The Use of Waste & Recycled Materials in Highway Construction

Currently, while there is significant use of waste and recycled materials, each application must be thoroughly investigated to determine the optimal beneficial use and any negative impacts.

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The amount of municipal solid waste generated in the Commonwealth of Massachusetts continues to grow and is a major concern for the state. In the 1994 Massachusetts Solid Waste Master Plan, the Massachusetts Executive Office of Environmental Affairs and Massachusetts Department of Environmental Protection (DEP) reaffirmed the goal of recycling and composting 46 percent of municipal solid waste generated within the commonwealth by the year 2000. Emphasis is being given to recycling because:

- It conserves natural resources and energy;
- It helps protect water and air quality by reducing the amount of waste that is landfilled or burned; and,
- It helps drive economic development by stimulating manufacturing industries capable of using the recyclable materials as raw material.

A necessary component of achieving that recycling goal is to develop sustainable markets for waste and recycled materials that are diverted from traditional disposal methods such as landfilling. The transportation industry has been identified as such a market. While transportation agencies — such as the Massachusetts Highway Department (MHD) — have been using waste and recycled materials (WRMs) in highway construction, many believe that there is significant potential for much greater use. However, since WRMs are not common construction materials, there are concerns about their suitability and practicability for use in transportation applications. Specific issues of concern include physical and chemical properties, constructability, quality control, field performance, long-term physical and chemical stability, and environmental impact.

Classification of Waste & Recycled Materials

The United States generates approximately

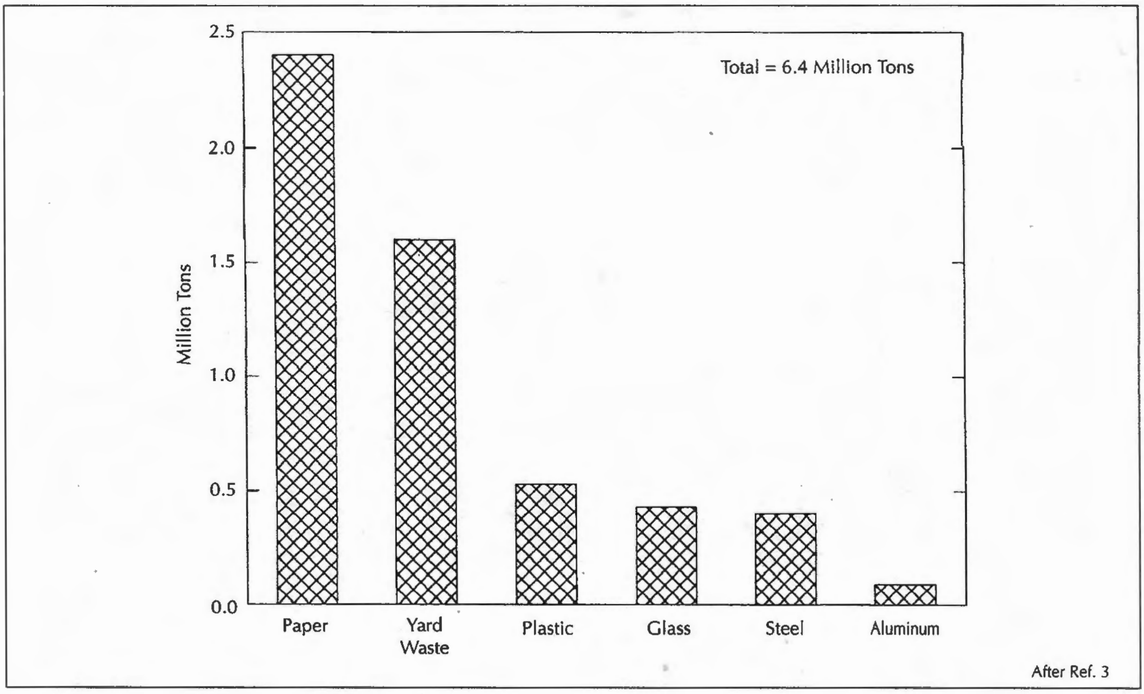

FIGURE 1. Estimated 1992 distribution of municipal solid waste in Massachusetts by weight.

4,500 million tons of waste per year. This waste can be classified into four major groups based on their generation source:[1]

- Domestic (200 million tons);
- Industrial (400 million tons);
- Mineral (1,800 million tons); and,
- Agricultural (2,100 million tons).

