ECONOMICS OF RECYCLING

Sanford P. LaHue, Federal Highway Administration

As a result of spiraling highway construction costs, the highway community is deeply concerned with identifying cost saving measures in planning, designing, constructing, and maintaining streets and highways. One cost saving measure that has been identified, researched, and demonstrated is asphalt pavement recycling. Labor, materials, and energy savings have resulted on many projects. Continued development of recycling equipment, identification of new, innovative processes and widespread use of available information are among the elements needed to refine the state-of-the-art practices. As petroleum products and quality aggregates become more scarce, recycling of pavements will emerge as a standard highway and street construction item.

The desirability of conserving resources and the increasing cost of construction materials have recently led many road building agencies to consider a pavement rehabilitation alternative called recycling. Among the specific factors that have caused the highway community to take a serious look at pavement recycling is inflation, the decreasing availability of good quality aggregates, reduced gasoline tax revenues, rising petroleum prices and the ever present threat of another oil embargo by OPEC countries.

Along with the entire highway community, the Federal Highway Administration (FHWA) has been deeply concerned about items just mentioned and their pronounced effect on the cost of highway construction. As we are aware, the FHWA construction cost index has increased more rapidly than the consumer price index since 1967. The FHWA is both disturbed and concerned about this rapid rise when we keep in mind that highway program managers are now stretching every dollar almost to the breaking point to meet their needs. In many cases there aren't enough dollars to go around.

Highway obligations have more than doubled since 1967, but as a result of inflation we have fewer real dollars to work with now, as compared to then, when our needs seem greater than ever.

Paving has also contributed to this significant rise in costs. Asphalt and portland cement concrete paving have almost kept abreast of the construction cost index.

The highway community has responded to these increased costs. To survive, industry has identified new equipment and new methods. Local, State, and Federal governments have taken close scrutiny of their operations to identify cost saving strategies. Research has been identified and undertaken.

The FHWA has been fighting the rise in costs or inflation for several years now. The biggest mandate we have had was President Carter's Wage Price Guidelines and resulting order by former Secretary Adams to develop an anti-inflation program. From that order, the FHWA developed and issued FHWA Notice N 5080.83 in March 1979. This Notice contained several anti-inflation measures. One of these measures is recycling of pavements.

This was not a new-found program area. As a result of great cost saving potential, the FHWA, nearly 3 years earlier in June 1976, formally initiated Demonstration Project 39, "Recycling Asphalt Pavements."(1) This project was developed and administered from our Region 15 Office in Arlington, Virginia.

The project was developed to promot various techniques of asphaltic pavement recycling. Since June 1976, FHWA has given over one hundred presentations on this subject in this country and Canada to over 14,000 individuals. The "Demo 39" project has provided partical funding for the construction and evaluation of approximately 50 demonstration installations concerning hot, cold, and surface recycling.

Through this project and many State projects, recycling has been determined to be a cost-effective method when used on a project-by-project basis. As new equipment is developed and further experience is gained, we must include this pavement rehabilitation method as a worthy alternative.

Recycling offers many potential benefits. Three of the major ones are cost reductions or savings, energy savings, and the conservation of natural resources.

On many projects, total cost is the primary consideration in determining the type of rehabilitation procedure to use. For recycling to be selected, it must usually be the least expensive of the alternative methods. Several highway agencies have conducted cost analyses on completed recycling projects. These analyses have compared the actual cost of the recycling projects (using bid prices) to the estimated cost of the same projects using the rehabilitation procedure that would have been selected had recycling not been available. Most of the agencies have reported cost savings as a result of recycling.

Examples of reported savings include:

1. $146,000 saved on a 47,896 ton project. $3.05 per ton savings (Wyoming)

2. $59,385 saved on a 60,700 ton project. $0.98 per ton savings (Oregon)

3. $138,418.33 saved on a 42,129 ton project. $3.29 per ton savings (Iowa)

It is important to point out that recycling is still a relatively new technique to some contractors; therefore, bid prices on several projects have probably been somewhat higher than they would have been if recycling was a standard rehabilitation procedure. Bid prices have been slightly inflated by the fact that contractors must recover the cost of the necessary plant modification for, say, hot recycling. Because of the experimental nature of recycling, most contractors have seemingly tried to recover this additional cost immediately. Once recycling becomes a standard procedure, contractors will be more willing to write off the initial capital expenditure for plant modifications over several projects. As a result, it will probably be several years before the true cost of recycling is realized and the actual cost savings can be accurately determined. Based on figures from past projects, it is reasonable to assume that recycling offers potential cost savings in the neighborhood of 30 percent over conventional rehabilitation methods, when lide amounts of asphalt mix tonnage or pavement thicknesses are compared.

