WASTE MATERIALS IN HIGHWAY CONSTRUCTION

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Highway Division
Iowa Department of Transportation

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in
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by

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INTRODUCTION

Recycling of materials is an important part of Iowa DOT construction practices. It reduces the use of natural resources and eliminates large piles of pavement rubble. Recycling of asphalt concrete in Iowa began with a secondary project in 1975. The thrust of the early research was to produce high quality hot mix asphalt pavement while meeting air quality controls. Iowa was one of the first states (if not the first) to meet all air quality requirements during a hot mix asphalt recycling project. By 1977, after three projects, recycling of hot mix asphalt concrete was established as a viable method of reconstruction, producing quality pavement without air pollution problems. Today, almost all Iowa asphalt concrete pavement rubble is recycled into new asphalt concrete pavement.

Iowa recycling of portland cement concrete pavement began in 1976. By 1978 the Iowa DOT had recycled the concrete rubble on three different projects and documented a cost savings, a conservation of natural resources and an elimination of a tremendous quantity of pavement rubble to be disposed of in landfills. Much of the early portland cement concrete pavement rubble was crushed, sized and reused in new portland cement concrete pavement. Today almost all pcc pavement rubble is recycled with much being used as permeable aggregate base beneath new portland cement concrete pavement. Beginning with the 1976 project and continuing to current projects, the reinforcing steel is removed and shipped to salvage companies for recycling.

The Iowa DOT is committed to conservation of natural resources, progressive waste management (1, 2) and cost effective recycling of waste products. The Iowa DOT has been following waste management efforts in other Midwestern states (3, 4, 5, 6). In recent years, highway designs have been improved in an effort to increase the design life from 20 to 30 years, thereby conserving natural resources. Use of waste products in highway construction and maintenance is evaluated by field or laboratory testing. If the testing indicates that the incorporation of the waste product does not reduce the life of the product, it is considered for use. If the use of a waste product reduces the life and/or quality of a product, it would require rehabilitation or reconstruction at a shorter life. This would require a greater use of natural resources for the more frequent rehabilitation or reconstruction. It would, therefore, be environmentally detrimental.

The demand for highway construction and maintenance continues to exceed the funds available. If the use of a waste product significantly increases the cost of construction, it also significantly reduces the highway construction funds and reduces the number of miles of highway that can be rehabilitated or reconstructed. This would be counter productive to the goal of providing the State of Iowa with the best possible highway system. In the cases where use of a waste product significantly increases highway construction costs, it may be more cost effective to seek other ways to use the waste product.

There is substantial variations in the characteristics of many waste materials over a given time period. The primary objective of power plants is to produce electricity and the primary objective of industrial plants is to produce parts or equipment. The waste materials generated from these operations are of secondary interest. The main concern is how to dispose of the waste. This poses a serious problem to the use of the waste material because there is, in many cases, little if any quality control to generate a relatively uniform waste material. Most highway uses require a uniform material with consistent characteristics.

FLY ASH

Fly ash is a waste product (now considered a by-product) of coal burning electrical generating power plants (7). With air quality control regulations the power plants were required to reduce the dust pollutants expelled from the smoke stacks. This was accomplished by the use of electrostatic precipitators that collect very fine round fly ash particles. There are many power plants throughout Iowa that collect fly ash. There are two types of fly ash. Type F ash is a by-product of burning eastern bituminous coals. Type C ash is a by-product of burning Wyoming coals with a higher calcium content. The coal source and operation of a power plant are major factors in the chemical content of fly ash. For some highway uses, the chemical content is very important to the performance.

Iowa production of fly ash varies depending on the demand for electricity which is highly dependent on the use of air conditioning. Current annual fly ash production is approximately 700,000 tons (approximately 350,000 tons of Class C ash).

Approximately 25% of the Iowa ash is used in the construction industry primarily as a replacement for portland cement in portland cement concrete. The lack of fly ash storage facilities hinders its use as the demand for quality fly ash can exceed the supply during the construction season.

Much research on fly ash in portland cement concrete has been funded by the Iowa DOT. In general, this research has shown that uniform high quality fly ash used in portland cement concrete produces high quality durable concrete.