Domestic Waste. Domestic waste is composed mostly of household and commercial trash, of which approximately 62 percent is landfilled, 22 percent is recycled and 16 percent is burned.[2] Many components of domestic waste can be recovered and used in manufacturing new products — with paper, glass and plastics being the most common. Leaf and yard waste make up a significant portion of the waste stream, yet its disposal in landfills has been banned in many states in an effort to encourage the processing of this waste material into compost. In many locations, wastewater sludge (or biosolid waste) is also diverted from landfills for processing into compost.

Other sources of domestic waste — such as scrap tires — are more problematic. Approximately 235 million tires are discarded annually, of which approximately 80 percent are landfilled and 10 percent are burned for fuel. However, in 22 states tires are not allowed in landfills, which has led to the stockpiling of approximately 2 to 3 billion tons of scrap tires across the country. Stockpiled scrap tires pose health and environmental hazards, since they are breeding grounds for mosquitoes and various rodents and can often burn uncontrollably.[1]

In 1992, Massachusetts generated a total of 6.4 million tons of municipal solid waste (see Figure 1), of which 47 percent was combusted, 28 percent was composted or recycled, 19 percent was landfilled and 6 percent was exported. As of 1992, Massachusetts had 122 active landfills and nine operating combustion facilities that processed 3 million tons of municipal solid waste.[3] Massachusetts also generates approximately 6 million scrap tires per year, with 5 to 10 million scrap tires already stockpiled as of 1993.[4]

Industrial Waste. Various industrial processes — such as the production of metals and coal and the burning of coal for energy — produce large amounts of waste. Some of the more common waste types are coal combustion by-products, blast furnace slag from iron production, steel slag, recycled asphalt and concrete, foundry wastes and roofing shingle waste. Approximately 100 million tons of recycled paving materials and 70 million tons of coal ash are generated each year, with approximately 50 percent and 25 percent, respectively, of these materials being reused.[1] Blast furnace slag and steel slag are typically recovered and sold in areas where iron and steel are produced. Waste foundry sand consists of natural sand that is used as molds for metallic castings, while roofing shingle waste consists of scrap material left over from the production of shingles and from construction and demolition.

Mineral Wastes. Mineral wastes are produced from mining processes, including waste rock from surface mining operations, mill tailings from ore concentration processes, quarry waste from stone washing and screening at quarries, and coal refuse from the cleaning of coal. The largest fraction of these wastes is waste rock, with approximately 1,000 million tons generated per year.[1] Mineral wastes are usually used as stone fill for embankments, riprap and subbase. However, their use is generally limited to the area of their production because of prohibitive transportation costs to ship them elsewhere.

Agricultural Waste. Crop wastes, animal manure, lumber and wood wastes, and other organic wastes make up the largest fraction of this waste stream. Of these wastes, the largest component generated is animal manure (at approximately 1,600 million tons per year).[1] Although agricultural wastes have limited application in highway construction, animal manure and crop wastes can be used as a soil amendment (*i.e.*, compost) for roadsides. Wood waste can be used for mulch and has been used experimentally as lightweight embankment fill. As is the case for mineral wastes, transportation costs are the major barrier to increased use of these waste materials.

Recycling Waste Materials

Recycling is one of the primary ways of reducing the volume of waste that needs to be disposed. It has been strongly encouraged by federal, state and local governments because it is believed to conserve natural resources and help protect the environment through reduced landfilling and incineration of waste. While there is some controversy regarding the cost effectiveness of these benefits,[5,6] it is clear that landfill area is becoming scarce. During the coming decade, many landfills will be closed due to a lack of the proper liner systems that are required by recently promulgated federal and state regulations; and it has become increasingly difficult to site new landfills. These problems have created the need for a plan to reduce the amount of material landfilled per year.

For example, the 1994 Massachusetts Solid Waste Master Plan called for the recycling and composting of solid waste to reach 46 percent, combustion to increase to no more than 50 percent, and landfilling to diminish from 42 percent to 4 percent by the year 2000.[3] These types of waste disposal goals are being met with help from legislative acts requiring recycling and the use of recycled materials, technical and financial assistance for recycling, and voluntary incentives for businesses to use recycled products. Out of the 351 municipalities in Massachusetts, 341 have a recycling program,[3] including 251 communities that compost their leaves.[7] While significant achievements have been made to reach federal and state recycling goals, attaining the future goals will require a greater effort, including the development and expansion of markets such as highway construction using waste materials.

