Technical Report Documentation Page

1. Report No.	2. Government Accession No.	PB80125776
FHWA-RD-78-114		

4. Title and Subtitle	5. Report Date
Installation of Incinerator Residue as Base-Course Paving Material in Washington, D.C.	December 1977
	6. Performing Organization Code
	8. Performing Organization Report No.
7. Author(s) R.D. Pavlovich, H. J. Lentz, and W.C. Ormsby	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Federal Highway Administration, Offices of R&D, Materials Division, Washington, D.C. 20590 and D.C. Department of Transportation, Materials R&D Division, Washington, D.C. 20004	FCP No. 44C1114
	11. Contract or Grant No. Staff Study
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Department of Transportation Federal Highway Administration Offices of Research and Development Washington, D.C. 20590	Interim Report June - December 1977
	14. Sponsoring Agency Code M/0476

15. Supplementary Notes

Residue processing and handling coordinated by the D.C. Department of Environmental Services.

16. Abstract

The use of municipal incinerator residue as aggregate in bituminous pavement construction was evaluated in the laboratory and in the field. A test installation, placed in Washington, D.C. in June 1977, consisted of a 4½-in.(114.3mm) bituminous pavement composed largely of incinerator residue. The base was placed in two lifts and finished over compacted subgrade. The base was covered with 1½-inches (38.1 mm) of a conventional bituminous surface course mixture.

Details of the residue production, laboratory evaluation, asphalt plant operation, placement and finishing of the test installation, and recommendations and precautions for future projects using incinerator residue are given in this report.

Preliminary results indicate that, with proper precautions, incinerator residue can be used as aggregate substitute or extender in bituminous base construction. However, even though it may be a technically viable aggregate material, its use will be determined by an interplay of economic, environmental, and energy factors.

17. Key Words	18. Distribution Statement
Incinerator residue, bituminous base, field test, laboratory evaluation.	No restrictions. This document is available through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	27	PC A03 MF A01

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

FOREWORD

This report presents results of a laboratory evaluation and field installation on the use of municipal incinerator residue in bituminous pavement base construction. Based on laboratory mix designs which incorporated large amounts of incinerator residue as aggregate, a test installation approximately 400 feet long was placed in Washington, D.C., in June 1977. Preliminary indications suggest that, properly handled, incinerator residue is a technically viable aggregate substitute or extender in base course construction. Its use, however, will be based on environmental, economic, and energy considerations.

The assistance of Dr. S. W. Forster in performing the petrographic analyses of the incinerator residue is gratefully acknowledged.

This report is being distributed to selected regional offices, division offices, and State highway agencies. Additional copies of the reports for the public are avilable from the National Technical Information Service (NTIS), Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

Charles F. Scheffey
Director, Office of Research

NOTICE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

This report covers the production and placement of approximately 400 tons (363 t) of bituminous-treated street-base using municipal incinerator residue as the major aggregate component. This project was constructed under the coordinated effort of the District of Columbia Department of Transportation (D.C. DOT), the District of Columbia Department of Environmental Services (D.C. DES), and the Federal Highway Administration (FHWA).

This installation is the fourth experimental section to use incinerator residue as a component of a bituminous road pavement. Previous projects have been constructed, and performance is being evaluated at locations near Houston, Texas, and Philadelphia and Harrisburg, Pennsylvania.

STREET LOCATION AND STRUCTURAL DETAILS

The paving location is the full width of 14th Street, SE., from W to Cedar Street in Anacostia, Washington, D.C. The street is approximately 400 ft (122 m) in length by approximately 30 ft (9.1 m) wide. The location is in a residential area with medium residential traffic and on-street parking. The reconstructed section includes curb and gutter on both sides.

Subgrade soils were not tested and classified, but they were reported to be wet clay, probably A-6, with poor drainage.

The structural section consisted of 6 in (152.4 mm) of bank run gravel subbase on the prepared subgrade. Four and a half inches (114.3 millimetres) of incinerator residue asphalt base will be surfaced with 1 1/2 in (38.1 mm) of District of Columbia Class C surface mix.

BACKGROUND ON INCINERATOR RESIDUE

Approximately 140 municipal incinerators are in operation in the U.S. which produce approximately 5 million tons (4.54 million t) of residue annually. Incineration of municipal solid waste (household trash and garbage) reduces the volume of waste by about 90 percent and the weight by about 70 percent. This remaining unburned residue presents a severe disposal problem for the agency utilizing incineration. For instance, the District of Columbia is faced with disposing of a residue stockpile of approximately 300,000 tons (272,160 t) that is accumulating at the rate of about 200,000 tons (181,440 t) annually. This annual accumulation amounts to approximately an acre (4 km^2) of ground covered by about 80 ft (24 m) of residue. There are several potential uses for this material: for embankments (fill), and in combination with binders, such as asphalt, for structural layers in pavements. This report addresses the use of residue with paving-grade asphalt cement as a binder.

