressed than others. In all cases, it requires new and creative ways of approaching your business. To be successful, it is necessary for those developing new management practices to understand these barriers and to develop solutions that overcome them. Several kinds of barriers to the development of innovative management practices for excess materials are described in this section.

2.4.1 Social Value Barriers

Social value barriers relate to public attitudes, perceptions or expectations. There is no pressure to change where nobody perceives that the existing practices are unacceptable. The need for action is context sensitive and related to public expectations. There are examples of practices that are acceptable in one locale, and unacceptable in another. This is because public concern has not reached a level where action is required. However, it is reasonable to expect that a practice that has become unacceptable elsewhere, soon could become an issue in your locale. This should be seen as an emerging issue. It provides an excellent opportunity to learn from others and to influence how the public and regulatory agencies will view your activities in the future.

In many areas, the rate of change of social values is slow. In other areas, social values are undergoing rapid change. Where the later is the case, there is genuine uncertainty as to what course of action to choose. This uncertainty can lead to inaction and maintenance of the status quo.

Some procedures are unpopular or even banned due to public concern or misinformation. For example, many inhabitants of urban residential areas will fight against large scale composting facilities because they perceive compost to

be equal to garbage, and are afraid that the facility will decrease the quality of their lives and neighbourhoods. These negative public perceptions are very difficult to change and can stifle creativity by those who are not prepared to take on the challenge of altering public attitudes.

Because it is so difficult to change public attitudes, it is important to anticipate emerging issues, and to manage them so that the public remains positive or at least neutral about your approach to handling your excess materials.

2.4.2 Economic Barriers

Often there is the willingness, and even the desire to use innovative materials management practices but there is a lack of funds. This is particularly true as Canada drags itself out of a recession, and governments are pre-occupied with debt-reduction. Because innovation can be costly in the short-run, the current climate of constraint represents a significant barrier.

In many areas, low landfill tipping fees combined with a lack of 3R's regulations, policies or guidelines makes landfilling more financially attractive than reducing, reusing or recycling. On-site disposal of materials at construction sites represents the lowest cost landfill option. Low cost land disposal options eliminate the financial incentive to establish new material end markets or to use more environmentally friendly management options.

High processing and/or transportation costs, drive up the costs of some management options. While these high costs will make some environmentally preferred options economically unattractive, they can also make the landfill option more costly thus producing the incentive for road authorities to find other less costly, yet more environmentally acceptable options.

Limited markets for excess materials also make new management practices economically unattractive. In some cases no local end markets have been established. In other cases, the market opportunities have not been fully explored by road authorities. Some transportation authorities do not generate enough excess materials from their projects to make recycling cost-effective. For example, the Yukon Territory has few roads and most are still very new. Consequently, they have little excess materials from maintenance or new construction, and limited need for new management options. It is unlikely that new markets will develop in this situation.

Even where there is a sufficient supply of excess materials and a demand for this material, there is sometimes an imbalance in the timing and quantities

between the source (supply) and uses (demand) for materials. For example, excess earth material from a cut operation may be produced in one year, but a use for that material (e.g. fill for another project) may not be available until another year. In addition, some quantities of excess material are produced regularly but it may take several years until sufficient quantity is available for a particular use. This necessitates the added burden of stockpiling and double handling of the material.

2.4.3 Regulatory Barriers

Barriers affecting the ability of material managers to seek out and implement new management options may be related to the local regulatory and policy framework.

Local environmental regulations may classify an excess material as a waste. In some cases this will eliminate certain 3R options. In other cases options are available, but the regulations impose rigorous and sometimes questionable management requirements on the material. The waste classification may also create inaccurate public perceptions of the material and proposed management process. In Ontario for example, anyone wishing to move a waste material to an intermediate site for consolidation and possible sorting before sending the material for disposal, may require a Certificate of Approval for a waste transfer station. The application for this approval refers to this transfer site as a "Waste Disposal Site". Normal practice is for the environment ministry to refer the application to the local municipality for comment. The letter to the municipality essentially states that "The Ministry of Transportation has applied to establish a waste disposal site within your community. Do you have any objections?" The municipality will consider this application in a public forum. The result may be a negative municipal and public reaction because the perception is that a waste disposal site is being established. Consequently, an otherwise desirable management option may become unacceptable because of inaccurate public perceptions created by regulatory terminology.

There are times when the materials may be contaminated with undesirable or toxic chemicals. In these cases, the regulations appropriately limit the available management options.

Often proposed new options for reusing or recycling excess materials have to go through a lengthy and costly approvals process before being accepted by the approving authority. This process can be too onerous for some and result in the proponents of these new options giving up either because they are tired of the fight, or because they can no longer afford the cost.

In addition, test methodologies could misrepresent the environmental significance of a material. Typically, an acid extraction will be used to determine if a material will create an unacceptable leachate if placed into the natural environment. However, the pH level of the liquid used for the acid extraction may be considerably lower than what the material will be exposed to in the natural environment. The test could therefore misrepresent the environmental hazard of the material. Similarly, the testing procedure for some materials may involve pulverizing the material before conducting the tests. In the case of concrete, this process will create a much higher pH reading (because of the increased surface area) than if the material was left in block form, which is how it is often reused (e.g. rip rap, armour stone, ballast). Such a test method would indicate that concrete should not be used in an aquatic environment, which is an inappropriate conclusion.

In some cases where a clear market does not exist, it may be necessary to give excess materials away to ensure that they are reused. In those jurisdictions having legislation regulating the disposal of Crown Assets, this practice may be prohibited. The unfortunate result may be that the materials are sent to disposal rather than reused. In these jurisdictions, it may be necessary to review the Crown Assets disposal legislation.

Sometimes the road authority's own standard contract specifications and policies will limit or discourage possible management practice. A requirement for virgin aggregate as roadbed material prevents the reuse of crushed concrete and asphalt. Similarly, a low permitted percentage use of recycled asphalt pavement (RAP) in asphalt will limit the recycling of asphalt. On the other hand, a specification that requires a certain percentage of crushed concrete and/or asphalt in the roadbed of a project will encourage the development of new processing plants and increased reuse.

2.4.4 Knowledge Barriers

During the research for this paper, virtually all contacts from across Canada stated that a key reason for not using innovative management practices is the lack of knowledge of other options. Information on new and innovative options, recycled/reused products, and their possible environmental effects, is difficult to find. There is very little information sharing amongst levels of government, provinces, government departments, contractors and companies. Some of the knowledge gaps that were identified include:

- The lack of understanding of the engineering properties of products made from excess and/or recycled materials. There are questions about whether products containing recycled materials will perform as well as the products made from new materials;

- The lack of knowledge of the fate of chemicals in the new product or use. Of particular concern are the potential for producing chemical leachates and their possible impact on the environment; and

- The possible misinformation or partial information about problems with a proposed materials management practice. As discussed in the earlier section, some people are reluctant to use concrete rubble as rip rap because they have heard of problems with high pH in water that comes in contact with the concrete rubble. In fact the problem with high pH relates to the slurries that are produced by the hydrojetting demolition process, and not to concrete rubble produced by physical breaking.

There is a clear lack of research to answer questions about engineering properties, performance, and environmental implications. This research is needed to remove uncertainty, and to add credence to new practices that have not yet received universal acceptance.

2.4.5 Equipment or Process Barriers

In many areas the technology, processes, equipment, or support infrastructure necessary to permit new management approaches are not available. This is either because they physically do not exist, or the cost of the process or equipment makes them economically unavailable.

The availability of equipment and support infrastructure is market driven. Therefore, until there is sufficient demand for the equipment, process or service to make them economically viable, they will not be developed.

2.4.6 Organizational Barriers

All of the barriers to innovation are not external to the transportation authorities. In many cases the barriers come from within. Innovation requires a certain degree of risk taking, and an organizational willingness to change. Innovation can be stifled by organizational and/or personal resistance to change.

Within road agencies there are three groups involved with developing innovative management practices. These include decision makers, technical specialists and operation staff. All of these groups must accept the need for change before new practices can genuinely be investigated, tested and implemented. Anyone of these groups can resist the change and thereby represent a barrier to change.

It is not unusual to encounter resistance from those who are satisfied with the status quo. These people are comfortable with the current system and do not see the need to change. This resistance to change is even stronger when no one external to the organization is challenging existing practices. This is the most difficult situation for those who seek change, either in response to an emerging issue, or because more environmentally acceptable practices are available.

In some cases, a lack of support from senior management, has caused frustration for some middle managers or line personnel who are trying to promote new environmentally acceptable practices. This hesitation by senior management is caused by concerns over cost, resistance to unfamiliar procedures, and/or comfort with the status quo. Senior management who are not proactive will need to be shown that new procedures work in other jurisdictions and, if implemented, can benefit the organization either through cost savings, improved public image, or the avoidance of political problems.

2.5 KEY CONSIDERATIONS WHEN DEVELOPING NEW PRACTICES

This section presents a series of short subsections describing pertinent philosophy, experiences, ideas or cautionary comments to guide people when developing new material management practices. The concepts below are bits of advice gathered from people who have gone through the experiences of incurring a material management problem, and identifying, testing, and implementing solutions.

2.5.1 Value System Considerations

Changing Social Values

Social values with respect to environmental issues are changing rapidly. An acceptable management practices in use today may become unacceptable tomorrow. Therefore the challenge is to anticipate social value changes and to predict how they might affect existing and proposed management practices.

To be proactive, and avoid having to respond to crisis situations, an organization must make an effort to identify trends in public attitudes, assess their potential implications for current practices, and initiate actions to respond to those trends that may become issues for the organization. Proposed new practices must also pass the test of social value acceptability. New practices which are sound technically and environmentally, have a high probability of failure if they are not socially appropriate.

An organization's ability to anticipate and respond to change is enhanced by monitoring the changes that are occurring in other jurisdictions, and by maintaining a working relationship with the strategic policy staff in the regulatory agencies. The information that is obtained through these contacts should be assessed regularly to determine the implications for your organization. Strategies should then be developed to address emerging issues.

Transition Periods are Confusing

People tend to be comfortable with the status quo, and uncomfortable with change. Change creates uncertainty and frustration as an organization moves from the familiar to the unfamiliar. This transition period is made more difficult when the need for the change is neither well understood, nor accepted by those affected.

Proper communication is key to ensuring that those responsible for implementing new practices understand, accept and support the need for the change. They must also understand the various components of the new approach. Failure to properly plan the human aspects of a transition from an existing to a new practice, including proper communications, is one major cause of failure of new management practices. The promoters of change must plan the transition and the communication supporting this transition to increase the ease and success of implementation of new practices.

It's OK To Be An Environmentalist

Many like to pigeonhole people according to their roles. There are planners, designers, lawyers, contractors, operators, environmentalists, etc. Some believe that these people must stick to their traditional roles and not venture outside of the bounds of their pigeonholes. Consequently, the operators cannot advise the designers; the planners don't consult the contractors; and the environmentalists work in isolation. This narrow view is a product of organizational structures in which people are given specific responsibilities, and not encouraged to work with other disciplines to achieve mutually beneficial

goals.

Fortunately, this is changing. People are realizing that they must work cooperatively with others in order to achieve their goals faster and more cost-effectively. As well, lines of responsibility between agencies are becoming blurred. No longer is environmental protection only the business of the environment agencies. It is becoming everyone's responsibility. Many people in transportation agencies are willingly accepting this new responsibility, not only because they are transportation professionals, but also because they are personally committed to protecting the environment for themselves and future generations.

Working cooperatively with environmental agencies can also pay dividends by improving working relationships, building mutual understanding and respect for each other's mandates, and finding solutions to problems that achieve the goals of both agencies.

Agencies that are proactive in dealing with their excess materials have realized that we are all in this together. Some have taken the philosophical approach - seeing the environment as something that we have all been entrusted to look after. Others have been motivated by a need to preserve limited financial resources by finding uses for excess materials, thereby reducing disposal and material costs.

Instead of just being a vocation, environmentalism has become an attitude. By finding ways to integrate environmental and transportation goals, we can minimize conflict, and work cooperatively towards a better future. At the same time, the transportation sector can improve its environmental image with the public, activist groups and regulatory agencies, thereby smoothing project acceptance.

Depleting Resources

Resource scarcity can significantly affect the rate at which some new material management practices are developed and adopted. Depleting aggregate sources are particularly significant because road agencies are large aggregate consumers.

Aggregates may become depleted in terms of the absolute quantities of supply, or the supply of certain qualities of aggregate (e.g. the depletion of high quality crushed coarse aggregate). Regardless of the nature of resource depletion, road agencies facing resource shortages will find greater motivation to seek new

material management practices than those in areas still experiencing abundant and economical aggregates.

As aggregates become scarce the laws of supply and demand take over. If the demand for aggregates does not decrease, the cost will increase in response to this diminishing supply. Haulage costs will also increase because of longer hauling distances.

When the cost of a depleting resource like aggregates increases, alternative pavement structures become economically competitive. For example hot mix asphalt concrete pavement over a crushed gravel base course, over a sand subbase is typically less costly than a Portland Cement concrete pavement in an aggregate abundant environment. On the other hand in an aggregate scarce environment, the Portland Cement concrete pavement can be more economically attractive.

As well, as aggregate costs increase, it becomes more economical to reuse and recycle existing aggregates salvaged from the reconstruction of pavements, structures, curbs and gutters, or sidewalks. It may even become economical to reclaim aggregate from abandoned road and railway beds.

Resource shortages will necessitate greater efficiency in the use and reuse of materials. Although this is of particular concern in aggregate scarce regions, those still having abundant aggregate sources should start to prepare for the day when their resources begin to run out.

Total Product Life-cycle Costs

Typically, new practices are evaluated using a benefit/cost analysis, whereby the overall benefits are related to the costs. The purpose is to determine if there will be a positive return on an investment. To be effective, this analysis must include the direct and indirect costs and benefits to the agency, industry and society, over the long-term. Some costs and benefits will be realized immediately. Others may not be realized until some time in the future. Because costs and benefits are realized at different points in the life of a facility, a life-cycle review is important when evaluating any new concept.

Often the evaluation of a new practice only considers the immediate and direct effects. It may ignore long-term implications, or the affects on others. The costs of a new practice are driven by the costs of the inputs (material, equipment, labour), the processes, and the outputs (waste disposal, air emissions). These costs must be considered for both the original construction

and future rehabilitation.

Some benefits, such as cost savings, are quantifiable . However, often the benefits are non-quantifiable. These benefits may include improved public image, less contribution to greenhouse gases, slower depletion of non-renewable resources, or reduced health effects.

This concept of life-cycle costs is illustrated in the following examples. There is considerable pressure to place foreign materials (e.g. rubber, glass, etc.) into asphalt concrete pavements. Although this may have advantages in solving an immediate disposal problem for these materials, and may even make economic sense in the short term, the value of this management option should be evaluated from a life-cycle perspective. Currently, asphalt pavements are recyclable, with some jurisdictions recycling or reusing most of their excess asphalt. If we add something to the asphalt mix that limits our ability to recycle or reuse it in the future, we will be adding to our future costs. These costs come in the form of increased waste disposal costs, and the need to replace recycled asphalt pavements with new asphalt. Furthermore, if changes in material composition requires equipment changes, then there is an impact on the construction industry which must be factored into the benefit/cost analysis.

Another example comes from the City of Regina, Saskatchewan. The city has used steel slag from the IPSCO steel mills in the city. This slag makes an excellent aggregate for asphalt concrete, particularly for pavement requiring ultra high stabilities. Asphalt concrete mixes produced from this slag have marshall stability values twice the minimum usually specified for high stability mixes. It is also an economically attractive resource to the City of Regina which is located in an aggregate scarce area where high quality coarse aggregate is hauled from sources 50 km to 100 km away.

The downside of using this material does not appear until these pavements need to be rehabilitated. Experience with milling these steel slag asphalt concrete mixes shows that their tremendous hardness, high density and toughness causes accelerated wear of the grinding teeth on the milling machines. Milling machine teeth only last 25 to 50% of the time they do when milling conventional mineral aggregate concrete mixtures. This added cost of milling and recycling these pavements should be considered as part of a life-cycle cost analysis when evaluating whether or not to use steel slag.

Other more subtle considerations pertain to air quality and health issues associated with the milling process and the subsequent handling of this steel slag asphalt concrete. There are trace amounts of heavy metals within the steel

slag. These heavy metals, (normally toxic on their own) are chemically bound and physically locked within the slag particles in the aggregate and therefore, create no adverse environmental or human health impact in the original application. However, the grinding process associated with asphalt pavement milling produces a fine dust, some of which contain chromium in a form that is hazardous in air borne dust. Therefore, milling of these steel slag aggregates may create dust with chromium levels exceeding local air quality standards, necessitating special and more costly handling procedures when these pavements are being recycled. Unless a life-cycle analysis is done, these costs would not be apparent. The added protection for workers that could be realized with an alternate process is an important benefit that should be considered when evaluating these alternate processes.

Another cost that is often overlooked, relates to project delays. Project that are delayed while road agencies wrestle with public or regulatory concerns over the way in which a material is being handled, can be costly. The avoidance of these costs is a benefit that should be factored into the analysis.

Because it may not be possible or practical to quantify all of the benefits and costs, decision-makers may have to chose between options on the basis of what, in their experience, seems to be the right option. However, the key to good decision-making is to consider the costs and benefits that could materialize over the project life-cycle.

Business Opportunities/Partnerships

Some areas of the country do not have the necessary technology, industry, markets or volume of excess materials to seriously consider better management options. There are cases where little can be done to address these shortfalls. However, in other cases the shortfalls may be overcome through creative partnerships amongst road authorities, regulatory agencies, and the private sector.

In those areas where the market forces have not coalesced to establish the needed private sector infrastructure, it may be necessary for road authorities to take special action. By forming alliances with others having similar material management problems (e.g. municipalities), those having a stake in solving the problem (e.g. regulatory agencies), and possible private sector partners, it may be possible to create a climate that favours the development of the needed technology and support infrastructure. This means working with regulatory agencies, municipalities and private companies to lower the barriers that are preventing private sector companies from entering the market.

It may be necessary for road authorities to provide some seed money or contract guarantees to help new companies through the difficult start-up period. New processes and end markets would establish themselves if policies, contracts and regulations stipulated that 3R's management options must be considered and proved inappropriate before less desirable processes such as burning or landfilling can be allowed. Banning recyclable, reusable, recoverable material from landfills or increasing tipping fees would also encourage the development of new end markets and 3R's technology.

The Yukon Government, through its contracts, has required wood salvage on new clearing and grubbing operations. Ontario has specified 3R options for managing excess materials in some of its road contracts to encourage innovative approaches by the road building industry. British Columbia's ban on open burning of excess wood will help to encourage the development of alternative wood management options.

Many areas in Canada have established material exchanges that bring people who have materials together with people who want materials. This may require the establishment of storage sites where excess materials can be stockpiled until an appropriate use for the materials can be found. Municipal landfill operators or contractors can play a key role in facilitating a material exchange program.

An effective materials management program requires private sector involvement. This involvement includes manufacturing and supplying processing equipment, and facilitating the exchange of materials. Where these services do not yet exist, there is an opportunity for entrepreneurs to establish businesses serving the material management needs of the construction sector.

2.5.2 Landfill Related Considerations

Many excess road construction and maintenance materials are disposed at landfills. The regulations pertaining to landfills and indeed the basic operations of landfills are changing and may become a key factor in forcing new materials management practices. For this reason we devote some attention to changing conditions at landfills.

Landfill Tipping Fee

The cost to dispose of materials at landfills (i.e. tipping fees) has increased in many areas to decrease the amount of materials flowing to landfills. The practice of disposing of excess road construction and maintenance materials at

landfills may have to be reviewed as increasing tipping fees make this option more expensive.

Landfill tipping fees may be varied to encourage or discourage the delivery of particular materials to be landfilled. Landfills typically need soils to provide daily cover on the compacted wastes for sanitation reasons. Because of this, landfills may permit clean earth or granular soils to enter at no charge. On the other hand materials such as concrete rubble or asphalt concrete salvage cannot be used as cover soil and do not necessarily have to be disposed of at landfills. Consequently, landfill operators may discourage the delivery of unwanted materials by charging high tipping fees on these materials.

A change in tipping fee policy could significantly affect your ability to use landfill disposal. Therefore, agencies that rely on landfilling as it primary materials management practice should monitor trends towards increased tipping fees, and seek out other management options.

Landfill Bans

The new generation of landfills in North America are highly engineered waste containment facilities. It is very costly to establish these facilities, mainly due to the cost for site investigations, environmental studies, environmental approvals, and construction. The construction may include: underdrainage systems to catch and contain leachate; natural groundwater control systems; surface water drainage and treatment systems; and methane gas collection and handling systems. These systems are designed to ensure that pollutants from the landfilled materials are contained and treated, and not released to the environment.

Many of the excess materials arising from road construction and maintenance are chemically inert and do not pose a significant threat to the environment or human health. These materials do not require the containment provided by the costly engineered facilities at new landfill or waste management facilities. To avoid using up valuable capacity with innocuous materials, many landfills are refusing to accept many of the excess materials produced by road agencies.

Because there is not always forewarning, proposed material bans can have significant impacts on current material management practices and the rate at which new management options need to be developed. Road authorities should monitor landfilling policies relating to the types of materials that will be permitted, and assess how proposed changes might affect future operations.

The Linear Landfill

"The linear landfill" is an expression used to refer to the use of linear facilities, such as a highway, as a repository for waste materials. This does not mean that the highway subgrade will be constructed of municipal garbage. Rather it means that the highway could become a repository for particular wastes such as glass, rubber, mining slag, carpet fibres, or ceramics.

Although the scope of this study does not include the incorporation of non-road generated materials into roads, the linear landfill concept is discussed here because it has implications on future management practices for excess materials from road construction and maintenance.

We have already discussed how increased landfill tipping fees and selected acceptance of materials at landfills, are putting pressures on the transportation sector. These trends are also affecting the manufacturing sector. In the past many manufacturing operations disposed of their excess materials at landfills. Increased tipping fees and material bans are forcing manufacturers to look for less expensive management options for their materials.

Many people perceive highways as large facilities, possibly able to accept their excess materials for incorporation into, and enhancement of, the road subgrade or pavement structure materials. In some areas, particularly the more highly industrialized or manufacturing areas in the United States, road agencies are being overwhelmed by offers of excess materials.

It is possible that some of these materials would make good substitutes for aggregate, provided it can be shown that the materials are inert, will not adversely affect facility performance, and can be recycled or reused when the facility needs to be rehabilitated in the future. This provides an opportunity for road authorities to work with the private sector to conduct jointly funded research to confirm that these materials can be used with no loss of properties or environmental quality. Both the road authority and the manufacturer may benefit from an exchange of materials. The road authority may be able to charge a disposal fee and substitute for new materials, while the manufacturer may gain a more economical disposal option than landfilling.

However, road authorities must be careful to properly assess the potential implications foreign materials can have for future materials management practices. As discussed in the section on Total Life-cycle Costs, anyone contemplating incorporation of other materials into their roads should ask themselves "Can the resulting product be recycled in the future?" For example

we know that traditional hot mix asphalt concrete mixtures can be recycled to produce recycled asphalt concrete pavement with suitable engineering performance properties, without adverse environmental impacts. However, we may not know if asphalt concrete incorporating non-traditional materials, can be initially produced and eventually recycled, without adverse environmental impact and with the desirable pavement performance properties. If these new material additives prevent recycling of the asphalt concrete, then we may be creating a significant waste disposal problem when the road needs to be resurfaced in the future.

2.5.3 Tactical Considerations When Developing New Procedures

There are several key aspects to ensuring that organizations develop and implement new environmentally sound practices in a cost-effective and timely way. The following subsections contain advice based on the experience of others who have tried innovative or proactive practices and pass on advice as philosophical comments, specific experiences or cautioning remark to other road agency staff seeking to improve their materials management practices.

TAC Environmental Code of Ethics

The Transportation of Canada (TAC) has prepared an Environmental Code of Ethics. It is included in this report as Appendix A. This Environmental Code of Ethics was prepared by TAC's Environment Council and approved by the Board of Directors in September, 1992.

The Code of Ethics consists of a preamble and 14 principles about the different environmental aspects of transportation in Canada. Each principle is a value statement intended to guide transportation decision makers as they develop specific programs, policies and practices. As each management practice for excess materials is developed or reviewed, it should be tested to determine which value statements apply. For those that apply, it should be determined if the management practice satisfies the values stated. If the management practice does not satisfy the goal of any particular value statement, then the practice may be inappropriate. In that case the practice should be reviewed and modified so that it does achieve the goals articulated in the Environmental Code of Ethics.

Codes of Practice

Although it was possible for TAC to create an Environmental Code of Ethics, it is felt to be inappropriate for TAC to be defining how different transportation sectors and individual transportation organizations apply the Code of Ethics within their sector or agency.

The Code of Ethics is intended to set out principles that will guide the development of codes of practice. These codes of practice are the specific procedures, methods and standards by which a particular agency achieves its goals. For example, a provincial highway department may have a procedures manual for its maintenance equipment repair garage. One section of that procedures manual may deal with the storage and disposal of excess or waste fluid from the garages. These fluids could include gasoline, oil, transmission fluid, brake fluid, windshield washer fluid, oily and/or salt-rich waters from the wash bays, and spent solvents. The maintenance manual should have very specific procedures, methods, and standards with respect to the handling, storage and disposal of each of these materials. These specific "Codes of Practice" should be compatible with the value statements contained within TAC's Environmental Code of Ethics.

Some agencies prefer to have their environmental codes of practice kept as separate volumes. However, the trend is to integrate the environmental aspects within comprehensive codes of practice which form the organization's design, maintenance, administration, and/or technical manuals.

These manuals prescribe procedures which are acceptable with respect to safety, economic efficiency and environmental criteria. As such, the environmental criteria are fully integrated within the manual of practice and not segregated. This is done to show that environmental considerations are just one of the many considerations required in a procedures manual. It is also done for ease of use of the manual, allowing staff to refer to one source for all the information on the appropriate procedures. Finally, this integrated approach reinforces the fact that environmental protection is everyone's responsibility.

New excess materials management practices are largely codes of practice which define how your agency handles a specific material in an economical, safe and environmentally acceptable manner.

Highest and Best Use

This term "Highest and Best Use" is borrowed from the land and building assessment professionals and refers to putting an asset to its highest valued use. There may be several options available for managing excess materials, however, the highest and best use of any excess material is usually its original application. Other uses, although environmentally acceptable, take advantage of a smaller percentage of the material's potential economic benefit. Any particular management option can be placed on a grid with environmental benefit on one axis, and economic value on the other. The preference is to choose the management option that is best environmentally, and takes greatest advantage of the economic potential of the material. Figure 2.1 illustrates this concept.

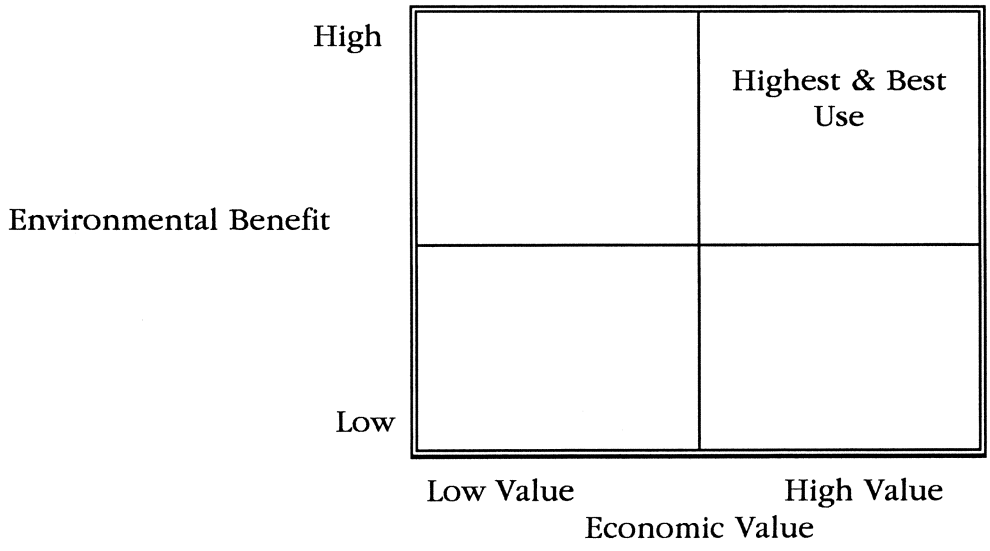

FIGURE 2.1

For example, consider salvaged hot mix asphalt concrete. The coarse crushed aggregate and the asphalt cement each has an economic value. Therefore, the highest and best use of salvaged hot mix asphalt concrete is as recycled asphalt concrete pavement, because value is drawn from both the aggregate and the asphalt cement.

The next best be used would be as a crushed granular base course. The third best use would be as crushed subbase or select granular material for the top of

a subgrade. The fourth best use would be as a granular subgrade fill or trench granular backfill. Disposal at a landfill where no value is derived from the material, is near the bottom of preferred options - slightly better than dumping the material on vacant lands.

As long as both the crushed aggregate and asphalt cement from the salvaged asphalt concrete meet the standards for recycled asphalt concrete pavement, the highest and best use practice is preferred. However, sometimes there are deficiencies in the aggregate or asphalt cement quality relative to new materials standards for recycled asphalt pavements. In this case the recycled asphalt concrete is not suitable for the highest and best use but may then be suitable for use in a lower quality recycled asphalt pavement for a lower standard of road surface or possibly as a crushed granular base course product.

An example of where the highest and best use was not possible, is the use of recycled asphalt concrete materials in new pavements in the province of Quebec. Rutting of asphalt concrete pavements has been a significant problem in North America during the past 10 to 15 years. The Ministère des transport du Québec did extensive studies and determined that, by adopting new aggregate standards, the quality of its asphalt concrete could be improved to eliminate historical rutting problems.

Much of the asphalt concrete pavements now being recycled comes from roads that were constructed 15 to 30 years ago, using aggregates which do not comply with current aggregate standards. Therefore these recycled asphalt concrete pavement materials cannot be put to their highest and best use. However, they are suitable for use on secondary or lower standard pavements.

Therefore, when seeking out new management options, material managers should give preference to options that use the excess materials in their highest and best use.

Someone Else Has a Solution for You, Usually

Your agency is not the only one in the country seeking to develop new excess materials management practices. In many cases some other agency has already faced similar problems and developed effective new management practices. It is much easier and less costly to copy a proven practice from another area and avoid the difficulty and expense of local testing. Unfortunately, many of the new excess materials management practices are developed, tested and implemented in a quiet and operational way without fanfare or reward. The new practices are seldom presented at conferences or published in technical

journals. Therefore, the challenge becomes finding those agency that have grappled with, and found effective solutions to the problem facing you.

The place to start looking for help is through the informal networks that you have developed with nearby government officials, consultants, manufactures, contractors or university researchers. As well, networks developed through industry organization such as the Transportation Association of Canada, local Construction Associations, local Road Building Associations, the Canadian Technical Asphalt Association, Recycling Councils, or the Provincial Public Works Association provide excellent sources of information on new solutions.

Excess Materials Practices Are Context Sensitive

Although you are encouraged to learn from the experiences of others, you must be careful when adopting a practice from another location. New excess materials management practices developed and found highly successful in one region of the country may be unacceptable in another region.

A shotgun approach to searching out solutions may not be the most efficient, since the applicability of a solution is context dependent. People who have experienced and resolved problems in a context similar to yours are your best source of information. Therefore, before seeking out agencies who may have experienced similar materials management problems as yours, pre-qualify these other agencies by assessing the similarity of conditions in their locale to those in your jurisdiction. This pre-qualification improves the probability of finding solutions that are directly transferable, or transferable with small modifications.

If conditions at the source location and your location are similar, then the new practice may be directly applicable with no modification. If your conditions differ, then some local modification may be required to make the practice suitable in your situation. Sometimes no amount of modification can make a successful practice from one location appropriate at another location.

When considering context issues, two factors are particularly relevant - cost and regulatory climate. The economic viability of a material management option relates to factors such as tipping fees, haulage costs and processing costs. These can vary significantly from one location to another. Therefore, a practice that is cost effective at one location may not be viable at another location. Similarly, the regulatory framework in one jurisdiction may favour a certain practice, whereas it may prohibit the same practice elsewhere.

Therefore, before blindly adopting a practice from another jurisdiction, it is important that you review the context in both locations to ensure that the new practice is workable in your locale.

Reduce, Reuse, Recycle or Dispose

Apart from recycled asphalt concrete pavements, road agencies in North America have done little to reduce, reuse and recycle excess road materials. Generally the accepted practice was to dispose of excess materials by: spreading them within or outside of the highway rights-of-way; excavating pits and burying the materials; burning wood materials; or hauling materials to landfills, gravel pits, or quarries. However, the cost of these disposal practices, expressed as handling and haulage costs, landfill tipping fees, or environmental costs, has increased to the point where disposal is becoming too costly, and environmentally and socially unacceptable. Consequently, many new materials management practices involve abandoning the disposal solution in favour of ones that reduce, reuse or recycle these materials.

The 3R options often require pre-planning and creative thinking. To reduce the amount of excess materials generated, planners and designers need to consider material management issues at the early stages of a project. The amount of excess materials produced from a project can be reduced by: better balancing of cuts and fills; avoiding problems soils; and minimizing areas requiring clearing and grubbing. As well the ability to reuse items such as signs and posts, culverts, and guiderails can be improved by more carefully removing these materials during construction. Even in those cases where a damaged item removed from one project may not be able to be returned to that same project, it may still be suitable for reuse on another project. For example, a bent guiderail from a freeway can be straightened, and although it may not meet the standard for reuse on a freeway, it may still be suitable for use on a lower volume road.

It is also possible for road agencies to reduce the amount of materials sent to disposal by replacing historically used materials with materials that do not have the same environmental concerns or are more easily recycled. For example, pre-cast concrete barrier curbs and median barriers can now be constructed from recycled plastics or recycled rubber tires. The new plastic or rubber curbs and barriers are chemically inert and durable under the aggressive weather environments that currently attack and accelerate deterioration of pre-cast concrete elements. In addition to having a longer life, these materials can be recycled into new curbs or barriers, whereas the badly deteriorated pre-cast concrete units have traditionally been sent to disposal or crushed to produce

aggregate for granular applications. Recycled and recyclable plastics are also being used to replace pressure treated wood in sign posts, thereby eliminating the disposal problem associated with pressure treated wood.

Future Record Keeping

In the sections on Life-cycle Costs and Linear Landfill, we discussed the importance of considering whether your new materials management options will create problems for you in the future.

Our traditional road maintenance and construction materials have been relatively uniformed in chemical composition. As such there has been no need to keep records of where specific materials were used. However, in our efforts to reuse excess materials, firstly generated by road construction and maintenance activities, and secondly generated by other industries, we are producing atypical materials. To facilitate reuse and recycling in the future it is possible that materials salvaged from various locations will be brought to central locations where they will be mixed together and put through a crushing and screening operation to yield one stockpile.

With the use of non-traditional materials in mixes, these stockpiles may no longer be homogeneous. They could start to bring together chemicals that were acceptable when isolated in a specific mix design, but may cause problems when combined. As well, if not careful, one bad batch of material brought to a storage site could contaminate the entire stockpile. For example, there were sections of roads constructed with asbestos modified asphalt concrete pavements before asbestos became a health related concern. Good records of where these pavements were used, were not kept. Now there is concern about the health effects associated with removal of these pavements. As well, if these pavements are inadvertently brought to a stockpile location, they could contaminate the whole stockpile. The same concern can arise with pavements that have been contaminated by chemical spills.

Most road agencies do not have the chemical technology or the record keeping systems that allow the tracking and management of atypical materials. As agencies consider using innovative material designs to solve excess material problems they must consider if a special tracking system for these materials is required to ensure proper management in the future.

Some Change Takes Time

The Canadian road construction and maintenance industry is large and uses

specialized equipment and staff trained to use traditional equipment and materials. Although the construction industry is continually adjusting to new requirements, in some regions of Canada, the industry's ability to use new management practices may be constrained by a lack of availability of the required equipment, and experienced personnel.

Some new practices will require a period of testing to confirm their acceptability. Once a new practice has been found to be acceptable, time and resources will be required to acquire the necessary equipment fleet and trained personnel to effectively implement the new procedure. Therefore the rate of change may be slow.

There is also a whole new industry developing around the supply of more environmentally acceptable products and processes. Road agencies can be barraged by sales people promoting the latest new solution to their environmental problem. It is important for road agencies to take time to properly assess these new products and processes.

However, the fact that some changes may be slow and difficult to implement should not be used as an excuse for inaction. The environmental and economic imperatives are sufficiently great that road agencies must genuinely seek innovative excess materials management practices. Therefore innovators must be clear in their goals and tenacious in their pursuit of these goals.

Monitor The Trends

In Section 2.5.1.1 we discussed changing social values and their implications for transportation agencies. It is not easy to keep abreast of changing values, regulations, policies and practices. However, in order to anticipate change and avoid having to respond to events once they have become a crisis, it is important that road authorities monitor trends in public attitudes and public policy.

This monitoring must not only track local trends, but also must track trends in other jurisdictions. Requirements for change do not usually hit across Canada at the same time. Rather they tend to start in one location and gradually move outwards at varying rates. By monitoring trends in other jurisdictions, you will be able to learn about emerging issues before they come to a head in your location. This will allow time to develop a response to the issue, drawing on the experiences of others.

The common term used to describe this monitoring is "Environmental Scanning". Most road agencies use environmental scanning to monitor trends in such areas as: vehicle weight and dimensions regulations; environmental regulations and standards; taxation; tariffs; and economic incentive/barriers. Material management practices should be monitored in a similar way.

The monitoring of environmental regulations is particularly important in ensuring that road agencies identify proposed regulatory changes that could affect their business, early enough that they can either influence the development of the regulations, or begin adjusting to the new requirements.

The air quality standards in the USA illustrate this need. In 1988, the Occupational Safety and Health Administration (OSHA) of the United States Department of Labour proposed a new air contaminant rule that would have listed asphalt fumes as a "Substance For Which Limits Are Based On Avoidance Of Cancer". This was after a considerable body of research had established that asphalt fumes were not harmful if kept below 10 mg/m^3. The regulators were still linking asphalt fumes to coal tar fumes. Although coal tar fumes are carcinogenic, this is not the case for asphalt fumes.

The air emissions of the asphalt concrete paving operations, particularly that arising from the spreader, exceeded the proposed new air quality standards. If this misperception was to prevail, the new Air Contaminant Rule might have passed, thereby adversely affecting the hot mix industry. Many of the practices commonly used by road agencies for hot mix asphalt concrete pavement maintenance would not comply with these proposed new air quality standards. Worst yet, there was no reasonably available technology which could be applied to reduce the emissions of concern.

Proceeding to implement these standards likely would have had the following results:

- The cancellation of hot mix asphalt concrete paving contracts;
- Business failures amongst hot mix asphalt concrete paving contractors;
- A switch by the construction industry to a Portland cement concrete pavement, necessitating a significant change in technology. This technology could be expanded in terms of its construction capability, but that would take time and

money; and

- Existing road agencies would have to find new maintenance practices that were within the new air quality standard, and would have to convert their equipment and skill sets from ones geared to hot mix asphalt concrete pavements to ones geared to Portland cement concrete pavements.