Federal & Massachusetts Regulations

As indicated above, state and federal regulations have played a key role in the recycling of waste materials and their potential use in highway construction. Although there has been a general increase in recent years in public awareness and concern over the impact of waste disposal on the environment, most waste reduction and recycling programs in the private and public sectors historically have been reactive rather than proactive — that is, individuals and businesses are often recycling waste materials because federal and state regulations require or strongly encourage them to do so. At the federal level, the 1976 Resource Conservation and Recovery Act and the 1984 Hazardous and Solid Waste Amendments pro-

TABLE 1.
Current & Potential Uses for Waste & Recycled Materials in Highway Construction

Waste & Recycled Material	Current & Potential Applications
Recycled Asphalt Cement Concrete	Asphalt cement concrete aggregate; Portland cement concrete aggregate; aggregate for base and subbase; embankment fill
Recycled Portland Cement Concrete	Asphalt cement concrete aggregate; Portland cement concrete aggregate; aggregate for base and subbase; embankment fill; rip-rap
Coal Combustion Fly Ash	Asphalt cement concrete; Portland cement concrete; roller compacted concrete; flowable fill; road base stabilization, embankment fill
Coal Combustion Bottom Ash	Aggregate for base and subbase; lightweight Portland cement concrete aggregate; sandblasting; embankment fill; deicer
Scrap Tires (Crumb Rubber)	Asphalt cement binder; crack sealant; stress absorbing membrane interlayer; railroad crossing mats; Portland cement concrete aggregate
Scrap Tires (Shredded)	Base course insulator; embankment fill; retaining wall backfill; blasting mats; noise walls; retaining wall blocks
Plastics	Asphalt cement concrete aggregate; Portland cement concrete aggregate; drain pipes; delineator posts; cones; fences; barrels; noise walls; miscellaneous construction items; guardrail offset blocks; speed bumps; sign blanks; car stops; plastic lumber; geotextiles
Glass	Asphalt cement concrete aggregate; Portland cement concrete aggregate; base course aggregate; drainage aggregate; embankment fill; traffic paint
Compost	Topsoil upgrading; turf establishment; landscaping; weed control; erosion control; siltation control
Blast Furnace Slag	Asphalt cement concrete aggregate; Portland cement concrete aggregate; base course aggregate; deicer; embankment fill
Steel Slag	Asphalt cement concrete aggregate; Portland cement concrete aggregate; base course aggregate; friction aggregate; blasting grit; embankment fill
Foundry Sand	Asphalt cement concrete aggregate; Portland cement concrete aggregate; flowable fill; deicer; embankment fill
Shingles	Asphalt cement concrete; cold patch

moted waste reduction through reuse and recycling. The 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) originally required specific quantities of crumb rubber in asphalt but has since been rescinded in the face of significant opposition from state departments of transportation (DOTs). The federal Environmental Protection Agency's (EPA) *Comprehensive Guideline for Procurement of Products Containing Recovered Materials* presents specific guidelines for the purchase and/or reuse of many materials that can be used in highway construction — such as fly ash, blast furnace slag, plastic products and compost. These guidelines must be used by federal procuring agencies and those governing bodies that receive federal funds when spending more than ten thousand dollars per year on a single item. In Massachusetts, the most significant legislative item is Section 71 of the 1994 Transportation Bond Bill that specifically requires the MHD to report to the governor and the legislature on its past, current and future use of waste and recycled materials.

Applications for Waste & Recycled Materials in Highway Construction

Table 1 summarizes some of the many current and potential applications for WRMs in highway construction. While some of these applications have long been common practice, others are still considered experimental. In fact, in some cases, it may eventually be shown that some of these applications are inappropriate.

Recycled Asphalt Cement Concrete. Recycled asphalt cement concrete or pavement (RAP) consists of old asphalt road surfaces that are milled away prior to repaving operations. Significant quantities of RAP are produced each year, and its reuse in highway construction has been common for many years. It is typically recycled into new asphalt pavement (hot in-place recycling) or grinded into a homogeneous mix and used in place as a base course (cold in-place recycling). When reused as an aggregate for new asphalt cement concrete, typical percentages used range from 15 to 50 percent (by weight). In addition to these quantity limits, the quality of the RAP source is very important (*i.e.*, whether from better quality mix design interstate highway versus lower quality mix design secondary roads). Typically, RAP is tested for such properties as gradation, asphalt content and viscosity, and, in some cases, additives may be used to bring the RAP to within specifications.