Residues consist of materials that were not burned during incineration and sometimes may include fly ash that is recovered from stack effluents.

Unburned materials consist of metals, ceramics and stone, and organic matter. The amount of unburned organic material is the result of incinerator operation and management as well as the variability of incoming waste and changing weather conditions which may not permit adequate, offsetting adjustments of the incinerator operation to insure complete combustion. The approximate composition of a typical residue is as follows:

Glass:	50 percent by weight
Metals:	30 percent by weight
Ash:	15 percent by weight
Stone, Porcelain, Organics, etc:	5 percent by weight
	100 percent

Generally the residue is odorless, chemically inert, nonpolluting, and essentially structurally sound with regard to most standard criteria for natural aggregates used in bituminous base construction.

Metallic components of the residue contain, as one should expect, a rather large variety of objects such as wire, cans, metal pipe, shock absorbers, etc. Some operations recover these objects for sale to scrap outlets. Removal is by a trommel, which is a rotating slotted-drum. Gradation of the trommelled residue complies with many specifications for bituminous bases, and for cases where the material does not comply, blending with small amounts of natural aggregate will usually produce a specification aggregate.

In summary, the use of incinerator residue in pavements should be considered as a means of disposing of the increasing accumulation of residues as well as the possible augmentation of aggregate supplies in some areas where inventories of quality and economical aggregates are low.

PRODUCTION OF RESIDUE FOR THE D.C. PROJECT

The residue was produced at the District of Columbia Solid Waste Reduction Center No. 1. Fly ash stack effluent is combined with the residue at this plant. The residue was then trucked to Blue Plains and stockpiled for further processing and disposal.

The material was then trommelled to recover metals. After trommelling, most, but not all, metallic objects greater than about 2 in (50.8 mm) were removed from the residue.

For purposes of this project, the material remaining after trommelling was transported to yet another location at Blue Plains for final processing and stockpiling to await later transportation to the asphalt hot-mix plant. Final processing consisted of mixing the residue with a front end loader and dumping it onto a bar grizzly to remove particles and objects greater than approximately 1 in (25.4 mm). The finished material was graded uniformly and ready for incorporation into the final mixture. Samples were taken from this stockpile for testing at the Federal Highway Administration's Fairbank Highway Research Station laboratories.

PROPERTIES OF D.C. RESIDUE AND BLENDED AGGREGATES

The gradation of the residue (particularly the minus 200 mesh fraction (0.075 mm)) would not meet the District of Columbia specification for asphalt concrete base. Accordingly, it was decided that as much as 30 percent (by weight of total aggregate) of natural aggregate would be permitted to be blended with the residue in order to lower the fines content.

The natural aggregate was a 50:50 blend of sand and stone. The sand was Charles County concrete sand from a Waldorf, Maryland, source, and the stone was Shenandoah No. 67, dolomitic limestone, from a Millville, West Virginia, source. Aggregate data are shown in Table 1.

ASPHALT

The asphalt was supplied by the Chevron Asphalt Company. The material was an AC-20 grade, steam-reduced at the company's Baltimore, Maryland, refinery. Crude source is unknown. The material is certified to meet AASHTO M-226-73. Data in Table 2 were furnished by D.C. DOT.

MIXTURE DESIGN

Tables 3 and 4 show Marshall method data, for Mix A (98.5 percent residue, 1.5 percent hydrated lime) and Mix B (68.5 percent residue, 15 percent sand, 15 percent stone, and 1.5 percent hydrated lime). Figures 1 and 2 show the design curves for both mixtures. The job-mix formula was as follows:

Mix B

68.5 percent residue
1.5 percent hydrated lime
15.0 percent concrete sand
15.0 percent dolomitic limestone

9.0 percent asphalt cement (AC-20)
(By weight of total mixture)

Recommended Temperatures:
Mixing: 295°F - 305°F (146°C - 152°C)
Compaction: 280°F - 290°F (138°C - 143°C)

In reviewing the data in Table 4 for Mix B, it is recognized that the above job-mix formula at 9.0 percent asphalt is less than optimal, primarily because of the low air voids value of 1.8 percent which is below the lower limit of the generally accepted range of 3 to 8 percent. More desirable levels of air voids can be noted for 8.0 and 8.5 percent asphalt; however, at these asphalt contents, complete coating of the aggregate particles could not be achieved. Coatability was considered extremely important. In light of the absorptive nature of the residue and the poor drainage of the wetclay subgrade, it was desired that the mixture be as impermeable as possible to mitigate any stripping problems. Therefore, despite the low air voids obtained in the laboratory, 9.0 percent asphalt was selected for the job-mix formula. Other combinations of residue and natural aggregate - for example, a higher percentage of natural aggregate - which may have provided for optimal mixture properties were not investigated. Since field compaction is generally less than laboratory compaction (D.C. DOT specifies a minimum of 94 percent of laboratory density), it is expected that the air voids in the finished pavement would be more acceptable (higher than 1.8 percent). Further, in considering the relatively low traffic volume involved, and that the mixture is an underlying layer (not a surfacing), it would not be expected that any significant increase in density above that provided by the rollers would occur.