The Iowa DOT specifications allow the use of fly ash meeting Iowa DOT specifications in most portland cement concrete. The Iowa DOT will continue to use uniform, high quality fly ash in portland cement concrete. Fly ash will be considered for embankments based on the most economical design and construction.

KILN DUST

Kiln dust is a by-product of the production of portland cement. Most cement plants produce kiln dust. Some use raw materials with a more favorable chemical makeup, thus eliminating kiln dust as a waste product. Iowa portland cement plants that produce kiln dust must meet environmental requirements for storage and/or disposal of kiln dust.

The portland cement plants that do produce kiln dust dispose of it through a marketing company that is the only purchasing source in Iowa. This company markets an estimated 3,750 tons per month, to municipalities for sewage sludge neutralization.

Some current uses of kiln dust are as an ag-lime substitute, a sewage sludge neutralization agent and as a soil stabilization agent.

Kiln dust is the result of an alkali reduction process during the production of portland cement. The dust is high in alkali and it would be detrimental to the durability of portland cement concrete. Kiln dust is a lime based cementaceous material and could be used for soil stabilization. Some secondary road departments use kiln dust for stabilization. In recent years, the Iowa DOT has had very few projects that included chemical soil stabilization.

GLASS

There are several regional sources of crushed glass in Iowa. These facilities collect, sort by color and crush beverage bottles, food jars and other glass items. Presently, all glass crushed in Iowa is transported out-of-state to be recycled into new glass products.

Crushed glass production figures vary widely among the processors surveyed. Estimated outputs range from 1,000 to 18,000 tons per year and processors indicate that production is seasonal.

A 1976 experimental project at the Iowa State Fairgrounds used crushed glass in a surface layer of asphalt concrete. The surface had some exposed sharp edges and was overlaid with asphalt concrete containing no crushed glass to cover the objectionable sharp edges. At the time of the experimental project, it was found that it cost $35 per ton of crushed glass to incorporate it into the asphalt concrete mix as opposed to $12 per ton to dispose of the same material.

The Iowa DOT Standard Specifications allow crushed glass as an aggregate in asphalt concrete, for layers other than the surface. Crushed glass is susceptible to stripping, so the addition of lime is required by the specification. Apparently it is more cost effective to use crushed glass in making new glass products than to use it as an aggregate in asphalt concrete as no glass has been used in asphalt concrete in recent years.

TIRES

Disposal of the approximately 3 million tires discarded annually in Iowa poses a serious problem for landfill operations. The worn out tire disposal may be compounded by the fact that there are three major recapping plants in Iowa that receive old tires.

Current uses dispose of only a small percentage of the discarded tires. There is a Waste Tire Abatement Study being conducted by the Iowa Department of Natural Resources to identify environmentally acceptable ways to dispose of waste tires.

Many Midwestern states have constructed experimental projects using recycled rubber in asphalt concrete in recent years. Asphalt rubber binder projects in 1990 in Kansas and Nebraska showed an asphalt mixture cost twice that of conventional asphalt concrete. A 1990 Federal Highway Administration report (8) states that "there is no conclusive evidence that asphalt-rubber systems are generally superior to conventional asphalt cement materials". The Minnesota DOT reports that the performance of recycled rubber in asphalt concrete (5, 9) and the performance of an asphalt rubber binder in asphalt concrete is similar to that of conventional asphalt pavement with no significant benefit that would warrant further use considering the substantial additional cost. Some states have reported improved performance of pavement when waste tires are used, although the long term cost effectiveness is questionable.

In 1985, the Iowa DOT constructed two experimental sections of asphalt concrete containing recycled tire chips. This was a proprietary product marketed with the claim that winter maintenance would be improved because it would flex enough to improve ice removal. Iowa DOT maintenance operations have not identified any improved winter maintenance or any significant improvement in performance. The initial cost of the asphalt concrete containing the rubber chips was approximately 70% more than conventional asphalt concrete.

Further evaluation of recycled rubber in asphalt concrete is planned for 1991 in research to be incorporated in a US 61 Muscatine County project. The research will include experimental sections with asphalt rubber binder using finely ground rubber. Experimental sections of asphalt concrete containing 1/4" to 1/16" rubber chips will also be included in the Muscatine research.

The Iowa DOT will evaluate the use of recycled rubber in asphalt concrete on the Muscatine research to determine if improved performance would justify the substantial increase in cost. If the use of asphalt-rubber is determined to be cost-effective, the Iowa DOT will use recycled rubber on other projects.