Recycled Portland Cement Concrete. Recycled Portland cement concrete (RPCC) from pavement and demolition debris is often used in highway construction for several applications. RPCC that has been removed from sites and processed (to remove reinforcing steel and to break it down into a suitable gradation) can be used as an aggregate source for Portland cement concrete, asphalt cement concrete, base and subbase (up to 100 percent) in new road construction, embankment fill and rip-rap. It is not recommended for use in Portland cement concrete that will be used in structural applications (for example, bridge decks, abutments, etc.) because of concerns about the presence of deleterious materials and reduced compressive strength.[8]

For other applications, the processed aggregate typically must meet the same specifications (for example, gradation, Los Angeles abrasion, etc.) as natural aggregates for the intended use. In some of the more densely populated regions of the country, RPCC is the major source of base course material because of depleted sources of natural aggregates and high hauling costs. For example, in the New York metropolitan area, nearly all material placed as subbase for state highways consists of RPCC.[9] Existing Portland cement concrete roads can also be fractured or crushed in place and compacted to serve as a base material for new asphalt cement concrete. This practice provides a particular benefit because it reduces construction costs for the removal and transportation of the waste concrete.

Coal Combustion Fly Ash. Fly ash is the finer-grained waste material that is recovered from flue gases during coal combustion. It is a pozzolon; therefore, when mixed with calcium and water, it will develop cementitious compounds. As a result, fly ash has long been used as a beneficial additive to Portland cement concrete as a substitute for Portland cement (typically 15 to 30 percent by weight). In fact, the American Society for Testing and Materials (ASTM) has developed standards for the use of fly ash in concrete. Fly ash is also a common ingredient in controlled density fill (*i.e.*, flowable fill) in quantities ranging from approximately 10 to 100 percent (by weight) and is also used in roller-compacted concrete and for soil stabilization.

Scrap Tires. The use of scrap tires in highway construction is one of the most controversial uses of waste and recycled materials. Ground-up scrap tires with the steel belt removed (known as crumb rubber) can be used as an aggregate in new asphalt (dry method) or, when heated, as a binder in new asphalt (wet method). It has been used successfully for over fifteen years in certain parts of the country (for example, in Arizona) and is reported to result in longer pavement life due to decreased thermal cracking, potholing, deformation and reflective cracking. It can also result in reduced driving noise due to the resilient nature of the rubberized asphalt.

However, critics of the use of crumb rubber in asphalt claim that its use involves a substantial increase in cost over conventional pavement mixes and can cause unacceptable air emissions during mixing and placement. ISTEA stipulated minimum percentages of asphalt containing recycled rubber that can be used on all federally funded highway construction. States that failed to satisfy these minimum requirements would have had a percentage of their federal highway apportionments withheld. Many state DOTs strongly opposed these requirements due to technical and economic concerns, and, as a result, Congress repealed this provision in the 1995 National Highway System Act. Some states have been successfully experimenting with lower rubber content and smaller rubber particles in crumb rubber modified asphalt than that originally mandated in ISTEA. For example, the Florida DOT has been using only 12 percent rubber (maximum nominal 40-mesh) by weight of asphalt cement in its open-graded surface mixtures and 5 percent (maximum nominal 80-mesh) in its dense-graded mixtures. While the initial cost for using the rubber asphalt is higher, Florida DOT feels that this increase is offset by improved performance of the highway and the salvaging of tons of waste tires from landfills.[10]

Shredded tires (without the belt removed) have been used as backfill material for roads, embankments and retaining walls. The scrap tires act as a lightweight, easy-draining backfill material and provide an insulating layer against frost penetration when used as a base or subbase aggregate.[11,12] These applications offer the potential to use significant quantities of scrap tires since, in some cases, up to 100 percent of the fill is made of scrap tires.