For many years, energy consumption on highway construction and maintenance projects was not a very important consideration. With the uncertain status of petroleum supplies during recent years, the former situation is changing. Energy consumption may become a primary factor in determining which rehabilitation methods are used on our existing highways.

Recycling can conserve substantial amounts of energy on many projects when compared to conventional rehabilitation methods. In determining energy savings, many factors must be considered for each project, including such factors as:

1. Amount of virgin aggregate required

2. Virgin aggregate haul distance

3. Amount of new asphalt cement required

4. Asphalt cement haul distance

5. Pavement removal method

6. Pavement crushing method

7. Haul distance from the project to the nearest pavement disposal site

8. Haul distance from the project to the crushing/mixing plant

9. Type of mixing plant

10. Moisture content of the salvaged asphaltic concrete and virgin aggregate

Three of the above items--virgin aggregate haul distance, amount of new asphalt cement required, and asphalt cement haul distance--will usually be the major factors in determining the potential energy savings of a recycling project compared to a conventional rehabilitation project.

Some recent typical projects have shown energy savings as much as:

1. 1.9 billion BTU's saved on a 53,000 ton project. Energy savings equivalent to 15,180 gallons of gasoline.

2. 3.8 billion BTU's saved on a 47,900 ton project. Energy savings equivalent to 30,220 gallons of gasoline.

3. 151 million BTU's saved on a 60,700 ton project. Energy savings equivalent to 1,210 gallons of gasoline.

The third major benefit of recycling is the conservation of natural resources. Both asphalt cement and virgin aggregates have the potential to be saved on every recycling project. To give an indication of the magnitude of these savings, the following figures have been accumulated from 27 major hot-recycling projects:

Recycle Mix (Total)	1,182,000 tons
Virgin Aggregates Conserved	771,000 tons
Asphalt cement conserved	42,800 tons

Cost savings, energy savings, and the conservation of natural resources are not the only potential benefits from recycling. Others may include:

1. Increasing the structural strength of the pavement without increasing its thickness

2. Correcting existing mix deficiencies

3. Correcting base problems

4. Eliminating reflective cracking problems

5. Maintaining curb, inlet, and manhole elevations along with existing drainage patterns

6. Maintaining overhead structure clearances

To take a more detailed look at the economics of recycling, I'd like to go through a series of slides showing several recycling projects which documented cost comparisons. Complete, bound reports are available for each of these projects should anyone want the complete story behind these project. I will only cover the project background and cost data.

The first project is in Millard County, Utah, (2) on Route U.S. 50. The pavement was recycled in September of 1977 and the project was 9.1 miles in length. The contract consisted of removing, crushing and stockpiling the old pavement; raising and widening the grade; recycling the reclaimed pavement; and relaying the recycled material on the finished subgrade. The contract was bid April 19, 1977.

The hot mix recycling method was used in a dryer drum plant.

The original roadway was constructed in the 1940's and widened to 21 feet in the 1950's. The average pavement depth was 3.3 inches. The pavement was constructed of roadmixed bituminous surfacing and had been repaired many times. Several type "A" cover aggregate courses had been applied to the surface.

The new recycled pavement was placed three inches thick at a finished width of 28 feet. There was approximately 21,800 tons of recycled material and 7,100 tons of conventional mix produced and laid.

There was a savings of $2.36 per ton when a comparison was made between the actual bid cost of the recycled asphaltic concrete and the actual bid cost of virgin asphaltic concrete on this project.

The second project is in Hidalgo County, Texas, (3) on Loop 374 between State Route FM 2062 and U.S. 83. The project was completed in May 1976 and was 1.5 miles in length. The project consisted of salvaging asphaltic material from State Highway 336 in Hidalgo County during construction on an active project. The pavement section of SH 336 consisted of a two course surface treatment applied in 1955, a 1¼ inch hot mix asphalt concrete overlay in 1959, and another surface treatment in 1964 for a total of approximately 2.5 inches. The recycled material was then to be laid as an overlay on Loop 374.

The type of pavement relaid, by hot recycling, consisted of three different mixes in three sections. These included 1) a mix using AC-3 asphalt adding up to 2.5 percent by weight, 2) a mix using flux oil added up to 1.6 percent by weight, and 3) a mix using Reclamite added at 1.6 percent by weight.