PLANT MIXING OPERATIONS

Asphalt Construction, Inc., of Washington, D.C., provided central plant mixing at its Brentwood, Maryland, plant. The plant is a central batch plant capable of 2 tons (1.81 t) per batch. The plant was manually controlled and was equipped with a bag house for air quality control. No major modifications of the plant were required to accommodate the incinerator residue. A small bar grizzly with openings of approximately 2 in (50.8 mm) was placed above the conveyor belt at the cold feed to remove occasional pieces of wire and stray metal. It should be noted that very few pieces of metal were removed during the course of this project.

Hydrated lime was added dry to the pugmill from bag storage. In order to facilitate production, the lime content was slightly adjusted from 1.5 percent to 1.37 percent (by weight of total aggregate) to allow the use of a single 50-lb (22.68 kg) bag of lime per batch and thus eliminate weighing. The residue content was increased to compensate for the reduced lime.

After mixing, the material was conveyed to a heated surge silo and later trucked to the pavement location. Inert gas was not used in the silo. Maximum time of storage in the silo was approximately 7 hours.

Prior to this experiment two pilot runs were made at the plant. The first run was made using residue that had not had metal removed by trommelling. Results of this run showed untrommelled residue to be unacceptable because of screen blockage by some of the metal and also because the mixed material contained wire and other metal objects that would prevent an acceptable finished surface. The second pilot run used trommelled residue and provided an orientation exercise for plant personnel. The second pilot run pointed up two areas of concern that require consideration in future residue projects. First, an unacceptable amount of dust was generated during plant operations, and second, organic matter included in the residue burned in the dryer which allowed a reduction in burner fuel requirements of the plant but changed gradation of the residue from that which was measured in the stockpile. This situation and recommendations for corrections will be more fully considered in the section on recommendations for future projects at the end of the report.

Another problem that was encountered at the plant was that the residue had a tendency to "hang up" and clog gates in the cold bins. This was only observed at the cold bins, whereas the hot bins appeared to function normally, probably because the sand reduced the internal friction of the residue. This problem can be eliminated by bin-vibrators or by manually hammering on the bin when necessary. This aspect required considerable attention and consideration because the residue had a relatively high asphalt demand, and reduction of the residue will produce batches that are highly overasphalted. Several batches on this project were overasphalted and produced mixes that would ordinarily be considered unacceptable. One characteristic of residue mixtures that should be kept in mind is that they are very sensitive to asphalt content. Anything that changes the proportions of binder-to-fines will produce mixtures that are harsh and difficult to place and finish, or that are overasphalted with consequent loss in stability. If residue cold feed bin gates are clogged and sand is not proportionally reduced, fines will be reduced, and if asphalt content remains constant, an overasphalted mixture will be produced.

PLACEMENT AND FINISHING

Placement was by the Troxler Asphalt Company of Washington, D.C., on June 14, 1977. Haul time from the hot plant to the job site was approximately 1/2 hour. A Blaw-Knox paver was followed by a steel-wheeled breakdown roller that also provided intermediate compaction. Finish-rolling was by a three-axle tandem roller per District of Columbia specifications. The 4½-in (114.3 mm) base was placed in two lifts. The project was held up for several days because of rain, and the subgrade was partially saturated when the residue base was placed.

Mixture appearance and workability were noticeably affected by temperature. At temperatures above approximately 275°F (135°C), the mixture in truckbeds appeared "fat" and very fluid and finished very easily. The finished surface at these higher temperatures was "fat" which may have been due to the combination of high temperature and reduced fines. In any event, at elevated temperatures the roller had to be held back for at least 1/2 hour to preclude shoving and lateral movement in much the same manner that is observed when tender mix problems occur. At temperatures below approximately 275°F (135°C), the mixture appeared harsh and stiff and required some effort to dump from the truck to the paver hopper. In fact, one man could not move the material with a hand rake. In spite of this apparent harshness, the material finished quite well if paver speeds were slow enough to prevent tearing by the screed. With the exception of hand-working, lower temperatures were desirable for this particular residue mixture.

On June 15, 1977, the day after placement, overasphalted ("fat") sections were removed by scraping away approximately 1/4 in (6.35 mm) with a front end loader over approximately 100 lineal ft (30.48 m) by 6 to 8 ft (1.83 to 2.44 m) wide.

PLANT-MIX AND PAVEMENT CORE EXTRACTION DATA

For illustrative purposes, plant-mix extraction data from two tests are shown in Table 5. These tests were performed by D.C. DOT plant inspectors on June 14, 1977.