Concerns have been raised over the potential for the leaching of contaminants from the tires to ground water. Therefore, some practitioners recommend using scrap tires only in the unsaturated zone. A more recent problem has risen in Washington state where two embankment fills made of scrap tires caught fire. The problem required the excavation and removal of the tire fill under difficult conditions and at considerable expense. It is still uncertain what the causes of the fires were, but one theory was that exothermic reactions may have been producing heat, which led to the oxidation of the steel belts and to microbial action on tire rubber.[13]

Scrap tires are one of the country's major waste disposal problems, and many have looked to the highway construction industry as a strong market for their reuse. While, in some cases, their use has proved to be successful, it is also apparent that there are still problems. Many organizations and universities are actively conducting research on the use of scrap tires, and it is likely that within the next decade the most appropriate uses of scrap tires in highway construction will be identified.

Plastic. Recycled plastic has many applications for highway construction, especially for non-structural items such as cones, barrels, delineator posts, rebar chairs, guardrail offset blocks, car stops, etc. The use of temporary fencing made from recycled plastic for construction site safety and snow fencing recently has become common practice. Plastic lumber has been in use for several years in non-structural applications (for example, picnic benches, landscape timber, etc.), in part because it has a much higher life expectancy than ordinary lumber. Plastic lumber is less susceptible to rotting and insect infestation, is more durable, does not splinter and is not considered to be hazardous material. It also can be recycled, unlike pressure-treated wood. In recent years, significant advances have been made in the structural properties of plastic lumber, making its use beyond non-structural applications more promising. ASTM is currently developing standard specifications for plastic lumber products. Designers have also been experimenting with the use of recycled plastic content piles in marine environments where treated wood piles have not performed satisfactorily due to problems with rot and marine life (such as marine-borer worms).

Glass. Mixed-colored recycled glass that is ground into cullet can be used as aggregate for many applications including asphalt cement pavement, pipe backfill, embankment fill and in reflective traffic paint. Glasphalt — asphalt cement concrete containing processed glass aggregate (PGA) — has been successfully used in the United States and Canada on low-volume or low-speed roads. Experience shows that PGA in asphalt cement pavement is acceptable up to a maximum of 15 percent by total aggregate weight, but should not be used in wearing or surface courses.[14]

Compost. The major application of compost is along highways as mulch, blended topsoil replacement, commercial fertilizer supplement and as a soil amendment. The compost is mostly derived from leaf and yard waste, but may also be produced from other fractions of

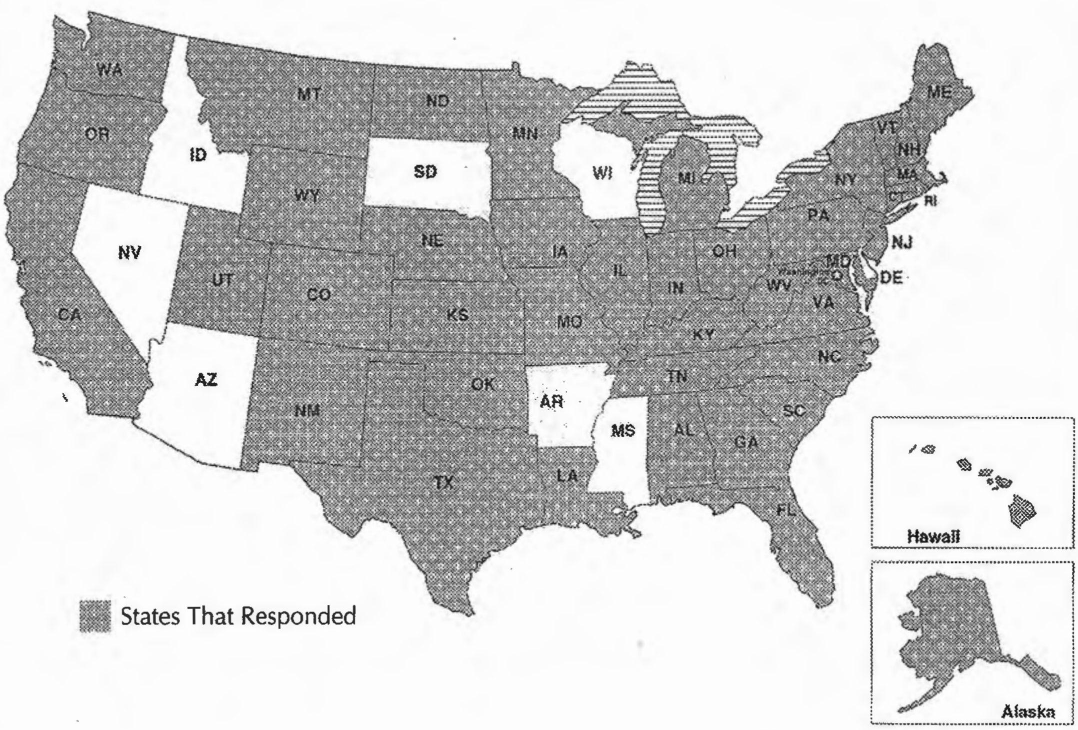

FIGURE 2. States that responded to the DOT questionnaire on WRM use.