The cost analysis for this project showed that the recycled material was nearly the same as a new hot mix asphalt concrete mixture in place. However, project personnel conclude that had it not been for construction inefficiencies, i.e., equipment problems, incorrect estimating of haul distances, and equipment and labor costs, the potential savings could have been $4.80/ton. I must also add that this was one of the first recycling projects attempted. A lot was learned by the Texas Highway Department and FHWA on this project.

The third project is located in Republic County, Kansas (4). It is a cold recycling project. The project was located on a county road and was two miles in length. Construction took place in July 1977. The project consisted of tearing up and pulverizing the existing surface, adding a predetermined amount of asphalt, then relaying the mix. The first mile was to be constructed with emulsified asphalt (mix and seal) and the second with cutback asphalt, also for the mix and seal.

The original surface was constrcuted in 1963 as a 5 inch sand-gravel subgrade modification project. The subgrade modification was surfaced in 1964 with an asphalt prime and dougle seal. In 1972, a 2 inch road mix asphalt overly with a swal coat was applied. During the period from 1964 to 1974 there have been two reseal applications with periodic asphalt patching.

The cost analyses for this project reveals that there was a savings of $26,644.56. The labor and equipment costs for recycling cost more but the significant savings resulted in the material costs.

The fourth project I want to cover is a hot-recycling project in the State of Virginia (5). I talk about this project to give a realistic view about recycling and some of the growing pains of new technology. This project was nearly 1 mile in length and located on U.S. Route 1 in Chesterfield County near Richmond. The project took place in 1976 and 1977.

A conventional asphalt batch plant was used. Two evaluations were to be made. The first considered the process in which the recycle mix is introduced into the cold feed and proceeds through the dryer, hot elevator, etc. It included modifications of the plant to reduce the adverse effect of the dryer flame being in direct contact with the crushed hot mix and resultant stack emissions. The second considered the process whereby the recycle mix is introduced into the hot bins, which is often called the Minnesota method.

The pavement to be replaced was a conglomeration of asphalt overlays on top a portland cement concrete pavement. The pavement structure dates back to the 1930's with asphalt overlays--totaling 5½ inches--being added periodically since then. Various depths and asphalt types made up the recycled pavement structure.

As a result of problems in producing the plant mix material, the project suffered several setbacks. In using the method by introducing the recycle mix into the cold feed, residual asphalt and minus 200 mesh material in the crushed pavement were sticking to the dryer and being drawn into the primary dust collector. Because this buildup had to be removed, along with slow removal of the material from the roadway and trying to eliminate a blue smoke emission, production was very slow and the project was temporarily terminated for reassessment.

After evaluating pavement removal procedures (which resulted in switching from Pettibone and Galion pulverizers to a ripper then crush the material) and plant modifications (using the heat transfer method by introducing the crushed pavement material directly to the heated virgin aggregate), the project was resumed in the spring of 1977 and better results were obtained.

I'm not able to cover all the project details at this time, but the cost analysis revealed that with all the problems the cost of the recycled material was $19.46/ton and a new pavement overlay would have been $13.44/ton. The cost of a new conveyor for plant modifications added $4.71 to the recycle mix.

Although this project is not truly indicative of the potential cost savings of recycling, it is a good example of the growing pains the highway community must endure to develop much needed technology.

The fifth project is a hot recycling project in Kossuth County, Iowa (6). The project was 10 miles in length and constructed in summer and fall of 1976.

The contract called for scarifying and removing 7½ inches of bituminous material. The 7½ inches included a 3 inch bituminous treated aggregate base and 2 inch asphalt concrete base course both applied in 1961 and 2½ inches of asphalt concrete base constructed in 1964. After hot mix recycling using a 2/3 recycled mix and 1/3 new materials ratio, a 6 inch depth pavement was to be replaced. The subbase was reworked to accommodate the new pavement. The contract was part of a four project recycling

package. The contractor overran the entire project by two weeks. The amount of recycled mix produced for the Kossuth County project was 42,129 tons and there were 82,000 tons produced for all four projects. 5¼ percent asphalt cement was required compared to 7½ percent required for all new materials.

The cost analyses revealed that the recycled mix cost $17.30/ton as compared to $20.59/ton for new materials, a $3.29/ton savings. Other savings included 171,825 gallons of gasoline and 948 tons of asphalt cement. No aggregate savings was given.

