SEMINAR ON ASPHALT PAVEMENT RECYCLING
OVERVIEW OF PROJECT SELECTION

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Project selection is the first necessary step to asphalt pavement recycling. This paper attempts to discuss the primary considerations necessary for a project selection which favors recycling. Such factors as pavement condition, economics, energy, contractor availability, selective rehabilitation, and engineering considerations are discussed. It is concluded that virtually all asphalt construction can be eligible for the use of recycled materials including new construction, reconstruction, resurfacing, restoration and rehabilitation. There are some obstacles which are causing recycling not to be considered as often as it should; for example, a lack of contractors with equipment and experience, and a concern for unverified engineering criteria. The major potential benefits of cost and energy are judged to be sufficiently compelling to justify some additional effort in design and construction to select one of several recycling alternatives, even though engineering and life cycle information is not fully documented. Research and information from demonstration projects indicate that material durability and structural capacity of recycled materials are comparable to new construction, and therefore, should not be a deterrent to project selection. An increase in contractor availability will occur if contractors can be assured of a continuing demand for recycling projects. Public agencies will need to take a leadership role in assuring that long term plans call for recycling of asphalt pavements as a major objective in pavement construction. This paper concludes that recycling procedures are available for a wide selection of projects and that engineers, contractors, and public agencies have a responsibility to promote recycling as a viable alternative for pavement construction and to support studies designed to verify needed engineering and construction criteria.

Asphalt pavement recycling would appear to be an idea or concept whose "time has come." In spite of this, the rate at which technology is being developed and contracts are being advertised appears to be relatively slow.

An analogy could be made to the current health craze taking place in the United States at the present time. The number of people who are exercising regularly has increased tremendously during the past several years; however, translated into the percentage of the total eligible population the number would be small.

Asphalt pavement recycling is not new. Some forms of recycling were used in California in 1952 on airfield construction for the U. S. Navy. The procedures at that time were somewhat primitive and equipment wear and tear in pulverizing old asphalt concrete was considered excessive and costly. Since that time metals and equipment have improved, and productivity has increased to a degree that recycling of asphalt concrete by a variety of procedures is increasingly attractive to the engineer and should be even more attractive to those people responsible for selecting construction alternatives.

Epps, et al (1) provide some compelling reasons for recycling including (1) conservation of aggregate, (2) conservation of asphalt, (3) conservation of energy, (4) environmental preservation; e.g. reduced mining for new aggregate and (5) selective rehabilitation; e.g. elimination of need for full width overlays on multi-laned highways. With all of these advantages, why do we see such a slow evolution toward asphalt pavement recycling, compared to other developments, such as the use of dryer-drum asphalt plants?

The nature of new developments in the highway industry often follows an almost predictable pattern; enthusiastic acceptance followed by diminishing interest based on isolated failures or less than spectacular benefits.

In any new development there are surely going to be some setbacks. Problems not anticipated will occur that will require some adjustments in the process. This should not be cause for abandonment of the procedure if the potential benefits are of significant importance. Remember that much of our engineering technology has been developed empirically; i.e. based on experience and that includes some premature failures.

The U. S. public is always looking for the spectacular fast result; no trial and errors, just results. U. S. engineers are no different; we always want spectacular benefits. For example, a five percent savings in cost may not be sufficient to justify the additional effort and risk associated with a new idea of procedure. However, if the long term benefits or needs can be identified, the economic benefits can be zero or even negative during the early stages of development.

In my opinion as a consultant, who deals with a variety of public agencies, we have very little choice but to move ahead with the use of pavement recycling procedures. The traditional choice of using all new materials is no longer a viable alternative. Somehow we must convince the decision maker to make the choice for recycling. In order for contractors to invest in special equipment and to train personnel, he needs to know that recycling is going to be a long range development with a significant amount of work expected in the future. Such an environment is necessary in order to create the competitive situation so necessary to the full exploitation of the recycling concept.

The success of any pavement design and construction process is first one of selection. Thus, the topic assigned to me is to review project selection procedures. I have elected to discuss some of the pros and cons of recycling. In this sense, cons are really some of the obstacles in the way of recycling as differentiated from the negative considerations. There are really no negative considerations; however, there are some obstacles.