the municipal solid waste stream. In addition, it may be derived from agricultural waste (manure and crop residues) and domestic wastewater sludge (biosolids). Recently promulgated federal and state regulations ban the disposal of leaf and yard waste in landfills, and as a result many towns and cities have separate stockpiles for leaf and yard waste that can serve as a source of compost. Furthermore, the number of municipal biosolids composting facilities has grown significantly in recent years to over 200 facilities as of 1994.[15] The use of compost in highway construction is becoming increasingly common because of concerns over the depletion of natural topsoil and the fact that leaf and yard waste, as well as wastewater sludge, represent a significant portion of the waste stream. However, concerns over the quality of compost have been a deterrent to its use. As a result, several organizations (for example, the Council of Northeastern Governors) have been active in the past years in developing standards for the use of compost in highway construction applications.

Blast Furnace & Steel Slag. Blast furnace and steel slag are waste products of iron and steel production, respectively. Blast furnace slag consists primarily of silicates and aluminosilicates of lime, while steel slag contains fused mixtures of oxides and silicates such as calcium, iron, unslaked lime and magnesium. Their most common use is as an aggregate for base courses, asphalt cement concrete and Portland cement concrete. Air-cooled blast-furnace slag in particular has been a well accepted source of aggregate for many years.[1]

Others. Many other WRMs have been used, or are currently in experimental use, for highway construction. Flowable fill, which has become a very popular replacement for compacted soil in trench excavations, has typically contained fly ash and there are now experiments being conducted using waste foundry sand as the aggregate. Pre- and post-industrial shingle waste have been ground and added to the drum-mix during the production of asphalt cement concrete. Most waste metals, particularly steel and aluminum, are recovered and re-

TABLE 2.
Number of State DOTs Actively Using Waste & Recycled Materials

Waste & Recycled Material	Number of State DOTs Actively Using	Number of State DOTs With Specifications
Recycled Asphalt Cement Concrete	40	34
Recycled Portland Cement Concrete	32	31
Coal Combustion Fly Ash	32	30
Scrap Tires	31	23
Blast Furnace Slag	19	21
Glass	14	13
Steel Slag	13	15
Plastic	13	4
Paper	8	5
Compost	6	4
Roofing Shingles	5	2
Others	7	3

Notes: These data were taken from a survey that was conducted in 1995. The total number of responses to the survey was 42 states.

used for the production of new metal products. Other WRMs that have potential for highway construction include carpet fiber waste, petroleum-contaminated soils, municipal solid waste incineration ash, paper products and wood waste.

Current State Departments of Transportation Use

In 1995, a questionnaire requesting information on the use of, and specifications for, various WRMs in highway construction was sent to all fifty state DOTs. Responses were received from 42 states as shown in Figure 2 (on page 11). The questionnaire data reveal that most states are actively using and experimenting with WRMs (see Table 2 and Figure 3), with some of the most commonly used WRMs being:

- Recycled asphalt cement concrete;
- Recycled Portland cement concrete;
- Coal combustion fly ash; and,
- Scrap tires.

Many states have developed specifications for the use of these WRMs and for other less commonly used WRMs. Typically, the number of states using a WRM is greater than those that have specifications due to the fact that most state DOTs prefer to develop a significant level of experience with a material before approving a specification.

In addition, some items (such as plastic products) generally do not have standard specifications but rather are part of an approved products list that state DOTs develop to indicate specific manufactured items that are allowed to be used on their construction projects. In terms of applications (see Table 3), the most common use of WRMs is as an aggregate in base and subbase layers, and in asphalt and Portland cement concrete.