It had not been the practice of the hot mix asphalt concrete paving industry to follow the development of air pollution standards. When industry members became aware of these draft air quality standards they had major concerns. The industry eventually mobilized its opposition to the new standards and increased efforts to educate the regulators about the health effects of asphalt fumes. These efforts were successful in convincing OSHA not to include asphalt fumes in the list of " Substance For Which Limits Are Based On Avoidance Of Cancer".

This case illustrates the potential impacts legislative changes can have and the importance of becoming involved early so that your interests can be considered as new legislation is developed.

Be Proactive

The example in the previous section about the impact legislative changes can have on an industry, illustrates the importance of being proactive. If the hot mix asphalt concrete paving industry had used a proactive approach, it would have established the nature of air emissions from its operations and advised the drafters of the new standards of these emission levels. This approach would have identified the conflict early in the process, and provided time for all parties to consider the implications and work out mutually acceptable solutions.

Environmental regulators cannot be aware of all of the possible impacts of their new regulations and standards. Road agencies and associations can help to ensure that regulations are practical and implemented with the least impact on their operations by being proactive, and becoming involved in the regulatory process. In doing so, however, it is important for a road agency to understand the purpose behind the proposed change, and to work with the regulatory agencies to find ways to achieve the regulatory goals while at the same time satisfying the road agency's needs.

Early involvement will also make road agencies aware of upcoming changes to environmental regulations and standards, and allow them to use the advance time to develop new and appropriate management practices that will be consistent with the new regulatory requirements.

Talk To Strangers

Twenty-five years ago few road agencies were actively talking to people outside of the transportation sector. Now road agencies routinely interact with specialists in different disciplines including specialties such as botany, fisheries, wildlife, and archaeology. In fact, many road agencies now have environmental specialists on staff. This has helped road agencies to develop improved relationships with these non-traditional disciplines, and to better understand how their interests can be incorporated into the daily activities of a road agency.

There are also technologies, equipment and processes currently available and well proven in industries far removed in subject content from the road agency's activities. Some of these may provide solutions to a road agency's excess materials management problems. Other industrial sectors may also have need of an excess material that is produced by a road agency.

By speaking with people in other sectors, it may be possible to develop material or technology exchanges that benefit both parties. This is not an easy process. It usually involves detective work to identify and follow up leads until a successful linkage can be made. You may go down several blind alleys before finding a potential partnership. The following sets out some steps you may want to take:

- Learn the chemical and physical properties of your material. Potential users of the material will want to know if it meets their quality standards;
- Contact the local waste exchange to see if they know of someone in need of your material;
- Contact people in the industries that would typically use your excess material; and
- Contact the suppliers of the material that you need to manage, and find out if they can use the material, or can tell you of industries that may be able to use your material.

For example, if you have sand to dispose of, then contact companies that supply or use sand to see if there is anything about your sand that would make it inappropriate for their use.

You will need to continuously follow up leads until you find companies that may be willing to take your surplus material as an input to their process. In the best case they may be willing to buy the material from you. This could offset your handling costs and possibly reduce the receiver's material costs, thus creating a win-win partnership.

2.5.4 Organizations and Proactive Concepts

To successfully develop and implement new materials management practices an agency must effectively deal with both the hard and the soft components of the issue.

The hard components are the technology, economics, engineering, chemistry, physics, biology, and construction and maintenance techniques. These are the nuts and bolts that make the new management practice work.

The soft components are the people and information related aspects. These deal with communication, both internal and external, and politics in both the formal and informal sense.

To be successful, road agencies must understand and effectively manage both the hard and soft components. Many beneficial practices that are sound with respect to the hard components fail during implementation because the soft components are poorly handled. The following sections discuss some of these soft issues that must be addressed when managing excess materials.

Develop New Practices by Team Work

Material management teams are an effective vehicle for identifying, assessing and implementing new material management practices. Specific teams should be formed for the identification, assessment, and implementation of specific excess materials management practices. Traditionally these teams have consisted of the technical, operational and management staff most closely related to the materials under review.

However, to be most effective, people representing the entire project development process, including planning, design, construction, maintenance,

reconstruction and retirement, should be involved. Often times the solution to an excess materials problem lies with the designer, or the contract specification writer. Therefore, when building a material management team, it is important to include people involved with the other stages of the facility's life-cycle. In addition, the team should include one or more environmental specialists.

If the skill sets and knowledge required by the development team are not available within the road agency then you should seek expertise from other agencies, or hire consultants.

It is often advantageous to include representatives from the regulatory agencies on the team. This will help to ensure that the solutions developed will be in compliance with legislative requirements, as well as help to build a cooperative relationship with regulatory agencies.

The teams should be small groups with minimal structure and formality, and maximum communications and efficiency. Team members should be selected on the basis of their commitment to a common goal, and willingness to work cooperatively with the other team members. Those who are not results-oriented, or are unable to work cooperatively, should not be involved.

Eventually new excess materials management practices must be passed to an operating group to implement, monitor and modify as necessary for the practice to remain effective for the agency. Since change is inevitable, particularly with respect to environmental requirements, road agencies must be prepared to modify new management practices as often as is necessary to remain consistent with environmental requirements. Once the practice has been successfully implemented, the team ceases to exist in a formal sense.

Do Not Segregate Environmental Management

There are many factors to be considered when carrying on business in a road agency. Virtually everything that the road agency does must be reviewed in economic, safety, staffing, political, and environmental terms.

The responsibility for addressing environmental factors can either be centralized or decentralized within an organization. Both approaches have their merits. However, road agencies cannot effectively incorporate environmental considerations into its practices if all responsibility for environmental issues is left to environmental officers in a centralized environment section. Consideration of environmental issues must be integrated into all decision making, and not left solely to a centralized group.

The technical and operation staff within the road agency that are most familiar with particular excess materials are the best people to identify, assess and implement new materials management practices. However, these staff likely will need extra training or information with respect to the environmental aspects of the material being reviewed.

Although lead responsibility for addressing material management issues should lie with the operational staff, there is merit in having a centralized environmental unit responsible for staying on top of new environmental requirements and for making the organization aware of emerging issues that require attention. This group could also provide environmental expertise to the operational groups within the organization as they develop and implement new procedures. Finally, the environment group could provide senior management with an independent review of how well the organization is doing with respect to reducing the environmental impacts of its operations.

Encourage Informed Risk Taking

Many people within road agencies are comfortable with processes that have been in place for decades. Often these people will only accept a new approach once it has been proven through years of field tests. Many who are comfortable with the status quo, will use a "look before we leap" argument as an excuse to delay change.

Strong leadership by people with a vision for a better future is required if organizations are going to break the bonds of tradition, and seek out new and better approaches to carrying on business. However, technical and operational staff are charged with a duty to provide decision-makers with reliable predictions as to the appropriateness of proposed new products and practices. Therefore, where the investment is high, time for proper assessment must be allowed.

A road agency must consider itself much like an investor making financial decisions. Financial investor must judge, within their value system, whether the risk associated with an action is commensurate with the potential return. In a similar way, road authorities must determine if the cost of obtaining additional information to better define the risk and payback, is warranted. Assessment processes require time and money, which may not always be available. Therefore road authorities must be prepared to take on the challenge, gather what information they can, make the decisions, and accept the consequences. Transportation professionals must have confidence in their ability to draw on their expertise and that of their colleagues, and to develop better ways of doing

business. You must make sure you have the necessary information to make informed decisions, while being careful not to get bogged down in analysis.

Plan Your Communications

Effective communications must be planned and form part of the development and implementation strategy for any new initiative. This must include all affected stakeholders, including those positively and negatively affected. For each new initiative, the project team should develop a written communication plan identifying the purpose of communication, who will be the focus of the communications, and what form the communications will take.

Communications must be directed both internally to the organization, and externally. Effective internal communication is necessary to ensure that the need for change is accepted; that new procedures are properly developed; and that those required to implement a new practice are properly prepared.

External communications are important for the organization to stay abreast of emerging issues; to learn about new procedures; to develop partnerships; to develop effective working relationships with regulatory agencies and the public; and to inform stakeholders of the efforts being made.

An effective communication strategy will help your organization to achieve the following:

- To strengthen ties with your supporters;
- To build bridges to your opponents;
- To keep abreast of emerging issues;
- To learn how others are dealing with similar issues;
- To establish networks for information exchange and possible material exchange;
- To solicit input to the development of new practices;
- To get organizational, regulatory, and public buy-in to new practices;

- To train those responsible for implementing new practices; and
- To inform others of new process that you have developed.

Do Small Trial Sections

Experience in your climatic, economic, regulatory, and social context is the most useful assessment tool when judging whether to implement new products or practices. Often new ideas come from agencies with conditions somewhat different than those in your locale. In many cases, road agency staff can assess the similarity of the practice and conditions in the two jurisdictions. However, some new methods may require local pilot projects, or in-situ full scale, full time test section to prove their applicability to your situation.

Pilot projects should be designed as a sound scientific experiment. It is important to define: the issues or parameters for testing; the methods of measuring to get the required information; the methods of data processing and analysis; and the standards by which the pilot project will be judged as a success or failure.

However, before you re-invent the wheel or work on an issue alone, consider all of your options. It is cost effective to learn from others, or to share in the development costs through cooperative research programs with other road authorities, regulatory agencies, private sector companies or industry associations.

Separation at the Source Needed

The production of the materials used in road building requires uniformity in the quality of both the inputs and the production process. This uniformity is necessary to create a material that complies with established standards which are known to give desirable performance in the road structure. Variations in the quality of inputs can result in the production of unacceptable materials. As well, other potential outlets for excess materials may require uniform characteristics. For example, one wood reprocessor may require softwoods, whereas another may need only hardwoods.

Excess road construction and maintenance materials come from a variety of conditions. Asphalt concrete salvaged from different projects can contain different types of asphalt cement or qualities of aggregates. As well, the extent of deterioration of concrete materials varies from sound to badly deteriorated.

These variations will result in the production of different qualities of aggregate when the material is crushed.

A mixed load may be unacceptable in a reuse and recycling process. A stockpile containing subbase sand, crushed base course gravel, slabs of asphalt concrete and sections of concrete curb rubble does not assist in reusing or recycling any of these materials in their highest and best use.

Therefore, the ability to reuse excess road materials may require separation of different materials into different stockpiles when the material is first being removed or salvaged. The obvious level of separation is by materials. However, in some cases it may be necessary to use more subtle separations such as concrete rubble by deterioration condition and hot mix asphalt concrete pavements by aggregate quality criteria.

Although separation at the source adds to the handling costs, this cost is balanced by the economic benefits of being able to obtain the highest and best use because the material is uniform and uncontaminated.

Time to Accumulate Excess Material

Excess road construction and maintenance materials accumulate on different time frames. Most often maintenance generated materials accumulate in small daily quantities on a continuing basis. Construction related excess materials can be created in small or large quantities over short or long time periods. Major, shorter schedule reconstruction projects generate large volumes of excess materials in short time frames.

Excess materials management practices must accommodate the varying quantities, frequency, and rates of material generation. Viable uses of materials may not always be readily available at the time the materials are generated. As a result, material managers need to coordinate the timing of supply and demand. For example, a project may generate excess earth material that could be used on another project scheduled for construction the following year. The material will have to be stored until the receiving project is ready to proceed. This may introduce special handling, stockpile maintenance, and permitting considerations. The preference would be to stockpile the excess material at the site of the receiving project. However, this would require that the design of the receiving project had proceeded to the point where fill requirements are known, that sufficient property had been acquired for the stockpile, and that the necessary approvals to proceed with the receiving project are in place. Significant coordination is required to ensure that the material can be reused

on other projects.

Often excess road construction and maintenance materials must be processed before reuse. Examples of this reprocessing include: crushing of slabs of hot mix asphalt concrete and concrete rubble to produce a granular aggregate; crushing or shredding of stumps; and screening of stockpile materials to achieve particular grain or chip sizes. These crushing and screening operations require a minimum volume of material to justify the cost of bringing specialized equipment to the stockpile site. It may be necessary to accumulate particular excess materials from several projects, over a period of time before there is sufficient quantity at the stockpile site to make the processing operation cost-effective.

Traditionally stockpiles of excess road maintenance and construction materials have not had the same priority status as stockpiles of new construction materials. These excess materials were often kept off to the side in case they were needed sometime in the future. Road agencies have not kept records of quantities and qualities of these materials stockpiles. Consequently, the materials were either not effectively used, or forgotten.

To address this problem, road agencies, such as the Manitoba Department of Highways and Transportation, have concluded that plans for the reuse of salvaged excess materials must be in place and executed as part of the construction activity that created the salvaged material. When preparing these plans, the preferred management option is to have the material salvaged from a project, processed and returned to the project. If the material can not be returned to the project from which it was generated, then it is allocated to another nearby project - both in location and time. This proactive approach to excess materials management ensures that the greatest value is obtained from the material, at the least cost.

Build Credibility

Transportation professionals tend to carry out their responsibilities without a lot of fanfare. As a result, many new and innovative products and processes go unnoticed.

Transportation agencies can improve their credibility with the public, environmental groups and regulatory agencies by profiling their efforts to implement measures that are more environmentally acceptable. By doing so, the agencies develop an image of caring for the environment. This image builds a level of trust between the transportation agency and other

stakeholders. Having this trust makes it easier to work together to address emerging issues, or resolve conflicts. In fact, once an agency has established a level of credibility with the media and regulatory agencies, it will often be consulted on issues of common interest.

Provincial transportation agencies often provide leadership in identifying and addressing transportation-related issues and transferring their newly acquired expertise to their municipal and private sector partners. This helps others in the transportation sector to learn about and apply new practices without having to incur the development costs. In a similar way, these new experiences should be shared with people in the transportation sector across Canada so that other jurisdictions can learn from, and build upon, your work.

By providing this leadership on environmental issues, provincial agencies can advance the principles of environmentally sustainable transportation, increase the pace of change in a more cost effective way, and enhance the credibility of the transportation sector with the public and environmental community.

3.0 A NEW MATERIALS MANAGEMENT APPROACH

The comments, advice and cautionary remarks given in Chapter 2 provide the philosophical background for the development of excess materials management practices. This chapter provides a 4 phased approach to addressing material management issues. It is intended to help transportation agencies to take an organized, proactive approach to resolving material management issues.

3.1 PHASE I - SETTING THE ORGANIZATIONAL CONTEXT

Before sending people throughout your organization in search of new ways of doing business, it is critical that the organizational context within which they are to work is clearly established. This context must be accepted by senior management and communicated throughout your organization. The context has two aspects. The first is the guiding principles for action, and the second is the basic organizational structure.

3.1.1 Set the Guiding Principles

Your organization must be clear about how it wants to proceed. Does it want to be a leader in finding more environmentally acceptable practices, does it want to be a close follower of others, or does it simply want to comply with the legal requirements? A proactive approach involves showing leadership that is guided by your vision of the future, rather than solely by legislated requirements. Your vision should be clearly expressed through a series of guiding principles. The Transportation Association of Canada (TAC) has prepared an Environmental Code of Ethics to help you to set these guiding principles. Your agency should either adopt TAC's Environmental Code of Ethics, or develop a similar code suitable for your circumstances. Your Code of Ethics will provide the philosophical basis for future action, and the environmental context for judging your current and proposed practices.

The Environmental Code of Ethics used by your agency must be understood and supported by senior management and staff. Without this support, it will be difficult to proceed in a consistent fashion, and to deal with the difficult tradeoffs that will have to be made.

3.1.2 Design the Organizational Structure

It will be necessary to define how your organization will handle the review of material management practices. One person must be assigned the responsibility to manage the process for identifying and resolving material management issues. This person may wish to establish a small steering committee to help guide the overall process, however accountability to senior management must be clear. The specific responsibilities of the process manager includes:

- Assembling and directing the steering committee;
- Directing the problem identification phase;
- Organizing the teams that will assess the specific materials;
- Monitoring the progress of the teams;
- Keeping senior management aware of the progress of the teams; and
- Monitoring the effectiveness of new excess materials management practices.

3.2 PHASE II - PROBLEM IDENTIFICATION

The purpose of this phase is to identify existing or emerging material management issues and to identify those materials requiring specific attention. This phase involves the assessment of the effects external influences can have on your internal processes, and the determination of which issues require immediate attention.

3.2.1 Environmental Scanning

Environmental scanning is the process of monitoring external trends that could impact on your operations. There are usually clues that forewarn you of impending change. By watching for these clues you can prepared you organization in advance so as to minimize the degree of upheaval the changes will cause. The following are some factors that your organization should document and monitor:

- Current and changing social and environmental values within your jurisdiction;
- Current and changing environmental regulations (municipal, provincial or federal) that apply in your jurisdiction;
- Changing technologies, processes, or equipment;

- Landfill issues such as tipping fees and material bans;
- Storage issues;
- The potential for cost increases for current excess materials management practices;

- The potential for materials supply scarcity or depletion; and
- Changes initiated in other jurisdictions.

Environmental scanning should be an ongoing process. It requires people who can recognize the signs of change and can predict what the potential changes could mean for your organization. Possible changes and their implications should be communicated to those who could be affected, both inside your agency, and within you private sector and municipal partners.

3.2.2 Document Your Materials

In order for you to assess the need for change, and to properly evaluate options, you must have a thorough understanding of your materials and current management practices. Therefore, you must take the time to perform the following two steps.

A. Identify and characterize the excess materials that are currently being generated, with respect to:

- the process leading to the generation of the material
- source (i.e. types of activities)
- nature of material (physical & chemical)
- volume
- timing
- environmental concerns
- potential value

B. Identify how each material is currently being managed. Classify the management practice according to the hierarchy of "highest and best uses". For example enter the percentage that is going to each of the following uses:

- Recycled into same product ___ %
- Reused by the agency ___ %
- Reused elsewhere (specify) ___ %
- Disposed of on-site ___ % (specify methods)

- Disposed of off-site (non landfill) ___ % (specify methods)
- Disposed of off-site (landfill) ___ %

3.2.3 Identify Potential Problem Areas

Your next step is to review the materials and current practices on the basis of the trends identified through the environmental scanning process. By doing so you can identify practices that are currently unacceptable, or are likely to become unacceptable in the future. A management practice may become unacceptable because of legal non-compliance, high cost, or environmental or social concerns. You should also review existing material management practices that do not represent the highest and best use for the material, for possible areas for improvement.

3.2.4 Identify Target Materials

The urgency with which a potential problem will need to be addressed is a function of two factors - severity and extent. The severity of an issue can be assessed on the basis of the following:

- Is there a compliance problem?
- Is it a crisis or a costly problem?
- How soon will the problem materialize?
- What are the implications of not resolving the problem immediately?

Non-compliance situations and emerging issues that could cause significant political or operational problems should be given highest priority.

The extent of a problem is related to both the volume of the material and the rate at which the material is generated. Changes in the approach to managing large volume materials are likely to have a greater impact on the organization than for small volume materials. Issues that could have a high degree of severity and are related to large volume materials should be dealt with first. This is illustrated in Figure 3.1.

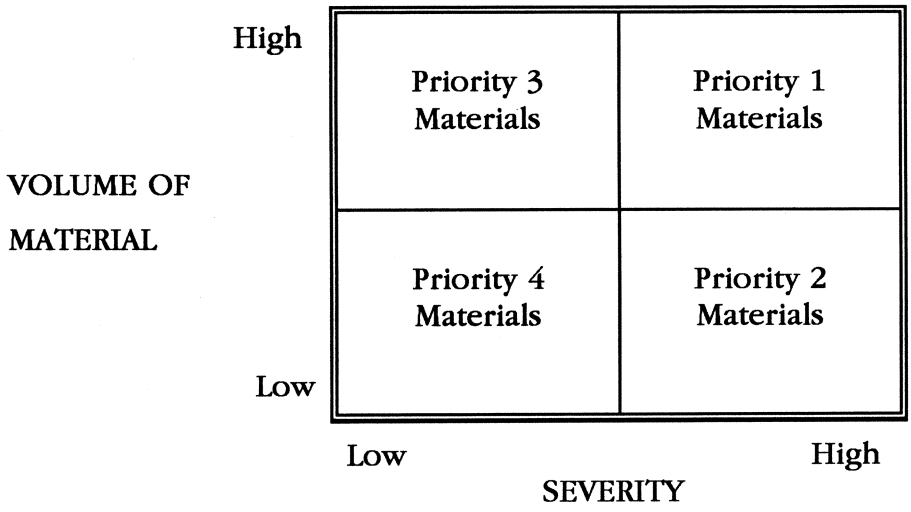

FIGURE 3.1

3.3 PHASE III - PLANNING

Once the priority materials have been identified, it is necessary to form specific teams to identify, assess, refine and implement new management options for each material. It is these teams that have the responsibility for developing the strategy to address a specific problem. The following discusses some of the required steps in this phase.

3.3.1 Organize the Teams

Once the priority materials have been identified, specific issue working teams should be organized to conduct the detailed analysis. The specific issue teams will refine the problem, identify alternate materials management practices, define and execute the assessment process including the acceptance criteria, and develop the implementation plan.

These must be results oriented, multi-disciplinary working teams. The size of the team will depend upon the scale of the problem, and the number of organizational units within your agency having a stake in the problem and the solution

The team's first task should be to prepare a workplan with specific milestones and a timetable. The workplan should include a plan for communicating the

team's progress to the overall program manager, senior management, and other key stakeholders.

Each specific issue teams will disband once its new materials management practice is implemented.

3.3.2 Refine the Problem

The characteristics of each material should have been documented during the **Problem Identification Phase**. These characteristics will likely need to be further refined by the team to ensure that it fully understands the nature and dynamics of the problem, before beginning to identify solutions.

The teams should consider whether or not the external influences that are driving the need for change can be neutralized. For example, your material may have been inadvertently caught during the drafting of a proposed new regulation. If it seems inappropriate for your material to be covered by the regulation, then the strategy should be to work with those drafting the regulation to convince them not to include the material. The following steps assume that a change in approach to managing a material is needed.

3.3.3 Define and Evaluate New Management Practices

When you determine that it is necessary to change your approach to managing a material, your team will need to identify and evaluate alternative approaches. The following provides some steps to follow in this process.

A. Canvas the literature. For most materials, you should not expect to find much in the literature. For materials such as abrasive blasting medium, and asphalt concrete, there has been a lot written. However, for most other excess materials there is little information in the literature;

B. Canvas your associates in other jurisdictions and industries for innovative solutions, equipment, processes or technology. This is one of your most valuable resources. It is far better to build on someone else's work then to reinvent a solution, or to spend time and money evaluating options that others have already disproved;

C. Think creatively in-house. Your own staff may have a better way of managing materials but have never been asked;

D. Identify opportunities for reducing the volume of material being generated. This may be accomplished through changes at the planning, design, or construction stages, or by changing maintenance practices;

E. Identify what markets are available to receive your material, or if new markets can be developed. You must be prepared to consider non-traditional partnerships;

F. Prepare a short list of alternative materials management practices;

G. Identify the barriers to implementing the potential new options. These barriers may relate to the following areas:

- regulatory
- economic
- market
- social
- internal standards
- organizational
- technical
- knowledge

H. Identify methods of overcoming the barriers; and

I. Prepare a short list of preferred new materials management practices for detailed assessment.

3.3.4 Assess the New Management Practices

Before being implemented, new practices need to be assessed to confirm their applicability to your organization, and that they will be beneficial over the long run. The following steps should be taken to assess new management options.

A. In many cases the benefits of the new practice will be obvious, and an experimental program to prove the benefits will not be needed. Where this is the case, the team can move on to define the implementation plan;

B. Where testing is warranted, the team will need to establish and implement an assessment program. The program must consist of properly defined and well documented experiments. It may include

laboratory and/or field work, formal test sections, or pilot projects;

C. The team must define the assessment criteria before any trials or test sections are done. These assessment criteria should relate to performance, cost, and applicable environmental factors;

D. The team should identify others to share the cost of these trials or test sections. Cooperative research on these topics is prudent, especially for those new excess materials management practices which require extensive testing and have widespread application;

E. Conduct the trials, with proper monitoring and documentation;

F. Assess results from the trials; and

G. If the results are unacceptable, the team should review the problem areas to see if modifications can be made to correct the shortcomings. If modifications are not feasible, then the option should be abandoned.

3.3.5 Define The Implementation Plan

If the results of the assessment are acceptable, the team must next develop an implementation plan. This plan should address the following:

A. Staffing needs, including training;
B. Equipment needs including what should be done with the old equipment;
C. Modification to governing documents such as standards, manuals, specifications, purchasing policies, guidelines, etc.;
D. Communication with internal and external stakeholders; and
E. Post-implementation monitoring.

When developing this plan, consideration must be given to both the needs of the road authority, and the needs of the construction industry. Since many of the new procedures will be implemented through contracts it is important that the team work closely with representatives of the construction industry to ensure that the necessary changes occur with a minimum of disruption for the industry.

3.4 PHASE IV - IMPLEMENTATION

3.4.1 Obtain Approvals and Resources, and Implement the Plan

Obtain the necessary approvals and funding, and implement the new procedure including:

A. Obtaining the necessary equipment or processes;
B. Recruiting, training, and equipping staff;
C. Modifying governing documents including standards, specifications, procedures manuals, purchasing policies, and all other pertinent documents; and
D. Implementing the communication plan.

This step will have to address both the internal and external infrastructure needs. Successful implementation requires the team to work closely with external partners such as the construction industry, the waste management industry, municipalities and regulatory agencies.

3.4.2 Monitor and Report

Once the plan has been implemented, it will be necessary to monitor the operations to see if the expected benefits are achieved, and to report the results to senior management, stakeholders, and transportation professionals in other jurisdictions.

4.0 SPECIFIC MATERIALS

INTRODUCTION

This chapter presents information on specific excess materials. The information was gathered through discussions with individuals across North America, and literature reviews. The opinions that were expressed by others were not validated, but have been presented to stimulate thought on possible new avenues for managing these materials.

This chapter is structured with sections that discuss the source and nature of the material, and its environmental implications. Next a list of previously reported management practices is presented. This information was gathered from existing reports and interviews, and lists practices reported to be used in North America. It is not an exhaustive list, nor do we comment on the environmental acceptability of these practices.

A bibliography and list of contacts is presented for each material. This is followed by a list of other possible management options. These other possible options are discussed from the perspective of the operation, any barriers to using the option, and possible research and/or policy changes that might be needed to promote the use of the options. In some cases existing practices have been dealt with in detail. We feel this would be helpful because, although the practice may be common place in one jurisdiction, it may be a new management option in another area of Canada.

Early in the study, current management options were identified for 12 materials. Of these, 9 materials were selected as priority materials for further study because they were of concern to most people consulted, and were the larger volume materials that road authorities need to manage. The current management practices for those materials that were not selected for further study are listed in Appendix E.

ABRASIVE BLASTING MEDIA

Source of Material

Abrasive blasting media is used for structural steel blasting to clean metal before repainting, and to prepare concrete surfaces for rehabilitation. In the case of concrete rehabilitation, the mixture of blasting medium and concrete dust can be managed in the same way as excess portland cement concrete.

Many of the bridges in Canada's transportation system are carbon steel structures built in the last 60 years. To prevent rusting, these structure were painted with alkyd intermediate and finish coats applied over a red lead primer. In the mid 1970's the industry moved away from lead based primer coats. Over time, these coatings deteriorate to the point where the structure needs to be recoated.

To prepare the steel for recoating, the old paint and rust must be removed. Typically this involves removing all the paint to a near white metal standard. This is accomplished using a high pressure abrasive blasting system, by which an abrasive material is blown at the painted surface. These abrasive blasting systems fall into two categories - one-time only systems, and recyclable systems.

In the one-time only system, the abrasive (e.g. silica sand) is used only once before being sent to disposal. With the recyclable system (e.g. Steel Grit, Steel Shot, Aluminum Oxide, Silicon Carbide, or Zirconium/aluminum oxide), the abrasive is recycled numerous times before being sent to disposal.

In most cases, the excess material remaining after the abrasive blasting operation is composed of the abrasive combined with the old paint and rust that is removed. In recyclable systems the excess material is the paint chips, rust, and smaller volumes of the spent abrasive. In a bridge painting operation using sand as the abrasive, 12-25 tonnes of abrasive materials may be used for each 1000 m^2 (12-25 kg/m^2) of bridge surface being cleaned.

Nature of Material

The abrasives used in blast cleaning operation are silica sand, steel grit, iron slag, copper slag, steel shot, aluminum oxide, silicon carbide, or Zirconium/aluminum oxide. Sand is usually only used once because it loses its abrasive qualities after the first use. Steel grit on the other hand can be reused several times before it loses its abrasive qualities. The excess material from the

cleaning operation contains the spent abrasive medium, paint chips with its component metals (e.g. lead, chromium, cadmium), and iron oxide.

Environmental Implications

Tests that have been completed on the spent abrasive indicate that it may contain elevated levels of lead due to the presence of the lead based primers removed from the bridge. The environmental concern is not the total lead content, but rather the amount of leachable lead that may be released if the material is buried in the ground. Tests carried out in the U.S. show no correlation between total lead and leachable lead. The leaching action is dependent upon the surface area of the lead-containing particles. The smaller the particles, the larger the surface area, and the higher the test results for leachable lead. The presence of lead limits the management options, and often necessitates some pre-treatment before being reused or recycled.

Many U.S. States are requiring the use of recyclable systems rather than sand, for two reasons. One is to address the waste management issues by reducing the volume of waste requiring disposal. This in itself is a waste minimization option. The second reason for specifying recyclable systems is to respond to concerns over the potential health effects associated with the use of silica sand (e.g. respiratory concerns).

Although recyclable systems reduce the volume of excess materials generated, the leachable lead levels tend to be higher because the paint is pulverized to a greater extent.

A study conducted by LaGoy and Wilder, estimates that, based on using 24 kg/m^3 of sand, the leachable lead levels in the spent blasting medium would be about 20 mg/L.

In many jurisdictions, a level of leachable lead above 5 mg/L makes the material a hazardous waste, necessitating special handling and disposal methods. Nova Scotia's Department of Transportation and Communications reports that 65% of samples tested exceeded 5 mg/L leachable lead. As well, recent tests carried out by the Ministry of Transportation of Ontario indicate that upwards of 60% of samples taken from bridge painting operations also exceed 5 mg/L of leachable lead. Samples analyzed in the State of Minnesota produced levels of 30-80 mg/L of leachable lead, and 8500 - 10,000 mg/kg total lead.

Summary of Previously Reported Management Practices

Previously reported management practices for this material include:

- disposal at a certified landfill site;
- clean and reuse as abrasive material. This is only an option for materials such as steel grit that retain their abrasive capabilities after being used;
- store;
- use as fill;
- clean and use in sand traps at golf courses; and
- recycled into asphalt or concrete.
- winter road sand

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Other Potential Management Options

The following possible options for managing lead contaminated silica sand have been identified; and are discussed in more detail in the following section:

- Runner sand for Steel Industry
- Aggregate in the Concrete Industry
- Combining Steel Grit with Silica Sand
- Encapsulation
- Stabilization and Solidification
- Structure Replacement
- Use in Asphalt
- Use in the Lead Industry
- Soil Washing

MATERIAL: **Abrasive Blasting Media**

USE: **Runner Sand for Steel Industry**

DISCUSSION:

In the steel industry, molten iron, and slag are discharged from the bottom of blast furnaces through runners. Sand is used in these runners to separate the molten iron and the slag. Once this runner sand is spent, it is allowed to discharge to the slag pit, where it mixes with the slag. A 5000 tonne/day furnace can use about 2 tonnes of runner sand, which eventually combines with around 1000 tonnes of slag. In Ontario, runner sand may cost in the order of $75/tonne.

Sand from bridge painting operations can be used for this purpose, because it is dry and free of prohibiting contaminants. The heavy metals that may be present due to the paint removal operation is not a constraint, and is diluted to the point that it is considered to be a trace element in the resultant slag.

This method of disposal requires an intermediary that will accept the spent blasting sand, process it for the steel industry, and arrange for outlets.

The economics of this operation is generally driven by trucking distances, processing costs, and the relative disposal costs of other options. In areas where the tipping fees at landfills are low, haul distances would be the controlling factor.

A concern was raised regarding the fate of the lead. It was suggested that the lead would be vaporized by the high temperatures, creating a potential health hazard for workers, as well as being discharged to the environment. However, others have suggested that the lead would be bound up in the metal.

BARRIERS TO USING THIS OPTION:

- Proximity to steel mills;
- Availability of an intermediary to process the sand and make arrangements with the steel industry;
- Questions about the potential health effects from vaporized lead; and

- The cost of spent blasting sand delivered to the steel mill must be less than the cost of new sand to make it competitive.

RESEARCH & POLICY CHANGES:

- Research into the possibility of workers being exposed to vaporized lead, and if so, ways of eliminating this exposure; and

- Confirm the fate of the lead in the process. Is the lead bound up in the slag, or does it pose a future problem for the management of the slag?

MATERIAL: **Abrasive Blasting Media**

USE: **Aggregate In The Concrete Industry**

DISCUSSION:

The portland cement concrete industry requires aggregate for its process. This aggregate can come from abrasive blasting operations, provided it is cleaned of debris, and is of the correct grade. In Ontario, there are intermediaries that charge about $30/tonne to accept and process abrasive blasting sand. They in turn supply the sand to the concrete industry.

Using this material in the concrete industry is similar to the stabilization/ solidification process discussed later, except that the product is being used as opposed to landfilled. In both processes, the solubility or mobility of the lead is limited by chemically or physically binding the lead (stabilization), and the contaminants are fixed in the cement (solidification). Lead tends to be more mobile in acidic environments where the acid more readily leaches the lead. The high pH of concrete buffers the acid in the environment into which the concrete may be placed, thereby reducing the solubility of the lead.

If not properly handled, the types of impurities that are present in abrasive blasting media can cause problems in making portland concrete. For example, increased levels of lead contamination can create longer set times and reduced strength. However, research shows that these concerns can be overcome. This would not be of concern in manufacturing low strength concrete and unshrinkable fill.

In some cases the concentrations of lead in the sand is reduced to acceptable limits through mixing the contaminated sand with clean sand.

For the option of using spent abrasive sand in concrete manufacturing to be viable, the following are required:

- An intermediary that will reprocess the sand to a condition that is acceptable to the concrete industry;
- A concrete manufacturer that is prepared to accept the sand; and
- A cost structure where the cost of haulage, plus the cost of reprocessing does not exceed the cost of alternative disposal options.

BARRIERS TO USING THIS OPTION:

- Aversion to the perceived risk of using a contaminated product in concrete;
- Availability of concrete manufacturers in close proximity to the supply of abrasive sand;
- Availability of intermediaries to handle the reprocessing of the contaminated sand before delivering it to the concrete manufacturers;
- Uncertainty regarding the leachability of lead from the concrete, over the long term;
- Whether the economics of abrasive sand is competitive with the cost of clean sand; and
- Local environmental legislation may limit this option.

RESEARCH & POLICY CHANGES:

- Transportation agencies should encourage the use of concrete manufactured from abrasive blasting sand;
- Research into new mix designs for concrete that can use lead contaminated sand; and
- Research into the long-term leachability of lead from concrete.

MATERIAL: **Abrasive Blasting Media**

USE: **Combining Steel Grit with Silica Sand**

DISCUSSION:

There are reports that abrasive cleaning systems using steel grit renders the lead non-leachable. A firm in the United States reports that by mixing 4% steel grit with non-recyclable abrasives (e.g. slags or silica sand) can reduce the leachable lead from 78 mg/L to 2.4 mg/L. A 10% mixture is reported to reduce the leachable lead level to below .5 mg/L. At US$350/ton (Can$535/tonne), a 4% mix can add US$14/ton (Can$21/tonne) to the cost of the blasting medium. This cost is offset by the reduced cost of taking the spent blasting medium to a landfill site, rather than a hazardous waste site. If the leachable lead can be reduced enough, the abrasive medium may be able to be used as fill. This process is being strongly endorsed by some U.S. States, whereas others are rejecting this option because of question as to whether or not the lead may be released over time.

This could be a viable option provided the question of long-term leachability of the lead can be resolved.

BARRIERS TO USING THIS OPTION:

- Lack of understanding of the long-term fate of the lead in this option.

RESEARCH & POLICY CHANGES:

- Research to confirm that mixing steel grit with silica sand will reduce the leachable lead to acceptable levels;

- Research into the long-term leachability of the resultant product.

MATERIAL: **Abrasive Blasting Media**

USE: **Encapsulation**

DISCUSSION:

Some U.S. states are investigating procedures for painting over lead-based paints before the paint deteriorates to the point of having to be removed. In some cases, the structure will require some localized cleaning to remove loose paint and corrosion. However, this still reduces the amount of excess material generated. This procedure delays the need to totally remove the lead-based paint, and in effect, spreads the disposal costs over a longer period of time.

BARRIERS TO USING THIS OPTION:

- Local policies of transportation agencies may prohibit this option.

RESEARCH & POLICY CHANGES:

- Research into the cost-effectiveness of this option, using a full-cost accounting basis; and

- If shown to be cost-effective, road authorities may have to change their policies to permit this option.

MATERIAL: **Abrasive Blasting Media**

USE: **Stabilization & Solidification**

DISCUSSION:

Considerable research has been done on stabilization/solidification processes. In these processes, spent abrasive is mixed with wetted silicate and cement kiln dust to lower the leachable lead levels and bind the lead. The hardened residue is disposed of at non-hazardous waste sites. It is reported that leachable lead can be reduced from 392 mg/L to 0.12 mg/L using this process. Often this stabilization process is followed by solidification in low-grade cement and landfilled at non-hazardous sites. The cost is US $140-$185/ton (Can $214-$283/tonne).

As discussed under the earlier section dealing with the concrete industry, this process could be used to make concrete products that could be used in the transportation sector. A project in Texas used this process to create concrete blocks that were used as filler material in dolphins around bridge piers to protect them from ship collisions. The cost was approximately US$90/yd^3. Each cubic yard of concrete used about 3 drums of spent blasting sand. If this material had been sent to disposal, it was estimated that the cost for transportation and disposal would have exceeded US$500 per drum (Can$695/drum).

BARRIERS TO USING THIS OPTION:

- Availability of companies that will perform the stabilization/solidification process;
- Local environmental legislation may not support this option; and
- Transportation agencies need to be willing to identify opportunities for using spent blasting sand in low-strength concrete. This will require creative risk taking and a willingness to be innovative.

RESEARCH & POLICY CHANGES:

- Research into the potential for use in low-strength concrete, and the long-term fate of the lead.

MATERIAL: **Abrasive Blasting Media**

USE: **Structure Replacement**

DISCUSSION:

Some jurisdictions have suggested that it may be cost effective to delay repainting a structure because it is nearing the end of its life. It may even be reasonable to advance the replacement of the structure and save the cost of repainting. This can be combined with the encapsulation process discussed above, in order to prolong the life of the coating until the bridge is eligible for replacement.

This option may require some rethinking of standard approaches to dealing with rehabilitation projects. Full life-cycle costs must be considered when making decisions regarding whether it is more cost-effective to repaint a structure, or to replace it. The disposal costs of the excess materials from both options has to be factored into the decision.

BARRIERS TO USING THIS OPTION:

- The internal processes for evaluating bridge maintenance options may not encourage consideration of the replacement option;
- A lack of a full life-cycle cost approach to evaluating alternatives could eliminate this alternative from consideration.