The apporach I have used in gathering information involves three sources; (1) literature, (2) discussions with federal, state, county and city officials and (3) my own experience and judgement applied to project selection for recycling.

The topics which I have selected for discussion pertinent to selection include:

1. Pavement condition
2. Contractor availability
3. Cost and energy comparisons
4. Environmental regulations
5. Engineering technology

Several of these topics will be covered in more detail by other speakers at this conference; however, this overview should serve as an introduction followed by more in-depth development.

Pavement Condition

One of the first decisions necessary in selecting a project for possible recycling is the condition of the pavement. For asphalt pavements, the need for resurfacing, restoration and rehabilitation or even reconstruction, is usually brought about by one or more of the following pavement deficiencies:

(1) Pavement roughness
(2) Excessive cracking of the asphalt concrete
(3) Excessive rutting in the wheel paths
(4) Low surface coefficient of friction
(5) Surface wear (raveling)
(6) Inadequate structure
(7) Inadequate traffic capacity

The subject of inadequate structure will be discussed further under engineering considerations. Inadequate traffic capacity can be cause for rehabilitation or reconstruction particularly if it is anticipated that truck volumes and weight will increase significantly. Inadequate traffic capacity will not be discussed further in this presentation.

The use of recycled material for new construction will be discussed under engineering considerations.

I believe that some type of recycling (surface, in-place or central plant mix) can be used to accomodate any of the first six deficiencies enumerated previously.

For purposes of this discussion recycling procedures include surface, in-place and central plant mix, essentially as defined by Epps et al in reference 1.

Surface recycling - Reworking and/or removal of the surface of a pavement to a depth of approximately 1 inch by heater-planer, heater scarifier, hot milling, cold milling or cold planing devices. The operation may involve the use of new materials (or recycled materials) including aggregates, modifiers and/or asphalt concrete.

In-place recycling, surface and base - In-place pulverization to a depth greater than 1 inch followed by reshaping and compaction.

Central plant recycling - Removal of the pavement from the roadway after or prior to pulverization, processing of material with or without the addition of a modifier, followed by laydown and compaction to the desired grade (and depth).

Pavement roughness in most cases can be corrected by surface profiling, by cold milling, or heater planing, combined with resurfacing, using recycled hot or cold mixes.

Specific criteria for selection of recycling procedures are provided by Epps et al (1).

Excessive cracking can be corrected by several of the available recycling procedures.

The Arizona DOT is one of the few agencies which has tentative guidelines for selection of recycling procedures related to surface cracking. A cracking index has been developed by Arizona which provides a systematic procedure for identification of the extent and severity of cracking (2). Based on this procedure, surface recycling is considered appropriate when the cracking index is 10 percent or more, and more extensive recycling; e.g. in-place or central plant mix, when the index is 40 percent or more.

Epps et al (1) have also provided guidelines for selection of recycling alternatives as a function of type and extent of cracking. Such recommendations include all three recycling techniques; i.e. surface, in-place and central plant mix recycling.

In the case of physical distress (cracking or rutting) it may be advisable to conduct an engineering investigation to evaluate the possible need for structural reinforcement.

Excessive rutting can generally be corrected by surface planing or milling in combination with a surface treatment or thin overlay. The thin overlay could be produced from a combination of recycled and virgin material on roads of medium and low traffic; e.g. less than 5000 vehicles per day.

In some cases surface recycling may not be sufficient to correct problems in the base or subbase, in which case in-place or central plant mix may be the proper option.

Low skid number can be corrected with surface planing or recycling with a minimum of new materials. In extreme cases central plant mix recycling with some percentage of virgin non-polishing aggregate may be required.

Severe raveling can be corrected without recycling in many cases. However, for heavily trafficked highways, surface recycling, with new or recycled materials added, may provide cost efficient benefits.