Pavement cores were taken by D.C. DOT on June 23, 1977, from the section that appeared to be overasphalted as well as from the section that appeared to be normal; that is, not overasphalted. Cores with a "C" suffix were from overasphalted sections whereas those with a "W" suffix were from normal sections. Cores 2C, 3C and 4C, and 1W, 2W and 4W were from station 5 + 50, and Cores 5W, 7W and 8W were from station 7 + 75.

Data from the analysis of these cores are shown in Tables 6, 7, and 8. Analysis of extracted asphalt is based on the extract from a truck sample of mixture.

The data in Table 6 indicate that for the overasphalted section (Cores 2C, 3C, and 4C), the average minus No. 200 (9.5 percent) is lower than the 13.2 and 11.9 percent shown for the normal sections (Cores 1W through 8W). Also, from Table 7, the total of plus No. 30 natural aggregate for the overasphalted section (53.9 percent) is much higher than for the normal sections (about 37 percent) and for the original gradation and an original laboratory Marshall design specimen (about 30 percent). A sufficient number of cores were not taken to permit testing for maximum specific gravity and, therefore, air voids could not be computed. Cores will be taken from the same locations at a later date and an assessment of air voids will be undertaken.

Obviously, the possible occurrence of such variations in the gradation and material make-up of residue mixtures must be carefully considered, particularly when blending with natural aggregate where variations can occur in proportioning. Thus, variations from batch to batch in a hot-mix plant seem inevitable. Probably any air voids value reported on the basis of routine laboratory testing could be in error by at least 1 percent for conventional mixtures. This, together with the uncertainty of the composition of residue mixtures suggests that air voids may vary, perhaps 2 to 3 percent, or more.

RECOMMENDATIONS FOR FUTURE INCINERATOR RESIDUE PROJECTS

Two areas need additional consideration in future projects. These are residue production at the incinerator and mixing operations at the hot plant.

Incinerator residue properties can vary considerably with time due to several conditions that have been mentioned such as plant management; moisture content and composition of incoming solid wastes; and the method of metal recovery and later stockpiling of the residue. Reduction of this variability to reasonable limits is necessary if residue is to be used in the production of acceptable paving mixtures. Past philosophy of incinerator management has been to treat both the residue and the captured fines from the stack as a waste material that requires disposal. To realize the full potential of incinerator residue as a construction material, concepts of treating the residue as a waste should be changed to consider it as a commercial product.

One of the first considerations is product uniformity which should be relatively easy to improve at the operational level. Of major concern is the amount of combustible matter remaining in the residue that will subsequently burn in the hot-plant drier. It is not necessary that this fraction be removed, but it should be relatively constant to mitigate constant burner adjustment at the hot-mix plant. Uniformity is also necessary because burning of the material can change gradation between the stockpile and hot bins. Since mix design will usually be based on stockpile gradations and since characteristics of these mixtures are sensitive to fines and asphalt content, the amount of material that will be removed by burning should be a predictable parameter. In this connection, tests are being devised (loss on ignition, etc.) that probably can be correlated with loss through the drier.

This experiment showed that dust at the hot-mix plant occurs in sufficient quantities to be rated as objectionable. Some of these fines can be eliminated by not including captured incinerator stack fines (fly ash) in the residue. This may or may not be difficult to implement and will depend on the design and operation of the particular incinerator that is producing the residue. A secondary, but by no means insignificant, benefit of removal of these fines is that they contribute heavily to the asphalt demand of the mixture. Design asphalt content is quite high, and even slight reduction of asphalt content, at present prices, will improve the economic posture of incinerator residue in bituminous mixtures. Another aspect of dust removal and hotmix plant operation is that dust can block the photo-electric cell that controls the burner and either shut the burner off or prevent downward adjustment that will produce overheated mixtures. Finally, removal of dust will reduce the amount of natural aggregate necessary to meet gradation requirements which will further improve the economics of residue.

Another area that should receive consideration is a lime-slurry application at the stockpile. Because of the high glass content of the residue and the high probability of water stripping of asphalt from these glass particles, lime will be required as an anti-strip agent unless an adequate agent is added to the asphalt. Experience has shown that slurried-lime is more effective than dry lime as an anti-strip agent. Since incorporation of lime-slurry at the hot-mix plant is not as practical as application at the stockpile, it is recommended that provisions be made to introduce slurried-lime at the stockpile. Elaborate and complicated procedures and equipment are not necessary. After the amount of material to be treated is determined, application can be made by either a simple pump and spray arrangement or by conventional highway distributors that are readily available.

With regard to hot-mix plant operations, two areas need to be considered. First is cold feed control and second is temperature control. Cold feed control should include a vibrator to prevent bridging in the bin as well as clogging of the gate.

Vibrators are common and can be found at many plants. In view of the sensitivity of workability to temperature, particular attention should be given to its control. This problem should be mitigated by reduction of variability in the amount of fines by modified incinerator operations, but temperature control should, nonetheless, receive close attention.