RESEARCH & POLICY CHANGES:

- Transportation agencies may have to implement a full-cost approach to identifying and evaluating bridge maintenance options that would assess rehabilitation and disposal costs, against replacement costs.

MATERIAL: **Abrasive Blasting Media**

USE: **Use in Asphalt**

DISCUSSION:

At least two U.S. states have explored the use of spent abrasives in asphalt concrete. It is speculated that the presence of lime aggregates and an hydrophobic environment in the asphalt concrete mix can reduce the leachable lead to below 5 mg/L. In Minnesota, the proposal was to put the material into cold mix asphalt concrete, and use it in the bed layer of the road to avoid tire abrasion. Minnesota did not propose using the material in hot mix to avoid potential concerns that heating the material would release the lead. This was despite their conclusion that the temperatures in the hot mix plant would not volatilize the lead.

Although this method demonstrated positive results, it has proved difficult to obtain support from the environmental regulatory agencies in some jurisdictions.

BARRIERS TO USING THIS OPTION:

- Institutional aversion to placing contaminated materials into asphalt;
- Reluctance on the part of regulatory agencies to accept this method of reusing abrasive blasting media;
- Spent abrasive sand must compete economically with other aggregate; and
- Asphalt concrete specifications may restrict the use of spent abrasive.

RESEARCH & POLICY CHANGES:

- Research into the leachability of lead; and
- Research into the implications for recycling asphalt concrete containing spent abrasive blasting media. This research would need to determine if the lead will become a health or environment problem when the asphalt is recycled.

MATERIAL: **Abrasive Blasting Media**

USE: **Use In The Lead Industry**

DISCUSSION:

The lead smelting industry requires silica as a flux in the lead smelting process. Cominco's lead smelter in Trail B.C. will accept spent blasting sand for use in its process, provided it is delivered to the plant in bulk, in an end-dump truck. At the plant, it is weighed and sampled, and placed into the process-feed material storage. From here it is blended in a computer controlled proportional bin, before being fed into the process. The heavy metal concentration in the material is of no concern, because it is insignificant to the process. The British Columbia Ministry of Transportation and Highways, sends all of its spent silica sand blasting media to the Cominco smelter.

Secondary lead smelters generate a slag that is not leachate toxic, but that has heavy metal levels high enough to require that it go to a landfill. This slag can be stabilized using silica sand, or portland cement. This process however is not cost-effective as long as local tipping fees are below $100/tonne. If in the future this stabilization process becomes mandatory, either through regulation or economics, this may provide an outlet for spent silica abrasive. However, the demand at any one plant would not likely be high.

BARRIERS TO USING THIS OPTION:

- The availability of a lead smelter within reasonable haul distances is the main constraint; and
- Low local tipping fees can be a barrier to other reuse options being available.

RESEARCH & POLICY CHANGES:

- None.

MATERIAL: **Abrasive Blasting Media**

USE: **Soil Washing**

DISCUSSION:

The State of Minnesota is working with a waste management company to extract the lead containing paint from the spent blasting medium using a soil washing process. The products of the process are a sludge that concentrates the paint; and the washed abrasive. The sludge, which is high in lead, is shipped to a firm in Texas, which makes arrangements to use it as a flux in lead smelters. The washed abrasive sand which has total lead concentrations in the order of 300-500 mg/kg (leachable lead < 1 mg/L) is used for engineered fill.

The volume of material being sent to disposal is reduced by 85%. The total cost of disposal is approximately US$240/ton (Can$367/tonne), which is about half of the cost of landfilling the original material.

BARRIERS TO USING THIS OPTION:

- The availability of a soil washing operation, and an intermediary to receive the sludge and make arrangements with a lead smelter; and

- Developing the necessary infrastructure for this operation may require the transportation sector to work with the waste management sector to create the market mechanisms that make the investment by the waste sector worthwhile.

RESEARCH & POLICY CHANGES:

- Transportation agencies and companies must be willing to work with waste management companies to develop new technologies/processes. This may involve providing seed money or guaranteed markets during the start-up period.

ASPHALT CONCRETE

Source of Material

Asphalt concrete is the dominant pavement surface material for paved roads in Canada. The majority of asphalt concrete is produced by a hot mix process involving heating aggregate and asphalt cement binder, mixing them together and spreading the resultant mixture while hot and workable. Compaction is performed while the mixture is hot. When the mixture cools it produces a stable, strong pavement surface.

On low volume roads and at remote locations, asphalt concrete can be prepared by a cold mixing process, done either at a central plant or on the road. In this case the asphalt cement is made liquid at air temperature in one of two ways. The first involves dissolving the asphalt cement in a petroleum solvent which later evaporates leaving the residual asphalt cement. The second method uses emulsified asphalt cement which breaks as the water evaporates and the asphalt cement is deposited.

Excess asphalt concrete is generated when asphalt concrete surfaces are removed for pavement reconstruction, major pavement maintenance, or to obtain access to buried utilities. The asphalt concrete is removed by milling or by ripping and loading slabs. Milling is a grinding process that produces a granular or milled salvaged asphalt concrete. Slabs may be crushed to produce a granular salvaged material.

Most salvaged asphalt concrete materials are generated by staff of road agency or paving contractors. These staff are familiar with the materials and are sensitive to proper salvaging operations to avoid contamination so that the material may be recycled to its highest and best use. However, a large quantity of asphalt concrete is salvaged by non-road agency staff and contractors. These people are involved with the repair or reconstruction of underground utilities or facilities demolition for other developments. Often these people are not sensitive to good recycling practices and the need to avoid contamination of the asphalt concrete materials during salvaging.

Nature of Material

Asphalt concrete is a mixture of mineral aggregate for bulk, durability and strength; asphalt cement as the binder; and a small amount of air which is necessary for the suitable in-service performance of the pavement. Asphalt concrete contain between 4.5% and 7.0% by mass of asphalt cement to dry weight of aggregate.

The aggregate is generally a crushed, well graded gravelly sand but sometimes specialized aggregate gradations are used. The petrographic quality of the aggregate varies, depending upon the performance requirements of the pavement. Manufactured or industrial aggregates such as steel slag are used to a minor extent in localities where these materials are economically available.

Asphalt cement is a residual material from petroleum refining. It contains hydrocarbon molecules ranging in size from small molecules like gasoline, up to very large hydrocarbons with molecular weights exceeding 25,000. The suitability of asphalt cement for road paving depends on the continuous presence of all the sizes of hydrocarbon molecules from the small to the large.

Asphalt cement properties vary by crude oil source. In some regions like the Canadian prairies, there are few crude oil sources used for asphalt cement and therefore the variation in asphalt cement composition is limited. On the other hand, near the Atlantic and Pacific Ocean, crude oil for asphalt cement may come from anywhere in the world. Therefore in these coastal areas and extending into Ontario in the east, asphalt cement properties may be very different from project to project.

Asphalt cement costs about $180 per tonne. One tonne of asphalt concrete salvage with 6% asphalt cement by weight contains about $10 of asphalt cement. During the mid-1980's, asphalt cement prices were just over $300 per tonne, making the asphalt cement in one tonne of salvaged asphalt concrete worth about $17. Since this asphalt cement is 100% recyclable, full recycling avoids the cost of new asphalt cement and slows the depletion of non-renewable petroleum resources.

The aggregate also has economic value. This value relates to the aggregate royalty, processing and haul costs. Typically hot mix asphalt concrete (HMAC) aggregate costs $6 to $15 per tonne, depending upon location.

In total, the value of aggregate and asphalt cement in salvaged asphalt concrete

is $20 per tonne or more at most Canadian locations.

Almost of all excess asphalt concrete generated by non-road agencies is in slabs. The original asphalt concrete is ripped, broken, lifted and loaded by a variety of equipment. Contamination of the asphalt concrete slabs with other materials such as granular base course or soil is more likely to occur when asphalt concrete is salvaged by ripping, breaking and lifting slabs. These slabs are broken into pieces small enough to allow loading and hauling, and then hauled to a stockpile. Most of these stockpiled slabs are crushed to produce a granular material. A small portion is used as slabs or chunks.

Milling is used on projects with large volumes of asphalt concrete to be salvaged. Specially built milling machines, now available in most parts of Canada, grind or mill up to 50 mm of asphalt concrete thickness in one pass. The milling machines have a large diameter drum with many carbide tipped teeth on the drum circumference. As the drum rotates these teeth cut the pavement surface. The machine advances slowly down the roadway cutting, collecting and conveying the granular salvaged asphalt concrete material into waiting trucks. This material is then stockpiled for future use.

Milled asphalt concrete is a dense graded gravelly sand with asphalt cement coatings. Milled material has the same maximum particle size as the original asphalt concrete but the gradation is almost always slightly finer and more densely graded due to degradation during milling. The millings are also slightly cohesive, with the extent of cohesiveness dependant upon the amount of asphalt cement used in the original mix. These millings vary from very cohesive for high asphalt contents and softer asphalt cements, to not cohesive for low asphalt contents or brittle asphalt cements.

Environmental Implications

Concerns have been expressed about adverse environmental and health impacts of some chemicals in asphalt cement, asphalt fumes from heating materials during construction, and leachates from stockpiled recycled asphalt pavements (RAP). For the most part, these concerns are based on misunderstandings and incorrect assumptions which have become broadly reported in Canada and the United States.

Interviews done in preparation of this report found two examples where RAP materials were treated as harmful to the environment. Those interviewed asked that no specifics be given because the situations are locally controversial. In one case, salvaged milled asphalt concrete was declared a toxic material and

had to be hauled to a disposal site outside the jurisdiction. In the other case, a municipal asphalt concrete slab stockpile was declared a contaminated site by a senior government department based on the concern that the leachate from the stockpile could drain overland to a river about 0.5 km away.

For decades, millions of tons of hot mix asphalt concrete have been, produced and recycled each year in North America. Only recently have the environmental and health impacts of this material been questioned. Consequently, there is only a small amount of recent data on these impacts. Most of this data finds no obvious adverse impacts from the chemicals in asphalt cement, largely because these potentially harmful chemicals are present in very small concentrations and are physically or chemically bound and unable to move from the asphalt concrete.

The paper by Thompson and Haas in the 1992 proceedings of the Canadian Technical Asphalt Association and titled, "Fumes from Asphalt and Leachates from Pavements; Are They Harmful?", is a comprehensive review of this question in the Canadian context. This paper describes the confusion between asphalt cement and coal tar pitch, two chemically different materials produced from different source materials. Coal tar pitch contains high concentrations of several known carcinogens. Asphalt cement contains very low concentrations of three chemicals, all polyaromatic hydrocarbons, that are characterized as "probably carcinogenic to humans". The confusion arises when asphalt cement and coal tar pitch are presumed to be the same material and asphalt cement is presumed to have the same serious environmental and health impacts as coal tar pitch.

Coal tar pitch was used prior to the 1920's and 30's for binding aggregates to make road pavements "roofing tar" before asphalt cement was available. Although coal tar has not been used in road resurfacing for over 60 years, there are still people who think that asphalt cement and coal tar are the same. They therefore, respond by incorrectly treating asphalt cement pavement as hazardous or toxic.

Thompson and Haas reported that exposure to asphalt fumes can cause abnormal fatigue and throat and eye irritations. The American Congress of Governmental Industrial Hygienists (ACGIH) has recommended a time-weighted average threshold limit value of exposure to asphalt fumes of 5 mg/m^3. This level was set on the basis that fumes above this level are health irritants and not because these fumes are carcinogenic.

There have been several toxicological studies of asphalt fumes in Scandinavian

countries. These studies, among others, have shown that concentrations of chemicals in asphalt fumes increase significantly as temperature is increased, and observed that health impacts from asphalt fumes are only generated when asphalt is heated to 250°C. In Canada asphalt paving materials are rarely hotter than 160°C, well below the temperatures at which harmful effects are reported.

The National Asphalt Pavement Association Special Report No. 134 describes studies of asphalt fumes at the different work areas, from unloading the asphalt cement at the plant, to the roller operators on two paving operations. No work sites were reported to have asphalt fumes in excess of the ACGIH threshold exposure limit of 5 mg/m^3.

Thompson and Haas report on "A Review of the Asphalt Health Literature Under the Strategic Highway Research Program, Contract A-001" reviewed 138 articles and concluded, in part, that:

- There was a tendency to confuse coal tar and asphalt;
- There was a tendency to combine road paving and roofing although each used different asphalt materials and roofing asphalt temperatures are much higher than those for paving asphalts;
- There are several studies that are incomplete, used improper sampling techniques, or that are marginally representative of asphalt paving conditions;
- Epidemiology studies were few and inconclusive; and
- The few environmental studies done found no evidence of damage to the environment.

Initial studies of leachates from new hot mix asphalt concrete (HMAC) by the Heritage Research Group found that leachate contained low concentrations (i.e. below the detection limit) of many heavy metals, semi-volatile organics and volatile organics.

One study of leachate from cores taken from a 15 year old pavement in Illinois found the same chemicals and concentrations in leachate from adjoining asphalt concrete and Portland cement concrete pavements. The study concluded that most of the chemicals in the leachate came from materials deposited from vehicles using the road and not from the pavement materials.

Some initial studies of the composition of leachate from RAP stockpiles done by the Ministère des transports du Québec found the leachate quality to be acceptable for release without adverse impacts.

Thompson and Haas made two recommendations in their paper. The first is that, "An epidemiological study of the chronic and acute effects of working in the asphalt paving industry in Canada should be carried out." The second is that RAP stockpiles should be stored under a roof. The roof will keep these materials drier and save asphalt plant energy costs, but more importantly, the roof reduces or prevents leachate generation. Their concern is, "the possibility that contaminates in RAP-whether they are materials intentionally incorporated in the asphalt mix or materials accumulated on the pavement as the result of traffic-would be leached into the groundwater surrounding the RAP pile."

The concern is not about the leachate from a RAP stockpile of only asphalt cement and aggregate, but rather from the leachate containing the wide variety of chemicals spilled or dropped onto the pavement surface before it was salvaged and stockpiled for recycling. This concern opens a much broader question about the contamination on the surface of operating pavements.

The Ontario Ministry of Natural Resources 1992 report prepared by John Emery Geotechnical Engineering Limited entitled, "Mineral Aggregate Conservation-Reuse and Recycling", describes this leachate question well. "While the technical data (three references cited) indicates that RAP is a non-leachable material and the Ministry of Environment [MOE] does not consider RAP to be a waste (MOE, 1988), the MOE and MTO [Ministry of Transportation-Ontario] are still concerned with the RAP leachability issue (Katona, 1991). It is important the question of RAP leachability be technically resolved in the Ontario context."

Recycling asphalt concrete in Canada began about 20 years ago, and is now standard construction method. It is well proven, technically and economically. Only in the past five years, have the environmental and health impacts of asphalt concrete recycling, and indeed of asphalt cement, been questioned. This is despite a substantial body of information that indicates that there are not significant environmental and health concerns associated with asphalt concrete. There remains a residual doubt about potential environmental or health impacts. This doubt will only be resolved by proper investigations of two complex and controversial scientific subjects, the toxicology of asphalt fumes and the leachate character from RAP stockpiles.

There are three other environmental issues associated with recycling asphalt concrete for pavements. These are:

- Fugitive dust from crushing asphalt concrete slabs;
- Smoke emissions at recycling asphalt plants; and

- Particulate and gas emissions from recycling asphalt concretes containing other materials like slag, crumb rubber from ground tires, sulphur or materials other than the traditional asphalt cement and the mineral aggregates.

Some high asphalt content and soft asphalt cements produce a sticky black dust when crushed. This dust, if carried by wind beyond the crushing area, settles on sidewalks, cars, buildings and clothing. The black dust sticks onto shoes and may subsequently marks flooring inside buildings. The problem seems restricted to crushing in urban areas during high winds.

In improperly operated asphalt recycling plants, particularly those using higher recycling ratios, the asphalt cement in the RAP material becomes too hot in the drum mixer. The excessively hot asphalt cement starts to smoulder or oxidize at high temperatures, releasing a blue smoke. This blue smoke may violate local air quality standards. Blue smoke is not a problem in properly designed RAP mixtures produced by appropriate asphalt plant equipment in proper working condition.

The asphalt paving industry has added materials other than asphalt cement and mineral aggregate to asphalt concrete to both consume material surplus to another industry, and to improve asphalt concrete performance. In many cases, the consumption of surplus or waste materials from another industry by the asphalt paving industry is environmentally appropriate. However, problems can arise and the implications of adding non-tradition materials to the asphalt mix should be carefully evaluated. A key question in this evaluation process is "Can these mixes be recycled without adverse environmental impacts?" Future "recyclability" was not always a criteria for assessment when these new mixtures were tested. Some of these mixtures may not be able to be recycled because of the adverse environmental impacts arising from the recycling process.

Increasing environmental awareness, higher landfill tipping fees, and materials prohibitions at landfills, have motivated many industries with excess materials to initiate research and pavement test sections of asphalt concrete containing all manner of materials or chemicals. The term, "the linear landfill", is used by some road agency staff opposed to the use of the highway for disposal of materials generated by other industries. These staff are uncomfortable with potential future environmental liabilities or operational problems related to these different materials being incorporated within the highway. As a general principle, additives should improve asphalt concrete performance, and not require special handling when recycled, before they are allowed.

In the past, there were experimental asphalt concrete mixes that incorporated asbestos, before the health implications of asbestos were known. The location of these pavements were not recorded, creating special concerns as these roads need to be rehabilitated. Special construction and handling techniques are required when these asbestos pavements are removed. As well, if these pavements are not properly identified, and are inadvertently integrated with a larger stockpile, they can contaminate the entire pile.

Slag has also been used as part or all of the aggregate fraction in some asphalt concretes. In addition, elemental sulphur from the petroleum industry has been used in asphalt concrete. Generally, well constructed asphalt concrete using slag or sulphur have improved performance. However, the heavy metal content in dust and leachate from slag aggregate RAP has been a concern. The heavy metal content in a recently milled slag aggregate mix in Ontario was sufficiently high that the RAP was classified as a special waste, not suitable for disposal at conventional landfills. Few sulphur asphalt mixes have been placed, therefore experience is limited. Test for the production of sulphur dioxide in the recycling asphalt plant will be needed before these mixtures can be recycled.

Recently, much work has been done on the use of rubber from ground tires in asphalt concrete. The performance improvements of the crumb rubber asphalt have been variable, and no clear conclusions are available. However, there have been excellent investigations and field trials on the environmental impacts of recycling asphalt concrete containing crumb rubber by the Ministry of Transportation in Ontario. This work demonstrated that crumb rubber modified asphalt concrete can be recycled without adverse environmental impacts.

Summary of Previously Reported Management Options

Interviews done for the preparation of this report found two distinct communities with respect to recycling of asphalt concrete. One group recycles large volumes of asphalt concrete. The other group recycles almost no asphalt concrete. This same observation was made by research engineers with the United States Federal Highway Administration while doing a nation wide study of asphalt concrete recycling practices.

The road agencies and contractors which recycle large volumes of asphalt concrete can be characterized as:

- Having access to large volumes of RAP materials;

- Having access to milling equipment and asphalt plant equipment for recycling;
- Having access to trained and skilled construction staff; and
- Having access to specialist materials engineering services and materials laboratory facilities for testing, mix designs and production quality control.

The road agencies and contractors which tend not to recycle asphalt concrete can be characterized as:

- Having small volumes of RAP materials available;
- Not having ready access to milling equipment and therefore produce largely slab RAP materials;
- Not having access to contractors equipped with asphalt concrete recycling plants; and
- Not having access to specialist materials engineering services or well equipped central materials testing laboratories.

The road agencies and contractors that can recycle RAP materials use them to make new asphalt concrete pavements. The road agencies or contractors that cannot easily recycle tend to use RAP materials for other applications or simply dispose of these materials.

Previously reported management practices for recycled asphalt concrete materials include:

- Recycle into asphalt concrete pavements through:
  - cold in place recycling;
  - hot in place recycling;
  - milling and hauling to a central plant for recycling;
  - ripping, crushing and hauling to a central plant for recycling;
  - milling, hauling, spreading, placing and compacting as a asphalt concrete pavement; and
  - cold mix asphalt patching.
- Reusing as:
  - granular base/shoulder base/subbase;
  - traffic gravel;
  - fill;
  - rip rap for shoreline erosion protection;
  - roller compacted concrete aggregate; and
  - Portland cement concrete aggregate.

- Disposal:
  - at landfills;
  - by burying; and
  - by turning materials to contractor for his use/disposition.

Most of these options are discussed in the following subsections.

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The following organizations have publications providing information pertinent to recycling asphalt concrete:

- The Asphalt Institute;
- The Federal Highway Administration (U.S.A.);
- National Asphalt Pavement Association (U.S.A.); and,
- Asphalt Recycling and Reclaiming Association.

The annual proceedings of the Canadian Technical Asphalt Association contain many excellent papers on recycling asphalt concrete in Canada, starting about 1970.

The provincial highway departments and many larger cities have experience and technical specifications for recycling asphalt concrete. These larger road

agencies in your region may be able to provide useful information.

Other Potential Management Options

The following management options have been identified for further discussion:

- Longer pavement life cycles;
- Foamed asphalt or emulsified asphalt treatments suitable for small volume applications by road agencies or contractors who do not have access to the equipment and technology used for recycling hot mix asphalt concrete.

MATERIAL: **Asphalt Concrete**

USE: **Cold In-Place Recycling of Asphalt Concrete**

DISCUSSION:

There are several cold in-place recycling practices. They vary from the simple to the very complex, in terms of equipment and technology. These are:

- Lift, pulverize, add an asphalt material and replace;
- Lift, mix, add an asphalt material and replace; and
- Cold in-place recycling trains.

Each practice is described in the following subsection.

Lift and Pulverize In-Place

The lift and pulverize practice is for spot repairs done by maintenance forces on lower volume, lower standard, asphalt concrete roads. When the pavements surface is bound with asphalt cement, the pavement pieces from the failed area are removed, pulverized with a grid pad or sheeps foot roller, spread on the patched area, sprayed with a liquid or emulsified asphalt, blade mixed on the road, placed, shaped and compacted. Often a seal coat is placed over this reworked patch material when it has cured sufficiently.

This practice is used more in the United States than in Canada. It is a low cost solution using equipment and materials readily available to maintenance forces in remote areas. This lift and pulverize practice is less effective in maintaining a long term patch in areas subject to seasonal freezing and numerous wet/dry or freeze/thaw cycles, such as occur in most places in Canada.

Lift and Re-mix In-Place

When the existing pavement surface is bound by a slow curing (SC) liquid asphalt, the bound surface can be ripped and removed by a motor patrol. Additional liquid or emulsified asphalt is applied to the material spread over the road surface by an asphalt distributor before cold mixing with a motor patrol. The mixed material is spread or windrowed to allow curing as necessary, then spread, shaped and compacted. Again this practice is usually done by maintenance forces using standard equipment and locally available materials on low volume or lower standard roads. This practice has a greater probability of success than the lift and pulverize practice used for asphalt cement bound

pavement surfaces.

Cold In-Place Recycling Train

The cold in-place recycling train uses three or four pieces of mobile equipment which pick up, process and put down the recycled asphalt pavement (RAP) material in one pass as the train moves slowly along one lane. There are contractors with this equipment in Ontario and British Columbia. The recycling train has four sections. These are:

- The milling unit which removes less than 100 mm but can remove up to 150 mm thickness in a single pass;
- The sizing unit which is a mobile screen and crusher;
- The mixing unit where rejuvinators, usually an emulsified asphalt, is added with the RAP material in a travelling pug mill for discharge to a pavement spreader like a Midland Mix Paver, or in some cases blade laying with a motor patrol; and
- Compaction by traditional asphalt concrete compaction equipment following placement.

This recycling practice requires appropriate sampling, laboratory testing, materials engineering, mix design and construction quality control testing. This engineering and laboratory work is required because:

- The resulting processed RAP is a high quality asphalt concrete pavement material which must meet specifications for satisfactory performance;
- The rejuvenating asphalt material must be selected to soften the aged, hardened asphalt cement to achieve properties specified for RAP materials; and
- The milling process makes the original aggregate gradation finer and more densely graded. The voids in the processed aggregate are often too low to allow sufficient void spaces for the old asphalt cement and the additional rejuvenating asphalt materials, while still leaving sufficient air voids to prevent bleeding. Often sand of a suitable gradation is spread on the pavement surface in front of milling equipment to introduce a gradation change to the aggregate.

Cold in-place recycling trains are a suitable practice when:

- The existing pavement cross section is fair to good without drainage problems and without excess deep failures which must be repaired before milling;
- The asphalt cement is aged and hardened and needs rejuvenation to perform properly as a binder in the asphalt pavement surface;
- The asphalt concrete surface is uniform with respect to spot patches, spot seals and crack filling materials. Some of the crack filling materials are elastic and string-like. These materials remain intact during the process and introduce too much variation in asphalt content and materials gradation within the recycled material to allow a uniform final product. Therefore, some crack filling materials and spot or seal patches should be removed before milling;
- The pavement is structurally adequate but the existing asphalt cement is aged and needs rejuvenation;
- Minimum traffic disruption is important;
- Central asphalt plant or aggregate stockpile sites are not reasonably available near the site; or
- Competitive economics may favour this practice.

The cold in-place recycling train material has been used as surface course on secondary or lower highway classifications, and on lower traffic classification city streets. The emulsified asphalt added needs a curing time of one to two weeks depending upon weather conditions before further layers such as seal coats or another layer of hot mix asphalt concrete (HMAC) are placed.

Cold in-place recycling trains may be used on higher traffic volume pavements if covered by a surface course of virgin aggregate HMAC and the RAP pavement has the required stability for the traffic.

The advantages of this practice are:

- Greater recycle depths;
- Applicable on more seriously cracked pavements than can be recycled using hot in-place recycling;
- Minimum traffic disruption;
- Central plant and stockpile sites are avoided; and
- All the old pavement material is recycled as new pavement.

The disadvantages of this practice are:

- There is a limited number of contractors with this equipment in Canada. Nonetheless, this equipment moves around the country. Road agencies within a region may be able to call sequential contracts which allow a contractor to do several projects in the region;
- Existing pavement conditions must be fair to good; and
- Lead time is needed for appropriate materials engineering and laboratory testing to design the process and materials.

Increased demand for cold in-place recycling work will increase the number of contractors with this equipment. As the number of contractors increase, the regional availability of these contractors will also increase.

More information about cold in-place asphalt concrete recycling for particular regions in Canada is available from provincial highway departments. The annual proceedings of the Canadian Technical Asphalt Association (CTAA) contain many excellent papers on Canadian in-place recycling experience. The 1991 CTAA proceedings paper by Emery is an excellent overview of "Asphalt Recycling in Canada". In the same proceeding, the paper by Bradbury et al describes a case study of cold in-place recycling in Ontario. Publications on in-place recycling by the Asphalt Institute and Asphalt Recycling and Reclaiming Association are recommended reading for those seeking additional information on asphalt recycling.

BARRIERS TO USING THIS OPTION:

- The limited number of contractors with this equipment in Canada. Contractor mobilization costs are excessive for small projects; and

- The lack of knowledge in smaller road agencies, of these methods, particularly the cold in-place recycling train.

RESEARCH & POLICY CHANGES:

- High mobilization costs for small projects can be reduced by connecting the schedules of several smaller projects to a larger project in the region. These sequential projects reduce the mobilization costs to each project. The provincial highway departments are in the best position to facilitate this project

coordination. The local road building association or construction association may also be used to facilitate this coordination; and

- Increased education of these recycling methods by presentations at conferences or demonstration projects will accelerate the implementation of these new practices within a region.

MATERIAL: **Asphalt Concrete**

USE: **Hot In-Place Recycling**

DISCUSSION:

Hot in-place recycling (HIPR) of asphalt concrete pavements is done by a train of equipment moving slowly along one lane of pavement to recycle the upper 50 mm to 60 mm. The pavement surface is heated, scarified or milled, picked up, mixed with asphalt rejuvinators and heated aggregate (either asphalt coated or uncoated), and placed with a conventional paver screed at the back of the train. Some of HIPR equipment trains can accept new asphalt concrete mix which is placed as an integral overlay by a second screed in the train. Compaction of HIRP asphalt concrete uses conventional equipment and procedures.

Canadian Technical Asphalt Association Proceedings papers by Gavin and McMillan (1993) and Emery (1991) provide good descriptions of the HIPR equipment, processes and experiences in the Canadian context.

There is an increasing demand of HIPR equipment during the past five years. Also during this time, the equipment manufactures and contractors have been making small modifications to improve their processes. There are new equipment developments every year. It is advisable to discuss HIPR equipment capabilities with the contractors during the planning of recycling projects to determine the most recently available capabilities.

Although all HIPR equipment do the same basic processes they use different mechanisms, options or variations. The basic processes, from the front to the back of these trains are:

- Heat the asphalt concrete surface to workable temperatures. Most often this is done with one to three large propane radiant heaters. Most trains also have heaters on other parts of the train to maintain the RAP at workable temperatures;
- Scarify the upper 50 mm to 60 mm with fixed teeth scarifiers or hot milling in one or two stages, depending upon the equipment;
- Collect the RAP materials in a windrow or on a conveyor belt;
- Apply the asphalt rejuvinator at a rate metered to the flow rate of the RAP, and mix;

- Import and add hot sand, either asphalt coated or not, to open the gradation and mix. Most systems use travelling pug mills or a series of ground level augers for mixing;
- Place the mixture with a strike off plate or screed similar to that on an asphalt paver; and
- Compact the finish surface.

The Asphalt Recycling and Reclaiming Association recognize three basic HIPR processes. These are:

- Heater-scarification;
- Remixing; and
- Repaving.

The heater-scarification process reworks the heated pavement surface without the addition of other materials. It is sometimes called "reforming", and it is not often used since it only allows reshaping of the surface.

Remixing involves heater-scarification plus additions of rejuvenating asphalt and additional aggregates or asphalt concrete to mix with the RAP materials to create modified materials properties.

Repaving includes all of the processes of remixing but adds a receiving, handling and a second screed to place a layer of new, imported asphalt concrete over the remixed, reshaped RAP material to form an integral overlay. The remixed RAP and new overlay are compacted as one hot lift.

The HIPR process requires advance core sampling, laboratory testing, materials engineering and mix design, to ensure that the recycled pavements have the desired properties. This is necessary to determine:

- the type and amount of asphalt rejuvenating agent needed; and
- the type and amount of gradation modifying sand or new asphalt concrete mix needed to correct the decreases in the voids and the mineral aggregate that occurs as asphalt concrete is scarified or milled.

Pavements that are suitable for HIPR have:

- Uniform surface materials without excess spot seals, spot patches or crack filling materials. Non-uniform surfaces can be prepared by cold milling the thin seal coats and patch materials before HIPR.

Some flexible crack sealants can be a special problem to HIPR or cold milling, and therefore, these sealants may have to be removed before HIPR work;
- Structural adequacy;
- Plain and flat surfaces without excessive rut depth or surface irregularities like deep failures;
- Good surface drainage that does not require correction; and
- Good quality asphalt concrete that has become excessively weathered but the surface is not extensively cracked.

The advantages of HIPR are:

- All asphalt concrete materials are recycled;
- Traffic disruption is minimal. The active construction zone is short, generally less than 300 m;
- The pavement riding quality is improved;
- Minor rutting or surface irregularities can be removed;
- Pavement surface grades for drainage and clearance below structures are maintained; and
- The hauling of cold millings from the road, and recycled materials to the road, are avoided.

The disadvantages are:

- It is suitable only on good condition pavements;
- Costs are higher. Alberta Transportation and Utilities reports costs from four projects done between 1989 and 1993, using different HIPR equipment/applications, as $2.12/m^3 to $2.95/m^3 (Gavin and McMillan 1993); and
- The properties of the recycled/rejuvenated asphalt concrete are not sufficiently high to be used as surface course for primary highways. Therefore the HIPR surface is overlaid with an imported asphalt concrete material on primary highways. The HIPR surfaces are acceptable on secondary highways.

BARRIERS TO USING THIS OPTION:

- The HIPR system are relatively new. A limited number of larger road agencies are developing initial experience with the technology. More education is needed to allow greater use of HIPR systems;

- Mobilization costs are high to move this equipment to outside Ontario and British Columbia where the limited number of HIPR contractors are based. As the amount of HIPR work increases, more contractors will obtain this equipment and access to it will increase in all regions; and

- Air emissions, specifically blue smoke and volatiles from the asphalt rejuvinators, have been of concern. To address this concern, one manufacture has included incinerating type emission control system on each piece of equipment.

RESEARCH & POLICY CHANGES:

- More education on HIPR will promote its broader use. This education is being done by conferences and publications. Road agencies staff are encouraged to become familiar with HIPR methods; they have applicability, especially in urban settings;

- Larger road agencies should continue with trial projects to develop the regional experience with HIPR. Some process or materials modifications may be needed for regional appropriate HIPR work; and

- Continue work with air emission control systems to ensure environmental standards are satisfied at HIPR operations.

MATERIAL: **Asphalt Concrete**

USE: **Mill and Central Plant Recycling of Asphalt Concrete**

DISCUSSION:

Milling and recycling treats the most common pavement deficiencies, the aged and hardened asphalt cement and/or fatigued failures. It is not the appropriate treatment for structural failure of materials below the pavement. Milling and recycling is a management practice that takes up the aged asphalt concrete, reconditions it and replaces it as a pavement layer with improved surface and structural performance.

Asphalt concrete pavements are milled and recycled because the asphalt cement is old, aged and hardened to the point that it no longer performs as required. Before asphalt concrete recycling, the aged pavement surface was ripped up and hauled to disposal if it was excessively aged, or covered with a new asphalt concrete overlay if it had sufficient structural quality.

Milling is the grinding of the asphalt concrete surface using a milling machine The milling machine is a crawler track vehicle equipped with:

- A powerful engine;
- A milling head, which is a drum about 800 mm in diameter and typically 3.66 m long, but can be other lengths, and equipped with about 800 to 1000 cutting teeth. The cutting teeth are mounted perpendicular to the drum or milling head circumference. Each tooth is about 25 mm in diameter and has a replaceable carbide tipped end for cutting;
- A collection and conveying system to deliver the millings to the rear of the vehicle to discharge to waiting trucks; and
- A grade and cross slope control system for automatic or manual control of the depth and cross slope of the cut.

The milling machine typically makes a pass, one lane wide and 50 mm to 70 mm deep. Although shallower cuts are more efficient for the equipment, deeper cuts are possible, but slower. The 50 mm to 70 mm cut depth is most common to avoid excessive "drop off pavement edge" where traffic will use the pavement during milling construction. Where traffic is not an issue deeper cuts may be made, however, cuts greater than 100 mm are not common.

Millings are hauled to a central plant for stockpiling and recycling as HMAC. The uniformity and lack of contamination with granular base course and soil in the millings are important stockpiling criteria to allow the future production of quality, recycled RAP materials.

Before milling, there must be appropriate engineering planning of the entire recycling operations. Data on the existing asphalt concrete is obtained from construction records, surface condition ratings and cores that are tested for aggregate gradation, asphalt cement content and asphalt cement hardness or penetration. Each lift of in-place asphalt concrete may have different asphalt cement or aggregate gradation, and therefore must be separated.

In the case of large projects, milling and central plant recycling is planned for each project to ensure process control and the production of the desired RAP material properties. In this situation, the quantities are large and the complete recycling process is under the control of one project.

However, often the material comes from maintenance milling or small pavement rehabilitation milling. This occurs most often in urban settings, however, it may also be associated with some rural highway work. The resulting central plant stockpile is composed of various amounts of millings from different projects. Care is required in the materials handling to construct stockpiles for each unique milling material. Fortunately most road agencies use one or two asphalt cements and typically less than four aggregate gradations for asphalt concrete. It is necessary to keep separate stockpiles of each unique material type, particularly where different aggregate gradation or different aggregate petrographic qualities have been used.

The benefit of millings stockpile management for uniform materials is:

- A uniform millings feed allows a more uniform RAP material; and
- The uniform and higher quality RAP can be used in the highest quality recycling use meaning as RAP rather than as granular fill.

The central asphalt plant uses drum mixers or conventional batch or continuous mix asphalt plant and the usual supporting equipment. The RAP materials are introduced mid-drum to reduce or avoid contact with the flame or higher drum temperatures near the flame end of the drum. If the RAP materials is added to the drum where it is too hot, the asphalt cement is over heated and becomes harder and more brittle which is undesirable, or it becomes so hot that an undesirable blue smoke is produced.

Most specifications allow for a maximum of 30% to 40% recycled material in the total mix for three reasons. These are:

- Most existing asphalt plant equipment cannot heat the RAP to the required mixing temperatures when more RAP materials, which usually contain moisture, are added;
- There can be excess steam and blue smoke problems as drum temperatures are increased to achieve the required mixing temperatures; and,
- There is a limit to the quantity of recycled materials containing old, hardened asphalt cement that can be softened by additions of new and softer asphalt cement without exceeding the total asphalt content of the mix.

It is possible to have higher recycling ratios (recycled material mass divided by total mass) using specialized or modified asphalt plants with microwave heating technology. As well, drier RAP materials can be recycled at higher recycled ratios but covered stockpile sheds, cold bins and conveyors are needed to keep these materials dry during the storage and handling.

A major technical issue in any recycled asphalt material is "softening" of the original asphalt cement. Asphalt cement ages or hardens by many chemical and few physical processes. Aging or hardening means it becomes less sticky and has less bonding strength on aggregate particles, and it is less flexible and more brittle. Aged asphalt does not bind the particles, particularly the larger particles, well. Therefore surface ravel of the larger particles occurs. Also aged asphalt cement is more brittle and it cracks and breaks when under a wheel load, rather than flex as is the case with younger and less brittle pavements.

The need to soften the aged, hardened asphalt cement prevents 100% recycling ratios. The hardened asphalt cement is softened by mixing it with a new and softer asphalt cement, often much softer than would be used for virgin aggregate mixes. The hardness of the blended old and new asphalt cement in the RAP must be greater than specified level for the RAP to perform well as a new pavement layer. If the old asphalt cement is very hard, a larger volume of new, softer asphalt cement must be added to achieve the required softening. There is a limit to the amount of new asphalt cement that could be added because the total asphalt content of a RAP mix is similar to any asphalt concrete mix. Therefore, in the case of the very hard, old asphalt cement material, the recycling ratio will be low, perhaps 10%. Where the recycled asphalt cement is not so hard, higher recycling ratios, up to 40% may be used before the lack of heating and/or blue smoke constraints restrict the recycling ratio.

Once the RAP material leave the central plant, it is treated like any other HMAC material. It is hauled, placed and compacted to a finished pavement layer.

Most road agencies place 100% virgin aggregate HMAC layers over RAP layers on primary highways or high traffic volume urban streets. RAP layers, sometimes with a seal coat, are used on secondary highways. These practices pertain to the stability or rut resistance and surface durability. Typically RAP mixes have high stability but some may be more porous than the 100% virgin aggregate HMAC. Local experience and practice should guide the selection of RAP mix applications. All provincial highway departments and most large cities have RAP experience to guide other road agencies in the region.