When analyzed by geographic region, the northeast appears to be the most active in the use of WRMs in highway construction, with the level of activity decreasing towards the west and south. This distribution may be due to the higher population densities and older infrastructure generally found in the north and east, which lead to higher disposal costs and a consequent increase in motivation to recycle. In addition, some WRMs have strong regional usage. For example, blast furnace slag is almost exclusively used in the northern and eastern regions (where most of the nation's iron is produced). Additional details on the survey and its results are presented in DeGroot *et al.*[16]

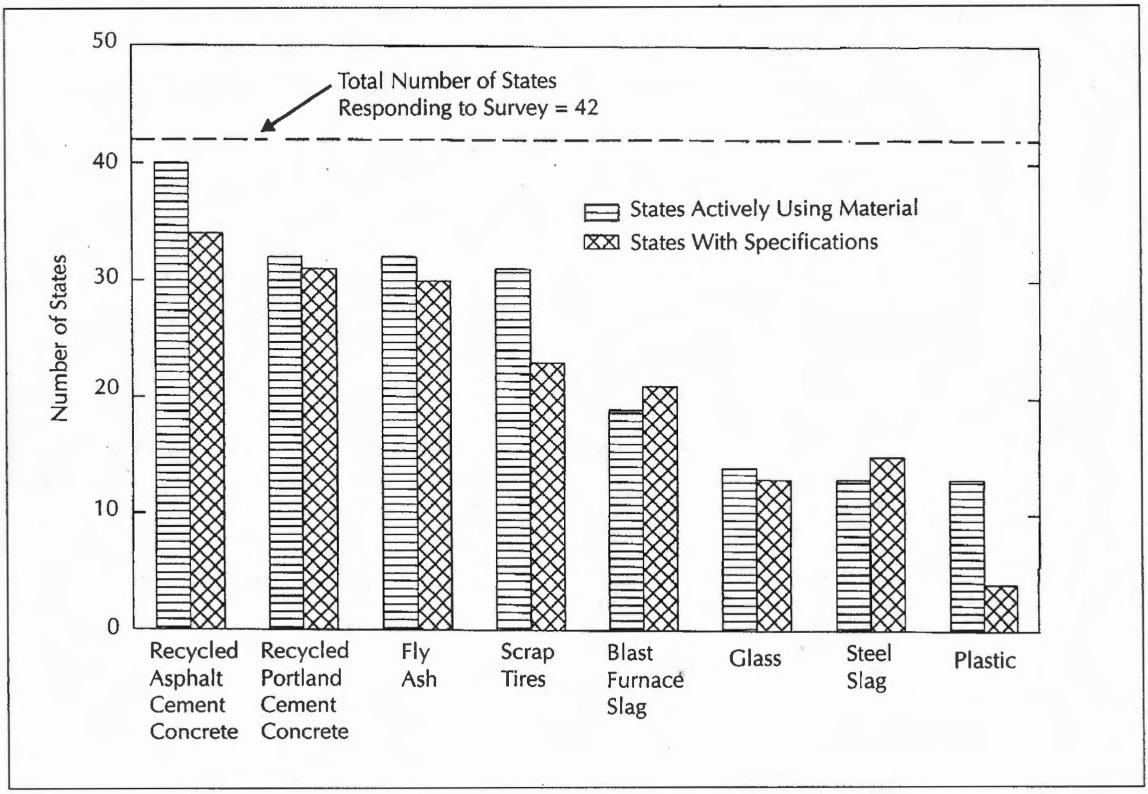

FIGURE 3. Most common WRMs used in highway construction by state DOTs.

Current Massachusetts Highway Department Specifications

All MHD construction practices and materials typically must conform to standard specifications issued by the department. The most recent version of these specifications include the 1988 *Standard Specifications for Highways and Bridges* (the so-called "blue" book) and its 1994 *Supplemental Specifications for Highways and Bridges.* MHD has been actively involved in the use of WRMs in their construction and maintenance operations, and currently has specifications for:

- Recycled asphalt cement concrete for use as an aggregate in new asphalt cement concrete (up to 40 percent by weight of aggregate depending on the process used) and as a base course material (up to 100 percent if it meets the physical properties required of virgin aggregates);
- Fly ash in Portland cement concrete (substitute up to 15 percent cement by weight), and controlled density fill (varying percentages depending on intended use);
- Processed planting material (*i.e.*, compost); and,
- Processed glass aggregate (up to 10 percent by weight of aggregate in new asphalt cement concrete and subbase).