Inadequate pavement structure can be corrected by increasing the depth of stabilization by means of in-place or central plant-mix recycling. In effect, this is increasing the structural number by increasing the depth of the stabilized layers. If necessary, a new wearing surface can be added as a precaution against accelerated surface wear. It would not be necessary to increase the elevation of the finished pavement if central plant mix recycling were used or if special provisions were made in connection with in-place recycling.

In summary, the range of alternative recycling procedures can be used to correct any deficiency that can be corrected by the use of new materials. This should not be construed as indicating there are no problems associated with recycling. There are some problems, but in concept the techniques are applicable to the full spectrum of design and construction, including rehabilitation.

There may be some skepticism as regards the use of recycled materials for overlay or as a wearing surface. However, as will be discussed, there is no engineering justification for such concern. Experience may prove otherwise, and some caution will need to be exercised in project selection for thin (one course) overlays or as a wearing surface. One recommendation would be to use recycled materials as a wearing surface only for pavements subjected to less than 5000 vehicles per day. Eventually, this limit could be increased.

Contractor Availability

In order to select a recycling alternative for a specific project, the engineer or agency needs to be sure that there are contractors in the area who are prepared to bid on the project. Contractor availability is a necessary consideration in project selection.

In general, contractors are available for surface recycling. The equipment is portable and can be moved over large distances quickly. As the volume of work increases, contractors can station more equipment in central locations and provide more competition in all areas. Also, a range of equipment, for large or small projects, and using hot or cold procedures, is available.

Contractors with the proper type of equipment for in-place recycling are somewhat more limited when compared with surface recycling; however, it is available. In-place mixing has been a standard operating technique in pavement construction and material stabilization for many years. These techniques have been perfected with new materials and can be perfected for recycling.

A recent experience in Walnut Creek, California points out the difficulty that can occur on relatively small projects. The project was designed to recycle the asphalt concrete surface and base by stabilization with cement, plus a new wearing surface; a procedure used on selected projects by Caltrans and Nevada DOT (3). The project was two lanes of a four lane highway, approximately 0.6 miles in length. Only one contractor bid on the project. An award was made in order to correct some aggrevated distress. However, it developed that the contractor did not have the proper equipment, as referenced in the specifications, and the contract was cancelled and subsequently awarded using a more conventional design.

It is believed that if more agencies in the area would specify in-place recycling, contractors would acquire the equipment which would create a more competitive situation.

If the project is sufficiently large the contractor can afford to bring in the proper equipment. The experience reported by E. Aguirre (4) of Victorville, California is such an example. In this case a $100,000 savings was reported by in-place recycling of two miles of city streets.

In many parts of the country the availability of contractors for central plant-mix recycling is very limited except for large projects. In the San Francisco Bay Area (nine counties) there is only one contractor who has acquired equipment especially designed for recycling. In Northern California there are only two contractors with plants designed or modified for use with recycled materials. In Los Angeles one contractor has retrofitted his batch plant to do recycling using the Minnesota process. However, in neither case are agencies beating a path to their door with projects selected for use of recycled materials. The Los Angeles contractor has had two recycling projects in three years. The San Francisco contractor has furnished 4000 tons in two years, all on private works. In Los Angeles the contractor offered a one dollar rebate on all recycled materials and could find no takers.

Contractors face a "Catch 22" situation with regard to spending money for equipment required for recycling. Before they can invest, they need to have some assurance that the specifying agencies will follow a long range plan requiring or allowing the use of recycled materials. However, specifying agencies are reluctant to use recycled materials unless there are a number of contractors in the vicinity who are properly equipped and who have experience in processing recycled materials.

In summary, contractors for surface recycling are available in most parts of the United States and competitive conditions exist in many cases. However, availability of contractors for in-place and central plant recycling is somewhat limited by the size of the project.

To improve the contractor availability situation, action will be required on the part of the larger agencies; e.g. federal, state and larger counties and cities. These agencies will need to take the leadership in establishing a continuing market for recycled materials.

Cost and Energy

Cost is the traditional criteria for selection between various design and rehabilitation alternatives. The alternative with the least cost, including initial and maintenance, is usually elected by the designer. Another consideration which may or may not be reflected by comparative cost is energy. Both of these subjects will be presented by another author at this seminar. However, a few comments may be appropriate in this overview.