Milling and central plant recycling of asphalt concrete pavement is suitable for:

- Removing a thin layer of excess asphalt content material, such as bleeding sections, or excess seal coats or fog coats used to hold a deteriorating surface before rehabilitation. These millings are not usually suitable to recycle as asphalt concrete;
- Pavements without excess crack sealing materials. Often these crack sealing materials must be removed before milling to avoid contamination because the sealing materials retain their elastic, stringy character through the milling process;
- Restoring surface cross sections such as removing ruts;
- Restoring surface cross slopes, mainly for drainage reasons;
- Recovering lost curb height;
- Maintaining vertical clearance below structures;
- Removing and replacing aged, hardened asphalt concrete layers;
- Removing and replacing fatigue cracked asphalt concrete layers;
- Restoring asphalt concrete layer properties to improve structural strength, with or without additional strengthening overlays;
- Select and remove small areas or strips along the pavement surface. This is particularly the case in urban settings where pavement drainage can be modified at curb and gutter reconstruction or excess ruts can be removed at intersections where rutting is most severe; and
- Fair to good pavement conditions and cross sections. It is not a suitable practice for pavements with numerous deep structural failures and uneven surfaces. The milling machine pulls out the chunks of pavements in the badly cracked areas. These chunks are a form of contamination that can be removed after the drum mixer on the hot screens, but only a small amount can be tolerated.

The advantages of milling and central plant recycling are:

- Traffic can be maintained during construction;
- The materials can be recycled to their highest and best use with savings of aggregate and asphalt cement materials and costs, and avoidance of disposal costs;
- Several surface problems can be corrected; and
- The RAP material properties can be modified for improved pavement layer performance.

The disadvantages of the milling and central plant recycling practices are:

- Special milling equipment is needed. This equipment is available in all regions of Canada except the Yukon and Northwest Territories where there is little HMAC. This equipment is easily transported;
- Specially equipment drum mixers are needed. This equipment can be transported but mobilization costs are high. Therefore larger projects are needed to justify mobilization costs. The small quantity of RAP materials in smaller urban areas does not justify these mobilization costs;
- Non-uniform pavement surface conditions, such as bleeding sections or excessive spot seal coats, require careful milling and the millings produced cannot be recycled as HMAC; and
- This practice is not suitable for all pavement conditions such as excessively cracked and deformed pavements.

As discussed in the section on environmental implications, misinformation about chemicals leaching from asphalt stockpiles may lead to restrictions being imposed on the siting of central recycling plants.

BARRIERS TO USING THIS OPTION:

- In smaller road agencies and smaller urban centres, the access to milling equipment is somewhat restricted; and the access to recycling HMAC plants is greatly restricted by the mobilization economics and small project volumes;

- Often there are no local specialized materials engineering and testing laboratories within smaller road agencies and smaller urban centres. The cost of obtaining these services becomes a factor. As well, the lack of familiarity with these services is a barrier;

- Sometimes RAP material cannot satisfy the high materials standards used for high volume primary highways. The Ministère des transports du Québec (MTQ) work is a good example of changing materials standards. The MTQ has developed new and higher aggregate petrographic standards as part of its solution to asphalt concrete rutting problems on major highways. The old asphalt concrete pavements which are now being milled were constructed 15 to 30 years previously using the aggregate petrographic standards of that period. The petrographic quality of the aggregates in the old asphalt concrete do not satisfy the standards for new primary highway system asphalt concrete materials. Therefore large volumes of recycled materials that are recovered by milling these primary highways cannot be recycled back to those highways. These materials must be used on lower standard pavement applications;

- Lack of familiarity with this management practice is a minor barrier. The equipment and technology are well known and proven in all regions of Canada where these practices have been applied for at least ten years and generally 20 years; and

- The leachability and leachate composition from RAP stockpiles was not given much thought for the past 20 years. Now this concern is a barrier in some special circumstances.

RESEARCH & POLICY CHANGES:

- Smaller road agencies, needing milling and central plant recycling, may be able to have this work done by coordinating their projects with nearby and larger highway projects which bring the properly equipped contractors to their area. This requires coordination and project schedule exchanges between larger and smaller road agencies. This coordination can be further enhanced by smaller communities advising the contractors and road building associations in the region of their potential work requirements;

- The education function is effectively performed by the current system of conferences, seminars and publications. No additional work is needed on education; and

- The leachability and leachate composition question, although substantially but perhaps not completely answered, persists as residual doubt. Proper leaching and toxicology studies are needed to give the Canadian context data and analysis to respond to this, residual doubt.

MATERIAL: **Asphalt Concrete**

USE: **Rip, Crush and Central Plant Recycling of Asphalt Concrete**

DISCUSSION:

This option is the same as "Mill and Central Plant Recycling of Asphalt Concrete" described in the previous section, except for the process by which the RAP materials get to the central asphalt plant. The ripping process to recover RAP is used where it is not possible or practical to recover the asphalt concrete with a milling machine. Ripping occurs when:

- There is a small pavement area to be removed for a pavement patch, underground utility installation or repair, or curb and gutter reconstruction;
- The site is remote with respect to economic or physical access to milling machines;
- The work site is too confined for the large, poor mobility milling machines. In large urban areas, smaller milling machines are available for use at small work sites where much manoeuvring is required;
- The work force removing the pavement are not familiar with asphalt concrete recycling and the appropriate practices; and/or
- The pavement is extensively cracked, broken and/or deformed so that milling is not possible.

Ripping asphalt concrete is done with commonly available equipment. Asphalt concrete bound with asphalt cement is usually too strong to rip with scarifying teeth on a motor patrol unless the pavement is extensively cracked and/or thin. Most often ripper teeth on crawler tractors or backhoes, or backhoes or telescopic rooting boom type excavators are used. Front end loaders may also be used to lift slabs of asphalt concrete once an initial cut has been made.

The ripping breaks the asphalt concrete into pieces of suitable size for loading, hauling and crushing. Pieces smaller than 0.5 m in any dimension are preferred for hauling and crushing. The ripping and windrowing/piling action often, but not always, breaks other materials like granular base course and soil from the asphalt concrete pieces.

Contamination of the asphalt concrete pieces with granular base course and/or soil is the greatest problem with the ripping salvage process. Often large slabs of asphalt concrete can be peeled off the underlying soil or granular base

course with little or no contamination when the asphalt concrete pavement is not extensively cracked or deformed, and careful workmanship is used. Extensively cracked and/or badly deformed pavements cannot be excavated without significant contamination with underlying materials.

Another materials contamination problem occurs when construction forces, usually those focused on underground utility construction or repair, do the asphalt concrete salvage. These forces are not familiar with asphalt concrete recycling, the importance of asphalt concrete salvage without contamination, or the availability of recycling stockpile opportunities. As a result, extreme materials contamination occurs and the asphalt concrete recycling opportunities are reduced.

The asphalt concrete rubble are collected at central stockpile sites. Separate stockpiles for significantly different asphalt cement and aggregate types may be kept, but rarely is there the ability to classify these materials upon their arrival at the stockpile site. In reality, there are two asphalt concrete rubble piles; these are:

- Clean asphalt concrete; and
- Soil or base course contaminated asphalt concrete.

The clean asphalt concrete rubble is crushed to become a feed for RAP. The contaminated asphalt concrete is crushed to become granular base course, subbase or general purpose granular fill because it contains excess fine materials or excess clay for use in HMAC. Unfortunately, in the later case, the value of the asphalt cement in the asphalt concrete rubble is lost.

The asphalt concrete rubble is crushed in a primary jaw crusher for initial sizing as feed to a cone or roll crusher. Conventional crushing equipment and processes are used. Care is required not to over crush and reduce the aggregate to smaller sizes. The crushed and processed asphalt concrete materials are stockpiled for reuse.

BARRIERS TO USING THIS OPTION:

- Lack of knowledge with respect to avoiding contamination of the asphalt concrete by other materials during asphalt concrete salvaging by ripping prevents production of the highest and best use recycled materials.

RESEARCH & POLICY CHANGES:

- Better education of those salvaging asphalt concrete by ripping techniques is needed to avoid or reduce contamination with underlying granular base course or soils. This education can be done easily within the road agency where most staff are already knowledgeable about asphalt concrete recycling;

- Urban governments could provide education to the underground utility staff and their contractors within their jurisdiction. Other underground utility companies like power, gas, phone or cable television, and their contractors also require this education; and

- It may be possible to make good asphalt concrete salvage and recycling practices a condition in the permit issued for excavation of asphalt concrete pavements by non-road agency forces.

MATERIAL: **Asphalt Concrete**

USE: **Mill, Haul and Place Recycled Asphalt Concrete as Pavement**

DISCUSSION:

This materials management practices has evolved from common sense and local experiments that showed some milled asphalt concrete materials in some climate conditions can be milled, hauled, spread, compacted and used like a hot mix asphalt concrete pavement. New pavements, successfully constructed using this method, have the appearance of conventional spreader placed HMAC.

Stockpiles of milled asphalt concrete are often left in maintenance or storage yards for future use. These stockpiles have three characteristics pertinent to the maintenance forces responsible for the stockpile site operations. These are:

- These stockpiles compete for space in the yard;
- These stockpiles have no defined ownership; and
- These stockpiles are a resource of granular materials at no cost to the maintenance budget.

Consequently, maintenance forces use these milled asphalt concrete materials in a wide range of applications, some of which are new and effective in the region. These successful uses are rarely the subject of conference papers or publications, largely because the staff at the local maintenance yards do not present conference papers or publish their work. There is significant local experience with milled asphalt concrete applications within the maintenance forces wherever this material has been stockpiled in maintenance yards in the past.

Mill, haul and place recycled asphalt concrete pavements have been used in Canada and the United States for the following applications:

- Low quality back lane pavements in urban commercial and residential areas;
- Low quality haul road pavements for mud and dust control at aggregate processing plants, quarries, aggregate deposits or central asphalt plants. These roads last two to five years depending upon the traffic, climate, and maintenance work done;
- Low quality shoulder pavements;
- Cold mix patch material for maintenance;

- Low quality pavements at entrances to maintenance yards and stockpile sites; and
- High quality asphalt concrete pavements on medium traffic commercial city streets.

Many of these applications are found where there is some milled asphalt concrete but the locality does not have sufficient volumes to warrant the mobilization costs of a HMAC recycling plant to the area. Therefore some of these applications may be the highest and best practical use for these milled asphalt concrete materials within that locality.

Although these applications are generally not designed or done after materials engineering study, there are some materials principals which explain the success or failure of these applications. There is excellent and pertinent formal research done on the use of RAP in granular base course in Ontario (Hanks and Magni, Senior) and in Quebec (Lupien, Bergeron-in preparation at the Ministère des transports du Québec). Elements of this formal work may be extracted for application to this mill, haul and place pavement application although the research was not done for this application.

The conditions needed for successful mill, haul and place recycled asphalt concrete pavement are:

- Hot, dry climates, like that of the Canadian prairies, with few wet/dry or freeze/thaw cycles and dominantly dry pavement conditions. The hot summer weather allows traffic compaction to maintain a dense, low permeability surface. The dry pavement conditions seems to avoid stripping degradation problems observed in wetter climates where these pavements have been attempted on shoulders of low volume paved highways;
- Milled, well graded granular asphalt concrete. The application can work for small pieces of asphalt concrete rubble that are pulverized and compacted together, typically on haul roads and at entrances to maintenance, central crusher, or asphalt yards. The work by Lupien demonstrates more compaction difficulties and poor compaction result with larger maximum particle sizes or pieces;
- High asphalt contents that are at or above the upper range of asphalt cement contents for most dense graded asphalt concrete mixtures. Asphalt contents over 6% by mass dry aggregate basis seem to be candidate materials;

- Softer asphalt cements. Aged and hardened asphalt cements do not remould and bond well. New asphalt concrete and those made with softer asphalt cement are better candidates;
- Asphalt concretes that have softer asphalt cements or excess asphalt contents by misfortune are candidates. Bleeding pavements are an example.

  On one section of pavement in North Battleford, Saskatchewan, there was a serious rutting problem on a main street in the city centre. Investigations of this ten year old pavement found the dense graded HMAC had an asphalt cement content of over 6% by mass dry weight aggregate basis, and bleeding problems. Further investigations found that the underlying base course was primed with slow curing (SC) liquid asphalt before paving. The diesel cutter stock odour from the SC prime was distinctly noticeable in the asphalt concrete cores. This rutted pavement was milled, hauled, spread and shaped by motor patrol and compacted with smooth steel rollers and rubber tire rollers to a uniform, dense surface on a rural cross section road in the industrial section of the city. The finished surface looks like a spreader placed surface.

  The City of Regina has similar experiences with 75 mm of milled asphalt concrete placed and compacted on a compacted subgrade in back lanes in residential and commercial areas. After several months, this material appeared like asphalt concrete pavement and the residents described their back lane as "paved";

- Hot weather during placement and compaction; and
- Major compaction effort. Finishing by rubber tire rollers is essential to close the surface.

There have been many successes and failures with applications of mill, haul and place recycled asphalt concrete materials. In many road agencies, some maintenance districts use the method with consistent success while neighbouring maintenance districts rarely find the application successful. Success also varies from year to year at the same location. Observation of these random success and failures with this management practice suggest that there are several criteria that need to be satisfied for a successful application. Some of these criteria are listed above. However, an additional factor is the lack of material specifications that quantify these criteria in a way that permits the necessary testing to estimate the suitability of the milled asphalt concrete for successful mill, haul and place operations.

BARRIERS TO USING THIS OPTION:

- The absence of materials property and construction procedure knowledge to use this method in predictable and successful applications;

- The material is available in small volumes and smaller urban centres. The majority of pavement materials research in Canada is performed, or funded by provincial highway departments. Surplus milled asphalt concrete is not a major problem to most of these highway departments; and therefore, research forces or funds are not applied. It is the smaller road agencies and the smaller urban centres who may benefit from research on this materials management practice. Unfortunately these agencies do not have the skills or funds to do this research; and

- The volume of this milled asphalt concrete available in smaller road agencies is not known. This may be a case of many small amount of milled asphalt concrete from a large number of locations resulting in a large volume of under utilized material in Canada. If some better, locally appropriate use for milled asphalt concrete materials was defined, more asphalt concrete milling and recycling would be possible.

RESEARCH & POLICY CHANGES:

- Determine the volumes of milled asphalt concrete or potentially milled asphalt concrete available and what portion of that material is not being recycled because asphalt recycling plants are not economically or physically available; and

- Do research to define rational design and construction methods to recycle milled or crushed recycled asphalt concrete as an asphalt bound material in the highest and best use suitable for locations where HMAC recycling plants are not available.

MATERIAL: **Asphalt Concrete**

USE: **Cold Mix Patching**

DISCUSSION:

Maintenance forces have been using milled or crushed asphalt concrete for cold mix patching for decades with varying success depending upon the properties of the RAP, the climate, and the patch application details. The RAP that works best as cold mix patching has:

- High asphalt content;
- Softer asphalt cement; and
- Appears alive and workable.

RAP that has low asphalt content, hard asphalt cement and appears dry and dull is not suitable.

The success of cold mix patching with this material is increased when used on a hot day and when a major compaction effort is applied such as several passes of loaded truck wheels.

RAP is not truly a cold mix patching material. Certain RAP materials, placed on a hot day with major compaction in climates with dominantly dry pavement conditions have been used successfully. Routine use of RAP is not recommended for cold mix patching.

BARRIERS TO USING THIS OPTION:

- None

RESEARCH & POLICY CHANGES:

- None

MATERIAL: **Asphalt Concrete**

USE: **Cold Pulverization In-Place to Granular Base Course**

DISCUSSION:

Cold pulverization in-place may start with cold scarifying of the asphalt concrete surface with a motor patrol. Thinner asphalt concrete surfaces or extensively cracked surfaces may be scarified and mixed by the pulvimixer which is the pulverization and mixing equipment. This method recycles the asphalt concrete into the base course to thicken the base course. Asphalt emulsion may be applied by spray bars in the pulvimixer or by direct application to the surface with an asphalt distributor. Pulvimixing continues until the mixture is uniform. There may be a delay before compaction, usually less than an hour, to allow initial curing of asphalt emulsions, if added. The mix materials are then compacted using conventional pavement compaction equipment. After compaction an additional curing period of about two weeks is required before any surface covering material such as a seal coat or new asphalt concrete surface course is placed.

Cold pulverization to base course is used when:

- The pavement cross section is fair to good with few deep failures;
- Short sections of pavement need rehabilitation;
- There is a need for structural upgrading of the pavement;
- The recycling opportunities for the existing asphalt concrete are restricted, often because the potential RAP quantity is small;
- The site is in a remote area where specialized HMAC recycling equipment is not available and the small amount of work does not justify the mobilization costs;
- The existing asphalt concrete is less than 100 mm and the existing base course is more than 100 mm thick; and/or
- The asphalt cement is aged and hardened, needing rejuvenation.

The advantages of cold in-place pulverization are:

- The old asphalt concrete is reused;
- The pulvimixer equipment is reasonably available; and
- The work can be done by maintenance forces or smaller local contractors.

The disadvantages are:

- The asphalt cement material is not recycled in asphalt concrete and therefore some of its value is lost; and
- RAP materials mixed with granular base course reduce the California Bearing Ratio (CBR) value.

The Ministry of Transportation of Ontario work reported by Senior restricts RAP use in Granular A Base to less than 30%. The Ministère des transports du Québec research done in early 1994 (Bergeron) also found this loss of base course CBR as RAP content in granular base course is increased.

BARRIERS TO USING THIS OPTION:

- There is a lack of knowledge of this method.

RESEARCH & POLICY CHANGES:

- There needs to be information collected and distributed on this method.

MATERIAL: **Asphalt Concrete**

USE: **Recycled Asphalt Concrete as Base Course**

DISCUSSION:

Processed RAP materials have been mixed with granular aggregate to produce granular base course in many locations. The character of the RAP materials, and particularly the portion of RAP materials added to granular materials, have considerable impact on the bearing capacity of the mixture. Several studies done in Ontario and Quebec prove that granular base course California Bearing Ratio (CBR) values decrease with increasing RAP content in granular base course.

The RAP material must be salvaged by milling or be crushed to a granular condition before use in granular base course. It is never used as 100% RAP base course. Ontario Ministry of Transportation specification limit RAP to a maximum of 30% in Granular A Base Course materials to avoid excess bearing capacity loss. The Ministère des transports du Québec is developing design methods to include RAP in granular base course but allows for the reduced bearing capacity of the RAP/granular base course mixtures.

The asphalt cement in the granular RAP has enough cohesiveness to resist compaction efforts in high RAP content granular base; high compaction efforts generally do not achieve the high density of compacted granular base course. The least compaction occurs when the RAP particle sizes are large and the temperatures are cold (Lupien).

The value of the asphalt cement is lost when RAP is blended in base course, but this may be the highest and best recycled use for the RAP in some conditions.

Conditions which favour use of RAP in granular base course are:

- The RAP is contaminated by soil or granular materials, making its fines content too high for use in asphalt concrete. This contamination is typical of asphalt concrete salvaged by ripping;
- The aggregate gradation or petrographic character of the RAP are not suitable for recycling as HMAC;
- The area is aggregate scarce;
- The disposal costs, typically landfill tipping fees, are high;
- The disposal of RAP is prohibited at some landfills; and/or

- There is more RAP available than can be recycled in HMAC and additional stockpile space for the RAP materials is not available.

BARRIERS TO USING THIS OPTION:

- The reduction in bearing capacity of the mixture restricts the percentage of RAP material that can be used in the base course.

RESEARCH & POLICY CHANGES:

- Road authorities may need to alter their specifications to permit the use of some RAP in the base course.

MATERIAL: **Asphalt Concrete**

USE: **Granular RAP as Shoulder Treatments**

DISCUSSION:

RAP materials are commonly applied on the surface of granular shoulders in eastern Canada. The RAP may come directly from milling, or from milled or crushed asphalt concrete stockpiles. Generally there is no intention that the RAP perform as a bound material although sometimes the RAP materials do compact and become bound like a pavement.

Granular RAP is used on shoulders of paved highways because it is readily available, often in small quantities. Milled asphalt concrete can be hauled directly to the shoulder from the milling machine without any double handling at stockpile sites. An added benefit is that granular RAP materials seem to be less dusty on granular shoulders than granular shoulder base.

If RAP materials are to be added to shoulder base course to form part of the mass in the shoulder base, then the same limits on the amount of RAP included apply as described for granular base course because these RAP materials reduce bearing capacity of granular base courses.

BARRIERS TO USING THIS OPTION:

- The reduction in bearing capacity of the mixture restricts the percentage of RAP material that can be used in shoulder base course.

RESEARCH & POLICY CHANGES:

- Road authorities may need to alter their specifications to permit the use of some RAP in shoulder base course.

MATERIAL: **Asphalt Concrete**

USE: **Granular RAP as Traffic Gravel**

DISCUSSION:

Granular RAP, either from milling or crushing, has been placed as traffic gravel on low volume, earth surface roads. This is a suitable use for RAP materials salvaged by ripping that has been contaminated with soil, where the soil contamination prevents recycling as HMAC or base course.

Regina and Saskatoon city staff prefer RAP as traffic gravel because it produces less dust than granular traffic gravel. The lower dust condition is true for an initial period. However, dust levels will increase as the asphalt cement film on the aggregate particles becomes coated with silt and clay particles.

This management practice is lower on the hierarchy of recycling uses for RAP materials. It becomes an acceptable management practice when the RAP materials are sufficiently contaminated to preclude their recycling to higher and better uses.

BARRIERS TO USING THIS OPTION:

- None

RESEARCH & POLICY CHANGES:

- None

MATERIAL: **Asphalt Concrete**

USE: **Fill**

DISCUSSION:

Asphalt concrete rubble or granular RAP have been used as fill. The rubble is placed in embankments with the benefit of adding to the mass of an embankment rather than filling a landfill. The granular RAP is used in structural fills, including trench backfill.

The bearing capacity of granular base course decreases with increasing contents of RAP. It is also more difficult to compact granular RAP than granular aggregate, especially if the RAP particles are large and the temperature is low (Lupien). Therefore RAP aggregate is not as desirable as a structural fill material as granular aggregates.

Some cities like to use granular RAP as the upper 200 mm of trench backfill at underground utility repair sites. The RAP provides a traffic gravel/base course function. The RAP seems to bond slightly to give a more stable and less dusty surface then crushed sandy gravel.

This is a low value recycling use suitable for soil contaminated RAP that may not be used for higher and better recycling applications.

BARRIERS TO USING THIS OPTION:

- None

RESEARCH & POLICY CHANGES:

- None

MATERIAL: **Asphalt Concrete**

USE: **Rip Rap for Shoreline Erosion Protection**

DISCUSSION:

Large slabs of asphalt concrete, thicker than 100 mm, have been used for shoreline erosion protection. There are several reasons why slabs of salvaged asphalt concrete are not a desirable rip rap material. These are:

- Wave energy washes through the large openings between slabs to erode shore materials;
- The slabs are plates, an undesirable rip rap shape. Cubicle or spherical shapes are preferred;
- Asphalt concrete slabs on shorelines weather and degrade over several years. The shoreline moisture conditions accelerate stripping deterioration. Wet/dry and freeze/thaw cycles also accelerate slab deterioration. Additional rip rap must be added every few years to maintain protection;
- Asphalt concrete rip rap has poor aesthetics; and
- Asphalt concrete rip rap provides poor footing at the shoreline. This can be a problem in urban areas where people, and children in particular, crawl over the rip rap to get to the water's edge.

In the past few years there has been increasing questioning of the leachability and runoff composition from asphalt concrete. Initial studies found asphalt concrete is not leachable and the runoff composition is not contaminated. On the other hand some testing of asphalt concrete cores from a 15 year old pavement in Illinois found undesirable chemicals, all dropped on the pavement surface from passing vehicles. The leachate issue is discussed in greater detail in the "Environmental Implications" section for asphalt concrete.

Asphalt concrete slabs make poor rip rap. Other recycling uses capture more benefit of the materials in these slabs.

BARRIERS TO USING THIS OPTION:

- Asphalt concrete slabs will not maintain durable erosion protection over the long-term.

RESEARCH & POLICY CHANGES: - None

MATERIAL: **Asphalt Concrete**

USE: **Roller Compacted Concrete Aggregate**

DISCUSSION:

Roller compacted concrete (RCC) is a mixture of dense graded aggregate, water for cement hydration and compaction, and cement. The hardened RCC is a high density, low water/cement ratio, high strength Portland cement concrete. The greatest use has been high strength industrial pavements.

Crushed, dense graded base course aggregate specifications with up to 10% by dry mass of -75μm material are excellent aggregates for RCC. The mixing water contents of 6% to 8%, about the standard Proctor optimum water content values, are used with about 15% cement by dry aggregate mass to produce concrete with 28 day compressive strengths of 40 MPa These materials are mixed in a pug mill with a cement feeder using equipment configuration similar to that used to produce soil cement base course.

The fresh RCC mixture is hauled by truck to conventional asphalt spreaders for placement. Spreaders with high energy tamping bars are preferred. Conventional pavement compaction equipment, vibratory steel wheel and high pressure pneumatic rollers, apply immediate compaction. The surface is covered with an emulsified asphalt curing seal or kept moist by a sprinkler system for an initial curing period.

Milled or crushed RAP aggregate has the suitable dense gradation to be part of the aggregate feed for RCC. The portion of RAP that may be acceptably used in an RCC aggregate has been studied by Todres and Manzi. This work found that the mixed aggregate produced a good quality RCC, suitable as a base course concrete for utility trench patches.

Todres and Manzi were seeking field methods for in-situ processing and recycling of asphalt concrete and Portland cement base materials removed at pavement cuts for trenching to repair natural gas pipe lines in the greater New York City area. The difficulty and cost of hauling these excavated materials to recycling or disposal sites, and the cost of supplying and hauling replacement materials in congested urban traffic, motivated them to devise methods to recycle existing pavement materials in-place. Their solution was to crush the asphalt concrete and Portland cement concrete base, add cement and water, make, place and compact RCC as a concrete base course to be covered with 50 mm to 75 mm of imported HMAC to finish the pavement cut at the utility

repair.

Their trial mixes included AC/PCC mix ratios of 0.25, 0.33 and 0.50. Most street pavements in their jurisdiction were 75 mm of HMAC over 150 mm of PCC base. If the actual pavement structure was excavated and crushed the AC/PCC mix ratio is 0.50.

The materials were separated, crushed and recombined to dense gradations with only minor fine sand additions for gradation modification. The laboratory testing of these recycled AC/PCC aggregate RCC found:

- Trial mixes batched and mixed well;
- Compressive and tensile strength decreased with increasing AC aggregate content. These decreases can be reversed by increasing the cement content;
- The CBR value of these RCC mixtures increases rapidly by factors of two or three from one hour to two hours after casting; and
- The laboratory RCC gained 60% of its 28 day compressive strength after 24 hours.

Todres and Manzi concluded the AC/PCC recycled aggregate produced a good quality of RCC and that field trials should proceed.

RCC is attractive as a material that can use recycled asphalt concrete and Portland cement concrete, including the fine materials passing the 5 mm screen in the recycled gradations. Asphalt concrete surfaces are frequently placed over concrete. The ability to salvage and crush these different materials together to produce an RCC aggregate is attractive particularly for urban areas. A further attraction is that RCC is produced using conventional paving equipment, existing contractor skills and known materials quality control testing.

BARRIERS TO USING THIS OPTION:

- Assessment of this practice is in its early stages. The concept is not proven in the field, land construction procedures are not available; and

- Although a proven material, roller compacted concrete is not a well known material in Canada. Therefore, the lack of knowledge becomes a barrier.

RESEARCH & POLICY CHANGES:

- More testing and development is needed to confirm the practice and define mix design methods and construction procedures.

MATERIAL: **Asphalt Concrete**

USE: **Portland Cement Aggregate**

DISCUSSION:

This practice is similar to the use of RAP aggregate in RCC as described earlier. The practice has been used at the field trial level for recycled concrete pavements in Austria (Report on the 1992 U.S. Tour of European Concrete Highways).

In Austria there are pavements with asphalt concrete surface courses over Portland cement concrete. It is possible to mill the asphalt concrete from the Portland cement concrete, then break, gather and recycle the concrete. Austrian laboratory studies found crushed coarse concrete aggregate could contain up to 20% asphalt concrete particles without impairing the quality of the new concrete. Therefore the asphalt concrete and concrete materials in the composite of pavements can be salvaged, processed and recycled into new concrete without separation.

BARRIERS TO USING THIS OPTION:

- The practice is new and needs evaluation in the Canadian climate.

RESEARCH & POLICY CHANGES:

- Laboratory and field investigations, followed by field trials, are needed to give the basis for design and construction using this practice; and

- If this practice is confirmed as suitable in the Canadian context, new or revised concrete pavements specifications will be needed.

MATERIAL: **Asphalt Concrete**

USE: **Disposal by Burying at Construction Sites**

DISCUSSION:

Rejected asphalt concrete materials occur at the asphalt plant during start up operations or at the plant due to materials problem. A smaller quantity of asphalt concrete is rejected at the spreader operations on the road.

Reject asphalt concrete materials have been buried at aggregate deposits or quarries where the asphalt plant is operating, or in the road ditch where the material is rejected at the spreader operation. Usually these materials are wasted because it is difficult to handle truck dumped mounds of hardened asphalt concrete.

The recyclability of the reject asphalt concrete materials is greatly improved if the rejected materials are dumped and spread as a thin, loosely placed layer in an aggregate deposit or quarry. Once these materials have cooled and hardened, they can be broken into a more granular form using front end loader or crawler dozer equipment typically found at these sites. This reworked asphalt concrete material may be used as a granular material or recycled into the aggregate stockpiles. The small quantity of asphalt cement in reject material is generally insignificant in its effect on the aggregate feed.

Burying reject asphalt concrete is a waste of non-renewable resources. It is not a recommended practice.

BARRIERS TO USING THIS OPTION:

- Some provincial environmental departments are reviewing road construction to identify unacceptable practices. Disposal of asphalt concrete by burial at the construction site has been identified as an unacceptable practice.

RESEARCH & POLICY CHANGES:

- Review standard contract documents with respect to materials disposal practices on construction sites and revise as necessary; and

- Develop and use methods to recycle reject asphalt concrete materials on construction sites.

MATERIAL: **Asphalt Concrete**

USE: **Make Surplus RAP Materials Available to Contractors**

DISCUSSION:

RAP materials have economic value in locations where HMAC recycling plants are available. In areas where these plants are not available, it has no economic value to a contractor. Therefore making RAP materials available to contractors with recycling plants creates an economic benefit for that contractor. This economic benefit may return to the road agency as some form of payment. The most probable form of payment is reduced bid prices for pavement construction.

In some End Product Specification projects or other projects where the contractor must supply the aggregate and asphalt cement, RAP stockpiles are truly a resource to the contractor, particularly if the stockpile is near the proposed construction. In these cases, it is common in the United States for contractors to purchase existing RAP stockpiles.

Often a contractor may have more opportunities to use RAP materials than are available to a road agency. For example a prairie paving contractor had a contract to mill use RAP materials, and place a virgin aggregate HMAC surface course on a highway project. The RAP quantities produced exceeded the quantity consumed during recycling operations. The excess RAP was stockpiled. This pavement rehabilitation project was near a small city with no asphalt concrete plant. Several local business persons approached the contractor for price quotations to pave roads and parking lots while his asphalt plant was in the area. If the surplus RAP from the highway rehabilitation was given to the contractor, he could use it to do this commercial paving and thereby recycle all the RAP generated by this project.

The use of road agency RAP for commercial paving is an economic benefit to the contractor. The contractor should pay its fair value to the road agency.

Generally Canadian road agency contract documents do not allow the sale of surplus materials to contractors. In this example, the sale of the surplus RAP to the contractor will facilitate its complete recycling. Often surplus RAP at remote locations remains stockpiled for undefined future uses. In reality these RAP stockpiles are slowly used by maintenance forces for a variety of granular material applications.

BARRIERS TO USING THIS OPTION:

- This practice is applicable only in areas where the RAP has immediate economic value; and
- Public tendering processes and public assets disposal processes may prohibit selling RAP to contractors.

RESEARCH & POLICY CHANGES:

- Investigate the economic benefits of selling RAP to contractors;
- Investigate the policy or legislative changes needed to allow disposal of RAP by sale to contractors either as direct sales or as a credit in the contract price for the work that produced the surplus RAP; and
- Provisions may have to be included in the contract to prevent contractors from wasting the RAP.

MATERIAL: **Asphalt Concrete**

USE: **Longer Pavement Life-Cycles**

DISCUSSION:

The aggregate and asphalt cement in asphalt concrete are non-renewable resources. As these materials approach depletion, their cost will increase. There are two possible responses to higher cost for basic road materials like asphalt concrete. These are:

- Road agencies will obtain increased funding to offset the higher materials costs to maintain existing construction and maintenance activity levels, and presumably the same quality of pavements; or
- Road agencies will obtain the same or less funding. Construction and maintenance levels will decline, and presumably the quality of pavements will decline.

Increased costs for essential aggregate and asphalt cement materials for pavement construction and maintenance will be a major issue for resolution by Canadian road agencies. These higher materials costs will impact on the quality of our road system. Long term monitoring and planning to eliminate or minimize these adverse impacts will be needed to avoid a decline in pavement quality in Canada.

The depletion of aggregate and asphalt cement can be slowed by extracting less virgin material. Extraction rates can be reduced by:

- Increased recycling; and
- Constructing and maintaining longer life pavements.

Studies indicate that less aggregate and asphalt cement is used to construct pavements having a service life of 30 years or 60 years, than would be used in the same period of time using conventional construction and rehabilitation methods. However, new maintenance materials and/or strategies will be required to extend a pavement's service life.

Recently completed Canadian Strategic Highway Research Program (C-SHRP) and Strategic Highway Research Program (SHRP) studies had several projects with new asphalt concrete specifications and maintenance methods that supported the concept of longer life pavements. The Long Term Pavement Performance (LTPP) programs will provide excellent data on the effectiveness of

pavement construction and maintenance strategies with respect to extended pavement life and improved pavement performance. The C-SHRP and SHRP projects represent a start towards seeking longer life asphalt concrete pavements.

Our current asphalt concrete design, construction and maintenance methods were developed in a resource-rich environment. As resources become depleted, our current design, construction and maintenance methods will become less applicable. We have not yet developed the materials and analytical methods that will be effective in the future resource-scarce environment.

BARRIERS TO USING THIS OPTION:

- There are no apparent asphalt concrete materials or technologies which could double or triple the service life of asphalt concrete pavements;

- Higher quality initial construction standards will cost more than our current standards. These higher costs will not be allowed without demonstrated longer life or reduced future maintenance costs. These benefits cannot be demonstrated at current knowledge levels; and

- Conditions change gradually from a resource-rich environment to a resource-scarce environment. Canadian road agencies are experiencing these changes on a yearly basis in small increments that do not raise special attention. The perception that there is no issue or no problem with depleting non-renewable resources prevents forward planning and analysis.

RESEARCH & POLICY CHANGES:

- Seek innovative pavement materials and construction technologies that produce asphalt concrete pavements with service lives that are two or three times greater than the current pavement service life of 15 years to 25 years;

- Seek innovated pavement management material and technologies that extend pavement service life;

- Develop methods to estimate or simulate future pavement materials performances. These methods may be computer simulations and/or accelerated testing;

- Prepare inventories of non-renewable aggregate resources available for road pavement construction and maintenance within your jurisdiction. Estimate the future aggregate consumption at current extraction levels for the next 50 to 100 years. Define future aggregate supply and cost scenarios as major aggregate sources become depleted. This series of investigation and analysis will provide road agencies with a sense of the potential economic impacts of aggregate and asphalt cement resource depletion within their jurisdiction; and

- Define new road materials management plans and economic analysis methods that function in the future resource-scarce environment.

MATERIAL: **Asphalt Concrete**

USE: **Foamed Asphalt Treatment of RAP**

DISCUSSION:

The foamed asphalt technology may have some application to recycling RAP in remote or smaller centres where HMAC recycling plants are not available. Foamed asphalt is produced when a small amount of cold water or steam is injected into hot (160°C) penetration grade asphalt cement. As the water vaporizes on contact, the asphalt cement foams. This foamed asphalt mixes well with cold and damp aggregates to coat particles. The foamed asphalt technology has been used to produce asphalt treated granular base materials which are hauled, spread and compacted.

Aggregates considered undesirable as granular base course have been treated with foamed asphalt to produce a good quality asphalt stabilized base course. Damp aggregates are also suitable for foamed asphalt applications, and no aggregate heating is required. A pug mill supported by a foamed asphalt generator does the mixing.

It may be possible to use RAP with higher fines content and some dampness with foamed asphalt applied by slightly modified asphalt plants or pug mill mixers in smaller urban centres or remote locations where HMAC recycling plants are not available. The potential products are asphalt stabilized base course, or cold placed asphalt concrete surface course for low volume roads.

Experience with foamed asphalt stabilized granular base course trials done in 1992 in Lethbridge, Alberta was reported by Dawley et al in the 1993 Canadian Technical Asphalt Association Proceedings. Although the foamed asphalt concept was developed in the 1950's, it has rarely been used in Canada. There is some use of foam asphalt in the United States and much more use of it for asphalt stabilize bases in Australia.

During the 1980's more research on foamed asphalt was done in the United States (Castedo-Franco and Wood, 1985) when it was identified as an environmentally friendly asphalt cement binder without the chemicals, vapours and/or high temperatures associated with liquid asphalt, emulsified asphalt or HMAC.

The foamed asphalt technology and mix design methods have been proven. No information on foamed asphalt treatment of granular RAP has been found.

Foamed asphalt technology is potentially applicable to making asphalt stabilize base course or cold placed asphalt concrete surface courses on low volume roads in small urban centres or remote locations where HMAC recycling plants are not available.

BARRIERS TO USING THIS OPTION:

- There is no experience with foamed asphalt and RAP aggregate products. The concept is untested.

RESEARCH & POLICY CHANGES:

- Conduct initial laboratory investigations to confirm the applicability of foamed asphalt technology using RAP aggregates. Define product properties and applications; and

- If the laboratory investigations confirm the technology is applicable and the product properties are acceptable, conduct field trials to develop construction procedures and monitor performance.

CATCHBASIN MATERIAL

Source of Material

Storm sewers containing catchbasins are associated with roadways having an urban cross-section. These catchbasins accept the stormwater from the roadway and often are designed with sumps that trap some of the sediments carried in the stormwater. In order to maintain the efficiency of these sewers, the catchbasins must be cleaned out periodically. This cleanout operation is usually done with a vacuum truck or special shovel equipment.

Nature of Material

The material removed from the catchbasin is a slurry consisting of water, sediments, and a variety of contaminants including oil and grease, heavy metals, and rubber.

Environmental Implications

A 1992 study by the Ministère des transports du Québec, indicated that this material is heavily contaminated with copper, zinc, and hydrocarbons. Ontario's Ministry of Transportation has been operating on the understanding that the material contains sufficient levels of heavy metals to require that it be taken to a landfill.

Summary of Previously Reported Management Options

The liquid is sometimes decanted or drained directly back into the storm sewers to a sanitary sewer, or to a sewage treatment plant. The solid portion of the catchbasin material is deposited at landfill sites or stored for eventual use as fill material. Sometimes the liquid is deposited with the solids in the landfill site.