Future experiments would also be more effective if adequate tonnages were involved to permit plant adjustments to compensate for material variability and plant trim. A minimum of 1,000 tons (907.2 t) appears to be a reasonable figure to insure a supply of material with low enough variability to allow for adequate evaluation of field performance of incinerator residue pavements.

LABORATORY EXTRACTION AND RECOVERY OF ASPHALT

Table 8 shows the results of physical tests on the asphalt recovered from a truck sample of mixture taken at time of placement. These results show that a normal amount of hardening of the asphalt occurred during the plant-mixing process.

PAVEMENT PERFORMANCE

Another report is planned to describe performance of this material after sufficient time has elapsed to observe behavior and performance trends.

USE OF INCINERATOR RESIDUE FOR SURFACE COURSES

Residential traffic was placed on the base before the surface was applied which afforded the opportunity to observe performance of incinerator residue as an aggregate in a surface course.

Very soon after the surface was opened to traffic, the asphalt film began to strip away from glass particles in the mixture. Sometime later, traffic started to pull the exposed glass particles away from the asphalt matrix that binds them into the mixture. The mechanism of this action has not been studied to determine whether tire action, water, or a combination of these forces is the main cause; hence, preventive measures such as additives or increased film thickness cannot be recommended. Cores taken during the performance evaluation period will be examined to determine the extent of stripping that can be attributed to water action.

Since this same stripping situation was observed at the Harrisburg, Pennsylvania, installation where residue was used in a surface course, it is recommended that incinerator residue be used only for base course construction and not be used in surface courses until solutions and preventive actions can be provided.

CONCLUSIONS

Based on this experiment and on the results of similar efforts at Houston, Texas, and Philadelphia and Harrisburg, Pennsylvania, and on the performance data being generated by the Houston experiment, municipal incinerator residue should receive consideration as an aggregate for construction of bituminous bases. While it is too early to completely evaluate performance, early indications are that the material should perform adequately for medium traffic situations.

Operations of the specific incinerator producing the residue should be considered, and attention should be given to removal of fines and the addition of slurried-lime to the stockpile. Acceptable mix design procedures and hot-mix plant control should, of course, be exercised in future use of the material.

SELECTED REFERENCES

1. "Technology for Use of Incinerator Residue as Highway Material, Identification of Incinerator Practices and Residue Sources," Federal Highway Administration, Report No. FHWA-RD-75-81, July 1975.

2. "Incinerator Residue in Bituminous Base Construction," Haynes, J. and Ledbetter, W. B., Federal Highway Administration, Report No. FHWA-RD-76-12, December 1975.

3. "Preliminary Mixture Design Information for Bituminous Base Course Containing Incinerator Residue," Smith, R. W., Federal Highway Administration, Materials Division Report, February 1976.

4. "Guidelines for the Use of Incinerator Residue in Highway Construction," Collins, R. J., Miller, R. H., and Ciesielski, S. K., Federal Highway Administration Report in Preparation, Fall 1977.

Table 1. Aggregate data.

Gradation 1/

Sieve	D.C. Residue	Sand	Stone	Hydrated Lime	Mix A 2/	Mix B 3/	D.C. Spec.
1" (25.0 mm)	100		100		100	100	100
3/4" (19.0 mm)	98		91		98	97	90 - 100
1/2" (12.5 mm)	91		50		91	86	71 - 91
3/8" (9.5 mm)	80	100	26		80	75	60 - 85
#4 (4.75 mm)	53	98	3		54	53	45 - 65
#8 (2.36 mm)	39	90	2		40	42	33 - 52
#16 (1.18 mm)	30	79	0		31	34	22 - 40
#30 (0.60 mm)	24	53			25	26	14 - 30
#50 (0.30 mm)	19	12			20	16	6 - 21
#100 (0.15 mm)	15	5			16	12	3 - 13
#200 (0.075 mm)	11.7	0		100	13.0	9.5	2 - 8

Specific Gravity and Absorption 4/

	D.C. Residue	Sand	Stone	Hydrated Lime	Mix A	Mix B	D.C. Spec.
Bulk Dry	2.174	2.601	2.821	-	2.176	2.313	-
Bulk S.S.D.	2.318	2.621	2.833	-	2.318	2.427	-
Apparent	2.541	2.654	2.856	2.343	2.538	2.597	-
Absorption, %	6.9	0.8	0.4	-	6.8	4.9	-

Calculated Surface Area 5/

	D.C. Residue	Sand	Stone	Hydrated Lime	Mix A	Mix B
Sq ft/lb	43.80	-	-	-	47.06	38.90

1 sq ft/lb = 2.04 m^2/kg

1/ AASHTO T-27, washed analysis.

2/ 98.5 percent residue, 1.5 percent lime (calculated).

3/ 68.5 percent residue, 15 percent sand, 15 percent stone, and 1.5 percent lime (calculated).