Alternative bid prices for three projects in Arizona (I-10-4/68, I-17-1/25, I-40-2/86) indicate that comparative prices between recycled asphalt concrete and new asphalt concrete would result in a savings of $0.43 per ton in favor of the new asphalt concrete or a difference of 2 percent.

Considering that bid prices do not always reflect actual costs, this comparison does not correctly reflect the potential benefits between the two techniques.

In Hawaii a project involving 15900 tons of asphalt concrete was modified by change order from all new to 30 percent recycled material, and the price was reduced by $0.80 per ton or 3 percent.

In California, four projects were analyzed which showed substantial savings as summarized below:

Project	Recycled Aggregate		Cost/Ton New	Recycled
I-80 (Gold Run)	50%		$16.81	$12.91
I-5 (Weed)	50%		$29.59	$20.09
SR 395 (Bishop)	100%		$22.66	$20.35
I-10 (Blythe)	55%		$22.08	$13.39
		Average	$22.78	$16.68

The total savings in dollars were estimated to be $761,500 with an average reduction of 26 percent in the asphalt requirement.

Discussions with one materials supplier, who does no laydown, indicates that the potential savings in using recycled mixes is $3.00 per ton, or 17 percent. In this case the contractor is using all cold millings, no crushing, which cost between $1.25 and $2.25 per ton delivered to his yard from projects within a 20 mile radius of his plant. Virgin aggregate costs the contractor $4.00 per ton.

Local dumps are charging $70 per load for dumping street rubble including asphalt concrete. Some contractors are now accumulating asphalt concrete for recycling by allowing contractors to dump materials in their yard at no cost. At this price, the contractor can afford to haul the material a considerable distance and still be economically ahead of dumping.

Thus, the economic benefits are there. Even in Arizona it is believed the benefits are real although the method of bidding may in some way disguise these benefits. Also, haul distances and plant location will have an effect on cost comparisons.

Economics on a particular project can also be affected by selling salvaged materials to contractors. For example, the salvaged materials can be retained by the agency or credited to the project by the contractor.

If the salvaged materials are to be retained by the agency, the contractor would be paid to remove, process (as specified) and deposit at a site designated by the agency which would be convenient for future applications. For example, the material could be hauled to the maintenance yard where it would be used for patching, tranch backfill or shoulder repairs. In this sense the material has value which should be credited to the job and to the process.

If the salvaged material is retained by the contractor, the bids should reflect the fact that he has retained all or some part of the salvage material.

The one area that can produce a real benefit is in energy savings. For example, the I-10-4(68) project in Arizona shows a savings equivalent to 19,400 gallons of gasoline for a project involving 57,500 tons of asphalt concrete or one-third of a gallon for each ton of mix. On the project the savings in BTU/ton amounted to 11 percent.

Peters et al (5) have summarized typical energy comparisons, including transportation, for new and recycled asphalt concrete. Based on their assumptions a typical energy requirement for new asphalt concrete would be 432,300 BTU/ton and for recycled asphalt concrete the value is 327,992 BTU/ton or a 24 percent reduction in energy.

Factors included were (1) manufacture of asphalt cement, (2) hauling asphalt cement, (3) crushing gravel, (4) haul salvaged A.C. to miles, (5) crushing salvaged material, (6) drying and heating materials, (7) hauling, spreading and compacting either type mix.

With some justification, many engineers believe that the benefits in energy savings will be reflected in energy costs. This would be the traditional approach; however, it may be time to examine that approach.

Is the real value of energy savings reflected in cost savings? An analogy can be made with water. Does the cost of water reflect the value of water? We need to conserve water because it is precious and not in ever increasing supply. For project selection some credit or value needs to be given to the energy savings which is not necessarily reflected in cost. I have no specific recommendation to make except to suggest that more sophisticated evaluations are necessary which go beyond standard economic comparisons.

Regulations

One possible concern for the use of recycling procedures is government regulations; specifically, requirements related to safety, noise and air pollution.