Other management practices for the waste liquid include:

- depositing the liquid at specially designated drying beds or lagoons (possibly at sewage treatment plants); and
- depositing it on the roadway and allowing it to drain to the storm sewers.

The solid portion of the catchbasin material has also been managed by:

- disposal at special fill sites;
- leaving it in the sewer system; and
- sieving and disposal as fill (sediments) and waste (large items: wood, litter, etc.).

In some cases, self-cleaning sewers are being designed, thereby eliminating the need for the cleanout operation, and therefore the excess material.

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Other Potential Management Options

The following management option has been identified for further discussion:

- Soil Washing

MATERIAL: **Catchbasin material**

USE: **Soil Washing**

DISCUSSION:

One company in Ontario has been trying to develop a business around handling catchbasin materials and road sweepings. The process involved washing the sand and discharging the wash water to sanitary sewers. Laboratory analysis commissioned by this firm indicated that the wash water complied with the model municipal sewer use bylaw. The washed sand was to be recycled in asphalt or as winter sand.

Start-up difficulties included the fact that prior to dewatering, the material did not pass Ontario's slump test, and therefore did not comply with the Ministry of Environment & Energy's requirements regarding the type of material the company could receive. In addition the company required a Certificate of Approval from the Ministry of Environment and Energy for a waste management facility because all of the material was not being recycled. Even after meeting the regulatory requirements, the viability of the project was jeopardized because of the company's inability to obtain guaranteed contracts with the Ministry of Transportation, and major municipalities that would make the estimated $1 million investment worth while.

BARRIERS TO USING THIS OPTION:

- The material has the appearance of a liquid industrial waste. Regulatory agencies are therefore cautious about endorsing new management options;

- Environmental Regulations have slowed the implementation of this option; and

- The lack of market agreements has prevented the company proposing this option from being able to develop a sufficiently convincing business plan to obtain start-up capital financing.

RESEARCH & POLICY CHANGES:

In some cases, transportation agencies may need to develop partnerships with entrepreneurs, in order to develop the industrial infrastructure to handle excess materials in more environmentally acceptable ways.

CONCRETE

Source of Material

Excess concrete is obtained by salvaging existing concrete items or demolishing concrete structures, from both road and non-road applications. The concrete may have been cast-in-place or precast. Sources of excess concrete are summarized in Table 3.

TABLE 3

ROAD: CAST-IN-PLACE Pavements Sidewalks Curbs and Gutters Bridges Retaining Walls Structure Foundations Slope Protection	**ROAD: PRECAST** Median Barriers Moveable Curbs Catch Basin/Manhole Barrels Concrete Pipes Light and Sign Bases Reinforced Earth Face Panels Unit Paving Stones Lighting Towers
NON-ROAD: CAST-IN-PLACE Airport Pavements Building Beams, Columns and Floors Building Basements and Foundations Private Sidewalks, Driveways and Patios Retaining Walls	**NON-ROAD: PRECAST** Columns and Beams Roof and Floor Panels Tilt Up Concrete Walls] Building Facing Panels Utility Poles/Towers Concrete Piles

Historically road users of recycled concrete have not used non-road sources largely because non-road recycled concrete quantities have been small and gathering systems did not exist. As recycled concrete became a valued product, most often in aggregate scarce areas or large urban areas, gathering and distribution networks for recycled concrete developed. In these areas road uses are the preferred method of recycling and disposition of excess concrete.

Nature of Material

Concrete means Portland Cement Concrete which is a mixture of mineral aggregates, cement, water and trace amounts of chemical admixtures to enhance specific concrete properties. The mineral aggregates, usually a coarse crushed fraction larger than 5 mm, and fine or sand fraction, provide the strength, bulk and durability. The cement and water form of paste which hardens to bind the aggregates and fill the voids. The aggregate, cement and water is mixed, placed and allowed to cure. The curing is a chemical process in which a series of calcium-aluminum-silicate compounds are formed. Lime is one of the components used to manufacture cement and it is both a part of, and a by-product of, the cement hardening reactions. The lime in plastic and hardened concrete gives these materials a high pH or strongly alkaline character.

Recycling operations need to differentiate concrete by type or condition. The differentiation criteria are:

- Plain concrete or reinforced concrete;
- Concrete condition with respect to durability and deterioration; and,
- Cast-in-place or precast concrete.

Plain vs Reinforced Concrete

Plain concrete contains no reinforcing steel or wire mesh. It can be broken and crushed like quarry rock.

Reinforced concrete contains steel reinforcing bars that are 6 mm to 55 mm in diameter or wire mesh that is 3 mm in diameter in a squared grid of 100 mm or 150 mm openings. Reinforcing steel gives the concrete increased tensile strength and provides load transfer across cracks. It is difficult to break reinforced concrete. Often power saws or cutting torches are used to cut the steel between pieces of concrete during demolition and recycling.

The reinforcing steel bars or mesh must be removed before final crushing of the recycled concrete because the steel damages the secondary crushers and the wire mesh that passes the secondary crushers is short, sharp pieces of wire that can puncture tires when the crushed recycled concrete is used as a granular road surface. Concrete with reinforcing steel requires additional processing for recycling. Therefore the reinforced concrete must be sorted and separated from the plain concrete.

Concrete Condition

The condition of the in-situ concrete may limit uses of the crushed recycled concrete aggregates (RCA). Two aspects of concrete condition controlling recycling applications are:

- Chemical content; and
- Strength, durability and deterioration.

The most common chemical content affecting recycled uses of concrete are chlorides, sulphates and acids. In rarer cases other chemicals that may be undesirable with respect to concrete properties or environmental impacts may be present. Excess amounts of these chemicals, introduced to new concrete using RCA, may reduce the quality of the new concrete or create environmental problems. Concrete with a history of undesirable chemicals may be better recycled as a granular product where these chemicals do not affect performance.

Concrete pavements, sidewalks, curbs and gutters salvaged from areas where deicing salt is used may have high chloride contents. Concrete in contact with sulphate-rich soils such as in basement walls, floor slabs or pavements, may have high water soluble sulphate contents. Concrete in contact with animal urine, manure, dairy products or organic storage such as silage may have high acid contents. These suspect concretes can be sampled and tested to determine the levels of these chemicals before recycling.

On rare occasions other agricultural or industrial chemicals may be present in recycled concrete at concentrations sufficiently high to make the RCA a special or hazardous waste. Therefore it is important to know the source of the recycled concrete proposed for use in road construction and maintenance.

The other concrete condition issue pertains to the concrete soundness in terms of strength, durability and state of deterioration. Sound, strong, durable, unweathered and undeteriorated concrete can be recycled as coarse concrete aggregate to produce high quality concrete. Friable, weak, deteriorated concrete produces a poor quality concrete aggregate when crushed and therefore it is not recommended for recycling as high quality aggregate.

The influence of the original concrete condition on the recycled concrete material is demonstrated by two roller compacted concrete (RCC) mix designs done by Clifton Associates Ltd. in Regina, Saskatchewan in 1987. One aggregate was a virgin, crushed, prairie sandy gravel; the other was RCA made by crushing

salvaged City of Regina concrete curb, gutter and sidewalks taken from street rehabilitation work. Both aggregate gradations were similar - 20 mm maximum size, dense graded, soil stabilized base course satisfying City gradation specifications. The RCA roller compacted concrete had 50% of the compressive strength of the virgin aggregate roller compacted concrete at the same cement contents. Close examination of the RCA roller compacted concrete found a predominance of soft, weak coarse aggregate particles and the test cylinder failure surfaces passed through these weak particles.

Cast-in-Place vs. Precast

The differentiation between cast-in-place and precast concrete pertains to the uniformity of feed stock rather than any quality issue. Typically cast-in-place concrete has larger maximum aggregate size, more variation in strength and properties, and lower compressive strength than precast concrete. Therefore for uniformity of RCA properties, the different types of concrete should be uniformly mixed, or processed separately if uniformity of the RCA is important. Normally precast concrete materials are a small part of the recycling feed. Therefore, blending precast concrete materials with the larger mass of cast-in-place concrete creates no difficulties.

The information given in the proceeding paragraph describes the nature of the concrete feed material for recycling. The following paragraphs describe the nature of recycled concrete materials.

Precast concrete elements like median barrier, moveable curbs or concrete pipe are salvaged for reuse with all the characteristics of the original precast element.

Concrete rubble, plain or reinforced, consists of large slabs and pieces of concrete. The size and mass of each piece is usually small enough to allow loading and truck haul. The demolition process can be modified to make the size of pieces best suited for subsequent use or recycling. Some concrete rubble is used in it's rubble form such as rip rap for shoreline erosion.

Most concrete rubble is crushed and screened to produce recycled concrete aggregate(RCA) materials. The crushing and screening operations are modified slightly to produce different products. The most common RCA products are:

- Coarse concrete aggregate which is larger than 5 mm with a maximum particle size typically between 25 mm and 40 mm;

- Residual fines from coarse concrete aggregate production. This aggregate is well graded sand, smaller than 5 mm and has a -75μm content too high for use as fine concrete aggregate;

- Dense graded aggregate base course; and

- Dense graded hot mix concrete aggregate.

All of these products may be produced by crushing, screening, and sometimes washing for coarse concrete RCA, from the same random concrete rubble gathered from an urban area or concrete pavement demolition.

The paper by Petrarca and Galdiero in Transportation Research Record 989 describes the granular materials test results on dense graded aggregate base course (DGABC) produced by an early commercial concrete recycler in Hicksville, New York. The test results confirmed "extremely uniform DGABC" produced from 1977 to 1981 from recycling over 1,000,000 tons of miscellaneous urban concrete, very little of which was from concrete pavements. In 1982, a third crusher was added to the processing system. Materials properties remained the same except the average California Bearing Ratio (CBR) value increased from 143 to 168 and the average maximum dry density (ASTMD Spare 1557) increased from 128 pounds per cubic foot to 130.0 pounds per cubic foot. Both property changes can be correlated with more crushed particles and denser grading from the additional crushing.

This paper continues to demonstrate the uniformity of the RCA products in the greater New York City area by describing another study done by the Port Authority of New York and New Jersey. This study tested DGABC material properties from RCA taken from five different commercial concrete recyclers in the area. All samples had materials properties identical to the Hicksville RCA. The Petrarca and Galdiero paper summarized several other studies of RCA used in the greater New York area as DGABC and hot mix asphalt concrete (HMAC) aggregate. All RCA materials met or exceeded existing aggregate materials specifications and gave equal or better performance as DGABC or HMAC. The uniformity of the RCA materials properties throughout the region was remarkable considering the RCA was processed from a miscellaneous urban concrete rubble feed.

Dense graded base course aggregate and dense graded hot mix asphalt concrete aggregate can be produced by crushing and screening concrete rubble using conventional equipment. Good quality coarse concrete RCA can also be produced. RCA is generally not suitable as fine concrete aggregate. RCA fines

are suitable as subbase, granular backfill, mineral filler in HMAC and aggregate in no-shrink fill (low strength flowable concrete fill).

RCA is a sound, durable material. In geological terms, aggregate particles are conglomerates of rock and minerals from the original concrete bound together with hardened Portland cement concrete paste. RCA has the grey colour of concrete.

Environmental Implications

High pH Conditions

Plastic concrete, still wet and unset, has a pH value between 12 and 14. There is free lime present in the wet paste. Bare skin in contact with plastic concrete or cement paste can become red and irritated. The condition is called contact dermatitis and is well known in the concrete industry. This dermatitis is prevented by avoiding skin contact with plastic concrete and wearing protective clothing. Once the concrete hardens, the lime becomes chemically and physically locked into the concrete mass.

Many people perceive that all concrete, both plastic and hardened, represent health and environmental risks based on the information about contact dermatitis and plastic concrete. However, hardened concrete, including concrete rubble and crushed RCA is not an environmental problem with respect to high pH leachate.

Recycled concrete aggregate has pH values greater than 11.0 and therefore it is strongly alkaline. This strong alkalinity is not readily dissolved or leached by water; therefore leachate from concrete rubble or crushed RCA is not excessively alkaline and creates no adverse environmental impacts. The New York State Department of Transportation studied the environmental impacts of RCA, including an extensive literature review, and concluded there were no adverse impacts. The International Grooving and Grinding Association (1990) found similar results.

There are two reported situations which require special treatment of RCA materials. These are:

- Increased galvanic activity and corrosion of metal materials in and near RCA backfill; and
- RCA crusher dust in contact with crushing staff.

The New York State Department of Transportation (NYSDOT) has observed accelerated galvanic activity and increased corrosion activity when RCA was used as backfill for trenches above and around aluminum and zinc galvanized pipe, some other types of metal pipes, and underground structures. It has not been determined whether this increased metal corrosion is caused by the increased conductivity of the RCA compared to granular soils or a direct corrosion attack by RCA leachate. The NYSDOT no longer allow RCA backfill at or near metal pipes or underground metal structures. This has resolved their problems.

Crusher dust produced when crushing concrete is fine particles of concrete with numerous freshly exposed surfaces. There can be small amounts of free lime on these dust particles. This lime irritates the moist linings of human and animal respiratory systems and eyes. Eye goggles, dust filter masks and washing thoroughly after working in this dust, prevent health impacts. The City of Regina uses a water mist in the crusher to greatly reduce dust generation.

Landfills Closed to Concrete Rubble

New landfills in Canada are highly engineered waste containment facilities. The cost to site, obtain environmental approvals, construct, monitor and operate these new landfill pits is high. Concrete rubble is chemically inert and produced in large volumes and does not need the containment provided by engineered landfills. Therefore, many landfills refuse to accept concrete rubble, while others discourage concrete rubble through high tipping fees.

The environmental implication is that there are fewer, and in some areas, no landfills which take concrete rubble. In continental United States, almost two tons of concrete is produced per person per year. In time, much of this will be concrete rubble which will not be accepted at landfills. Alternates to landfill disposal will be required.

Aggregate Scarce Areas

The cost of aggregate supply and haul in aggregate scarce areas is the economic force for the local industry to recycle concrete for its aggregate value. Concrete recycling technology and equipment are either in place, or readily available. This technology and equipment will be used once the high aggregate royalty and haul costs exceed the concrete recycling costs.

Aggregate is a non-renewable resource. Any reuse of aggregate, such as concrete recycling, extends the time before aggregate depletion. Although aggregate can be hauled from greater distances at greater costs, at some level increased aggregate costs are no longer affordable. Therefore, the aggregate sources are either physically depleted or not economically available. Current road agency aggregate consumption is not sustainable in the long term, particularly in aggregate-scarce areas.

Road agencies must have aggregate to build, maintain and rehabilitate roads. Aggregate depletion greatly increases aggregate costs, hence road agencies will require more funding to maintain current construction, maintenance and rehabilitation activity levels. If road agencies are not able to increase their funding, they will have to reduce their costs. This will either lead to a decline in the quality of the road system, or the development of aggregate replacement technology suitable for road agencies.

Clifton Associates Ltd. did a study of aggregate depletion scenarios over a 40 year period for the southwest corner of the plains region in Saskatchewan. The study area was 450 km by 300 km. Parts of the area have become aggregate scarce, with haul distances of 50 km to 100 km. That study found aggregate resource decisions were different, depending upon where the region aggregate supplies were positioned with respect to aggregate-rich or aggregate-scarce conditions. This study also found aggregate management practices were very different when the planning time was changed from 5 years to 40 years; short term planning consequences preclude effective long term planning.

Recycling concrete is one of several necessary materials management practices needed to respond appropriately to the depletion of our non-renewable aggregate resources.

Summary of Previously Reported Management Practices

The principal of highest and best use should guide the choice of surplus materials management practices. The aggregate in concrete is a non-renewable resource. Any aggregate loss from the aggregate recycling system accelerates aggregate depletion.

The management practices currently in use include:

- Concrete rubble disposal by burying on or near the right-of-way;
- Concrete rubble disposal in nearby soil borrow pits or depleted

aggregate deposits or quarries;
- Concrete rubble disposal at landfills;
- Concrete rubble disposal at surplus materials broker's facilities;
- Concrete rubble fill on land or in water;
- Concrete rubble as shore line erosion protection (rip rap);
- Concrete rubble as gabion basket fill;
- Crushed RCA as concrete aggregate;
- Crushed RCA as asphalt concrete aggregate;
- Crushed RCA fines as mineral filler for hot mixed asphalt concrete;
- Crushed RCA as no shrink, low strength concrete fill aggregate;
- Crushed RCA as cement treated base.
- Crushed RCA as granular base;
- Crushed RCA as trench backfill;
- Precast concrete median barriers and curbs as planters and terraced landscaped beds;
- Precast concrete median barriers and curbs as materials fences in stockpile sites;
- Reject or salvaged manhole catch basin barrels or concrete pipes as materials fences in stockpile sites; and,
- Salvage and reuse any precast concrete products in their original use.

Although these are previously reported management practices for concrete, some practices are not known or not well documented. Therefore a brief description of these known management practices will be given in the subsequent sections.

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Mr. Harry Sturm, Canadian Portland Cement Association, Toronto, Ontario.

Mr. Ray Van Cauwenberghe, Manitoba Highways and Transportation, Winnipeg, Manitoba.

The following agencies have publications providing information pertinent to recycling concrete:

- Canadian Portland Cement Association;
- Portland Cement Association (in the U.S.A.); and,
- American Concrete Paving Association.

The provincial highway departments in some province and some larger cities have experience and technical specifications for recycled concrete. These larger road agencies in your region may be able to provide useful information.

Other Potential Management Options

The following potential options for managing concrete materials have been identified, and are also discussed in more detail in the following sections:

- Crushed RCA fines as anti-stripping agents in hot mix asphalt concrete;
- Crushed RCA fines as winter sand; and
- Construct and maintain concrete for longer life.

MATERIAL: **Concrete**

USE: **Concrete Rubble Disposal by Burying**

DISCUSSION:

Concrete rubble disposal by burying is the historical method. Most often the burial was within the right-of-way, but could be on other road agency land or private property. The concrete rubble would be covered by 1.0 m to 1.5m of clean soil to avoid conflicts with surface use, vegetation or shallow excavations.

This practice is generally not followed in urban areas because the buried concrete rubble is a potential conflict with the future trench developments. The practice is, and will be, used at remote locations where little concrete rubble is generated and the haul costs to processing sites are deemed prohibitive.

Disposal by burying is usually the least cost management practice. However, it goes counter to environmental consideration, particularly aggregate conservation. Burying terminates the potential aggregate recycling and hence hastens aggregate depletion in the area.

BARRIERS TO USING THIS OPTION:

- This practice cannot be used at locations of thin or no soil cover over bedrock. Sites with a water table near surface make this practice difficult;

- Burial of concrete rubble is a waste of aggregate resources and accelerates the date of aggregate depletion in the area; and

- Buried concrete creates an obstacle to future excavations.

RESEARCH & POLICY CHANGES:

- Concrete rubble disposal by burying should be prohibited. All concrete rubble should be hauled to a stockpile site where it is available for future recycling when the opportunity arises.

MATERIAL: **Concrete**

USE: **Concrete Rubble Disposal In Nearby Soil Borrow Pits Or Depleted Aggregate Deposits Or Quarries**

DISCUSSION:

This is a variation of concrete rubble disposal by burying. Borrow pits, depleted aggregate deposits or quarries allow larger quantities of concrete rubble to be disposed. If the disposed concrete rubble is not covered with soil, then this becomes a stockpile site, making the concrete rubble available for future recycling.

BARRIERS TO USING THIS OPTION:

- There are increased haul costs to transport concrete rubble to borrow pits, depleted aggregate deposits, or quarries for stockpile storage; and

- The land surface at the borrow pit, depleted aggregate deposit or quarry cannot be completely landscaped and returned to a land use or habitat which is aesthetically pleasing and stable for a long period. Part of the area will remain a stockpile and future aggregate processing site with road access. Control of the land will remain with the road agency for some time after construction.

RESEARCH & POLICY CHANGES:

- Concrete rubble disposal by burying in borrow pits or depleted aggregate deposits or quarries should be prohibited. It is acceptable to stockpile concrete rubble at these sites for future use or processing.

MATERIAL: **Concrete**

USE: **Concrete Rubble Disposal At Landfills**

DISCUSSION:

This is the historical disposal practice in urban areas. Concrete rubble is not a desirable landfill material because it cannot be used as temporary or permanent cover soil placed over municipal wastes for sanitation reasons.

Often concrete rubble stockpile sites are established at landfills. In this case the landfill acts as a collection and stockpile site. Once sufficient concrete rubble is stored, the crusher mobilization costs can be justified. Alternately the concrete rubble can be taken from the landfill site for other rubble uses.

BARRIERS TO USING THIS OPTION;

- Increasingly, concrete rubble is denied access to landfills. Therefore, alternate management practices will be required; and

- Burial of concrete rubble is a waste of aggregate resources and accelerates the date of aggregate depletion in the area.

RESEARCH & POLICY CHANGES:

- The landfill can be a suitable location for the accumulation and sorting of concrete rubble for future use or crushing. Landfills should refuse entry of concrete rubble for landfilling purposes but allow the entry of concrete rubble for stockpiling purposes. Landfill operators should work with the aggregate industry to facilitate concrete recycling.

MATERIAL: **Concrete**

USE: **Concrete Rubble Disposal At Surplus Materials Brokers' Facilities**

DISCUSSION:

Several large Canadian cities have excess or waste materials brokers in commercial operation. These brokers accept and often pay for, among other things, concrete rubble delivered to their site. The brokers then process the concrete rubble or sell it unprocessed in large quantities for reuse or recycling.

Contractors or road agencies with concrete rubble for disposal find it economically attractive to dispose of this rubble at a nearby broker site at no charge or for payment rather than incur the high costs of landfill disposal.

Some road agencies, including the New Jersey Department of Transportation, have used cost incentives to encourage materials reuse and recycling practices by contractors supplying to the State. Incentives or subsidies may be necessary to help a local, fledgling waste brokerage industry to become established. Although the provision of incentives and subsidies goes counter to traditional payment methods, sometimes these types of innovations are needed to help establish the necessary infrastructure to support effective materials recycling.

The concept of industrial ecology has been described in "The Cement Kiln Contribution to Sustainable Development" published by The Canadian Cement Council. The concept of an industrial ecological system parallels that of natural ecological systems. In nature, waste materials are decomposed and eventually broken down into their basic elements, which are used to support new growth. In this way old waste organic matter becomes the building blocks for the creation of new living organisms.

The concept of industrial ecology transfers natures model to the industrial setting. Concrete rubble is broken down into components which can be reused in new construction. This ecological model works best when the process of breaking down and reuse occurs at, or near the source of the excess material and therefore, does not require excessive transportation. In urban areas this may go counter to traditional views of compatible land uses. To follow the industrial ecology model, it would be acceptable to have a concrete rubble stockpiling and reprocessing facility within an urban central business district in which new construction is occurring. Implementation of this concept will necessitate changes in traditional thinking on land use compatibility.

BARRIERS TO USING THIS OPTION:

- This management practice must be economically competitive with lower cost disposal options available to contractors and road agencies;

- It would be desirable to have surplus materials brokers facilities located uniformly throughout large areas. However, there cannot be so many brokers that each broker's market share is too small to be commercially viable. Generally the traditional commercial forces will regulate the number and distribution of brokers; and

- Conflicts with adjacent land uses and the high cost of urban land, particularly land in or near the central business district, can prevent the siting of recycling facilities.

RESEARCH & POLICY CHANGES:

- Road agencies should support commercial surplus materials brokering operations. Where appropriate, road agencies could deliver concrete rubble to these brokers and in turn purchase processed recycled aggregates; and

- The industrial ecology concept should be applied to urban land use planning to facilitate the reprocessing of materials near the location where these materials were originally created and will be reused.

MATERIAL: **Concrete**

USE: **Concrete Rubble Fill On Land Or In Water**

DISCUSSION:

Concrete rubble can be used to create fill for embankments on land or in water. When concrete rubble is used as fill, it is removed from aggregate recycling and therefore contributes to the depletion of non-renewable aggregate resources.

Concrete rubble is attractive as fill in water because the rubble resists erosion during placement. Fill in water using soils tends to erode under wave action or in flowing water to create a sedimentation problem. Concrete rubble may be used for breakwaters or for perimeter starter dikes to form lagoons which could then be infilled with soil.

Some agencies prefer to use reinforce concrete for fill and thereby avoid the extra processing costs of removing the steel during recycling. Reinforcing steel bars protruding from concrete rubble is a threat to equipment and people, particularly children, who play on these rubble piles in urban areas. Some agencies cut protruding steel from concrete rubble placed in areas accessible by children.

Soil fill must be placed over concrete rubble to form the final layers of embankments. Concrete rubble at shore lines is often deemed unsightly. The poor appearance may be improved by covering the concrete rubble with a natural rock.

BARRIERS TO USING THIS OPTION:

- Concrete rubble placed in fills is lost to the aggregate recycling process and accelerates the depletion of non-renewable aggregate resources; and

- Some jurisdictions discourage the use of concrete rubble in water because of a perception that the high pH will create aquatic impacts. Although this is not the case, the perception can remain a barrier.

RESEARCH & POLICY CHANGES:

- Where concern remains regarding the aquatic impacts of concrete rubble, research may be required.

MATERIAL: **Concrete**

USE: **Concrete Rubble As Shoreline Erosion Protection (Rip Rap)**

DISCUSSION:

Concrete rubble makes an excellent shoreline erosion protection material commonly called rip rap. Some concrete rubble is badly deteriorated and not sufficiently durable for the weathering exposure for rip rap. These poor quality concrete deteriorate to a grey granular material that no longer functions as rip rap.

The fundamental principles of good shoreline erosion protection design must be applied when using concrete rubble for this purpose. Generally there is no review of the concrete rubble rip rap design and therefore erosion problems continue even though large masses of concrete have been placed on a shoreline. This is because water can wash through the large openings between the concrete rubble to erode the soil below.

BARRIERS TO USING THIS OPTION:

- Concrete rubble placed in fills is lost to the aggregate recycling process and accelerates the depletion of non-renewable aggregate resources; and

- Concrete rubble shoreline protection is often judged as having poor aesthetic quality. The aesthetic quality of the concrete rubble may be improved by placing a thin layer of natural rock over the concrete rubble to improve it's appearance.

RESEARCH & POLICY CHANGES:

- Require concrete rubble be designed as a shoreline erosion protection to ensure its effectiveness.

MATERIAL: **Concrete**

USE: **Concrete Rubble As Gabion Basket Fill**

DISCUSSION:

Gabion baskets are a proprietary product used for slope erosion control, canal and ditch linings and low to medium height retaining walls. The gabion baskets are galvanized wire mesh baskets of different dimensions with an attached top. The size of the rock or rubble fill can be chosen for specific site requirements.

The bottom basket is placed on a prepared foundation and filled with rock or concrete rubble pieces generally about 100 mm diameter and the lid closed and secured. Adjacent baskets are connected to the first basket with wire connectors. The baskets are progressively filled with rock or concrete rubble and more empty baskets are added until the slope protection or retaining wall is completed.

Gabions are a favoured option where site access prevents large vehicle entry or large working areas are not available. The method is also favoured where construction impact must be limited to a small area in sensitive settings. The work is done by hand assisted by small skid loaders or back hoes.

Plain concrete rubble should be processed by primary crushing to the desired size. Reinforced concrete is not recommended for gabion basket fill. Sound concrete should be selected for this application; low durability or badly deteriorated concrete is unsuitable.

BARRIERS TO USING THIS OPTION:

- Concrete rubble placed in fills is lost to the aggregate recycling process and accelerates the depletion of non-renewable aggregate resources; and

- Concrete rubble shoreline protection is often judged as having poor aesthetic quality. The aesthetic quality may be improved by placing a thin layer of natural rock over the gabion basket.

RESEARCH & POLICY CHANGES:

- None.

MATERIAL: **Concrete**

USE: **Processing For Recycled Concrete Aggregate**

DISCUSSION:

The crushed recycled concrete aggregate (RCA) products are:

- Dense graded base course aggregate;
- Dense graded hot mix asphalt concrete (HMAC) aggregate;
- Coarse concrete aggregate; and
- Residual fines or well graded sand from the coarse concrete aggregate production.

All materials are produced by the same processing methods with minor variations for each product. Most concrete rubble feeds are suitable but some screening, as discussed in the section on "Nature of Materials" for concrete, may be required. The processing described here applies to all crushed RCA products.

There are a series of distinct processes used to take in-service concrete through to a crushed RCA. These processes are described in the following subsections.

Breaking or Demolition

The original concrete structure or element must be broken into pieces for hauling to the processing site. Different breaking equipment is best suited for different concrete structures. The objectives of breaking and demolition are:

- To demolish and remove the existing concrete structure;
- To minimize the contamination of the recycled concrete with other building demolition rubble and with underlying granular or soil materials;
- To produce rubble sizes suitable for:
  - Loading and hauling;
  - Processing as feed to the primary crusher; and
- To remove as much reinforcing steel as possible on site.

The wrecking ball is used on building structures, sidewalks and concrete pavements. Concrete is broken into suitable sizes. Often power saws or cutting torches are used to cut reinforcing steel joining rubble. Hand held pneumatic hammers or jack hammers are used for small volume projects or

small working spaces.

Sidewalks, driveways, curbs and gutters, concrete pipe, and manhole and catchbasin barrels are excavated with backhoes, front end loaders, motor patrols or crawler dozers. The resultant rubble is broken into smaller pieces by the same equipment.

Recently, major concrete pavement recycling jobs have driven the development of special high capacity pavement breaking equipment. This equipment is described in the paper on concrete pavement pulverizing equipment by Dykins and Epps. Concrete pavement can be broken/removed by:

- Cold milling with milling machines;
- Slab breaking (the most commonly used); and
- Cutting and lifting panels.

Cold milling concrete pavement is rarely done because of its high cost and slow production rates. Cold milling concrete pavement is two to three times more costly than milling asphalt concrete paving (Dykins and Epps). Reinforcing steel creates special problems for cold milling in concrete pavements.

Cutting and lifting panels is used for trenching or underground utility repair. The cut, made by large diameter wheels with carbide tipped teeth or commercial diamond saws, gives a neat edge for patching. This method is slow and does not produce rubble material suitable for loading and hauling, and therefore it is not frequently used.

Common slab breaking methods described by Dykins and Epps are:

- Crane and drop ball (wrecking ball);
- Gravity drop hammer;
- Hydraulic or pneumatic hammer/breakers which are boom mounted on large backhoes;
- Trailer mounted diesel hammers. The hammer strikes the pavement at 80 blows per minute as it is towed slowly along the surface;
- Spring-arm whiphammer which delivers a blow with about 300,000 pounds of force via a 7' long steel spring with a breaking foot at the end of the spring. The whip hammer is mounted on the back of the single axle truck;

- Vibrating - beam breaker. This is a large section steel beam about 3.6m long mounted beneath a wheeled carrier vehicle. It impacts the concrete with high frequency, low amplitude blows. This is the preferred breaker for high production in urban settings;
- Breakers using bending moments. This is a large hook placed under the edge of the a concrete slab. The hook is lifted as a hydraulic bar pushes down on the top of the slab near the hook. This breaker has been called "The Nibbler" and is used in the United Kingdom; and
- High pressure water jets.

The crane and drop ball are available in all parts of Canada. Backhoe boom mounted hydraulic hammer/breakers are available, or could reasonably be moved to many areas in Canada. The specialized pavement breaking equipment would have to be brought to site on a rental or subcontract basis from specially equipped contractors. The special pavement breaking equipment would only be needed for large concrete pavement recycling projects.

The subgrade bearing capacity greatly influences grade supported concrete breaking, piece size, breaking effort and productivity. Strong subgrades are best for concrete breaking. Some concrete breaking equipment imparts high energy to the pavement and surrounding soils. The vibrations and noise may be unacceptable in some urban areas. The very high energy equipment can damage underground services and utilities.

Steel Removable at Site

Some breaking equipment effectively breaks the concrete/reinforcing steel bonds. Diesel hammers are best at breaking bonds. Otherwise, steel removal is made easier when the concrete is broken into smaller pieces. Wire mesh can be removed by large backhoe mounted hardened steel hooks.

Most steel is removed on site by shaking, banging or dragging the steel from the rubble or by hand cutting and removal. Steel removal on site is still slow and labour intensive. This is an area where productivity improvements are needed.

Loading and Hauling

Concrete rubble is windrowed or pushed into small piles for loading with front end loaders. Plain concrete pavement rubble can be loaded from its original position by skimming it off the base course or subgrade.

The following should be considered when loading and hauling concrete:

- Avoid contamination of the concrete rubble with soil and granular materials, or other demolition materials;
- Operate rubber tire vehicles with caution or clean the driving surface to avoid tire punctures by protruding reinforcing steel;
- Make rubble pieces small enough to load;
- Do not drop large pieces of rubble into trucks to avoid truck box and suspension damage; and
- Avoid large dimensions slab pieces. These fill truck boxes with very little mass being hauled. Small pieces allow more efficient hauling.

Gathering and Stockpiling

Single project generators of large recycled concrete volumes are not common in Canada with some notable exceptions like the Sky Dome Complex in Toronto, and part of the port area in old Montreal. These larger projects recycle, process and use RCA within the project.

The dominant Canadian situation is the generation of small volumes of concrete rubble by many public and private works. For example, the City of Regina gathers and recycles 50,000 tonnes of concrete each year. This concrete comes from hundreds of sources and is delivered daily in varying amounts by different haulers. Other cities and commercial recyclers operate on this basis.

Gathering and stockpiling systems must be in place to capture urban concrete for recycling. This system can be publicly operated like the City of Regina which welcomes concrete rubble at the city landfill without tipping fees. This is because Regina is in an aggregate-scarce area where RCA is available at lower costs than virgin aggregate. The gathering system can be privately operated as done by quarry operators in Montreal. The quarry operators receive and sometimes pay for concrete rubble which is processed at their stationary crushers/screening plants for resale or their own use.

Concrete rubble generators and haulers need to know that gathering sites

exists. They also need to know that the concrete rubble should be free of contamination and sorted by load for stockpiling as either plain or reinforce concrete.

Stockpile sites must have large areas for the storage of concrete rubble, processed RCA and the crushing/screening equipment to do the processing. Small centres may stockpile concrete rubble for many years until there is enough volume to justify the cost of crusher/screener mobilization to process the RCA.

Initial Sizing and Steel Remove at Processing Site

Concrete rubble gathering sites receive a variety of rubble sizes and steel contents. Rubble must be broken into pieces small enough to feed the primary jaw crushers. The size of the jaw opening on the crusher will govern the size of the feed pieces.

The rubble is broken using a crane and drop ball, backhoe mounted hydraulic hammer/breaker or hydraulic cutters, backhoes, crawler dozers and hand held pneumatic hammers (jack hammers).

As much steel as possible is removed using the breaking equipment and hand picking. The common reinforcing steel and wire mesh in concrete pieces do not cause problems in jaw crushers. However, large structural steel elements do cause problems, and must be removed from the feed to avoid damage to the jaw crusher.

Primary Crushing and Sizing

Jaw crushers with large openings are the primary crushers that break the reinforcing steel from the concrete and reduce the rubble to typically 75 mm or 100 mm maximum particle size. The final steel removal is done with electric magnets or magnetic conveyor belts on the primary crusher discharge. The removed steel is sold as scrap metal.

Secondary Crushing and Final Sizing

The steel-free and sized concrete rubble is fed into cone or roll crushers for final sizing. Any steel remaining in the feed can damage these crushers. The crushing and screening circuits are those conventionally used to size aggregates.

BARRIERS TO USING THIS OPTION:

- The cost of handling and processing RCA may be more than the cost to extract and process virgin aggregate. Traditional competitive tendering processes favour the least cost material in construction; therefore, relative cost is the most common barrier;

- There are insufficient gathering systems in Canada to collect concrete rubble for recycling. There are effective gathering systems in Calgary, Regina, Winnipeg, Toronto and Montreal, and probably at many other locations;

- The low cost of disposal and low tipping fee for concrete rubble at landfills provides no economic incentives to recycle concrete;

- Many agencies feel they do not generate sufficient concrete rubble to justify recycling and therefore their concrete rubble is hauled to disposal rather than to a stockpile site. Their mindset that the small amount of rubble is waste, rather than an excess material with future value, is a barrier; and

- The lack of knowledge on concrete recycling prevents its greater use. Contractor concerns about damage to tires and crushers by steel pieces makes them reluctant to process RCA.

RESEARCH & POLICY CHANGES:

- Road agencies could offer a cost incentive to contractors using RCA as a premium payment per tonne for the use of RCA. The extra income will offset the cost of new equipment, like magnetic conveyor belts, and compensate for training costs. This cost incentive can motivate the local industry to develop a concrete recycling capability;

- Road agencies could promote gathering systems by developing partnerships with landfill operators and the aggregate industry. Road agencies could further support developing gathering systems by delivering concrete rubble into the systems and later purchasing their RCA products;

- Increased landfill tipping fees for concrete rubble and/or the prohibition of wasting concrete rubble from road agency projects will make the processing of RCA more attractive; and

- Road agencies can provide education to their staff, contractors and consultants who would be recycling concrete. The Manitoba Roadbuilders Association had a seminar on recycling concrete, using the Manitoba Highways and Transportation 1992 test recycling of concrete pavements, as an example. Department staff and the contractor gave presentations and answered questions. Several contractors attending the seminar indicated that they plan to start stockpiling or recycling concrete for their own use.

MATERIAL: **Concrete**

USE: **Crushed RCA As Granular Base**

DISCUSSION:

Crushed RCA satisfies the gradation and other material quality specification of most road agencies for dense graded granular base course. The crushed RCA has a -71μm content of 5% to 15%. The fines are non-plastic and non-frost susceptible. The aggregate is cubical with rough surface texture. California Bearing Ratio (CBR) values vary from 95 in Regina using crushed prairie gravels to 160 in the New York City area as reported by Petrarca and Galdiero. Ontario contractors like RCA base course because it "locks up" well, meaning it transfers load well when placed on a weaker subgrade (John Emery Geotechnical Engineering Limited). These contractors also like the high yield, meaning it's lower compacted unit weight of 2,060 kg/m^3 versus dense graded base course unit weights of 2,200 kg/m^3 gives more cross section volume filled per tonne of material hauled.

Recycled crushed concrete is frequently used on Ministry of Transportation of Ontario contracts in granular base and recycled crushed concrete is allowed up to 100% in granular A base materials (Senior). Recycled concrete aggregate meeting material specifications may be used as granular A, B and M on Ministry of Transportation contracts (Hanks and Magni).

In most cases RCA makes dense graded base course. Typically good quality concrete made from high quality aggregate will produce high quality RCA base course. Aggregate and concrete quality can very regionally in Canada and therefore each region must confirm the character of locally produced RCA with respect to base course gradation and quality specifications. The source of concrete rubble feeding the RCA process should be reviewed for the possible presence of environmentally undesirable materials. If this initial screening finds some probability that undesirable materials are present, environmental testing of the rubble or the RCA may be warranted.

BARRIERS TO USING THIS OPTION:

- The incremental additional cost of RCA base course above virgin aggregate base course is a barrier when contracts are most often awarded to the lowest bidder;

- Concrete quantities are small on rural highways. These small

quantities do not justify processing for RCA base course;

- Larger quantities of concrete rubble are generated in urban centres but there is a knowledge barrier which prevents some urban centres from actively pursuing this rubble as a source of RCA base course;

- The absence of local experience with RCA base course, it's properties, expected performance and structural equivalencies for pavement thickness design makes road agency staff reluctant to use unknown materials; and

- Most aggregate specifications, including those for base course, prohibit undesirable quantities of deleterious materials such as rubble.