MHD has also used other WRMs that have not yet had specifications approved or that are still considered experimental — including scrap tires for crumb rubber modified asphalt cement concrete and stress absorbing membrane interlayer, compost, recycled Portland cement concrete, plastic lumber, blast furnace slag and guardrail offset blocks.

In addition to the standard specifications, the MHD's Research and Materials Division compiles a list of approved materials, products and manufacturers or suppliers that can be used by contractors and project managers on state highway construction projects. The approved products list covers many miscellaneous construction items that can contain a recy-

TABLE 3.
Most Common Applications of WRMs Base on State DOT Use

Waste & Recycled Material	Application	Number of State DOTs Using
Recycled ACC	ACC aggregate	36
Coal Combustion Fly Ash	PCC	23
Recycled PCC	Aggregate for base, subbase, etc.	22
Recycled ACC	Aggregate for base, subbase, etc.	13
Scrap Tires (Crumb Rubber)	ACC binder (wet process)	13
Recycled PCC	PCC aggregate	8
Glass	ACC aggregate	8
Glass	Base course aggregate	8
Scrap Tires (Crumb Rubber)	ACC aggregate (dry process)	8
Blast Furnace Slag	PCC aggregate	7
Blast Furnace Slag	ACC aggregate	7
Coal Combustion Fly Ash	ACC	7
Recycled PCC	ACC aggregate	6
Steel Slag	Asphalt cement concrete aggregate	6
Compost	Topsoil upgrading, turf establishment, & landscaping	5

Notes: These data were taken from a survey that was conducted in 1995. The total number responses to the survey was 42 states.
ACC = asphalt cement concrete; PCC = Portland cement concrete.

cled content — including joint sealers and fillers, traffic attenuators, traffic cones, highway workzone barrels, sign posts and flexible delineator posts.

Other organizations in Massachusetts are also actively involved in the use of WRMs in highway construction and maintenance. The Massachusetts Turnpike Authority has been using animal manure for a number of years as a soil amendment. The manure is first tested for basic organic/nutrient content to determine if any additives need to be used to improve the source material (for example, lime to increase pH), then it is mixed with a sandy soil and stockpiled for use as a direct soil amendment or as a soil bed amendment. Many town departments of public works in the comonwealth have also been active in the use of WRMs, with the most common ones involving the use of recycled asphalt pavement, recycled plastic items such as cones and barrels, compost, and scrap tires for asphalt pavement and stress absorbing membrane interlayer. In many cases, the towns refer to MHD's standard specifications when specifying these items in contract bids.

Summary & Conclusions

In the 1994 Massachusetts Solid Waste Master Plan, the Massachusetts Executive Office of Environmental Affairs and DEP reaffirmed the goal of recycling and composting 46 percent of municipal solid waste generated within the state by the year 2000. A necessary component of achieving this goal is to develop sustainable markets for waste and recycled materials that are diverted from traditional disposal methods such as landfilling. The transportation industry has been identified as such a market. Some waste materials such as recycled asphalt cement concrete have been successfully used for years by transportation agencies, and many others have the potential to be used in significant quantities. However, it is important to recognize that most WRMs are not common construction materials. Each must be carefully investigated through laboratory testing and field trials to evaluate their physical and chemical properties, environmental impact, constructability, and initial and life-cycle costs.

Results from a survey of state DOT practices show that many states are actively using and experimenting with waste and recycled materials in their highway construction and maintenance programs. The most common application for waste materials is as an aggregate in base and subbase layers, and in asphalt and Portland cement concrete. Some of the most commonly used waste and recycled materials are recycled asphalt cement concrete, recycled Portland cement concrete, coal combustion fly ash and scrap tires. Of these materials, scrap tires use is still controversial because of both technical and cost concerns. As a result, many organizations are actively investigating the use of scrap tires in highway construction, and it may be sometime before the issues of concern regarding its use are resolved.

Some materials — such as blast furnace slag and steel slag — have strong regional usage in and around where these waste materials are generated. Other materials — such as glass, plastics and compost — are becoming increasingly common, with many state DOTs recently adopting standard specifications for their use. Of these materials, compost has the greatest potential for growth since the waste material it is produced from (*i.e.,* yard waste, biosolids, animal manure, etc.) is a significant portion of the waste stream and because it has many potential applications in the establishment and maintenance of vegetative growth along highway rights-of-way.

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