4/ AASHTO T-84 and T-85.

5/ Factors from the Asphalt Institute MS-2.

Table 2. Asphalt data.

Viscosity Grade AC-20

Specific Gravity, 77°F (25°C)	1.032
Viscosity, 140°F (60°C), poises	1893
Viscosity, 275°F (135°C), cSt	437
Penetration, 77°F (25°C)	72
Solubility, trichloroethylene, %	99.9
Flash Point, COC, °F (°C)	630 (332)
Thin-Film Oven Test:	
Loss, %	0.02
Penetration, 77°F (25°C)	45
% Original Penetration	62.5
Viscosity, 140°F (60°C), poises	4411
Ductility, 77°F (25°C), cms	100+

NOTE: Data furnished by D.C. DOT.

Table 3. Marshall design data. 1/

	Mix A 98 1/2 Percent Residue 1 1/2 Percent Hydrated Lime					Criteria
	2/	2/	3/	3/	3/	
% Asphalt (Mix Basis):	8.5	9.5	10.0	12.0	14.0	
% Asphalt (Agg Basis):	9.3	10.5	11.1	13.6	16.3	
Mix Appearance:	Dry	Dry	Dry	Good	Rich	
Bulk Specific Gravity 4/	2.018	2.057	2.065	2.076	2.050	-
Max. Specific Gravity 4/	2.209	2.182	2.169	2.117	2.067	-
Air Voids, %	8.6	5.7	4.8	1.9	0.8	3-8 6/
V.M.A. %	15.1	14.4	14.6	16.0	19.0	14 min 6/
V.F.W.A. %	43.0	60.4	67.1	88.1	95.8	65-75 7/
Unit Weight, Pcf	125.9	128.4	128.9	129.5	127.9	-
Absorbed Asphalt, %	5.7	5.7	5.7	5.7	5.7	-
Effective Asphalt, %	3.3	4.3	4.9	7.0	9.1	-
Film Thickness, microns	3.4	4.4	5.1	7.2	9.4	6.0 min 8/
Dust/Asphalt Ratio	1.40	1.24	1.17	0.95	0.80	1.2 max 9/
Stab. at 140°F (60°C), lbs	2941	2960	-	1721	1032	500 min 6,7/
Flow, 1/100"	16	16	-	22	28	8-18 6,7/
Effect of Water on Stability (24 hours at 140°F (60°C)) 5/						
Stab. at 140°F (60°C), lbs	-	2363	2186	-	-	500 min 5/
Flow, 1/100"	-	20	20	-	-	8-18 5/
Retained Stability, %	-	79.8	-	-	-	70 min 9/

1 lb = 0.4536 kg; 1 in = 25.4 mm

Notes:
1/ AASHTO T-245, 50 blows each side. Mixed at 295/305°F (146°C/152°C); compacted at 280/290°F (138°C/143°C).
2/ Average of triplicate specimens.
3/ Single specimen determination.
4/ Based on an effective aggregate specific gravity of 2.471 as measured by AASHTO T-209, Bowl Determination.
5/ Not required by T-245, but considered desirable.
6/ The Asphalt Institute, Manual Series No. 2, March 1974. (A range of 3-11 air voids is specified in 7/.)
7/ AASHTO interim guide for design of pavement structures - 1972.
8/ Campen et al., AAPT, Vol. 28, January 1959.
9/ Goode, ASTM STP No. 252, June 1959, for AASHTO T-165 Immersion-compression test.

Table 4. Marshall design data. 1,2/

	Mix B 68 1/2 Percent Residue - 1 1/2 Percent Hydrated Lime 15 Percent Sand - 15 Percent Stone					Criteria
% Asphalt (Mix Basis):	8.0	8.5	9.0	9.5	10.0	
% Asphalt (Agg Basis):	8.7	9.3	9.9	10.5	11.1	
Mix Appearance:	Dry	Sl. Dry	Good	Good	Rich	
Bulk Specific Gravity	2.186	2.195	2.201	2.198	2.194	
Max. Specific Gravity 4/	2.270	2.256	2.241	2.227	2.213	
Air Voids, %	3.7	2.7	1.8	1.3	0.9	3-8 6/
V.M.A. %	13.1	13.2	13.4	14.0	14.6	14 min 6/
V.F.W.A. %	71.8	79.5	86.6	90.7	93.8	65-75 7/
Unit Weight, Pcf	136.4	137.0	137.3	137.2	136.9	-
Absorbed Asphalt, %	3.9	3.9	3.9	3.9	3.9	-
Effective Asphalt, %	4.4	4.9	5.5	6.0	6.5	-
Film Thickness, microns	5.5	6.1	6.9	7.5	8.1	6.0 min 8/
Dust/Asphalt Ratio	1.09	1.02	0.96	0.90	0.86	1.2 max 9/
Stab. at 140°F (60°C), lbs	2878	2587	2510	2143	1837	500 min 6,7/
Flow, 1/100"	14	14	16	17	19	8-18 6,7/
Effect of Water on Stability (24 hours at 140°F (60°C)) 5/						
Stab. at 140°F (60°C), lbs	-	2172	2108	-	-	500 min 5/
Flow, 1/100"	-	17	17	-	-	8-18 5/
Retained Stability, %	-	84.0	84.0	-	-	70 min 9/
(4 days at 120°F (48.9°C)) 5,10/						
Stab. at 140°F (60°C), lbs	-	1783	1754	-	-	500 min 5/
Flow, 1/100"	-	19	19	-	-	8-18 5/
Retained Stability, %	-	68.9	69.9	-	-	70 min 9/