RESEARCH & POLICY CHANGES:

- Develop experience with local RCA base course. Do the laboratory test with local RCA materials. Do planned and monitored test section to confirm RCA base course performance; and

- Revise standard materials specifications with respect to rubble being a deleterious material when the agency allows RCA base course.

MATERIAL: **Concrete**

USE: **Crushed RCA As Cement Treated Base Course**

DISCUSSION:

Cement treated base course is a dense graded granular material which has a small quantity of cement added, usually less than 5% by weight, to improve base course properties. The cement is not intended as a bonding agent to give strength, but as a modifier to reduce the plastic influence of excess fines in the base course aggregate. Cement modification of high fines content base course increases bearing capacity and reduces frost activity.

Cement treated base courses are most often used with concrete pavements. There are few cement treated bases or concrete pavements in Canada.

Some crushed RCA have fine contents above the maximum gradation limits for base course. Cement modification can improve the performance of these high fines base courses. The cost of cement treated base course is high and therefore used only when the supply of better quality base course is also relatively costly.

The residual fines from coarse concrete RCA production are a marginal quality aggregate for base course. With cement modification, these RCA fines may make a suitable cement treated base course.

BARRIERS TO USING THIS OPTION:

- The cost of cement increases the cost of cement treated base course so that these are only economically competitive in seriously aggregate scarce areas.

RESEARCH & POLICY CHANGES:

- Materials testing using local RCA as an aggregate for cement treated base course is needed to confirm materials properties. Economic analysis is needed to confirm the feasibility of using RCA for cement treated base.

MATERIAL: **Concrete**

USE: **Crushed RCA as Hot Mix Concrete Aggregate**

DISCUSSION:

Crushed RCA is a durable, angular, rough surface texture, dense graded aggregate. It is a desirable hot mix asphalt concrete (HMAC) aggregate. The one caution is that the -75μm content of RCA may be marginally high for most HMAC gradation specifications. The marginally high fines content may be reduced by changing the RCA processing, extracting fines at the asphalt plant, or adding gradation adjusting aggregates.

HMAC has been produced using RCA in Ontario (John Emery Geotechnical Engineering Limited). The paper by Petrarca and Galdiero describes laboratory testing and test pavement results for 100% RCA in HMAC in the New York City area. The HMAC in these tests had 60% more stability and 16% less unit weight than a crushed stone/natural sand mix of identical gradation. This work also found the RCA mixes had Marshall Design optimum asphalt cement contents of 0.5 % to 1.0% by mass higher than that for crushed store/natural sand mixes. This higher demand for asphalt cement has been reported by others.

In Canada the potential quantities of RCA available from rural highway construction is too small for use. Most rural highways are asphalt concrete except in Manitoba where several primary highways are concrete pavements. There are sufficient quantities of concrete rubble potentially available in urban centres for use in HMAC.

There are no materials quality barriers to using RCA in HMAC. The high stability property of RCA mixes is attractive for the prevention of plastic rutting in asphalt concrete pavements. The high volume yield per unit mass of material increases the economic competitiveness of RCA mixes.

BARRIERS TO USING THIS OPTION:

- The relative cost of RCA in HMAC restricts it's use in a tendering environment which usually awards construction works to the lowest overhead. The cost barrier differential is further increased by the need for 0.5% to 1.0% by mass more asphalt cement in RCA mixes compared to virgin aggregate mixes. For example this incremental asphalt cement content is sufficient to prevent the City of Regina from using RCA for HMAC in an aggregate scarce area;

- The urban concrete rubble gathering systems are not collecting sufficient volumes of RCA to supply the HMAC market or a practical segment of that market;

- Lack of knowledge of RCA in HMAC in urban centres prevents it's use. The RCA mix may be a lower cost method of producing high stability asphalt concrete pavements than some of the high stability mixes in current use; and

- Pavement materials research in Canada tends to be led by the provincial highway departments. Research into RCA for HMAC is not a provincial priority because there is little concrete to recycle from the rural highway system. The RCA is available in urban areas where municipal governments have responsibility for roads. Most municipalities do not have pavement materials research staff to lead the testing and analysis of local RCA use in HMAC.

RESEARCH & POLICY CHANGES:

- Investigation of the technical properties of HMAC produced using local urban RCA is needed. There should be a companion analysis of the economics of RCA versus other high stability HMAC mixes. The high stability benefits may justify the increased cost of RCA mixes;

- Urban gathering systems for concrete rubble need development to capture sufficient volumes to produce economic volumes of RCA needed for high stability asphalt concrete mixes;

- Education is needed. Most people are not aware of RCA in HMAC or it's potential benefits; and

- Municipalities need some basic investigation of the annual quantity of concrete rubble available as RCA in HMAC and other products. If suitable quantities are available, initial materials testing of local RCA is needed to confirm its performance and cost.

MATERIAL: **Concrete**

USE: **Crushed RCA Fines For Gradation Modification Of Hot Mix Asphalt Concrete Mixes**

DISCUSSION:

Manitoba Highways and Transportation has found that the residual RCA fines from coarse concrete aggregate production are not suitable for recycling in concrete. However, these residual fines are an excellent filler sand to improve gradation and other properties in HMAC (Van Cauwenberghe). The RCA fines are dense graded and pass a 5.0 mm screen. The fines are angular, rough and harsh, and have an excellent potential to increase stability of HMAC mixes when added in small amounts.

Hot mix asphalt concrete plant operators are skilled at adding small amounts of different granular materials to modify aggregate gradation and improve mix properties. These residual RCA fines can be added at the existing asphalt plant using existing equipment and procedures.

BARRIERS TO USING THIS OPTION:

- These RCA residual fines must be sufficiently close to the asphalt plant that haul costs do not prohibit their use. Haul costs are minimized where the RCA processing is done at the same site as the asphalt plant; and

- There is limited local knowledge about the effect of RCA residual fines as a mineral filler in HMAC.

RESEARCH & POLICY CHANGES:

- Provide education and information about RCA residual fines to the HMAC industry; and

- Conduct laboratory testing to demonstrate and quantify RCA residual fines improvements to HMAC properties.

MATERIAL: **Concrete**

USE: **Crushed RCA as Concrete Aggregate**

DISCUSSION:

Manitoba Highways and Transportation successfully recycled an existing concrete pavement as the replacement concrete in 1992 (Van Cauwenberghe). This work was done based on a decade of experience with recycling concrete pavements by the North Dakota Department of Transportation which works with similar soil, aggregate, traffic and climate conditions to Manitoba. Recycling concrete pavements as concrete has been done since the early 1980's in Michigan, Wisconsin, Minnesota, North Dakota, Iowa and Wyoming (Yrjanson). Most of these states have similar soil and climate conditions to many Provinces in Canada.

Highway concrete pavements are high quality concrete made from high quality aggregates. The benefits of recycling concrete pavements are described in Dykins and Epps as follows:

- Providing aggregate where high-quality aggregate is no longer economically available;
- Eliminating the need to waste large amounts of pavement rubble;
- Conserving present aggregate sources;
- Reducing the need for disrupting land for quarrying purposes;
- Saving fuel and energy by reducing aggregate transportation;
- Reducing damage to haul roads near paving projects; and
- Achieving a monetary saving while constructing high-quality roadways.

Design and construction procedures are well described in the 1993 "Recycling Concrete Pavement" publication by the American Concrete Paving Association.

Concrete pavements have been proven as an excellent material for recycling, mainly because the original aggregate and concrete were high quality, uniform materials subject to quality control testing during their original construction. Miscellaneous urban concrete, being more diverse in source and quality, may not be as uniform as the RCA produced from concrete pavements.

The materials property tests of RCA produced by a Hicksville, New York recycling contractor over five years using miscellaneous urban concrete rubble with little concrete pavement, were amazingly uniform (Petrarca and Galdiero).

The sodium sulphate soundness and Los Angeles abrasion test results were uniform, suggesting that the coarse concrete aggregate fraction of these dense graded aggregate base course products would produce a uniform quality RCA. Laboratory testing using locally produced RCA concrete mixtures are needed to confirm the suitability of local RCA as a coarse aggregate concrete.

Experience with recycling concrete pavements has confirmed that the course concrete fraction of RCA is an excellent material and that the fine concrete fraction is an undesirable material for making concrete. The fine concrete aggregate fraction contains excessive -75μm material and has high and variable absorption. Use of RCA fines in concrete creates variation in water/cement ratios, strengths, concrete workability and always makes marginally unacceptable to unacceptably harsh mixes. Therefore RCA fines are not generally used and are not recommended for use in making concrete.

The processing of concrete pavement can produce 50% to 80% of the rubble mass as coarse concrete aggregate; the yield variation being controlled by the breaking and aggregate processing methods. Typically concrete contains about 60% coarse concrete aggregate. Therefore all the coarse concrete for new concrete pavements can be obtained from recycling the old concrete pavement. There is good probability that excess coarse concrete aggregate will be produced if the same pavement thickness is replaced. Only new fine concrete aggregate, cement and water are imported.

Concrete produced using coarse concrete RCA from concrete pavements is equal to or better than the original concrete produced using virgin aggregate. The technology is proven and routinely used in the United States, Europe and Japan. There has been little concrete pavement recycling or concrete recycling into concrete in Canada but this technology is being used more, particularly in aggregate scarce areas.

BARRIERS TO USING THIS OPTION:

- The potential variability of miscellaneous urban rubble makes materials engineers cautious about the uniformity of coarse concrete RCA properties. Uniform aggregate properties are essential for the production of uniform, high quality concrete;

- Urban concrete rubble gathering systems either do not exist, or are poorly developed and do not capture enough concrete rubble to supply the volumes of RCA needed for economic concrete production;

- With a few exceptions, like Toronto, little is known about concrete rubble generation volumes or quality in urban areas. Practical concrete recycling plans can only be defined after some estimates of quantity and quality available are made;

- Urban centres do not generally have pavement materials research staff. Except for a few large cities, this research staff is in the provincial highway departments and to a lesser extent in universities, provincial or national research councils, and consulting engineering offices. The urban centres generate the concrete rubble and may benefit from using RCA in concrete, but do not have the staff to do the testing or research needed to confirm that local RCA is suitable for concrete production; and

- Improper handling and separation of materials can limit the ability to recycle concrete rubble from buildings. For example, gypsum board and plaster contain predominantly gypsum or hydrated calcium sulphate. These materials, common in building demolition rubble, introduce water soluble sulphates into concrete if the RCA was contaminated with them. Excess water soluble sulphates attack concrete paste and reduce concrete quality. Therefore, contaminated concrete may not be suitable for producing concrete aggregate.

RESEARCH & POLICY CHANGES:

- Urban road agencies need estimates of concrete rubble volumes and quality generated in their area. Studies can be done to get these estimates. With this information in hand, it is necessary to identify potential and practical RCA products consistent with the quantities and quality available. Do initial economic analysis to estimate concrete recycling benefits;

- Obtain data on the uniformity of local RCA properties for all products including coarse concrete aggregate. Decide if there is sufficient uniformity for high quality products like coarse concrete RCA; and

- If economically viable quantities and qualities of concrete rubble and RCA are available, define appropriate RCA uses for the urban centre and do the initial laboratory materials testing to give the basis for design and construction using these RCA products.

MATERIAL: **Concrete**

USE: **Crushed RCA as No-Shrink Flowable Concrete Fill**

DISCUSSION:

There are several generic and proprietary product names for this material which is a low strength concrete material. Its main use is trench and excavation backfill in urban areas where traditional compacted soil backfill procedures conflict with other demands for the area. The important characteristics of no shrink fill are:

- It flows to take the shape of excavation with little working;
- It has low strength when hardened, allowing it to be excavated in the future with the same efforts used to excavate the adjacent soils;
- It has a strength/bearing capacity similar to the surrounding soils;
- It is not subject to shrinkage on curing; and
- It gains strength to allow cover within one day.

No-shrink fill is made from fine concrete aggregate, cement, flyash, water and other additives such as accelerators or plasticizers. RCA residual fines from coarse concrete aggregate production have been used as the fine concrete aggregate in no shrink fill with good success. These RCA fines have suitable gradation and are rough textured, giving good particle to particle locking and increased bearing capacity. Any free lime remaining on the RCA fines is available for cementing and/or pozzolanic reactions to increase strength.

BARRIERS TO USING THIS OPTION:

- There are none other than the competitive economics of the supply of the RCA residual fines versus virgin aggregate;

- There is a lack of knowledge of the use of RCA residual fines for no shrink fill; and

- Any gypsum board or plaster from building demolition material is an undesirable material with respect to any concrete or concrete like material such as no-shrink fill. There is some risk that gypsum board materials on concrete rubble from building demolition will add water soluble sulphates to the RCA.

RESEARCH & POLICY CHANGES:

- Provide information on this management practice to potential users;
- Conduct mix design testing to confirm the suitability of local RCA residual fines as aggregate for no-shrink fill in those areas where no-shrink fill is used; and
- Create and operate a systems for monitoring concrete rubble to detect undesirable material like gypsum board or plaster in rubble designated for recycling as concrete aggregates.

MATERIAL: **Concrete**

USE: **Crushed RCA as Trench Backfill**

DISCUSSION:

Dense graded RCA is a desirable granular material with good compaction characteristics. The low unit weight of the compacted RCA provides more fill volume per tonne than virgin aggregate.

Crushed RCA generally qualifies as high quality, dense graded base course. Where high quality base course strength structural fills or trench backfills are needed, crushed RCA works well. For other general fill applications, use of crushed RCA is a waste of aggregate quality. Lower quality granular materials, such as the RCA residual fines, make suitable general-use fills.

BARRIERS TO USING THIS OPTION:

- The relative cost of competing virgin aggregate materials can be a barrier; and
- Use of crushed RCA as general granular backfill is a waste of a high quality aggregate for purposes adequately served by lower quality aggregates.

RESEARCH & POLICY CHANGES:

- Education about this material and its use will encourage its greater and wiser use.

MATERIAL: **Concrete**

USE: **Precast Materials as Planters And Terraces**

DISCUSSION:

The British Columbia Department of Transportation and Highways made an employee suggestion award to a staff member who planned and designed low height terraces and planting beds using surplus concrete median barriers. Geotextiles are used to retain soil within the terrace planters and to act as horizontal tiebacks retaining the structure on the slope.

Slightly damaged or flawed concrete pipe can be placed vertically and filled with soil to serve as a planter. Several of theses pipes placed at different elevations creates a grouping effect and good appearance.

BARRIERS TO USING THIS OPTION:

- None.

RESEARCH & POLICY CHANGES:

- Encourage employees to suggest innovated uses for surplus materials.

MATERIAL: **Concrete**

USE: **Precast Concrete Elements as Stockpiled Material Fences**

DISCUSSION:

Maintenance staff at Alberta Transportation and Utilities have made low fences or materials bins to separate adjacent, close spaced stockpiles of different granular materials in maintenance yards. These materials fences are made from surplus, reject or salvaged precast bridge decks and beams that had been placed in the maintenance yard because they were too good or too expensive to dispose of by wasting.

These materials are often stored at a maintenance yard as an inventory item, intended for future use. However, they sometimes are forgotten. In Alberta's case, innovative staff used these stored precast beams to improve the use of yard space.

In a similar way, redi-mix concrete plant operators at many locations use damaged, reject or surplus concrete pipe as materials fences for aggregate stockpiles in their yards. Pipes are placed on end in lines to define the materials fence, and filled with sand to give mass and stability. These materials fences can be moved to suit changing stockpile needs by staff and equipment that are normally on site.

BARRIERS TO USING THIS OPTION:

- Precast concrete materials are one of many surplus materials stored in road agency maintenance yards with undefined plans for reuse. Typically these materials are not recorded in any inventory or retrieval system. After a few years the actual ownership or responsibility for these excess materials is forgotten, and consequently the likelihood of reuse is minimal.

RESEARCH & POLICY CHANGES:

- Responsibility for the storage, inventory control and reuse of surplus materials like precast concrete materials must be assigned;

- Manitoba Highways and Transportation has become aware that surplus materials from construction and maintenance projects are stored at the end of the project, and soon forgotten. The result is

stockpiles of many surplus materials, some of which are used by others, but most of which occupy storage space without any future use or plans. That Department's response is to dispose, recycle or reuse all surplus materials before the project is considered finished;

- The Ministry of Transportation of Ontario is experimenting with the wasteless highway concept. All surplus materials generated by these construction projects are reused or recycled, with prior planning. This concept attaches responsibility for the surplus materials to the construction activity. This forces the discipline to manage the generation and reuse of excess materials; and

- Perhaps many of these surplus materials could be sold by public auction or tender to see them removed from indefinite storage and placed in some other use.

MATERIAL: **Concrete**

USE: **RCA Fines as an Anti-Stripping Agent in Asphalt Concrete**

DISCUSSION:

No reference to this management practice was found in the literature but it was a paper by Hanson and Angelo titled, "Crushed Concrete Fines Recycled For Soil Modification Purposes", that started thinking towards this use.

There can be a problem called "stripping" in hot mix asphalt concrete pavements. When asphalt concrete strips, the bond between the asphalt cement and the mineral particles breaks in the presence of water. This stripping appears as loose aggregate or ravelling of the pavement surface at an early age. Stripping is caused by surface charge incompatibility between the aggregate particles and the asphalt cement. This problem only occurs for some mineral aggregate/asphalt cement combinations.

One commonly used solution to stripping is the addition of a small quantity of hydrated lime, usually about 1% by mass of aggregate. RCA residual fines from coarse concrete aggregate production has free lime on its surface. This free lime is available for chemical reaction. With exposure to air, the reactivity of this lime decreases. Slow carbonation of the lime, using carbon dioxide from the air, forms calcium carbonate or limestone, making the fines no longer reactive.

The use of RCA residual fines as a sharp angular filler sand in hot mix asphalt concrete for gradation and possibly stability improvements may also act as an anti-stripping agent.

BARRIERS TO USING THIS OPTION:

- This management practices is untried. Some laboratory testing is needed to determine how much, if any, reactive lime is present and available for reaction in the RCA residual fines. If there is reactive lime present, further preliminary testing may be useful to confirm if any stripping improvements are created by adding RCA residual fines to hot mix asphalt concrete mixtures.

RESEARCH & POLICY CHANGES:

- Conduct preliminary laboratory tests and economical analysis to determine the feasibility of this concept.

MATERIAL: **Concrete**

USE: **RCA Fines as Winter Sand**

DISCUSSION:

The RCA fines gradation may be suitable for winter sand with the exception that -75μm content may be too high. The -75μm material is not plastic and therefore it may not adversely affect the performance of the de-icing sand.

The RCA fine aggregate is durable. It's angular, rough surface may give "grittiness" or "grip" on ice surfaces.

The RCA residual fines are a lower quality granular material. Reuse of these fines as de-icing sand delays virgin sand extraction for a short time and avoids its disposal by wasting at other locations.

BARRIERS TO USING THIS OPTION:

- There is no experience reported with this management practice.

RESEARCH & POLICY CHANGES:

- Conduct laboratory testing to define the gradation and plasticity of RCA fines before doing limited control field trials to test its potential for use as winter sand.

MATERIAL: **Concrete**

USE: **Construct and Maintain Concrete for Longer Life**

DISCUSSION:

Concrete, initially fabricated with higher quality materials to a higher standard and maintained with greater diligence and cost, will have a longer service life than concrete fabricated and maintained to current standards. Longer service life concretes will not be recycled as often as our typical service concrete.

The concept of life-cycle costing is used in the design of buildings and pumping systems. Life-cycle cost analysis for road materials like concrete or asphalt concrete, gives a rational, economic basis to assist decision making on the economic return on a higher quality, higher initial cost investments. Traditional life-cycle costing includes initial cost, maintenance cost and residual or salvage value at the end of one or more analysis periods. Different initial cost and maintenance strategy combinations are analyzed and compared to identify the least life-cycle cost, not the least initial cost which has been the cost on which project decisions traditionally are made.

Life-cycle cost analysis for concrete road elements like pavements, curb and gutter and sidewalks can be more complex when other costs, including non-money costs, are included in the calculation. These other costs are:

- Traffic disruption costs for major rehabilitation or reconstruction;
- Future aggregate source depletion and replacement aggregate costs;
- Habitat and environmental impacts of new quarries or aggregate deposit operations, and haul from these new and distant sources;
- The rehabilitation costs for the accelerated pavement deterioration on aggregate haul road pavements; and
- The direct cost of new materials, like cement, for reconstruction and the indirect environmental costs like increased greenhouse gasses (CO_2) generated in the manufacture of the new cement.

Some of these are hard costs to which a dollar value can be assigned. Others, like environmental impact costs, are less easily quantified. These are subjective costs that benefit/cost analysis has avoided in the past. However, if all costs are factored into the analysis, longer-life concrete pavements may prove to be cost-effective.

BARRIERS TO USING THIS OPTION:

- Existing concrete performance data has been compiled during the past decade using computer based pavement or infrastructure management systems in the larger road agencies. There is a lack of experience knowledge about the service life possible from different concrete quality and maintenance strategies;

- Some of the emerging concrete technologies produce superior properties and are predicted to double service life. Unfortunately there is no experience to confirm that a new superior, and more costly, concrete mix will give this predicted 60 year service life. Without reliable performance data, it is difficult to produce defendable economic analysis justifying these new concrete designs;

- Traditionally, road agencies analyze road materials using a time period that is based on the expected life of the road element. In a study of aggregate resource depletion in southwest Saskatchewan, Clifton Associates Ltd. found that using different analysis periods (i.e. 15, 30 and 45 years) will produce different aggregate resource allocation and pavement type (e.g. asphalt concrete versus Portland cement concrete) decisions. Our commonly used shorter economic analysis period is a barrier to getting the broader, longer term analysis of aggregate resource use that is called for in a life-cycle cost analysis for concrete; and

- We have developed our road materials technologies and economic analysis methods in a resource-rich environment. These technologies and methods are not likely to be fully valid in a resource-scarce environment. Comfort and familiarity with the old technologies and methods is a barrier to our exploration of the new technologies and methods we will need in future resource-restricted environments.

RESEARCH & POLICY CHANGES:

- Continue with the implementation and enhancement of pavement or infrastructure management systems to develop the data base and analysis to know what performance we can expect from different initial quality and maintenance strategies for concrete road elements;

- Develop reliable accelerated performance tests for new concrete

materials. These tests provide some laboratory data to guide our estimates of future performance in life-cycle cost analysis; and

- Examine our engineering and economic analysis methods developed in resource-rich environments as to their validity in future resource-scarce environments. Usually restricted resources cause their costs to increase. At what cost is concrete use prohibited? At what cost does an alternate material to concrete become economically competitive?

EXCESS EARTH MATERIALS

Introduction

Some excess earth materials are mineral soils with desirable construction properties but must be removed from the project because they are surplus to the quantity of earth materials needed for embankment construction. Other excess earth materials have undesirable characteristics that make them unsuitable for embankment construction and therefore excess to the project.

There are several different undesirable earth materials. This section addresses the following materials:

- Wet clay or silt. These soils are too wet to be placed and compacted in embankments or trench backfills;
- Wet and/or organic ditch cleaning soils;
- Wet trench excavation materials at watermain or sewermain breaks;
- High organic content mineral soils which include topsoil and depression bottom sediments; and
- Organic soils - peat and duff.

Each of these soils has unique properties, present unique construction and environmental problems and require unique management practices. Because of the variation in soil characteristics, and their associated management problems, this section is structured differently than the other sections in this report. We have sub-divided this section into subsections for each of these soil materials.

Contaminated earth materials are not included in the study terms of reference; and therefore, management practices are not presented.

There has been an increase in the number and severity of construction and environmental problems with excess earth materials over the past decade. These problems are increasing because of two opposing trends. The first trend is the increasing volume of excess earth materials caused by more unbalanced earthwork designs and greater wasting of undesirable earth materials from projects having higher standard subgrades and pavements. The other trend is the increased awareness of the negative environmental impacts of past "waste earth" disposal methods.

Road construction and maintenance staff find themselves with more volumes of excess or undesirable earth materials to dispose of, and fewer disposal options. The problems are largely caused by a changing value system, towards more environmentally appropriate practices. Traditional management practices are no longer acceptable. Despite this need for change, few new management practices have been defined and tested.

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Todres, H.A. (Alan) and Manzi, Leo S., "Roller or Rammer Compacted Concrete Made From Recycled Asphalt Concrete and Portland Cement Concrete, Recovery and Effective Reuse of Discarded Materials and By-Products For Construction of Highways Facilities"; Symposium Proceedings, Federal Highway Administration and Environmental Protection Agency, Denver, Colorado, October 19-22, 1993.

General Contacts for Municipal Road Agencies

Provincial highway departments and many larger cities have standards, guidelines, typical designs and lists of locally proven or approved materials that may be applicable for other municipalities in the region.

Locally used and proven erosion control methods for use on agricultural lands are available from provincial agriculture departments.

Composting information is available from provincial Waste Reduction Councils, local environmental groups, local gardening clubs, or the waste management or waste reduction sections of provincial environment departments. Composting techniques vary slightly from region to region, largely in response to climate differences; and therefore locally developed techniques are favoured over those developed in different climates.

Contacts

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EXCESS MINERAL SOIL

Source of Material

The source of the large majority of excess mineral soils from road construction and maintenance activity are:

- Unbalanced earthworks designs where the quantity of excavation exceeds the quantity of embankment required; and

- Major maintenance excavations or post-construction modifications such as construction of drainage ditches or removal of approach fills.

There are two factors which have increased unbalanced earthwork designs. The first is the increasing geometric and performance standards used to construct new roads. These new roads are higher, wider, flatter, straighter and stronger than previously constructed roads. These higher standards are needed to accommodate more and heavier vehicles at higher speeds in a safer road environment.

The second factor is the increased competition for space, particularly in the urban setting. Road corridors are being forced onto terrain, usually typographically too rough for other land uses. This combination of difficult topographic conditions and higher geometric standards creates more unbalanced earthwork designs.

At the same time as new construction is tending towards more unbalanced earthworks designs and a generation of greater volumes of excess soils, the traditional excess soil disposal sites are less available because of new environmental standards. The road construction and maintenance industry has increased difficulty disposing of larger volumes of soil in traditional disposal areas.

Nature of Material

Excess mineral soil is clay, silt, sand, gravel and mixtures of these textures, at water contents suitable for embankment construction or trench backfill. These soils have desirable engineering properties but are simply excess to the project needs.

Environmental Implications

In the past excess or undesirable earth was stockpiled or wasted at sites perceived as economically nonproductive or waste land. Most often these waste lands were low areas such as depressions, marshes, intermittent pond areas or small water bodies. The earth was used to fill and eliminate the depression. These depressions often provided habitat for certain plant and animal species. Consequently, filling these areas results in habitat destruction and species displacement.

In addition, the low areas historically favoured for disposal of excess earth are part of a surface drainage system. When depressions, marshes, and small ponds are filled, the surface runoff and flooding characteristics of the area are changed. This may lead to increased flooding, accelerated erosion and road washouts. Generally habitat and surface drainage consideration were not included as factors in planning disposal activities or selecting disposal sites.

Earth excavated from maintenance or small post-construction modifications, usually involving ditching to modify drainage, is sometimes placed as a low ridge on one side of the ditch, or around a natural depression. These low ridges, usually placed without complete understanding of the surface runoff implications, can dam and divert natural runoff to cause flooding, erosion and stream sedimentation problems.

Often surplus earth must be hauled longer distances for disposal. These longer hauls impose an economic cost on the road authority, and result in energy consumption, greenhouse gas emissions, land consumption, dust generation, and additional axle loadings on the existing roads.

Summary of Previously Reported Management Practices

Previously reported management practices for this material include:

- Seek balanced earthwork designs;
- Haul to disposal in nearby topographical depressions;
- Haul to stockpile for future defined or undefined use by the road agency;
- Flatten embankment side slopes, increase the size of approach fills or increase the fill in the medians of divided roadways;
- Haul or cast ditch excavation material into ridges adjacent the excavation;
- Haul to disposal in depleted soil borrow pits, aggregate pits or

quarries; and
- Haul to municipal landfills as cover soil for temporary or final cover.

Other Potential Management Options

Possible options for managing excess mineral soil are:

- Place greater priority on balanced earthwork designs; and
- Create an earthwork materials exchange to include all public and private agencies involved with earthworks construction in the locality. Organizations would list their anticipated volumes, types of materials and dates available for either excess or needed soils. This exchange list would facilitate the matching of the supply of excess earth materials with the demand for these materials in the locality.

MATERIAL: **Earth Materials**

USE: **Better Balancing of Earthworks**

DISCUSSION:

The key to minimizing the amount of excess materials leaving a job site lies in the planning and design phases of the project. The planning and design staff must work together to ensure that facilities are laid out so as to avoid unsuitable soils wherever possible. Furthermore, greater priority must be placed on balanced earthwork designs so that most materials generated on site can be used on the project.

The disposal of excess excavation soil should be included in the early planning phases of the project. This creates an advanced opportunity to revise geometric standards to achieve a more balanced earthwork design before the design starts. It also gives time to communicate with other public and private agencies to identify potential receivers of excess earth materials.

BARRIERS TO USING THIS OPTION:

- Often in urban settings, there is insufficient space to provide the flexibility to vary the design and balance the earthwork; and

- Planners and designers are not used to working together to identify options for minimizing and managing the amount of excess materials generated by a project.

RESEARCH & POLICY CHANGES:

- Amend new road planning practices to include earthwork balance considerations and disposal options for excess earth materials early in the planning process. This creates the opportunity to make planning decisions geared towards achieving earthwork balances during detailed design. It also provides ample lead time to broker excess earth to suitable uses; and

- Road embankment design standards could be modified slightly to accept small amounts of wet clay and silt soils in non-critical parts of the subgrade structure such as the toe of the side slopes.

MATERIAL: **Excess Earth Material**

USE: **Exchanges**

DISCUSSION:

The Regional Municipality of Peel in Ontario has established a free of charge clean fill exchange. Persons or companies who have excess clean fill (including clay topsoil, sand, concrete, rubble or any combination of such materials) can phone the Regional Municipality and receive a list of people in the area who are in need of fill. The list of people could include concrete companies, farmers and individual home owners.

A municipal or regional materials exchange could be ideal for transportation construction companies in many ways. The contact list provides a wide variety of people and companies looking for inert fill and, therefore, increases the opportunity for the excess material to be reused and not landfilled or dumped illegally. Because it creates contacts within a local area, trucking costs can be minimized.

The Provincial and Federal Waste Exchanges have a similar system, but on a provincial or national scale. This could provide a wider market for larger and more steady volumes of clean fill. However, because of the scale of the exchange, hauling costs may become a factor. These exchanges often carry a service charge for membership.

Swamp material will be more difficult to dispose of, but could similarly be reused through these exchange systems.

With the establishment of clean fill exchanges, excess earth materials should be easier to dispose of in a more environmentally friendly manner.

There is still considerable concern with receiving fill that has not been tested and certified to be free of contaminants. This can be a costly and time consuming process.

BARRIERS TO USING THIS OPTION:

- Some earthwork design and construction agencies, meaning individual government departments or individual private sector developers, seem to have a "within the agency compartmentalization mind set". This can limit the search for partnerships with others who may be able to use an excess earth material; and

- There is considerable concern that excess earth materials may be contaminated, and potential receivers of this material are cautious about taking materials that have not been tested for contamination. Costly and time consuming testing programs for fill material, could interfere with exchange programs.

RESEARCH & POLICY CHANGES

- Promote more local exchanges in municipalities, regional municipalities and similar area groupings;

- Develop guidelines for low risk soils that eliminates the need for testing;

- Develop legislation, policy and practice that facilitate excess earth materials brokering in a surplus earth materials exchange registry; and

- Develop policies and practice that encourage inter-agency coordination with respect to the generation and consumption of earth materials.

WET CLAY OR SILT SOILS

Source of Material

Wet clay of silt soils are obtained from construction and maintenance excavations in wet soil conditions including:

- Excavations near or below the water table;
- Soil saturated by recent rain or snow melt; and
- Soil made wet by water discharging from broken underground pipes like sewer or water pipes.

Nature of Material

These are high water content cohesive mineral soils. The higher water content makes them undesirable embankment material or trench backfill under roads. These soils are too soft to compact and carry construction traffic, or too sticky to handle easily.

Environmental Implications

Wet clay or silt soils have all of the environmental implication listed previously for excess mineral soil with the additional constraint that these soils are too wet to be compactable or trafficable. The wet condition means that these soils cannot be used directly for embankment or trench backfill.

Wet clay or silt soils are difficult to stockpile into compact piles. The piles tend to be one truck dump high and cover a large area. As well, stockpiles of loose, wet soils are highly susceptible to erosion in heavy rains, leading to excessive material transport and potential watercourse sedimentation problems.

The temporary stockpile site for wet clay or silt soils must be used for an extended period because it takes time for the soils to dry to a point where they can be used. Typically these piles are excavated slowly, using the exterior material, where some drying has occurred.

Summary of Previously Reported Management Practices

Previously reported management practices for these materials include:

- Actively dry the material on site by spreading it over a large surface and moving it with a motor patrol to encourage drying. Favourable

Favourable drying weather and adequate space on the site are required to make this practice effective;

- Mix the wet soil with drier soils to achieve a workable water content;
- Haul wet excavated soil to a storage yard, stockpile and allow the soil to dry. When dry, or at least the outside of the pile is dry, use the soil as fill or trench backfill;
- Haul the wet trench excavation soil to a landfill to use as soil cover;
- Trenchless underground utility pipe repair and replacement techniques are available. These methods are more costly than trench repairs and must be done using specialized and imported equipment and staff;
- Add hydrated lime to chemically adsorb water and reduce plasticity to make the wet soil workable in-situ. This solution is a higher cost practice however it is used when no natural drying is occurring for a wet soil that must be used before the end of the season or to meet a construction schedule; and
- Construct berms and sediment trap/ponds at stockpile sites to contain eroded sediments.

Other Potential Management Options

Other potential options for managing this material include:

- Thermal drying; and
- Trench Backfill - on-site reuse.

MATERIAL: **Earth Materials (Wet Clay or Silt)**

USE: **Thermal Drying**

DISCUSSION:

There are soil shredding and dryer systems used in the thermal remediation of hydrocarbon contaminated soils. These plants are capable of artificially reducing the soil water content by drying. The cost for this drying depend upon energy costs but typically thermal remediation of hydrocarbon contaminated soils can be done for about $100/tonne. Drying wet uncontaminated soils would be done for less than $100/tonne but probably for more than $60/tonne.

Assuming a thermal remediation plant was nearby a site with wet clay or silt soils, the $60+/tonne cost could rarely be justified.

When the cost to haul wet soil to a disposal site is compared to other management options, there is no economic incentive to develop other methods to dry these wet soils in place or at a drying site.

BARRIERS TO USING THIS OPTION:

- The high energy cost of artificially drying soils makes this option uncompetitive when compared to land disposal.

RESEARCH & POLICY CHANGES:

- Research into economical ways to quickly dry large volumes of wet soil.

MATERIAL: **Earth Materials**

USE: **Trench Backfill - On-site Reuse**

DISCUSSION:

Areas having residences serviced by municipal sewer and water systems are continually faced with pipe breaks. The repair of these facilities produces wet soil that is removed from around the broken pipe.

The volume of material removed tends to be small when compared to most highway or road excavations. Although these soils are excavated by staff whose functions focus on sewer and water lines, the overwhelming majority of sewer and water pipe repair excavation and subsequent backfill occur under roads. As such, the correct backfill and compaction of these trenches is essential for a smooth pavement without the dips.

Trenches for buried pipe repairs that are not under roads can be backfilled with the wet excavated soil, which could settle over several years without adverse impacts. However, trench backfill under roads must be uniformly compacted to provide suitable long-term subgrade support for pavements. Therefore the wet, uncompactable excavation soil must be replaced with a suitable compactable backfill soil. This usually necessitates the removal of the old materials, and importing of new materials. In urban congested traffic it can be difficult and costly getting trucks to the site of a utility repair. Therefore, it is desirable to use as much of the original material as possible, to backfill the trench following the repair.

The paper by Todres and Manzi, given at the 1993 FHWA Denver Symposium on the Recovery and Effective Reuse of Discarded Materials, reported the laboratory test results of a concept to recycle excavated soils and pavement structure materials on site in a major urban centre. The concept involves using the excavated sandy soil from the trench as the trench backfill to the top of the subgrade. Salvaged asphalt concrete and Portland cement concrete would be crushed on site to be the aggregate feed for on site mixing of roller compacted concrete. Roller compacted concrete is a damp mixture of aggregate, cement and water that cures and hardens to Portland cement concrete properties after it has been placed and compacted in an excavation. The roller compacted concrete materials is compacted into the trench to become a concrete base course. The surface is finished with imported hot mix asphalt concrete. No or little material is exported from the trench repair site and a small amount of hot mix asphalt concrete is imported. Therefore, truck movements are kept to a

minimum.

BARRIERS TO USING THIS OPTION:

- Truck haul of materials from and to pipe excavation trenches in an urban area is slow and costly. Several large Canadian cities have reduced urban haul distances and time by having several yards for stockpiling various materials, included wet trench excavation soils. These stockpile yards are distributed throughout the city to minimize the length of urban haul for materials taken from repair trenches or taken to these excavations as suitable backfill; and

- Cold winter temperatures freeze the wet excavation soil into lumps, making it unsuitable for compacted backfill. These soils can also freeze into truck boxes if the haul distance from the trench excavation to the stockpile site is long.

RESEARCH & POLICY CHANGES:

- Research and field trials are needed to develop soil modification and pavement material improvements for on site processing and recycling of all excavated materials as trench backfill and replacement pavement structure.

WET AND/OR ORGANIC DITCH CLEANING SOILS

Source of Material

The ditches along rural roads collect materials eroded from side slopes, ditch bottoms and adjacent lands. Eventually, these soils need to be excavated by maintenance crews, to restore the original ditch grade and cross-section and allow the ditch to operate effectively. Typically these excavations are less than 0.5 m deep.

Nature of Material

The soils removed from ditches are loose, wet and often organic-rich. Frequently they have very high water contents and are, or approach, a slurry condition once excavated. Often these wet soils are temporarily deposited on the road sideslope to allow water drainage and drying before they are loaded into trucks and taken to disposal sites.

Environmental Implications

All the environmental implications listed previously for wet clays or silt soils apply to ditch cleaning soils with the further constraint that these soils often have very high water contents, and contain sufficient quantities of organic matter to make them undesirable as embankment material.

The ditch cleaning operation does not remove all of the materials. Newly cleaned ditches are subject to accelerated erosion during heavy rain with small amounts of the disturbed soils being washed away, potentially leading to sedimentation problems in receiving streams.

In addition, stockpiles of these materials are highly erodible because of their wet, loose and often dominantly silty or silty fine sand texture. Unless properly protected, stockpiles can erode and cause sedimentation problems in nearby streams.