The sixth project is Contract No 03-205404 west of Gold Run, California, in Placer and Nevada Counties (7). The total length of the project was 24.5 miles. The project, which consisted of recycling the asphalt concrete shoulders and ramps, was constructed in the summer and fall of 1978. The project is located in the snow belt of the Sierra Nevada Mountains at an elevation of about 3,000 feet at the lower (west) end and 5,000 feet at the upper (east) end. The pavement is subjected to air temperatures of from 10°F± in the winter and 90°F± during the summer. The mean annual snowfall within the limits of this job varies from 24"± at the west end to 200"± at the east end.

The shoulder section consisted of 3 inches of asphalt cement, 6 inches of cement treated base, and 15 inches of aggregate subbase. The ramp pavement section was 3 inch asphalt concrete, 9 inch asphalt base, and 12 inches of aggregate subbase.

Approximately 1 inch of the shoulder and ramp surfaces were Roto-Milled. This material was used in a 50-50 blend for recycling.

In addition to the 1 inch asphalt concrete removed, a 4-foot wide section adjacent to the PCC pavement was milled another 3 inches. This 4 inch "trench" was backfilled using the recycled mix, then the entire shoulders and ramp were overlaid with 0.1 inches recycled mix.

The cost analysis for this project showed the recycled mix cost $12.91/ton with using 3.5 percent new asphalt cement and a 50/50 blend mix. The cost of using virgin materials would have cost $16.81/ton with a 6 percent asphalt cement content. A total of $169.000 was saved for the 43,365 tons of recycled AC placed on this project.

As I previously mentioned, all of the individual projects I briefly discussed along with many more recycling projects are documented in report form and these can be obtained through FHWA's Region 15 Office in Arlington, Virginia.

On a statewide basis, the State of Wisconsin has done recent cost comparisons on the project cost of recycled mixes (50/50 ratio) vs. non-recycled mixes. According to data published by Wisconsin in March of this year (shown on slide No. 16), there was a savings of $4.30 per ton. This cost savings was derived from six nonrecycled projects averaging 34,000 tons of mix per project and seven recycled projects which averaged 37,000 tons. The average bid price per ton excluding asphalt cement was $7.60/ton for the nonrecycled mixes and $6.20/ton for the recycled mixes for a $1.30/ton savings. The nonrecycled mixes had an average of 5.9 percent of asphalt cement added compared to 3.6 percent for the recycled mixes. The asphalt cement cost per ton of total mix was $7.50 for nonrecycled vs. $4.60 for recycled--a savings of $2.90. This all equates to a total bituminous mix cost of $15.10 for nonrecycled mixes and $10.80 for recycled mixes, or the $4.30/ton savings.

In conclusion, I have shown cost data from several projects using various construction methods. The State highway departments and FHWA research that went into these projects and many others has revealed that recycling of asphalt pavements can be a cost effective alternative that needs to be considered when asphalt pavement rehabilitation is necessary. Obviously, certain factors such as material and equipment availability, haul distances, etc., come into play when determining cost-effectiveness, but the highway community has shown that asphalt pavement recycling is here to stay.

References:

1. FHWA, Region 15. Recycling Asphalt Pavements, Demonstration Project No. 39. April 1979, FHWA Publication No. FHWA-DP-39-15.

2. Wade B. Betenson, P.E. Recycled Asphaltic Concrete Pavement (Draft). Presentation at Annual Meeting of the Assocation of Asphalt Pavement Technologists. February 19-21, 1979, Denver, Colorado.

3. Charles H. Hughes. Recycling Asphalt Concrete Pavement. Texas State Department of Highways and Public Transportation. August 1977. FHWA Publication No. DHT-1-9-76-524-1-F.

4. Clarence W. Smith. Recycling Asphalt Pavements. Republic County, Kansas. August 1978. FHWA Publication No. FHWA-DP-39-1.

5. C. S. Hughes. Recycling Asphalt Pavements. Virginia Highway and Transportation Research Council. February 1979. FHWA Publication No. FHWA-DP-39-14.

6. Richard P. Henely, P.E. Recycling Asphalt Pavements. Kossuth County, Iowa. February 1979. FHWA Publication No. FHWA-DP-39-10.

7. R. N. Doty and T. Scrimsher. Recycling Asphalt Pavements. California Department of Transportation. September 1979. FHWA Publication No. FHWA-DP-39-17.