STEEL SLAG

Steel slag is a by-product of the steel producing industry. It is a very hard, porous and durable material that fractures into sharp angular pieces when crushed. Raw materials are melted in a furnace and the impurities, or slag, separate from the melt. The slag floats on top of the molten material and is drawn off. There are plants in Iowa that produce steel slag.

Steel slag can be crushed and used as an aggregate in asphalt concrete. It exhibits excellent skid resistance when used in flexible pavement surface layer mixes. It has some expansive properties because it is rich in lime, so it may be unsuitable for use in rigid portland cement concrete mixes. Its use as an aggregate is limited to areas where it is available.

The Iowa DOT allows the use of steel slag in asphalt concrete pavements.

IRON SLAG

Iron slag is a by-product of foundry casting. It is a very hard, porous and durable material that fractures into sharp angular pieces when crushed. There are several large foundries and many smaller ones located across the state producing slag from their operations. Iron slag is often part of the foundry sand waste stream and is rich in silica, alumina and lime.

Some foundries are investigating the retrieval of iron from the waste stream to be recycled in their casting processes. Finding cost effective uses for iron slag is hampered due to its inclusion in the foundry sand waste stream which may contain undesirable impurities. This practice may also yield a very nonuniform waste product.

Very little information is available to the Iowa DOT on the physical and chemical characteristics of iron slag. This information is necessary before the Iowa DOT could ascertain if there were cost effective uses.

BOILER SLAG

Boiler slag is the residue from the bottom of coal-fired boilers of electrical generating power plants or residue from industrial boilers. It is a hard, brittle, highly porous material that can be crushed into a sand-like filler. There are many electrical generating plants and industries in Iowa that are potential sources of boiler slag.

In some states, boiler slag has been crushed into sand sized particles and used where manufactured sand would be used. Minnesota has used it as an alternative for road deicing sand

and Illinois has used it in asphalt sealcoating. Some municipalities that have boiler slag supplies nearby use it on local roads and park trails.

Boiler slag has been used for ice control aggregate in Iowa in the past. The Iowa DOT has tested some boiler slags for use as ice control aggregate in the 1980's. Some problems with this use may be high sulphate content and insufficient strength to resist pulverization under traffic.

FOUNDRY SAND

There are many foundries manufacturing metallic castings in Iowa that produce waste foundry sand. A typical Iowa foundry (10) generates approximately 7,000 tons of waste foundry sand per year.

The Wisconsin DOT has constructed a foundry sand embankment. Their state environmental regulations are requiring continual leachate monitoring. Wisconsin personnel have stated that an embankment without requiring foundry sand would have been less expensive. Michigan DOT personnel relate that leachate monitoring of foundry sand embankments is required.

There are three major problems with use of foundry sand in highway construction. First, it is a relatively fine sand that will not meet gradation requirements for many uses. Second, the production is constant and the necessary volume is normally not readily available at a given time at a given location to construct an embankment. Third, leachate monitoring and/or encapsulation may be required because of concerns that heavy metal or other contaminates may be present in the foundry sand.

Because of the potential additional costs involved, the Iowa DOT has been unable to identify a cost-effective use for foundry sand.

PLASTICS

There are several types of plastics in Iowa's waste stream. Most common are low density and high density polyethylene (LDPE and HDPE), polyvinyl chloride (PVC), polypropylene (PP), polystyrene (PS) and polyethylene terephthalate (PET). This wide array of plastics is used in products ranging from foam coffee cups and hamburger containers to dish soap and laundry detergent bottles. Plastics are used in industry to manufacture tubing and conduit, automotive and machine parts and some household items.

Plastics make up 6% to 9% by weight of Iowa's solid waste stream. Estimated quantities of waste plastics range from 130,000 to 200,000 tons per year, and the percentage of plastics in the waste stream is increasing every year.

Today, only about 1% of waste plastics are recycled. The amount is low due to several factors including an inadequate or nonexistent collection network, wide array of types of plastics, quality of reprocessed material versus quality of virgin material and lack of recycling facilities. All recycled plastics are mixed with virgin materials and made into new plastic products.