The introduction of these materials to streams, either from ditch cleaning operations or stockpile erosion, can lead to the loss of aquatic habitat. The finer sediments such as clay, silt and fine sands, cover the coarse sand and gravel stream bottoms used by fish as spawning areas. This destruction of fish habitat can lead to charges being laid under the Federal Fisheries Act. As well, there are examples where the release of materials into a waterbody, causing degradation of the aquatic environment, was determined to be a spill. As such,

the agency responsible was charged under the local spills management legislation. Sometimes, the charges are made against individual staff and not the road agency. The fear of prosecution has lead some road agency employees to refuse to do ditch maintenance or cleaning at locations where there is the potential for a stream sedimentation violation. The resulting failure to properly maintain ditches can lead to drainage problems that adversely affect the road and/or adjacent lands.

Summary of Previously Reported Management Options

Previously reported management practices for this material include:

- Appropriate and timely erosion control works on newly disturbed soils is the preferred, albeit more costly, practice that prevents erosion and greatly reduces the need to clean eroded sediments from ditch bottoms;
- Appropriate tillage practices on adjacent agricultural lands draining to the roadway ditch also reduces the amount of eroded sediments delivered to the ditch;
- Use environmentally appropriate ditch clearing methods that do not allow stream sedimentation;
- Allow the wet excavated soil to dry on the side slopes before removing it from the site;
- Deposit excavated materials in areas that provide containment of surface runoff and sediments; and
- For small volumes of very wet ditch bottom sediments in sensitive areas, use a vacuum truck to remove and haul the soil.

Other Potential Management Options

A possible option is to minimize the amount of material that needs to be removed from ditches by employing timely and effective erosion control practices.

MATERIAL: **Earth Materials**

USE: **Erosion Control - Ditches**

DISCUSSION:

The volume of material that needs to be removed from ditches can be reduce by using erosion and sedimentation control measures on newly disturbed soils, both within the ditchline, and on adjacent lands.

Often erosion and sedimentation control measures are given a low priority, and not applied until late in the contract. This results in unnecessary regrading and removal of materials deposited in the ditch. To be effective, control measures must be applied immediately following the establishment of final grades.

BARRIERS TO USING THIS OPTION:

- The cost of erosion and sedimentation control works limits their greater use on newly constructed or recently disturbed soil surfaces;
- The lack of incentives or penalties for contractors to implement proper control measures early enough to avoid the need to regrade or clean the ditches;
- Road agency staff who are not applying erosion and sedimentation control practices on a routine basis are not keeping abreast of new products and methods;
- The adverse environmental costs of ditch erosion and ditch bottom cleaning have traditionally been judged to be less than the economic cost of effective erosion control works; and
- Often the sediments being removed from the ditch bottom originate from adjacent privately owned land. The road agency that has used effective ditch erosion control works is not assured that ditch cleaning of erosion sediments from private land will not be required.

RESEARCH & POLICY CHANGES:

- Road agencies should develop incentives and/or penalties to encourage contractors to implement erosion and sedimentation control measures as soon as possible following construction;

- Ensure that erosion control measures are included in contracts, and that they are properly installed and maintained.

HIGH ORGANIC CONTENT MINERAL SOILS

Source of Material

There are two high organic mineral soils found in road construction and maintenance activities. These are:

- Topsoil found at the surface; and
- Depression bottom sediments.

The topsoil is stripped to expose the mineral soil in preparation for an excavation or the placement of an embankment. Usually topsoil is stockpiled for future use. Occasionally, topsoil is hauled directly to a newly constructed area for surface dressing and seeding.

Depression bottom sediment is a broadly applied name describing the organic-rich soil found in small depressions. These depressions may be dry, intermittently flooded, or permanently wet. Because these organic soils are compressible, they usually are removed to expose mineral foundation soils before embankments are placed.

Nature of Material

The significant difference between topsoil and depression bottom soil is the environment in which these soils are formed. The topsoil develops in an oxygen-rich environment and therefore has the aerobic, oxygen dependent, microbial community that is needed for healthy vegetation growth. Depression bottom soils are usually organic, wet, soft and highly compressible. They develop in a wet, low or no oxygen environment, and therefore have an anaerobic microbial community that produces unpleasant odours as the organic matter decomposes. Depending upon the soil characteristics, depression bottom soils may or may not be suitable for slope dressing.

These soils, particularly when present in large volumes, cause some construction difficulties often resulting in delayed schedules and increased costs.

Environmental Implications

There are no special environmental implications arising from these two high organic content mineral soils other than that they may be excess in volume and/or have undesirable properties for use on the project. The environmental implications arise when these soils are sent to disposal.

Topsoil is a valuable natural resource, particularly in dry climate regions like the Canadian prairies, and should not be wasted.

Because they develop in anaerobic conditions, depression bottom soils will not initially support vegetation and therefore make a poor topsoil when first placed as surface dressing. Over time the aerobic microbial community needed for vegetative growth, will develop. Therefore, the soil character of depression bottom soils should be determined before these soils are used as topsoil slope dressing.

Summary of Previously Reported Management Options

Previously reported management options for this material include:

- Using topsoil for dressing finished slopes in preparation for seeding. The topsoil may be either excavated and directly placed or excavated and stockpiled for future use;
- Mixing topsoil with mineral soils at embankment if:
  - there is excess topsoil for the project needs; and
  - there is no current or future need for topsoil dressing on or near the project;
- Mixing small volumes of depression bottom soil with drier mineral soil to consume this material in embankment construction;
- Placing depression bottom soils in non-critical positions in the embankment, such as at the toe of the sideslope, on the surface of the sideslope, or in the sideslopes of an approach fill; and
- Hauling excess topsoil or depression bottom soil to waste disposal, most often to fill depressions. On rare occasions, when a landfill is near the project, these excess soils may be hauled to the landfill for use as temporary and permanent cover.

Other Potential Management Options

Other potential management options for this material includes:

- Making greater uses of depression bottom soils for slope dressing. This requires assessment of the soil character by agricultural or pedological soil specialists, who can design soil modification additives. These soils and suitable soil enhancements are regionally unique; therefore local specialists should be consulted.

MATERIAL: **Earth Materials**

USE: **Top Dressing**

DISCUSSION:

Topsoil is a valuable natural resource that should not be wasted, particularly in dry climate regions like the Canadian prairies. There is usually a need for topsoil to be placed as a top dressing on newly constructed slopes to support vegetative growth.

The extent to which soil will support vegetative growth depends upon its chemical and microbial characteristics. If the soil environment is anaerobic (i.e. lacks oxygen) it will not contain the aerobic microbial community that is needed to support healthy plant growth.

Depression bottom soils develop in anaerobic conditions and therefore make poor top dressing soils until aerobic conditions and proper chemical composition can be established. This may require an assessment of the soil character by agricultural or pedological soil specialists, who can design soil modification additives. These soils and suitable soil enhancements are regionally unique; therefore, local specialists should be consulted. These soils may need to be aerated for a period of time before being used as a top dressing.

As well, topsoil in the bottom or centre of large stockpiles is in an anaerobic condition. Therefore, topsoil stockpiles should be used within two years of their creation. After about two years the aerobic microbial community begins to die and is replaced by an anaerobic microbial community.

Windrows about 3 m high allow topsoil to remain aerobic in storage for longer periods. These windrows are more costly to construct and consume more storage area than the single large stockpile.

BARRIERS TO USING THIS OPTION:

- There are few barriers to using organic soils as top dressing. The main requirement is a proper management system that ensures that this resource is removed, properly maintained in an aerobic environment, and used; and

- Some soils may require additives to allow them to support vegetative growth.

RESEARCH & POLICY CHANGES:

- Pedological soils knowledge is advancing. Many road agency organic soils handling methods were developed as historical practices or using pedological knowledge formed several decades ago. Old practices should be reviewed and revised using the current knowledge.

PEAT AND DUFF

Source of Material

Peat and duff are predominantly organic materials that are generated as a result of construction through forests or wet depressions. Peat provides an undesirable foundation for road embankments because of its high compressibility. In many cases, it can be displaced by placing embankment fill into the peat deposit. Depending upon its strength, the peat will either be compressed or displaced to the side. In either case it is not removed, and does not become a management issue. However, where this is not possible, the material is excavated and therefore needs to be managed.

Duff layers, typically 0.3 m thick, are removed before excavation or embankment construction. Where volumes are manageable and land is available, this material is often pushed into piles at the edge of the right-of-way (pushouts). Larger volumes of this organic material may need to be stored or sent to disposal.

Nature of Material

Peat is an organic soil made of decomposing organic material with little or no mineral soil. It is found in wet depressions in forested lands throughout Canada. Young peat has visible recently dead organic material at the surface. At greater depth, the peat is older and more decomposed. Fully decomposed peat forms a saturated, black, amorphous ooze.

Duff is the layer of accumulated and partially to fully decomposed organic matter at the surface in forested areas. It is mostly decomposing or decomposed leaves with some decaying pieces of trees and shrubs. At its contact with the mineral soil there is some mineral soil within the duff.

Environmental Implications

Peat and duff are decomposing, acidic organic soils. Leachate from piles of these materials is acidic. Acidic leachate draining to a muskeg or peat bog is no problem because the ambient condition is acidic. However, acidic leachate draining to a fresh water pond or small stream can adversely affect the natural aquatic habitat.

Within large piles or soil covered layers of peat or duff, the decomposition process continues in an anaerobic (without oxygen) environment. Anaerobic

decomposition produces methane gas. The methane gas is toxic and combustible, and can accumulate in poorly ventilated buildings located near covered organic soils. This creates a potential for an explosion if a flame or spark is introduced in the building.

Pushouts of peat and duff can be unsightly. Some road authorities use L-shaped areas so stockpiles of peat, duff, shrubs and trees are not visible from the road. In some cases pushouts are covered with soil to create small mounds. Over the decades these stockpiles decompose naturally.

Summary of Previously Reported Management Options

Previously reported management options for this material include:

- Disposal of excavated peat and duff in push-outs;
- Where population centres or tree nurseries are nearby, peat and duff can be used as a mulch. Limited volumes are used because the local soils are typically highly organic, slightly acidic, and do not require additional organic matter;
- Haul to disposal in depleted soil borrow pits or depleted aggregate sources or quarries; and
- Haul to disposal at landfills at locations where landfills are sufficiently close to justify the haul cost.

Other Potential Management Options

Most viable options for managing this material have been used. There may be room for more innovative ways of mixing the material with mineral soil to maximize on-site reuse.

MATERIAL: **Earth Materials - Peat & Duff**

USE: **On-site Reuse**

DISCUSSION:

Where push-out disposal is prohibited, spread peat and duff on the bare soil surfaces following road construction. Mix the organic into the upper 100 mm to 200 mm of the surface using a large roto-tiller or pulvimixer. Compact the soil surface so that it is less subject to erosion than loose soil.

The road agency could do windrow composting of peat or duff materials if large quantities of green, nitrogen-rich, organic matter such as hay, lawn clippings or fruit and vegetable materials could be obtained to mix with the peat and duff to supply the correct nutrient balance for effective composting.

Stockpiled duff could be shredded using a hammer mill mechanism or a combination hammer mill/knife slicer mechanism. Knife slicer mechanisms alone tend to block with damp duff. Selection of the screen sizes in the shredder is also important for efficient, high volume shredding without excessive blocking of the screens. The highly pulverized duff could be blown into adjacent forest to form a thin layer of new duff to decompose naturally.

New mulching and shredding equipment has been manufactured for use in urban solid waste processing. Some of this equipment may be effective for shredding peat and duff into a finer material. Shredded and finer material may be mixed with surface soil to improve it's ability to support new vegetation.

BARRIERS TO USING THIS OPTION:

- The cost of other management practices exceeds that of push-outs. Therefore push-outs are usually favoured except in areas where these are prohibited.

RESEARCH & POLICY CHANGES:

- Field trials to determine suitable equipment, methods and costs are needed to develop and confirm the suitability of these new methods.

MANUFACTURED/TREATED WOOD

Source of Material

Manufactured wood materials are wood that has been processed into lumber, plywood, utility poles, posts, piles, etc. In some cases the wood has been treated with chemicals to provide longer life and resistance to insects and rot. Roadway-related uses for manufactured wood include sign posts, guide rail posts, fence posts, concrete pouring forms, scaffolding, wood culverts, and wooden bridges.

Manufactured wood becomes excess during the construction or maintenance of structures associated with transportation projects (e.g. bridges, curbs), and the repair and replacement of sign posts, guiderail posts, and utility poles.

Nature of Material

The management practices are different for treated wood and untreated wood. Treated wood has been partially or totally coated with chemicals [e.g. coal tar creosote; pentachlorophenol (PCP); ammoniacal copper arsenate (ACA); Chromated copper arsenate, Type C (CCA-C); and copper naphthenate (CuNap)]. Table 4 indicates the primary roadway uses of treated wood.

TABLE 4

PRIMARY ROADWAY USES OF PRESERVATIVE TREATMENTS IN CANADA

Primary Use	PCP	CCA	ACA	Creosote	CuNap
Poles	*	*		*	*
Lumber		*			
Fence Posts	*	*		*	
Bridges/Timbers	*	*	*	*	
Marine Piles			*	*	
Fresh Water Piles	*			*	

Source: Pressure Treated Wood in Canada: Task Force Report

Environmental Implications

Dr. J. Sanders of the Academy of Natural Science (Philadelphia, P.A.) has been studying the leaching of toxic compounds from treated lumber into the environment. Wood treated with Chromated Copper Arsenate (CCA) is used on land and in some water applications. Studies have shown that on land, chemicals from the wood are found in a very limited volume in the soil adjacent to the structure, with insignificant leaching further away. In water, however, copper, arsenic, and chromium, leach from CCA treated wood in greater amounts.

The researchers found that sensitive species of algae would not grow in water that had been exposed to CCA treated wood. They expect that CCA could also affect other aquatic organisms in negative ways (Academy of Natural Sciences - News, January 1991).

The Ontario Ministry of Environment and Energy advises that CCA should not come into constant and direct contact with food or water; or apiaries. (Environment Information, M.O.E., winter 1992).

Other forms of wood treatment are also known or are expected to have adverse environmental effects (Pressure Treated Wood In Canada -Task Force Report", 1992, Ministry of Transportation). These effects are described below:

- Copper Naphthenate has been used to treat telephone poles. Studies have found that copper contamination around treated telephone poles is very localized and does not extend further than 100 cm from the pole. Because of the relative immobility of copper in soils and the fact that terrestrial organisms are fairly tolerant of copper contamination, Copper Naphthenate causes little concerns in terrestrial ecosystems.

  Alternatively, aquatic ecosystems are very sensitive to copper contamination. Very low concentrations of copper can be toxic to many aquatic organisms. Therefore, Copper Naphthenate treated wood should not be used in or near water.

- Creosote is composed of many compounds in varying quantities. These compounds are known to have a range of toxic and carcinogenic effects; but, very little is known regarding the impacts of creosoted wood in terrestrial or aquatic ecosystems.

In aquatic uses, it is believed that the polycyclic aromatic hydrocarbons may accumulate in sediments and aquatic organisms. Also, creosote may be biodegraded in some natural circumstances. Much research is needed on creosote and its environmental effects.

- Pentachlorophenol (PCP) is known to have limited mobility in soils. Concentration of PCP contamination lessens to background levels at 100 cm from the inplace treated wood. Therefore, it is not considered to have significant environmental effects on terrestrial ecosystems. However, PCP is toxic to aquatic ecosystems at low concentrations and is mobile in water.

- Ammoniacal copper arsenate has similar environmental concerns as those for chromated copper arsenate.

- Uncontrolled burning of any treated wood could create hazardous air emissions and ash that may adversely affect the natural environment and human health.

Summary of Previously Reported Management Practices

Previously reported management practices for excess untreated wood products include:

- reusing for the same purpose. For example, concrete pouring forms can be cleaned and reused, and sign posts that are not damaged can be reused;
- recycling into another useful product. For example, cedar poles can be made into cedar shakes; and utility poles that have been cut and therefore are too short to reuse as utility poles can be recycled into guiderail posts;
- chipping for mulch, landscaping material, fuel, bulking agents, or compost;
- storing;
- depositing at landfill sites;
- burying; and
- burning.

Treated wood poses greater management problems because of the health and safety, and environmental problems associated with cutting, re-treating cut ends, burying and burning these materials. Previously reported management options for treated wood include:

- reuse for the same purpose. For example sign posts that are not damaged when removed can be reused;
- recycling into new products. For example, sign posts that are cut could be recycled into sign braces; and
- disposal at a certified landfill.

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Mr. Erwin Leonov, WCI - Wood Conversion Inc., Brampton, Ontario

Mr. Harvey Poon, Worthing Industries Inc., Calgary, Alberta

Mr. Rick Thompson, Guelph Utility Pole, Guelph, Ontario

Other Potential Management Options

The following management options have been identified for further discussion:

- Bioremediation;
- Incineration;
- Fast Pyrolysis;
- Recycling - Encapsulation
  - Re-use

MATERIAL: **Manufactured/treated wood**

USE: **Bioremediation**

DISCUSSION:

Microterra Inc., a Florida-based company, has a method of recycling creosote treated wood (e.g. telephone poles and railway ties). The process begins by shredding the wood into match box-sized chips, and washing it. This allows a reclamation of up to 90% of the creosote. The recovered creosote is used to treat new wood. The washed wood chips are inoculated with creosote eating microbes. After 21 days of composting, less than 1 mg\kg of creosote is left in the chips and the wood is ready for recycling into such things as paper, chipboard and possibly rayon.

Currently in the United States it cost $1 to landfill a railroad tie. However, one can receive up to $1/tie from landscapers. Comparatively, Microterra's estimated 1992 processing price was $16/tie and $88/phone pole. The cost to have creosote treated excess materials process appears to be high in this one-of-a-kind facility in Florida, but the company President states that the cost is cheap compared to the remediation of a creosote polluted landfill. (Calgary Herald March 2, 1992 and Microterra press releases).

BARRIERS TO USING THIS OPTION:

- A method of separating hard and soft woods within the process is required to ensure that the correct material(s) are available for the different recycling methods and end users; and

- Haulage costs would be high because bioremediation plants are not widely available.

RESEARCH & POLICY CHANGES:

- Research into the viability of this process within Canada, and the availability of Provincial markets should occur; and

- All environmental aspects of the process must be investigated. (eg. the management of processing wastes, emissions, etc.).

MATERIAL: **Manufactured/treated wood**

USE: **Recycling - Encapsulation**

DISCUSSION:

Some research is being done on the encapsulation of treated wood fibre in cement. The fibre is incorporated as an aggregate in the cement and used in outdoor applications such as sign posts, retaining walls and noise barriers.

BARRIERS TO USING THIS OPTION:

- The main barrier is that this process is not yet commercialized.

RESEARCH & POLICY CHANGES:

- Research into the viability of this option and how it can be commercialized; and
- Research into the implications for recycling concrete made using wood fibres.

MATERIAL: **Manufactured/treated wood**

USE: **Recycling - Re-use**

DISCUSSION:

At the second International Symposium of Wood Preservation (8-9 February, 1993) in France, Dr. Paul Cooper of the University of Toronto presented a study undertaken for the Ontario Ministry of Transportation and Bell Canada Ltd. The study investigated the potential re-use of telephone poles, made of treated lumber, into poles, posts, timber, lumber, cedar roof shingles and firewood. The paper concluded that, although some wood retreatment may be required, this method of recycling is a viable option.

Since many of the poles removed from service were western red cedar, they can be used to make cedar shakes and shingles or lumber. Poles made from other species (eg. red pine and jack pine) can be used to make lumber.

Poles may also be reused as telephone poles, provided they are still sound, and meet the length requirements. In some cases they may require some retreatment.

Processes that involve sawing of treated poles will require special handling and disposal processes for the sawdust and any wood residual.

Treated lumber has been re-used by some road authorities for landscaping at highway facilities or within interchanges.

BARRIERS TO USING THIS OPTION:

- Coordination is required to ensure that wood that is removed from service is not damaged and is properly sorted and stockpiled.

RESEARCH & POLICY OPTIONS

- Generators of excess treated wood need to identify local outlets for their wood products.

MATERIAL: **Manufactured/treated wood**

USE: **Fast Pyrolysis (Recycling)**

DISCUSSION:

Trans Alta Utilities Corporation and Worthing Industries Inc. of Calgary, Alberta, have joined forces in a treated utility pole recycling venture (TWT Technologies Inc.). The process first peels the chemically treated outer-layer from the poles. The peeled pole (which is uncontaminated) is then ready for retreatment and reuse as utility poles or other wood products. Treated chips peeled from the pole are heated to extremely high temperatures, then quickly cooled in a separate process called fast pyrolysis. During this temperature treatment, the preservative laden oil is vaporized, removed from the chamber and condensed for re-use. The now clean chips can be used in soil treatments for landscape mulch, or other recycling processes. The entire procedure is closed-looped, meaning that no emissions or wastes reach the environment. Every product and by-product from this process is marketable.

Not all treated wood can be recycled by this process. The process only works on oil-based preservatives such as Creosote, Pentachlorophenol (PCP) and, Copper Naphthenate. At present, only Creosote and PCP treated poles are accepted.

The technology is soon to be commercialized and demonstration projects using a mobile facility, are planned for the spring of 1994. Although no price for the process has yet been established, it is expected to be comparable to the costs of landfill tipping fees for treated wood.

BARRIERS TO USING THIS OPTION:

- Processing plants are not widespread.

RESEARCH & POLICY CHANGES:

- The use of fast pyrolysis on other kinds of treated wood (eg. lumber, bridges, piers), as well as other types of wood treatments (eg. C.C.A., A.C.A.) should be investigated.

MATERIAL: **Manufactured/treated wood**

USE: **Incineration**

DISCUSSION:

Once all opportunities for reusing or recycling treated wood have been exhausted, the residual could be incinerated in an energy from waste facility. Dr. Paul Cooper of the University of Toronto explained that pentachlorophenol, creosote and chromated copper arsenate treated wood can be burned in controlled situations. Creosote and pentachlorophenol require high temperatures and dwelling time to breakdown the preservatives into innocuous compounds. This process is possible with current technology.

Incineration of inorganically treated materials is a problem because the preservative cannot be destroyed. The fly and grate ashes from burning CCA will contain arsenic and chromium. Therefore, burning of wood treated with CCA requires proper containment and management of air emissions and ash. This method is more difficult than that for creosote, but is still technically available.

At present in Canada, it is difficult to get a permit to burn any treated wood except at certain toxic waste disposal facilities. This regulatory atmosphere is the major barrier to a treated wood waste management option. the United States has allowed the burning of treated wood at co-generation facilities and cement kilns as a means of recovering some value from the wood while disposing of a waste stream.

BARRIERS TO USING THIS OPTION:

- Public opposition to the incineration of wastes, especially wastes perceived to be toxic, can be a severe barrier to the creation and use of treated wood burning facilities;

- Environmental policies and regulations often prohibit the burning of treated wood; and

- The cost of treating emissions and ash from combustion of treated wood would increase costs of operations.

RESEARCH & POLICY CHANGES:

- Research into the environmental and health effects of burning treated wood should occur; and

- If incineration is feasible, the restrictive government policies should be changed to allow facilities to be built and used.

METALS

Source of Material

Excess steel resulting from roadway construction and maintenance include corrugated steel pipe culverts, multiplate culverts, steel beam guiderails, steel sign posts, noise barrier materials, steel bridge railings, steel bridge members, light standards, concrete reinforcing steel, and guardpost cabling.

Nature of Material

Excess metal usually consists of steel or aluminum that may be bent, broken or obsolete.

Environmental Implications

The environmental implication of burying metal is mainly aesthetic. Iron can dissolve in certain conditions and contaminate ground water. This will lead to unpleasing tasting water, iron precipitate, brownish water colour, and, in some cases iron bacteria. However, burying metal does take up valuable space in land fill and wastes energy. It takes less energy to recycle a metal product than to create a new one.

Summary of Previously Reported Management Practices

The previously reported management options for these materials include:

- taking them to a scrap metal dealer for recycling;
- reusing materials that are still in good condition;
- disposing of the material at a certified landfill site; and
- making it the property of the contractor.

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Other Potential Management Options

Other potential or new management options were not found for excess metals.

There is a sufficient number of scrap metal dealers and yards in Canada that transportation companies and departments do not feel that there is a problem in managing their excess metals. Metal posts, culverts, etc. that are in good condition can often be reused or sold for reuse, while poor quality excess metal is eventually recycled into new products.

Most scrap yards will pay for excess metal. Depending upon the amount and quality scrap metal dealers may pay from $30 to $60 per tonne. If there is a significant quantity of metal, some dealers will pick the metal up from the site.

Because scrap metal yards and dealers are usually located near urbanized areas, the cost of hauling excess metal to the yards from rural areas may become a factor in choosing this management option.

Some Provincial and Municipal governments have had difficulty because too many people (e.g. farmers, small companies, etc.) want the used culverts. Because they do not have a system for deciding who will get the culverts, they

keep them in storage or send them for disposal. Where this is the case, transportation agencies need to develop a system that ensures that the reuse option is taken advantage of, and not avoided because they cannot decide on a fair way to give away or sell these materials. Exchanges as previously described in the Excess Earth Materials - Exchanges Section, could also be a viable option for excess metal management.

In less populated area, (e.g. the Territories), there are few, if any, scrap metal dealers. However, most of the metal culverts are relatively new and excess used culverts is not yet a problem.

NATURAL WOOD/STUMPS

Source of Material

Natural wood is considered to be wood that has not previously been coated, glued or treated. The most common road-related source of large volumes of excess natural wood (i.e. stumps, trunks and branches) is clearing and grubbing operations that occur during the construction of transportation projects. Clearing is the removal of the above-ground portion of the tree, and grubbing is the removal of the stump and root ball.

Nature of Material

The material is natural wood, and falls into two components. The portion that is above the ground (i.e. trunk and branches), and the portion that is below the ground (i.e. stump).

Generally speaking, the management of the tree trunk and branches is less of a problem than is the management of the stump. The stump often contains earth and rock which complicates reprocessing options.

Environmental Implications

In Ontario, concern over the burying of wood materials has been of concern because the material is putrescible. As it decays, it will subside, causing structural problems for anything built over buried wood. As well, decaying wood may produce methane gas which could be a problem when in proximity to buildings having basements where gas can collect, possibly creating an explosive situation. In addition, concern has been expressed over potential impacts on ground water quality, however documentation of such impacts is limited.

A standard method for disposing of excess wood has been open burning. Although still carried on in many jurisdictions, open burning has been banned in some areas because of air quality concerns.

Summary of Previously Reported Management Practices

Previously reported management options for the above-ground portion of the tree include:

- selling to sawmills, pulpmills, or particle board manufacturers;
- selling or giving away as firewood;
- stockpiling;
- using in engineered fills;
- placing into pushouts and covering;
- chipping for mulch or landscaping cover;
- using as boiler fuel;
- using as a bulking agent in sludge composting;
- shredding for animal bedding;
- composting;
- using as a soil amendment in road beds;
- burying in low lying areas; and
- field burning (either in the open, or using an air-curtain device.)

The management options for stumps include:

- cutting flush with ground and leaving in place;
- taking to certified landfill;
- crushing and/or chipping stumps and using as fuel, bulking agents, mulch, compost, soil amendment, or fill;
- field burning;
- using as stump fences;
- using to create fish habitat; and
- using in river bank erosion control.

In some provinces, wood material is being banned from landfill sites because of the large volume, and the fact that it is a natural material that should be put to better use than taking up scarce and valuable landfill space.

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Other Potential Management Options

The following management options have been identified for further discussion:

- Chipping/shredding
- Wood as Energy
- Wood Processing By-products
- Recycling - Wood Plastic Composites
- Wood Products
- Controlled burning
- Wood Composting

MATERIAL: **Natural wood/stumps**

USE: **Chipping/shredding**

DISCUSSION:

Many wood management options accept excess wood only after it has been pre-processed in some way. The wood may be required to meet size standards (eg. chips, sawdust), quality standards (eg. clean of foreign materials), or shape standards (eg., chips vs. shreds). To help those making decisions amongst different machinery and/or the contractors for the required pre-processing, a short review of some of the available equipment is provided below.

This list of equipment is not exhaustive and does not represent support for the equipment or companies mentioned. It is simply a record of equipment identified during the investigation for this report. Other, and possibly better, equipment more suitable for a specific job or process may be found outside of this small listing. Readers should note that every excess material situation or process will have its own criteria, problems and peculiarities. Thus, each type of machine listed below may not be suitable for every job or company.

Tumble Grinders

Tumble grinders are patented and manufactured by Innovator Manufacturing Inc., of London, Ontario. A tumble grinder consists of an inclined steel mesh or screen tub with a hammer mill to grind wood. The screen can be adjusted to allow different sizes of dirt or foreign materials to be separated from the feed stock prior to grinding.

The mesh area screens dirt, sand and material already in the product range. After pre-screening, the remaining woody material is shredded by the hammer mill. The product size can be adjusted by changing the clearance between the hammers and the wear-bars to anywhere between ½ inch and 3 inches. The tumble grinder is designed to process any material from land clearing contracts including stumps. Contractors have indicated that the tumble grinder is an excellent primary processor which works well with a secondary processor such as a tub grinder.

The different tumble grinders retail between $310,000. to $390,000.

and can process wood waste at a rate of 35 tonnes/hr. to 100 tonnes/hr. depending on the model.

Tub Grinders

A tub grinder generally consists of a large upright rotating drum with flailing hammers (hammer mill) that shreds wood. Most do not include a loading device therefore, an excavator with a hydraulic thumb, or a similar machine, must be used in conjunction with most tub grinders. Because the tub grinders are based on a gravity feed, a loading device is sometimes required to help push the feed into the path of the hammer mill.

The Innovator 20900 tub grinder can take any type of wood or brush material including stumps. The size of the product can be varied by changing the clearance between the hammers and the wear bars. The range of clearance is from ¼ inch to 2 inches. The 20900 tub grinder can process 6-10 tonnes/hour and has a retail price of $146,000.

A Diamond - Z is a specially made tub grinder that was developed in the United States. Tub grinder operators have indicated that the Diamond - Z grinder was able to handle wood waste and especially stumps better and faster than other machines.

The equipment produces mulch sized chips that have been used by landscape companies, nurseries, and companies that require bedding for animals.

The Diamond - Z can be hired for $40.00 to $70.00 per hour depending on the job to be done. It retails for approximately $500,000. (U.S.) and apparently there is only one Diamond - Z known in Canada.

Morbark Industries Inc. in Winn, Michigan, has produced five models of tub grinders. All but one of the models include a knuckleboom attachment for loading. The most popular model (1200) is the second largest of their tub grinders. It can accept feed stock of up to 4 feet in diameter. The machine has been used as a primary or secondary processor depending on the size of the feed stock. Size of product can be adjusted.

The 1200 model has a retail price of approximately $265,000. (US). These tub grinders are being used in Canada.

Shredders

The Rome Mauler, marketed in Ontario by Greatario Industrial Storage Systems Ltd., is a large waste shredding unit that can be made in a mobile, stationary, or skid form. Low speed claw-like shredders pull the feed stock into the cutting table while they shred. The shredders are spaced apart to allow abrasives like dirt or rocks to fall through to prevent rapid dulling of the cutting claws. A plate can be added to vary the size of the final product. The shredded material ranges in size from 1 foot to 3 foot lengths that have a maximum circumference of 6 inches. According to the supplier, the machine can reduce the material volume by up to 30% of the original feed stock volume.

One contractor and owner of a rome mauler reports good performance from his mobile mauler. Any stump, tree, culvert or appliance that could fit into the hopper (12.3 ft. x 5.5 ft. x 2.5 ft. or .375m x .228m x .078m) was easily shredded by the machine. The contractor felt that the mauler worked quickly and efficiently. The wood mulch that is produced, is sold to composting companies, and to mulching companies for further reduction for pulp/paper feed stock. Due to the size of the product, further processing may be required before distribution to different markets.

The contractor rents his services with the mauler on a price per job contract, but states that at least $300.00 per hour of work just covers his costs. Transportation costs may be extra depending on the size and difficulty of the job, as well as the distance to the job site. The mauler takes only half an hour to set up and can handle 150 to 250 cubic yards per hour (114.7 to 191.2 cu. m per hour). The price of the Rome Mauler is under $600,000.00 (U.S.).

Trommel Screens

A trommel screen consists of rotating drums made of webbed or mesh steel. The two drums rotate opposite of each other and allow small particles to fall through the mesh. These trommel screens have been used to separate materials such as small sized contaminants (eg. stones, dirt, nails) from the shredded wood. It can also be used to

separate different sizes of wood chips and to break up and sort compost and soils.

Innovator Manufacturing Inc. has produced several models of Trommel Screens

Contractors have indicated that a trommel screen is adept at separating excess material into 3 sizes - small products, medium products, and over-sized material that may be returned to the size reduction process. Different sizes of screens will allow a variation in product size separation.

A trommel screen can cost from $126,000. to $180,000. depending on the make and model.

Whole Tree Chipper

A "Chiparvester" is a whole tree chipper manufactured by Recycling Systems Inc. (Winn, MI, U.S.A.). The chiparvester consists of a feeding port and a chipping disc. A loading arm that is either inclusive or exclusive of the machine, loads the trees, trunk - first into the feeding port. The Chiparvester Model 23 is reported to chip up to 6 acres of trees in a day and produce good marketable quality chips for pulp mills or biomass generators. The chiparvesters are reputed to be designed to accept 100 feet of tree per minute. However, they will not handle stumps.

The cost of a chip harvester is approximately $290,000. (US). Several models are being used throughout Canada.

Hydraulic Shovels

Some contractors use hydraulic shovels instead of bulldozers to remove stumps. It was felt that bulldozers are not as efficient at removing the stumps and too much dirt is left on the stump. One contractor has created an attachment that allows the hydraulic shovel to better clean stumps of dirt and debris. The EL 200 Caterpillar (Hydraulic Shovel) was chosen for this attachment because it has the power of the 225 Caterpillar, but is light weight enough to manoeuvre in soft earth and marshy areas. An EL 200 caterpillar is priced at approximately $180,000.

Stump Grinders

A stump grinder is a machine that uses a circulating chain to rip/grind a stump while the stump is on site. This type of machine does not remove the stump from the ground, but grinds 25% to 50% of the stump. The machine scatters the chips, making them difficult to collect and therefore not very marketable. The roots and portions of stumps left in the ground can cause difficulties during grading operations. However, it is a reasonable choice for an urban forest setting where the ground would not be graded or developed. Seigmiller Construction Ltd. in Kitchener, Ontario, has used an asphalt milling machine on a backhoe to grind stumps in-place and mix the wood chips with the topsoil.

MATERIAL: **Natural wood/stumps**

USE: **Wood as Energy**

DISCUSSION:

Several Provinces have already introduced some biomass fuelled power and/or heat generating stations as functioning projects. The Prince Edward Island Department of Transportation & Public Works uses wood chips in a wood-to-heat facility to provide heat and hot water to approximately 50 buildings in Charlottetown. In Alberta, the waste wood from a sawmill/strand-board factory is being proposed as the feed stock to a cogeneration facility which in turn, will provide heat and possibly electricity to the factory. Excess electricity will be sold to the Provincial power grid. A typical plant in Northern Ontario would use 110,000 tonnes of wood wastes to generate 15.6 megawatts of electricity each year. Several other cogeneration-type facilities exist throughout Canada. Generating plants such as these could use the excess natural wood, from leaves to stumps, produced by transportation projects.

The provinces tend to prefer those facilities that have a market for all of the energy produced and that do not expect the provincial power grid to buy excess energy.

Some wood burning facilities are designed to burn green wood, while others burn dry wood. Depending on the facility, some pre-processing of the wood may be required. Crushing very large stumps would be required to allow the wood to be more easily sized for placement in the furnace or processing machinery. Metal contaminants, such as nails, can be accepted with the biomass and removed from the ash after combustion.

This management method does not necessarily require an intermediary to handle the wood between the supplier and the user. However, drop-off sites might provide greater access and less haulage cost for the owner of the excess wood. Haulage costs could be high depending on the number and location of these energy producing plants. The cost of depositing wood at a wood fuelled energy plant can be up to $50.00/tonne in areas where landfills do not accept wood waste. In areas where landfill costs are low, the haulage and disposal costs will determine if this option is economical. In the maritimes, some wood burning facilities buy wood chips for approximately $35 per tonne from transportation construction contractors.

Ontario was the only Province that was reported to be 'unsupportive' of wood-

to-energy plants. In 1991, the Ontario Provincial Government promoted the use of alternate fuels to produce or replace electricity. The Ontario Ministry of Environment and Energy report "Wood Waste Generation and Management in Ontario", recommended that wood burning facilities be established in urban areas to be fuelled by demolition and construction wastes. At present, in Ontario, the Provincial Government supports the use of the 3 R's (Reduce, Reuse, Recycle) before recovery. Since wood to energy is considered recovery (recovery of energy), wood-to-energy facilities are not currently supported as the preferred environmental management option for excess wood.

Although there is no Ontario regulation prohibiting the incineration of wood, there are also no incentives. Ontario's Ministry of Environment and Energy felt that supporting wood to energy plants could cause:

- the promotion of incineration in general to which the Ontario Government is opposed (some exemptions apply); and

- the increase of the surplus of energy already existing in Ontario.

Thus, the wood to energy companies are finding that it is too difficult and time consuming to get approval in Ontario.

Some research into more efficient wood burning furnaces has been conducted in Finland and supported by Sweden. The promoters feel that the furnaces can be feasible and profitable. Canada also researched into an early model of a high efficiency wood burning turbine generator. It was created in Mississauga by Ortech International. The turbine was run through 50 hours of tests, generated 200,000 watts of electricity and was considered a success. It was not commercialized due to a lack of client funding for the final research stage.

Some of the pollutants produced from burning wood can be removed with scrubbers. Therefore, the biomass fuelled energy plants have minimal effects on the environment, use scrap or excess materials, support other industries (eg. forestry), and provide a usable, marketable product (electricity and/or heat).

The ash produced at these facilities is normally landfilled, but has been known to have good fertilizing qualities. An employee of the P.E.I. Department of Transportation and Public Works felt that the ash could be sold for up to $60 per tonne as a fertilizer, but the ash is difficult to get into a spreadable form. Grinding or pulverization is required. At present the ash from P.E.I.'s facility is landfilled.

Friendly Fuels Inc., a Calgary based company, has invented a wood pelletizer. This equipment produces compact fuel pellets from wood waste for use as fuel in both commercial and residential wood burning facilities.

The pelletizer chips the wood to a 1" square size, then using a hammer mill with screens, reduces the size to less than 1/8 inch square. A conditioner adds steam to the chips to start the softening of the wood lignin. Once softened, the chips are forced through a die and a knife attachment sizes the pellets. No foreign products (e.g. nails) are allowed within the final product.

Commercial/industrial grade fuel can be made from all types of wood; however, residential fuel is made from white conifers. Deciduous trees have a change in growing season which causes an increased amount of minerals to deposit in the tree's growth rings. The higher the mineral content in wood, the more non-combustible ash is left after the burning of the pellets. Since most wood burning residences can not easily dispose of excess ash, the residential fuel is made of coniferous wood to decrease the nuisance of ash disposal.

Using well dried wood (moisture content of less than 8%), the pelletizer can process 15-20,000 tonnes of wood per year. It would take twice as much green wood to produce the same amount of product due to high moisture content in green wood. Therefore, the wood must first be mechanically dried using such equipment as a rotary drum drier.