1 lb = 0.4536 kg, 1 in = 25.4 mm

Notes: 1/ AASHTO T-245, 50 blows. Mixed at 295/305F (146°C/152°C); compacted at 280/290F (138°C/143°C). 2/ Av of 3 specimens. 3/ Single specimen only (not applicable for this table). 4/ Based on eff agg spec grav of 2.535 per AASHTO T-209, bowl. 5/ Not required by T-245 but considered desirable. 6/ Asphalt Institute MS No. 2, Mar 1974. (Range of 3-11 voids is specified in 7/.) 7/ AASHTO Interim Guide for design of pavements - 1972. 8/ Campen et al., AAPT Vol. 28, Jan 1959. 9/ Goode, ASTM STP 252, June 1959, for AASHTO T-165 test. 10/ After immersion period, specimens were conditioned for one hour in 140°F (60°C) water bath.

Table 5. Plant-mix extractions.[1/]

Sieve	Percent Passing	
1" (25.0 mm)	100	100
3/4" (19.0 mm)	97	97
1/2" (12.5 mm)	88	90
3/8" (9.5 mm)	80	80
#4 (4.75 mm)	60	59
#8 (2.36 mm)	47	44
#16 (1.18 mm)	38	34
#30 (0.60 mm)	28	27
#50 (0.30 mm)	16	19
#100 (0.15 mm)	10	14
#200 (0.075 mm)	7.2	10.6
Time	11:10 a.m.	4:15 a.m.
% Asphalt (mix basis)	8.57	9.54
% Moisture	0.05	0.09

1/ Performed by D.C. DOT plant inspectors on June 14, 1977.

Table 6. Analysis of pavement cores.

	Station 5 + 50 (appeared normal)				Station 7 + 75 (appeared normal)				Station 5 + 50 (appeared overasphalted)			
	1W	2W	4W	AV	5W	7W	8W	AV	2C	3C	4C	AV
% Asphalt (mix basis)	9.26	8.71	8.57	8.85	6.76	7.21	8.06	7.34	8.10	8.10	8.34	8.18
Bulk Sp. Gr	2.222	2.224	2.224	2.223	2.247	2.251	2.258	2.252	2.264	2.272	2.267	2.268
					(Percent Passing)							
1" (25.0 mm)					100	100		100			100	100
3/4" (19.0 mm)	100	100	100	100	99.1	98.7	100	99.3	100	100	98.7	99.6
1/2" (12.5 mm)	94.4	94.1	93.5	94.0	90.4	91.8	89.2	90.5	91.3	92.9	94.6	92.9
3/8" (9.5 mm)	84.3	86.9	86.1	85.8	82.6	84.4	81.0	82.7	83.9	83.9	87.4	85.1
#4 (4.75 mm)	64.1	64.8	64.0	64.3	63.4	62.2	62.4	62.7	62.8	60.7	64.4	62.6
#8 (2.36 mm)	48.6	49.9	49.8	49.4	50.0	48.9	48.5	49.1	48.3	46.7	49.1	48.0
#16 (1.18 mm)	38.4	39.3	39.2	39.0	40.3	39.1	39.1	39.5	39.0	37.7	39.2	38.6
#30 (0.60 mm)	30.6	30.9	30.8	30.8	32.4	30.8	31.5	31.6	29.8	29.5	30.1	29.8
#50 (0.30 mm)	21.7	22.9	22.7	22.4	22.3	22.1	22.0	22.1	18.9	17.9	18.0	18.3
#100 (0.15 mm)	16.0	17.0	17.4	16.8	15.8	16.2	15.9	16.0	12.7	11.6	11.8	12.0
#200 (0.075 mm)	12.9	13.3	13.4	13.2	12.8	12.7	13.1	11.9	9.5	9.4	9.6	9.5

Table 7. Petrographic analyses.