Of these three, the only one that appears to be significant is air pollution and particularly opacity requirements associated with central plant mix requirements. This problem has not yet been satisfactorily resolved (6). The current solution is to spray water on the cold feed materials, to increase the amount of virgin material or decrease plant production. None of these is entirely acceptable and each tends to increase the cost of construction using recycling procedures.

Some modifications in equipment have helped to reduce the air pollution problem; however, the general solution is to reduce the amount of virgin aggregate used in the mix. An upper limit of 60 percent recycled material is the figure most frequently quoted. This is not ideal; 100 percent recycled would be preferable. However, the surplus can be used for new or reconstruction projects or for strengthening existing projects by in-depth stabilization.

Engineering Considerations

Project selection can be divided into two catagories; (1) surface recycling and (2) in-place or central plant-mix recycling. If the project can be restored by corrections to the surface with a minimum of new materials, surface recycling will prove satisfactory. If substantial corrections are required, more extensive actions will be necessary which can be achieved by in-place or central plant mixed procedures. Some of the major advantages and disadvantages are enumerated in Table 1.

Specific engineering considerations or design parameters which will influence project selection are:

1. Mix design
2. Durability of recycled mixture
3. Structural properties
4. Construction uniformity

A detailed discussion of these items is beyond the scope of this report; however, some summary remarks are pertinent.

Table 1

Advantages and Disadvantages of
Recycling Asphalt Pavements

Recycling Procedure	Advantages	Disadvantages
Surface Recycling	1. Reduces reflection cracking	1. Limited structural improvement
	2. Promotes bond between old pavement and recycled material	2. Potential air pollution problems (dust, smoke)
	3. Reduces tendancy for raveling at conforms	
	4. Corrects a variety of distress types at all levels of severity	
	5. Selective rehabilitation	
In-place Recycling	1. Significant structural improvements	1. Problems of quality control
	2. Corrects all distress types at all levels of severity	2. Some design parameters unknown
	3. Selective rehabilitation	
Central-plant Recycling	1. Designed improvement in structural capacity	1. Improved quality control required
	2. Corrects all distress types at all levels of severity	2. Some design parameters of questionable reliability
	3. Improved quality control over surface and in-place recycling	3. Potential air pollution problems
	4. Selective rehabilitation	

Mixture Design

The elements of mixture design have been rather thoroughly researched and summarized in the literature (1, 3, 7, 8, 9). Basically, the mix design approach used by investigators is to produce a mixture which meets all standard material specifications for the type of mix being produced.

The mix design procedure proposed by Kari et al (9) and which is generally representative of procedures proposed by others is summarized in Table 2.

Table 2

Recycle Mix Design Process

1. Evaluate salvaged material
   . gradation
   . amount and consistency of asphalt
2. Establish consistency requirements for recycled material
3. Determine proportions of recycling agent; i.e. low viscosity asphalt or special petroleum derivative, required to provide desired consistency.
4. Determine proportions of recycled material, recycling agent and virgin aggregate necessary for stability and other mix design requirements, including water susceptibility, by appropriate laboratory procedures.

Once the appropriate proportions are determined for a range of percentage of virgin aggregate, the mixture design is ready for field trials.

All available information indicates that recycled mixtures should be equivalent to new asphalt concrete (1) and would be suitable for all types of construction including surface recycling, in-place or central plant mix applications.

Durability of Recycled Mixtures

Based on laboratory evaluations (1, 6, 7, 8) the durability properties of the asphalt in recycled mixtures should be equivalent to that of conventional asphalt concrete. Only time will tell if the traditional tests used to evaluate asphalt durability will apply to recycled materials. At the present time there is no reason to suggest they will not. More research is needed to confirm this assumption.

Structural Properties

For in-place and central plant mix recycling it will be necessary to establish coefficients appropriate for both structural enhancement by increasing the thickness of the stabilized layers and for overlays.

Epps, Little et al (1) summarize extensive studies made to evaluate the structural properties of recycled materials. The procedure used to make such comparisons was largely by means of computer simulation using recognized mechanistic procedures. Some effort was made to incorporate AASHO Road Test Data into their analysis in-so-far as it was applicable to the procedures used. Also, a number of field projects were included in the study by means of core sampling, testing, and dynaflect measurements.