The Iowa DOT has evaluated the performance of recycled plastic for a rest area picnic table. The Michigan DOT has proposed a study of the cost effectiveness and suitability of recycled plastic in guardrail posts (11). Quite often, the problem with recycled plastic products is that they are not cost competitive with the material they are proposed to replace.

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APPENDIX
Iowa DOT Waste Material Research

Asphalt Concrete Recycling

1. HR-176, "Recycled Asphalt Pavement"
2. HR-188, "Evaluation of Air Pollution Control Devices for Asphalt Pavement Recycling Operations"
3. HR-1008, "Evaluation of Recycled Asphalt Concrete Pavements"
4. HR-1011, "Recycling of Asphalt Concrete From I-80 in Cass County"
5. MLR-79-3, "Penetration Characteristics of Asphalt in a Recycled Mix"
6. MLR-85-4, "The Effect of Rejuvenators on Asphalt Cement"
7. MLR-85-7, "Asphalt Mixes From Broken P.C. Pavements"
8. MLR-88-3, "A Comparative Study of the Frictional Properties of Recycled vs Virgin Aggregate Asphalt Pavements"

Portland Cement Concrete Recycling

1. HR-506, "Recycled Portland Cement Concrete Pavements"
2. MLR-77-3, "P.C.C. Utilizing Recycled Pavement"
3. MLR-77-4, "Iowa DOT's Experience With Recycling P.C. Pavement and A.C. Pavement"

Fly Ash Recycling

1. HR-68, "Soil Stabilization in Experimental Road in Webster County"

2. HR-194, "Mission-Oriented Dust Control and Surface Improvement Processes for Unpaved Roads"

3. HR-200, "Fly Ash in PC Pavement - Monona County"

4. HR-201, "Fly Ash in PC Pavement - Woodbury County"

5. HR-206, "Cement Produced From Fly Ash and Lime"

6. HR-225, "Characterization of Fly Ash for Use in Concrete"

7. HR-259, "Low Cost Fly Ash-Sand Stabilized Roadway"

8. HR-260, "Optimization of Soil Stabilization With Type C Fly Ash"

9. HR-286, "Development of a Rational Characterization Method for Iowa Fly Ash"

10. HR-294, "Ammonium Phosphate/Fly Ash Road Base Construction"

11. HR-327, "Evaluation of Chemical Durability of Iowa Fly Ash Concretes"

12. MLR-81-2, "Report on Fly Ash Variability"

13. MLR-81-3, "Report on Fly Ash as a Soil Additive"

14. MLR-81-6, "Fly Ash Concrete Compressive Strength and Freeze-Thaw Durability"

15. MLR-84-2, "An Evaluation of Fly Ash in Bridge Deck Concrete"

16. MLR-84-4, "Durability of Concrete With Additives"

17. MLR-84-6, "Strength-Temperature Study of Fly Ash in Concrete"

18. MLR-84-7, "Evaluation of Fly Ash in Water Reduced Paving Mixtures"

19. MLR-85-1, "Lime-Fly Ash Subbase Stabilization"

20. MLR-85-2, "Fly Ash Effects on Alkali-Aggregate Reactivity"

21. MLR-85-3, "Fly Ash in PCC Bases Mixes"

22. MLR-85-8, "Durability of Fly Ash Concrete With Class II Durability Aggregate"

23. MLR-86-1, "Fly Ash in PCC Base"

24. MLR-87-3, "Field Evaluation of Class A Subbase With Fly Ash"

25. MLR-88-7, "Fly Ash Effect on Alkali-Aggregate Reactivity"

26. MLR-89-4, "Evaluation of a Precast/Prestressed Mix Design Using Fly Ash for Prestressed Concrete Operations, Iowa Falls Plant"

27. MLR-89-9, "Durability of Durham Mine Stone in Fly Ash P.C. Concrete"

28. MLR-89-10, "Evaluation of Class V Aggregate in Fly Ash Concrete Using the Wet/Dry Method"

29. MLR-90-1, "Evaluation of a Test Method to Measure the Response of Aggregate Cement-Fly Ash Combination to Deicing Chemicals"

Rubber Recycling

1. HR-330, "Evaluation of Recycled Rubber in Asphalt Concrete"

2. MLR-89-15, "Laboratory Evaluation of Asphalt-Rubber in Asphalt Paving Mixture"