A company owned pelletizer would have a basic operating cost of approximately $40 to $60/tonne of wood. (This does not include the cost of the machine itself). Pellets can be sold for approximately $100/tonne to both industrial/commercial and residential markets.

One drawback of the pelletizer is that although it is transportable, it requires a permanent industrial or commercial electrical hook-up for the 700 hp engine. Thus, the pelletizer is not mobile. However, the company is creating a mobile hydraulic pelletizer that is powered by a portable diesel generator. The new mobile pelletizer is expected to be available within a year.

The company reports an increasing market in both the residential and commercial areas.

BARRIERS TO USING THIS OPTION:

Energy from Wood:

- Excess wood may require extensive processing before being accepted as feed stock for certain types of furnaces/plants. Costs will increase with the amount of processing needed;

- Trucking cost can become high depending on the number and locations of the wood-as-energy plants;

- In areas of low cost landfill, the feasibility of these plants would depend on haulage and deposit costs;

- Wood as energy plants require a steady supply of feed stock and, therefore, require established contracts with suppliers. It is unknown if all such plants will accept extra wood from sources outside these established suppliers; and

- Provincial, environmental and energy situations and policies can make companies reluctant to use and develop wood-as-energy facilities.

Pelletizer:

- Wood needs to be dried to less than 8% moisture content. This can increase costs and work time, if green wood is used as feed stock;

- The present pelletizer is not mobile and requires a significant electrical power source. Therefore, the location of the pelletizer is restricted and haulage costs must be included in the cost of pelletization. These problems will be somewhat alleviated with the creation of the mobile pelletizer; and

- Because no foreign matter (eg. nails) can be allowed in the final product, an extra effort, mechanically or manually, may be required to remove these materials from the feed stock;

RESEARCH & POLICY CHANGES:

Much research has already been done in the wood-to-energy field in North America and around the world. Most provinces already support the use of wood as energy facilities.

- Governments should support the use and development of wood to energy facilities as a valid excess wood management option where the preferred 3 R's options are difficult or impossible to achieve.

MATERIAL: **Natural wood/stumps**

USE: **Wood Processing By-Products**

DISCUSSION:

The use and/or marketing of by-products from a wood recycling or reusing program provides a more complete use of excess material which, in turn, can help decrease any operating costs. Generally, the options that maximize the use of the excess material is preferred environmentally, provided that any waste stream from the process is properly managed.

The process used by Domtar Ltd. in Ontario to create cardboard produces a sweet sticky liquor by-product from the wood sap. This liquid is mainly composed of water, with some sodium carbonate and wood sugar (sodium ligno-carbonate). It is reported that because of its harmless chemistry, its moisture holding qualities, and its manner of hardening on gravel roads, several Ontario cottage country Townships are using it as a gravel road top dressing. The Townships feel that it works as well or better than the traditional oil or calcium chloride dressings. Its use has been approved by the Ontario Ministry of Environment and Energy. Other mill processes can produce sodium ligno-sulphonate which has similar road binding capabilities.

The sodium ligno-carbonate is considered a waste by the Ontario Ministry of Environment and Energy and must be treated as such. The manufacturer is attempting to have it classified as a product to reduce the negative connotations that comes with the waste classification. It is hoped that this change would make the road binder more marketable and environmentally acceptable to the public.

In the Northwest Territories ligno-sulphanate has been known to cause an oily sheen if it reaches water courses. More environmental and engineering studies may be required to address concerns with ligno-sulphanate.

Another Ontario based company is investigating the marketability of resins and turpentine produced from one of their wood recycling processes. Turpentine used to be derived from stumps in the U.S. until the kraft pulping process provided a cheaper turpentine supply. At present, a large supply of stumps would be required to make the turpentine process feasible. Because the turpentine would be a by-product of another process of this Ontario company, the resin/turpentine operation may be feasible.

BARRIERS TO USING THIS OPTION:

- The listing of a by-product as a waste could cause the product to be unmarketable due to the negative health and environmental connotations associated with the word "waste".

RESEARCH & POLICY CHANGES:

- Research into new or presently used recycling processes should include investigation of any by-products for potential uses. The more complete the recycling of excess materials, the more environmentally friendly the process becomes. Also, providing the recycler with more marketable products could decrease the cost to the supplier; and

- Road agencies can support the wood recycling industry by using byproducts such as ligno-carbonate as a dust suppressant.

MATERIAL: **Natural wood/stumps**

USE: **Recycling - Wood Plastic Composites**

DISCUSSION:

Wood and plastic experts have been researching the use of reconstituted wood fibres in wood plastic composites. The process involves the combining of cellulose fibres, recycled plastics and additives specific to the requirements of the end product. It has been reported that this mix, with correct processing, could be used for injection moulded, extruded, calendered and compression moulded products.

At present in Canada, some car manufacturers use interior car door frames that are made with wood flour. Wood flour is easier to make, but is not as strong as wood fibre in products like car door frames.

An intermediary would be required between the excess material owner and the wood/plastic composite facility in order to process the wood into the proper quality of fibre.

Since facilities of this kind are few in numbers, haulage for the owner or the intermediary, as well as the cost of processing, would be a factor in the economics of this recycling method. In Canada the cost of depositing wood at a recycling company can range up to $75.00 per tonne, depending on how clean the material is.

It is necessary to clean rocks and metal from wood material in order to provide high quality, uncontaminated wood for the creation of higher value products.

BARRIERS TO USING THIS OPTION:

- In Ontario, wood recycling companies have mentioned that it is difficult to keep their operations in compliance with the changing regulations and policies;
- Lack of technology for creating clean, high quality wood fibre; and
- Lack of machinery or processes that can use wood fibre.

RESEARCH & POLICY CHANGES:

- Research into the machinery or process changes required to use wood fibres is needed; and

- Technology to produce high quality 100% clean wood chips and fibres should be developed.

MATERIAL: **Natural wood/stumps**

USE: **Wood Composting**

DISCUSSION:

Composting is a process whereby complex organic matter is reduced to simpler and more stable compounds with the use of micro-organisms. Composting is becoming a regular service in many municipalities, often motivated by scarce landfill capacity and/or regulatory changes.

There are many different methods of composting organic matter but most can be categorized under a general process such as turned windrow; static pile (forced aeration), in-vessel (i.e. in a drum or tank); and hybrid (i.e. a combination of the previous elements). Some restrictions (eg. particle size) may be applicable to one or all of these methods. Depending on the method, wood chips and fibrous materials are recommended to be an optimum size of 2-3 inches (5 to 7.5 cm), while fresh green plant material (eg. leaves, lawn clippings) should be no smaller than 2 in. (5 cm).

A proper carbon to nitrogen (C/N) ratio is important to efficient composting operations. The ideal ratio is about 20 to 25 parts of carbon to 1 part of nitrogen. Wood materials are high in carbon and will raise the C/N ratio in a compost. C/N ratios can be lowered by adding nitrogenous materials such as grass clippings, green vegetation, non-ruminant animal manure or sewage sludge.

Wood is high in carbon and releases any nitrogen in the lignin too slowly for effective composting. Therefore, wood composting requires the addition of nitrogenous materials. However, according to a survey of biosolid composting facilities in New England reported in the May 1994 Journal of Water Environment & Technology, wood chips are the preferred amendment for composting biosolids.

Most composting companies request only clean uncontaminated wood sawdust or chips. Removing any metal or plastic contamination from the wood before or after the shredding will increase costs. The shredding equipment with operator can be rented for $400 to $700 per hour. A tub grinder is $125-$150 per hour with an operator.

Good quality sawdust can be sold to some compost companies for $1-$2/yd^3 ($.75-$1.50/m^3). Hardwood sawdust or chips is preferred at composting

operations because some soft woods can release toxins that kill the microbes necessary for the composting of organic matter.

Because of the need for land and equipment and the desirability of a mixed stream of compostable material, partnerships between transportation agencies, construction companies and municipalities could provide a cheaper composting option with less start up costs.

Possible end markets for compost includes: landscaping companies, nurseries, homeowners, farmers, soil stabilization/rehabilitation projects, grass growers, and top dressing on rights-of-way.

A British Columbia firm (Envirowaste), has successfully created a large scale composting facility. The feed stock consists of waste from restaurants, farms, residences, as well as trees and garden trimmings that are collected from within a 50 mile radius of the plant. Materials are usually delivered by private carriers or the generators, with a deposit fee. The compost produced is sold as high quality horticultural products. The company reports that a better quality compost product is created using source separated organic wastes and materials.

Although many people support the idea of composting and even have a composter in their backyards, composting companies have had difficulties with residents near their proposed facility location. The public often regards large scale composting facilities as garbage dumps. They think that the compost will stink, attract vermin and lower land values. This can make the siting of composting facilities a difficult and costly process. A public education program dealing with composting regulations/guidelines/policies/facts should be part of any plan to establish a composting site.

A potential offshoot of composting is the production of biogas. This is a gas consisting of approximately 65% methane that is produced from the anaerobic decomposition of organic material. The biogas can be used as fuel for boilers and furnaces, while the remaining sludge can be used as compost. However, wood cannot be the sole source of feed stock for the production of biogas.

Biogas systems have been used in India and Europe for the heating or electrical needs of communities. Very simple to extremely sophisticated equipment is available for the use of Biogas.

BARRIERS TO USING THIS OPTION:

- Government regulatory requirements (e.g. monitoring cost and operation restrictions) can add additional costs and operational problems that discourage potential composting operations;

- Although they support individual composting, many people feel that a large scale composting site is equal to a garbage dump. The "not in my backyard" syndrome can cause residents to oppose the location of a compost site near their neighbourhoods; and

- Some provinces allow the burial and/or burning of brush and stumps with, or possibly without, a permit. Such an inexpensive option for the disposal of woody material discourages the development of 3R options.

RESEARCH & POLICY CHANGES:

- Education of the public on large scale composting facilities is necessary;

- Municipal, Provincial and Federal governments should provide stronger recycling incentives in order to reduce the amount of wood burned on work sites; and

- Joint pilot projects between transportation agencies and municipalities should be encouraged.

MATERIAL: **Natural wood/stumps**

USE: **Wood Products**

DISCUSSION:

Many products can be made from natural wood. The most obvious are lumber and pulp/paper. However, the production of these products require certain types and sizes of wood material. This requires contractors to sort the material on-site and minimize contamination of wood stockpiles.

Sawmills or pulp/paper mills that produce a variety of products can often accept a wide variety of natural wood. This can cut costs by reducing the amount of sorting required by the contractor.

In Western Canada, some pulp/paper or lumber mills are accepting trembling aspen and poplar of certain sizes to make oriented strand board. Because of their diversity, such sawmills can accept a wide variety of salvageable wood, with the exception of a very few rare or lumber worthless species. The mills pay from $16. to $50.+ per tonne depending on the type and quality of the wood.

Other companies that make building components such as chipboard/particle board accept and pay for chipped wood and sawdust. Combiboard in Ontario was paying $15.-$20./tonne for mixed sawdust and $40.-$50./tonne for softwood chips in 1990-1991. All wood was accepted provided it was 100% contaminant free, and sized to their specifications. The factory was able to process 150,000 green tonnes of softwood chips per year and a similar amount of mixed sawdust. Combiboard has since closed its doors due to the drop in wood prices during the recession. The new owners of the factory plan to reopen the plant in 1994.

IKO Industries Ltd. in Brampton, Ontario uses wood chips to make the paper backing for asphalt shingles. Unlike fine papers, this paper can be made from a broader range of wood. IKO will accept hardwood and softwood chips, provided the chips are within their size requirements.

The key limitation is that the chips need to be clean. Although the company has not used stump chips, they are prepared to work with generators of stump chips to see if the pulping process can accept this material. IKO pays up to $20/tonne delivered for bone dry wood. Price reductions are made for wood with higher moisture content.

BARRIERS TO USING THIS OPTION:

- Pulping companies generally have specific quality requirements with respect to wood type, size and moisture content. Contaminants such as dirt in the feed stock can make the wood unacceptable; and

- To use this option, contractors will need to handle the wood in a fashion dictated by the needs of the company receiving the wood. These handling procedures will have to be worked out prior to the preparation and award of the contract.

RESEARCH & POLICY CHANGES:

- Research into cost effective ways to produce clean chips from stumps; and

- Develop, through partnerships with contractors and wood users, clearing, grubbing, stockpiling and processing procedures that will maximize the usefulness of the wood.

MATERIAL: **Natural wood/stumps**

USE: **Controlled Burning**

DISCUSSION:

In the United States where open burning is prohibited, controlled open burning can be permitted with the use of certain machines such as the "Air Curtain Destructor" (by Concept Productions Corporation). The manufacturer reports that these machines are effective in reducing the emissions of the particulates, organic gases, and carbon monoxide. They also aid in the combustion of wastes by containing the particulates and gases in a high temperature mixing zone and by supplying excess oxygen (air) to the fire.

All waste to be burned is put into a rectangular pit (20 ft. x 8 ft. x 15 ft. (depth)), with vertical sides. The machine is set along the length of the pit and blows a curtain of air diagonally into the pit towards the opposite corner. This curtain of air supplies oxygen to the burning wastes and contains the combustion process within the pit. Smoke is picked up by the air curtain and reintroduced to the burning pit. Wood waste volume can be reduced to approximately 1% with this process.

Although this method reduces the amount of landfill, the wood burned is still wasted. It is, therefore, an option of last resort when 3R options have been exhausted.

BARRIERS TO USING THIS OPTION:

- Recycling policies, local regulations, or contract specification may eliminate this process as a management option.

RESEARCH & POLICY CHANGES:

- Local permitting may be required to allow this option.

STREET/ROAD SWEEPINGS

Source of Material

This material is a product of winter operations in which sand is deposited on the roadway to gain traction during the winter, and swept up in the spring.

Nature of Material

The sand is often contaminated with oil and grease and heavy metals from vehicles, salt used in deicing operations, and litter.

Environmental Implications

Because the sand is contaminated with heavy metals, oils and grease, it may not be suitable for all uses. In Ontario, this material is disposed of at landfills.

Summary of Previously Reported Management Practices

If the material is located on a road with a rural cross-section, it is often swept onto the road shoulder. In other cases, the material is collected and managed in the following ways:

- deposited at a certified landfill site (including use as top cover);
- use as fill (e.g. at ski hills or "clean fill wanted" sites);
- use as shoulder material;
- stockpiled; and
- recycled for winter road applications.

Bibliography/Contacts

Contacts

Mr. Clare Hilsden, District Manager, Ontario Ministry of Transportation.

Mr. John Slobodzian, Environmental Office, Ontario Ministry of Transportation, Downsview, Ontario

Other Potential Management Options

Other potential management options include:

- reuse as winter sand.

MATERIAL: **Street/Road Sweepings**

USE: **Reuse As Winter Sand**

DISCUSSION:

In some areas of Ontario, the provincial Ministry of Transportation has experimented with reusing winter sand. This is only done where it is not practical to sweep the sand to the shoulder. Where sweeping to the shoulder is possible, this is preferred because of the reduced handling costs, and because it makes a good supplement for the shoulders.

Where highways have centre barriers, the sand needs to be collected and removed. This sand is taken back to the patrol yard where it is screened to remove the litter, and larger sized materials. The waste materials that are removed through screening are taken to a landfill. The Ministry reports that after one season, the sand still meets their standard for winter sand.

The reclaimed sand is either used 100%, or mixed 50:50 with virgin sand. It is also mixed with salt in the standard ministry proportions. The Ministry found that in some cases, the mix that used 100% reclaimed sand, created some caking problems because of a higher moisture content. This was reduced when a 50:50 mix was used.

It is not known if the sand would meet the standard for reuse after a second year. It would be preferable to use the reclaimed sand on a lower volume road where it can be swept to the shoulder in the spring. In this way, the sand is used twice as winter sand, and then used as shoulder material. This avoids using "worn" sand in high risk settings.

BARRIERS TO USING THIS OPTION:

- Limited knowledge of the abrasive properties of sand after successive uses.

RESEARCH & POLICY CHANGES

- Research into the changes in abrasive properties of winter sand with successive uses.

5.0 CLOSURE

This report represents an investigation of existing and potential options for managing excess materials generated from road construction and maintenance operations in Canada.

It is intended to guide transportation agencies as they seek to identify and implement more environmentally appropriate material management practices. Chapters 2 & 3 review the various barriers to innovation, and discuss the organizational and cultural conditions that must be dealt with in a road agency before material management issues can be effectively addressed.

Chapter 4 provides discussion on specific materials to help material managers to understand what is being done elsewhere in North America. It is hoped that this information will seed some ideas that might encourage readers to try new and innovative approaches, and to build partnerships that will help to foster the development of the necessary infrastructure to support greater reuse and recycling of road-relate excess materials.

To be successful, transportation practitioners must be willing to break the bonds of tradition and venture into unfamiliar territory. However, it is important to remember, that what is unfamiliar to you, may be standard practice for your colleagues in other jurisdictions. Those in the transportation sector must share their successes and failures broadly across Canada, so that the learning curve can be shortened, wasteful duplication of effort can be eliminated, and new cost effective and environmentally sound practices can be implemented more quickly.

APPENDIX A

TAC'S ENVIRONMENTAL POLICY AND CODE OF ETHICS

TAC ATC POLICY

Transportation Association of Canada Association des transports du Canada

Environmental Policy and Code of Ethics

Approved by the TAC Board of Directors
September 15, 1992

The Transportation Association of Canada (TAC) is a national non-profit association of more than 550 voluntary corporate members and includes the federal, all provincial/territorial and many municipal governments, passenger transport services, goods carriers, contractors, manufacturers, consultants, academic and research groups, and others. The Association's organization includes a ***Board of Directors****; an* ***Executive Committee*** *of the Board; as well as seven* ***Councils*** *and supporting* ***Standing Committees*** *and* ***Project Steering Committees****. In the following Environmental Policy and Code of Ethics, TAC refers to the Board of Directors, the Association's councils and committees and its Secretariat.*

TAC's mission is to promote the provision of safe, efficient, effective and environmentally sustainable transportation services in support of Canada's social and economic goals. In carrying out this mission, TAC encourages its members to:

- *adhere to the following Environmental Policy and Code of Ethics in support of achieving environmentally sustainable transportation services; and*
- *provide leadership in developing their own supporting policies, guidelines and practices.*

ENVIRONMENTAL POLICY

The Transportation Association of Canada (TAC) is committed to protect and enhance the environment when providing transportation services, so as to sustain the earth's ecosystem.

TAC is dedicated to establishing harmony and balance between the transport of people and goods, and the environment in order to achieve a sustainable social and natural environment.

ENVIRONMENTAL CODE OF ETHICS

The Transportation Association of Canada encourages its members to adhere to the following Code of Ethics and to use it as a basis for the development of transportation-related codes of practice. The essence of this code of ethics is to espouse an understanding of, and respect for, the rights of people and the environment and their inter-relationships.

Mainstreaming Environmental Concerns
Every activity, be it policy or project development, operations, or influence, has positive and negative environmental effects. Therefore, environmental considerations should be integrated into day to day activities and long-term decision-making, fostering a commitment to environmental protection within the transportation sector.

Continuous Improvements
Environmental protection and enhancement are an ongoing responsibility. Therefore, policies, plans, programs, projects and activities should be monitored, reviewed and improved on an ongoing basis.

Incremental Effects
Environmental degradation results from the aggregation of many small impacts over extended periods of time. Therefore, the cumulative environmental effects of transportation activities should be assessed and remedial action taken to minimize those effects.

Partnership and Awareness
To enhance the decision-making process and raise awareness about transportation-related environmental issues and problems, open communication and partnership with all stakeholders should be encouraged.

Public Participation
In recognition of the need for open communications and partnerships with stakeholders, actions should be sensitive and responsive to the public's concerns and their right to know about transportation-related environmental issues. The public should be involved in the resolution of these issues.

Proactive Planning
Environmental problems should be anticipated and addressed when developing policies, plans, programs, standards and/or guidelines.

Integrated Transportation Planning
A healthy environment depends on sound planning. Therefore, land use, transportation, and environmental planning should be integrated, fostering a multi-modal approach to meeting Canada's transportation needs. A full range of alternative solutions should be considered, emphasizing the management of the demand for, and supply of, transportation services.

Research and Development
In recognition of the importance of knowledge to environmental protection and enhancement, leadership in the research and development of environmentally compatible transportation technologies and methods should be provided and openly shared with others.

Product Stewardship
All materials (hazardous and non-hazardous) should be handled in a way that protects health and the environment.

Products and Processes
In recognition of the need to integrate environmental concerns into all aspects of transportation, environmentally compatible products and processes should be used.

Atmospheric Protection
Transportation-related air emissions, especially those that contribute to global warming, urban smog, ozone depletion, acid rain, as well as other adverse effects on health and the natural environment should be minimized or eliminated.

Surface and Ground Water Protection
In recognition of the necessity of clean water to health, the economy, and the ecosystem, discharges of transportation-related contaminants to surface (fresh and salt water) and ground water should be minimized. Water should also be used in a wise and efficient manner.

Land Protection
Transportation facilities should be planned so as to conserve land resources generally and to preserve and protect lands that are needed to sustain future generations. Furthermore, site contamination should be avoided and land clean-up undertaken as appropriate.

Conservation of Resources
Energy and other resources should be conserved with particular emphasis on reducing dependence on non-renewable resources.

Waste Management
Waste discharges to the environment should be continually reduced through the development and application of 3R (Reduce, Reuse and Recycle) programs and technologies.

Special Spaces and Species
Given the importance of natural habitats to the long-term survival of plants, animals, and aquatic life, these areas should be protected and enhanced. As well, areas containing physical features of significant interest should be protected.

Noise Reduction
Transportation-related noise impacts should be minimized.

Appreciation of Canada's Cultural Heritage
Historical sites, archaeological resources and other aspects of our diverse cultural heritage should be preserved for future generations.

Aesthetics
Transportation facilities should be planned, designed and constructed with due consideration for the visual environment into which they are placed.

ENVIRONMENT ADVISORY COUNCIL

The Environmental Policy and Code of Ethics was prepared by TAC's Environment Advisory Council on request from the Board of Directors.

The objectives of this council are to:

- raise awareness of environmental issues in transportation for the TAC membership;
- provide a forum for discussion and education about environmental issues; and
- encourage and assist TAC members in seeking effective resolution of specific environmental issues.

The membership of this council includes federal and provincial governments (transportation and environment), municipal governments, vehicle manufacturers, roadway contractors, carriers (truck, transit, rail, air, ports) motorists, academics and consultants.

For additional copies of this policy and code, or for more information on the activities of the Environment Advisory Council, please contact:

Russ Smith
Secretary, Environment Advisory Council
Transportation Association of Canada
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APPENDIX B

STUDY METHODOLOGY

STUDY METHODOLOGY

DETAILED TASK DESCRIPTIONS

The study was conducted in 6 Phases. The following details the purpose of each phase, and how they were carried out.

Phase I - Project Start-up:

Discussions were held with TAC to finalize the terms of reference, the workplan, and the schedule.

Phase II - Identification of Excess Construction and Maintenance Materials and Current Practices.

This phase involved obtaining, and reviewing relevant literature on the type, nature, and management of excess materials that are generated by the construction and maintenance of roads. During this study, construction included both new construction and reconstruction. The study also focused on the field aspects of maintenance, rather than address excess materials from garages and patrol activities.

The relevant information was extracted and summarize in an interim report that was presented to the Steering Committee in April, 1993. The finding of this Study Phase formed the basis of the summary of previously reported management practices provided in Chapter 4 of this report.

Phase III - Prioritize Materials

Since there are many different kinds of materials, it would not be practical, to deal with each one in an exhaustive way within the budget set for this study. On the other hand, if not handled in sufficient detail, the report will be of little use for helping transportation authorities to move forward in dealing with their problems. Therefore, a priority list was prepared.

The prioritization was done on the basis of the following criteria:

i) the volumes of materials being produced;

ii) the environmental acceptability of current management practices;

iii) the relative cost of current management practices; and

iv) the extent of difficulty currently being encountered by those

managing these materials.

The views of people in the transportation sector across Canada were solicited by phone and questionnaire. On the basis of the comments received, a prioritized list of materials was developed and reviewed with the Steering Committee. Table A-1 shows the list of materials that were selected for detailed study.

TABLE A-1

LIST OF PRIORITY MATERIALS

1. Asphalt Concrete
2. Abrasive Blasting Medium
3. Stumps
4. Concrete
5. Excess Earth Materials
6. Metals
7. Treated Wood
8. Street/Road Sweepings
9. Catchbasin Material

Phase IV - Identify and Evaluate New Management Options

Having obtained agreement on the priority materials to be studied, Phase IV of the study consisted of a search for, and evaluation of, management options. Since a lot is already known about current management options, the study focused on searching out new options, and options that are not universally understood across Canada.

The premise of the study was that there are opportunities for greater use of the materials by the transportation sector. As well there are other industries that have need for some of the materials that are excess to transportation operations.

An effort was made to identify potential users of the priority materials. This was done by surveying industries having need for the priority materials. In addition to a literature review, the study team consulted waste exchanges, industrial associations, recyclers, and those in the transportation sector that need to manage these materials.

Phase V - Identify Research Needs, and Changes to Operational Standards and Policies.

Through the analysis carried out in Phase IV barriers to opening up new outlets for the priority materials were identified. Some of these included:

- Poor understanding of the chemical and physical properties of the materials with respect to the environmental standards;
- Poor understanding of the engineering properties of the material;
- Regulations prohibit the option;
- Limited market for the product makes it uneconomical;
- High transportation and/or processing costs make it uneconomical;
- Policies and standards limit market availability;
- Incompatibility in timing between the supply side and demand side; or
- Necessary technology is unavailable.

The opportunities and barriers were identified, and recommendations have been made regarding the necessary actions to break down these barriers and open up new options. Information gaps warranting further research, are identified.

Phase VI - Identify How to Encourage Road Authorities to be More Proactive in Using Environmentally Responsible Management Practices.

It is clear that not everyone in the transportation sector is being proactive in managing their excess materials in the most environmentally acceptable manner. Road authorities tend to be predisposed to using more environmentally acceptable practices if they are aware of them, and the practices are practical, easy to administer, and cost-effective.

Those responsible for managing the excess materials and determine why they choose to use, or not use, new management options were surveyed through telephone and questionnaires. This included a cross-section of provincial, territorial, and municipal road authorities.

Based on this, we have recommended strategies for encouraging greater initiative amongst transportation authorities, to seek out and use innovative management options.

This report includes guidelines for implementing management practices. These have been designed to help road authorities to understand the need for, and optional methods of, managing excess materials in more environmentally acceptable ways. It is believed that with an increased understanding of options that are available, and being used elsewhere in the country, those in the transportation sector will be in a better position to convince decision-makers of the need to be more proactive.

APPENDIX C

QUESTIONNAIRE

TAC SURPLUS MATERIALS STUDY
QUESTIONNAIRE

1. AGENCY DATA:

This data allows the study team to draw observations of similarities or differences between issues and concerns with the management of surplus materials among various jurisdictions.

Agency Name: _____

Contact Person: _____

Address: _____

_____

Phone Number: _____ Fax Number: _____

Agency Type: Urban __ Rural/Country __ Province __ Federal __

2. LIST OF ROAD SURPLUS MATERIALS (CONSTRUCTION AND MAINTENANCE)

In order to prioritize the materials that will be investigated in more detail in this study, we need to know the type and rough volume of materials you handle. It is not necessary to list all the material, but rather you should focus on those for which you are currently, or expect to have difficulty managing.

Please complete Table #1, on the basis of your current knowledge, off the top of your head. We do not want you to do any special research to complete this survey.

The following explains the categories in the Table.

Note 1 Give an estimate (m^3/yr or t/yr) if easily available, otherwise indicate large, medium, or small.

Note 2 Indicate the degree of problem this material currently causes you - High, Moderate, Low.

Note 3 Indicate the degree of problem this material is expected to cause you in the next 5-10 yrs - High, Moderate, Low.

Note 4 Rate as High, Moderate or Low, your priority for the development of improved management options for this material.

TABLE 1

Surplus Material Type	Annual Quantity Note 1.	Current Practice					Problem/Solution Ratings		
		Waste %	Reuse %	Recycle %	Sell %	Give Away %	Current Note 2.	Future Note 3.	Priority Note 4.
Concrete									
Asphalt									
Stumps									
Blasting Medium									

3. COMMENTS ON SPECIFIC SURPLUS MATERIALS

For the top 5 materials identified in Part 2, please provide a short comment in response to the questions set out below.

3.1 How are you currently managing this material?

_____
_____
_____
_____

3.2 In your opinion, how environmentally acceptable are these management practices?

_____
_____
_____
_____

3.3 Do you find the costs of these management options to be acceptable? Why? Can you quantify the costs?

_____
_____
_____
_____

3.4 What degree of difficulty are you experiencing in managing these materials?

_____
_____
_____
_____

3.5 Do you have any thoughts on what other management options may be promising? Who might have use for these materials?

_____
_____
_____
_____

3.6 Who else might we talk to about these materials?

_____
_____
_____
_____

3.7 a) What is standing in your way when trying new management options?

_____
_____
_____
_____

b) Do your engineering standards limit the 3R options for these materials?

_____
_____
_____
_____

c) Do the environmental regulations in your area limit the 3R options for these materials?

_____
_____
_____
_____

3.8 Do you have a good understanding of the environmental and physical properties of these materials?

_____
_____
_____
_____

3.9 Are there potential markets for these materials? If so, what is limiting these markets?

_____
_____
_____
_____

3.10 What research do you think is needed?

_____
_____
_____
_____

4. WHERE SHOULD WE BE GOING ON THE SURPLUS MATERIALS ISSUE?

4.1 Given that new management options are being identified in other jurisdictions, what is preventing you from trying these new approaches?

_____
_____
_____
_____

4.2 What can TAC do to encourage you to use more environmentally acceptable management options?

_____
_____
_____
_____

4.3 What do you need from this study?

_____
_____
_____
_____

APPENDIX D

LIST OF PEOPLE ASSISTING THE STUDY

LIST OF PEOPLE ASSISTING THE STUDY

PROVINCIAL/FEDERAL

Mr. Albert Arklie, Newfoundland Department of Works, Services & Transportation, St. Johns, Newfoundland.

Mr. G. Bell, Ministry of Transportation, Kingston, Ontario.

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Ms. Trish Bolten, Ontario Ministry of Environment & Energy, Toronto, Ontario.

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Mr. Keith Foster, Newfoundland Department of Work, Services and Transportation, St. John's Newfoundland.

Mr. B. Fulcher, Yukon Department of Community & Transportation Services.

Mr. James Gavin, Nova Scotia Department of Transportation and Communications, Halifax, Nova Scotia.

Mr. Claude Girard, Chef du service de l'environnement, Ministère des transports du Québec.

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Pavements Standing Technical Committee Discussions, Transportation Association of Canada.

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Mr. Joseph Romeo, Manitoba Dept. of Highways & Transportation, Winnipeg.

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Mr. E. D'Antoni, City of Calgary, Alberta.

Mr. D. Gibson, City of Winnipeg, Manitoba.

Mr. Don Grasley, City of Regina, Regina, Saskatchewan.

Mr. Tony Espisito, City of Winnipeg, Manitoba.

Mr. Jack Jensen, City of Prince Albert, B.C.

Mr. V. Jeancart, City of Prince Albert, B.C.

Mr. Bob Kinash, City of Weyburn,

Mr. Max Miner, City of Ottawa, Ontario.

M. Gerald Pelletier, Ville de Montreal, Montreal, Quebec.

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Mr. Rick Bell, Bell & MacKenzie, Hamilton, Ontario.

Mr. Stephen Black, Diamond Construction Limited, Frederickton, New Brunswick.

Boliger Stephan Associates, Ontario.

Mr. David Brown, Brampton Brick, Brampton, Ontario.

Mr. Al Bruins, Flow-Kleen Technology Limited, Waterdown, Ontario.

Mr. Reg Bulyea, IGL Canada Ltd., Edmonton, Alberta. (trenchless pipelines and pipeline repair)

Mr. Michael Card, Canadian Eagle Recyclers Inc., Brampton, Ontario.

Mr. Ed Cieciela, Grow Rich.

Mr. Ralph Clayton, Philip Environmental, Hamilton, Ontario.

Mr. Brad Cobbledick, Brampton Brick, Brampton, Ontario.

Dr. Paul Cooper - University of Toronto, Faculty of Forestry.

Mr. A. Drexler, Drexler Construction Co., Rockwood, Ontario.

Mr. Kevin Dwyer, G. M. Sernas & Associates Limited, Whitby, Ontario.

Dr. John Emery, John Emery Geotechnical Engineering Ltd., Etobicoke, (Toronto), Ontario.

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Mr. K. Gardner, Vortex Energy Systems, Vancouver, B.C.

General Motors of Canada, Oshawa, Ontario.

Mr. Fred Helmer, Domtar, Cornwall, Ontario.

Mr. Dave Hogan, Consumers Glass, Toronto, Ontario.

Mr. Peter Irwin, Canada Metals, Ontario.

Mr. John Jory, Greatario Industrial Storage Systems Ltd., Guelph, Ontario.

Mr. Jim Labossiere, Clifton Associates Ltd., Battlefords, Saskatchewan.

M. Francois Lacroix, Canadian Portland Cement Association, Montreal, Quebec.

Mr. Sergio Legati, Tonnoli Canada, Mississauga.

Mr. Erwin Leonov, W.C.I. - Wood Conversion Inc., Brampton, Ontario.

Mr. Gordon Mattson, Cominco, British Columbia.

Ms. M. Marquardt, Ontario Painting Contractors' Association.

Mr. Jim McKee, Domtar, Trenton, Ontario.

M. Stéphan Montambeault, Association des constructeurs de routes et grands travaux du Québec, Quebec City.

Morbark Industries Inc.

Ontario Waste Exchange (ORTECH INTERNATIONAL), Mississauga, Ontario

Mr. Gordon Parchewsky, North American Construction Group, Edmonton, Alberta.

Mr. George Parthimos, Unamin , Toronto, Ontario.

Mr. John Pelletier, Westman Salvage, Manitoba.

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Mr. Gerry Pyre, Innovator Manufacturing Inc., London, Ontario.

Mr. Jim Regular, Weston Road Wholesale Lumber, Toronto, Ontario.

Mr. K. Robertson, IKO Industries Ltd., Brampton, Ontario

Mr. B. Rosen, Bio-Energy Systems Inc., London, Ontario.

Dr. Byron Ruth, University of Florida, Gainesville, Florida.

Mr. Tim Seigmiller, Seigmiller Construction, Ontario.

Mr. Bob Serne, Canadian Portland Cement Association, Edmonton, Alberta.

Mr. Don Shaw & Mr. Ron Baskott, Bar Min Inc, Waterdown, Ontario.

Mr. Sittler, Sittler Excavating Ltd., Elmira, Ontario.

Mr. Keith Smith, Keith Smith Contracting Ltd., Orillia, Ontario.

Mr. Mike Stephen, Peerless Metal Powders & Abrasive, Detroit Michigan.

Mr. John Storer-Folt, Canada Brick, Streetsville, Ontario.

Mr. Harry Sturm, Canadian Portland Cement Association, Toronto, Ontario.

Mr. Don Thiessen, Friendly Fuels, Calgary, Alberta.

Mr. Rick Thompson, Guelph Utility Pole, Guelph, Ontario.

Mr. John Williams, VTC, Sarnia, Ontario.

Mr. Rudi Wasmeier, Newfoundland/Labrador Road Builders Assoc.

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APPENDIX E

TABLE OF MATERIALS, SOURCES AND PREVIOUSLY REPORTED MANAGEMENT OPTIONS

TABLE OF MATERIALS, SOURCES AND PREVIOUSLY REPORTED MANAGEMENT PRACTICES

MATERIAL	SOURCE	MANAGEMENT PRACTICE
Asphalt	- Asphalt pavement full depth reconstruction - Surface milling of asphalt road surfaces	- stockpile until recycled into asphalt pavement - use as granular material in road construction - use as fill, slope flattening, erosion control and for construction of parking lots - disposal at certified landfill sites
Concrete	- Roads, structures, curbs, sidewalks, foundations	- use in engineered fill, in shoreline erosion protection and as granular material in roadbeds - use as lakefill, as gabion fill - use crushed as sewer backfill and in asphalt production - disposal at certified landfill or specified fill - burial
Granular Material	- Road reconstruction	- use anywhere the original product was used - use as roadbed material, inert fill, backfill, slope flattening - disposal at an inert fill or certified landfill site
Earth Material/ Topsoil	- Site preparation	- use anywhere the original material was used - use as fill or top dressing for slopes before seeding - stockpiling - use as cover at landfills, in slope flattening, as fill in washout areas, in berm construction and as lakefill - spread on farmer's fields - disposal at mono-fill site - sell as topsoil
Steel Products	- Culverts, guard rails, sign posts, noise barriers, railings, light standards, reinforcing steel, guard post cabling	- recycle at scrap metal dealer - reuse - disposal at certified landfill sites - make it property of contractor
Natural Wood	- Clearing and Grubbing	<u>Above Ground Portion</u> - sell to sawmills, pulp mills or particle board manufacturers - sell or give away as firewood - stockpile or compost - chip or shred for mulch or animal bedding - place into pushouts and cover - bury or burn - use as boiler fuel, soil amendment or as bulking agent in sludge composting <u>Stumps</u> - cut flush with ground and leave in place - disposal at certified landfills - crush or chip and use as fuel, bulking agents, mulch, compost, soil amendment or fill - burn - use as stump fences - use to create fish habitat - use in river bank erosion control

MATERIAL	SOURCE	MANAGEMENT PRACTICE
Swamp Material	- Construction in swamp or marsh areas	- place in pushouts and side-casting - use in flattening of side slopes, as cover at landfill sites and in berm construction - spread on farmer's field - disposal as fill or in certified landfill site - mix with topsoil and sell or give away
Rock	- Rough Grading, Rock Cuts	- use as inert or common fill, rip rap, lakefill, landscaping material and embankment material - crush and use as granular material
Manufact. Wood	- Construction or Maintenance of Structures, Signs, Utilities, Guard Rails Posts	<u>Untreated Wood</u> - reuse for same purpose - recycle into other product (e.g. cedar shakes, guard rail posts) - deposit at landfill sites - chip for mulch, landscaping material, fuel, bulking agents or compost - store - bury - burn <u>Treated Wood</u> - disposal at certified landfill - reuse for same purpose - recycle to new products (e.g. sign braces)
Abrasive Blasting Media	- Structural steel cleaning; concrete surface rehabilitation	- clean and reuse - disposal at certified landfill - storage - use as fill - clean and use in golf course sand traps - recycle into asphalt concrete
Catchbasin Material	- Maintenance of Storm Sewers and Catchbasins	<u>Liquid</u> - decant or drain to sewers - deposit at specially designated drying beds or lagoons - deposit on roadway to drain to the sewers <u>Solid</u> - disposal at registered landfill site or stored for eventual use as fill - disposal at special fill sites - leave it in the sewer system - sieve and dispose as fill (sediments) and waste (large items: wood, litter, etc.)
Road Sweepings	- Road Maintenance	<u>Rural Roads</u> - swept to the road shoulder <u>Urban Roads</u> - deposit at certified landfill sites - use as fill or shoulder material - stockpile - recycle for winter road applications

APPENDIX F

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