The conclusions reported in Volume 1 of reference 1 are summarized as follows:

1. Based on a structural evaluation, recycled asphalt concrete bases stabilized with either asphalt emulsion, cutback, cement, lime, or with the addition of an asphalt modifier are superior to aggregate bases in terms of load distribution.

2. Recycled bases in this study are structurally equivalent to or superior to conventional stabilized bases.

3. Although there was considerable variability in results, the in-situ properties as determined from an analysis of dynaflect measurements, are comparable with properties of conventional materials. It can be concluded that overlay designs would not be affected by the use of recycled materials.

In summary, project selection would not be affected by structural differences associated with the load distribution or performance properties of recycled materials.

These conclusions should be considered somewhat tentative. However, the information is sufficiently conclusive to justify using conventional design parameters for project selection.

Selective Design Alternatives

Arizona DOT has pioneered a design procedure which combines recycling procedures (5). Specifically, for multi-laned highways, ADOT has designed several projects with surface recycling and thin overlay in the passing lane, and for central plant mix recycling in the truck lane, also with an overlay. The procedure takes full advantage of various recycling combinations in order to minimize the overall cost.

The selective use of heater scarification and overlays on an as-needed basis has also been used by ADOT to maximize the benefits of recycling.

Construction Uniformity

One of the major concerns of engineers with regard to the use of recycled materials is construction control.

Quality control of construction is important whether it be for all new construction or recycling. Because of non-uniformity of salvaged materials, or handling techniques, uniformity may be somewhat more of a problem in recycling than it would be in conventional materials. Some additional attention will need to be given to monitoring recycling projects to assure uniformity.

Summary

In the preceeding sections of this report a brief discussion has been presented concerning selection of projects for asphalt pavement recycling. Based on the information available it would seem reasonable to conclude that recycling procedures are an acceptable alternative for all types of design including new construction, resurfacing, restoration and rehabilitation.

Some additional engineering effort will be required in connection with mix design and construction control. The potential benefits in cost and energy should easily justify the additional effort required.

Unfortunately, in the absence of contractor capability, there appears to be some reluctance to establish a long-range policy to implement recycling as an alternative for every construction project. Contractors need that reassurance before they can acquire for themselves the proper equipment and experience necessary to improve their capability.

There is a need for technical literature for use with recycling projects. Reference 1 is a significant beginning to meet this need. However, additional mix design guidelines are needed and most specifically, model specifications and construction control requirements need to be put in the hands of public agencies and consulting engineers.

References

1. Epps, J. A., R. J. Little, R. J. Holmgreen, R. L. Terrel, and W. B. Ledbetter, "Development of Guidelines for Recycling Pavement Materials", Vol. I, II, III Final Report, NCHRP Project 1-17, July 1979.
2. Way, George B., "Asphalt Properties and Their Relationship to Pavement Performance in Arizona", Proceedings, Association of Asphalt Paving Technologists, 1978, p. 49.
3. "Recycling Materials for Highways", NCHRP Synthesis of Practice, Report 54, 1978.
4. Aguirre, Edmundo, "Recycling Saves $100,000 on Two-Mile Job", Rural and Urban Roads, July 1980, p. 62.
5. Peters, R. J., R. D. Peters, and J. B. Ritter, "Asphalt Pavement Recycling in Arizona", paper presented to the 29th Annual Arizona Conference on Roads and Streets at the University of Arizona, April 1980.
6. Bentenson, W., "UDOT's 5-year Probe of Hot-Mix Recycling", Rural and Urban Roads, July 1980, p. 30.
7. "Recycling of Bituminous Materials", Special Technical Publication 662, ASTM, 1977.
8. "Symposium - Recycling of Asphalt Materials", Proceedings, Association of Asphalt Paving Technologists, 1979, p. 238.
9. Kari, W. J., L. E. Santucci and L. D. Coyne, "Hot Mix Recycling of Asphalt Pavements", Proceedings, Association of Asphalt Paving Technologists, 1979, p. 192.