Composition of Material Retained on #30 Sieve (0.60 mm)
(Percent of total)

	Incinerator Residue			Natural Aggregate		
	Glass	Non-Glass	Rock	Concrete Sand	Dolomitic Limestone	Total of Natural Aggregate 1/
Original Gradation 2/	32.5	36.8	1.2	9.6	19.9	30.7
Marshall Core 3/	39.4	30.1	1.7	10.7	18.1	30.5
Pvt Core - 4W 4/	34.6	28.6	15.5	14.5	6.8	36.8
Pvt Core - 7W 4/	35.6	26.3	18.7	12.0	7.4	38.1
Pvt Core - 2C 4/	23.8	22.3	23.5	25.0	5.4	53.9

NOTES:
1/ Includes rock listed under incinerator residue.
2/ As used for Mix B (see Table 1).
3/ After extracting asphalt from an actual Mix B laboratory core.
4/ Sampling locations shown in Table 6.

Table 8. Properties of asphalt extracted from truck sample of mixture 1/

	Mixture 2/
Viscosity, 275°F (135°C), cSt	654
Viscosity, 140°F (60°C) poises	5,083
Penetration, 77°F (25°C)	45

1/ AASHTO T 173, using reagent grade trichloroethylene.

2/ Taken at 10 a.m., 6-14-77.

FIG. 1 98.5% RESIDUE (MIX A)

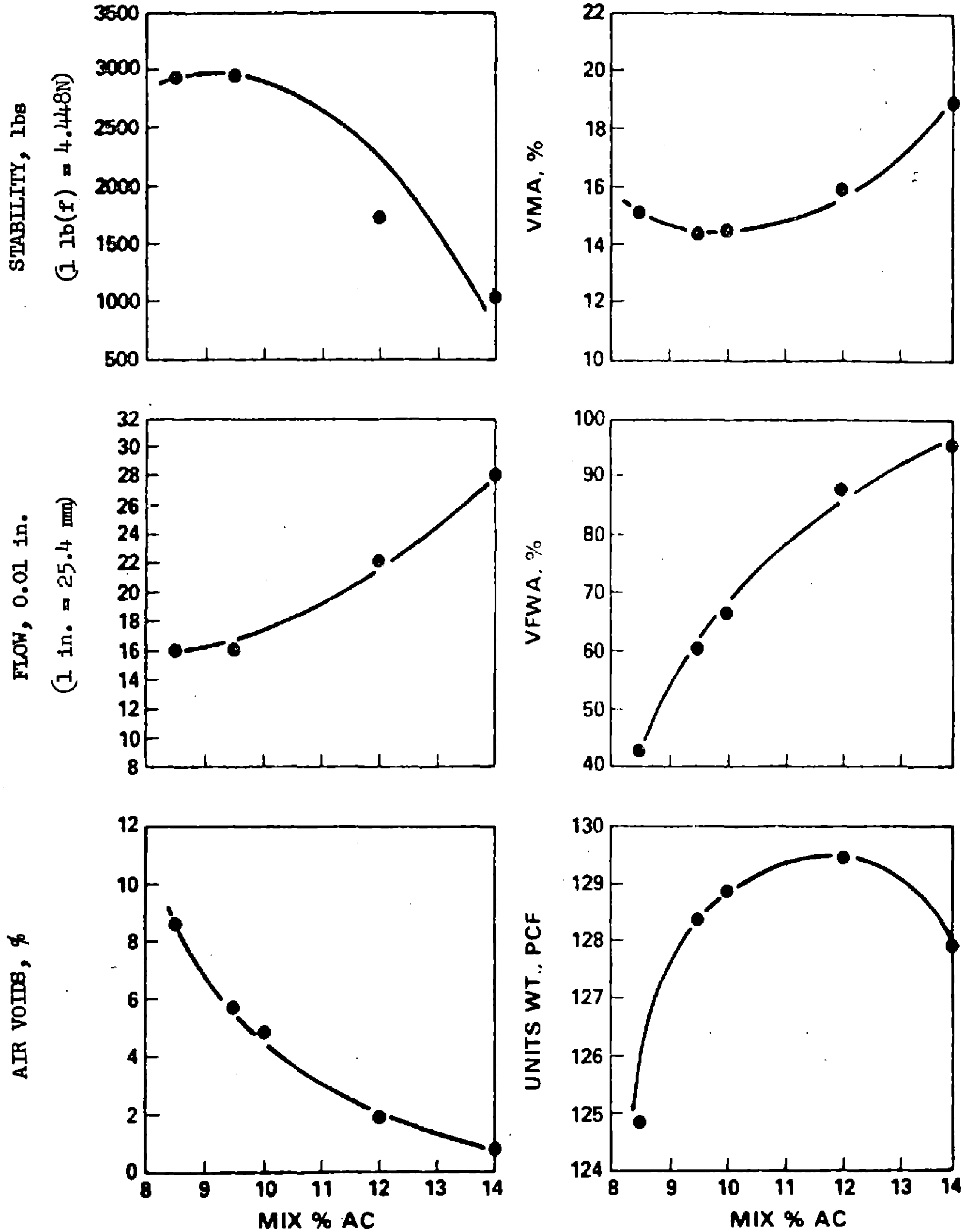
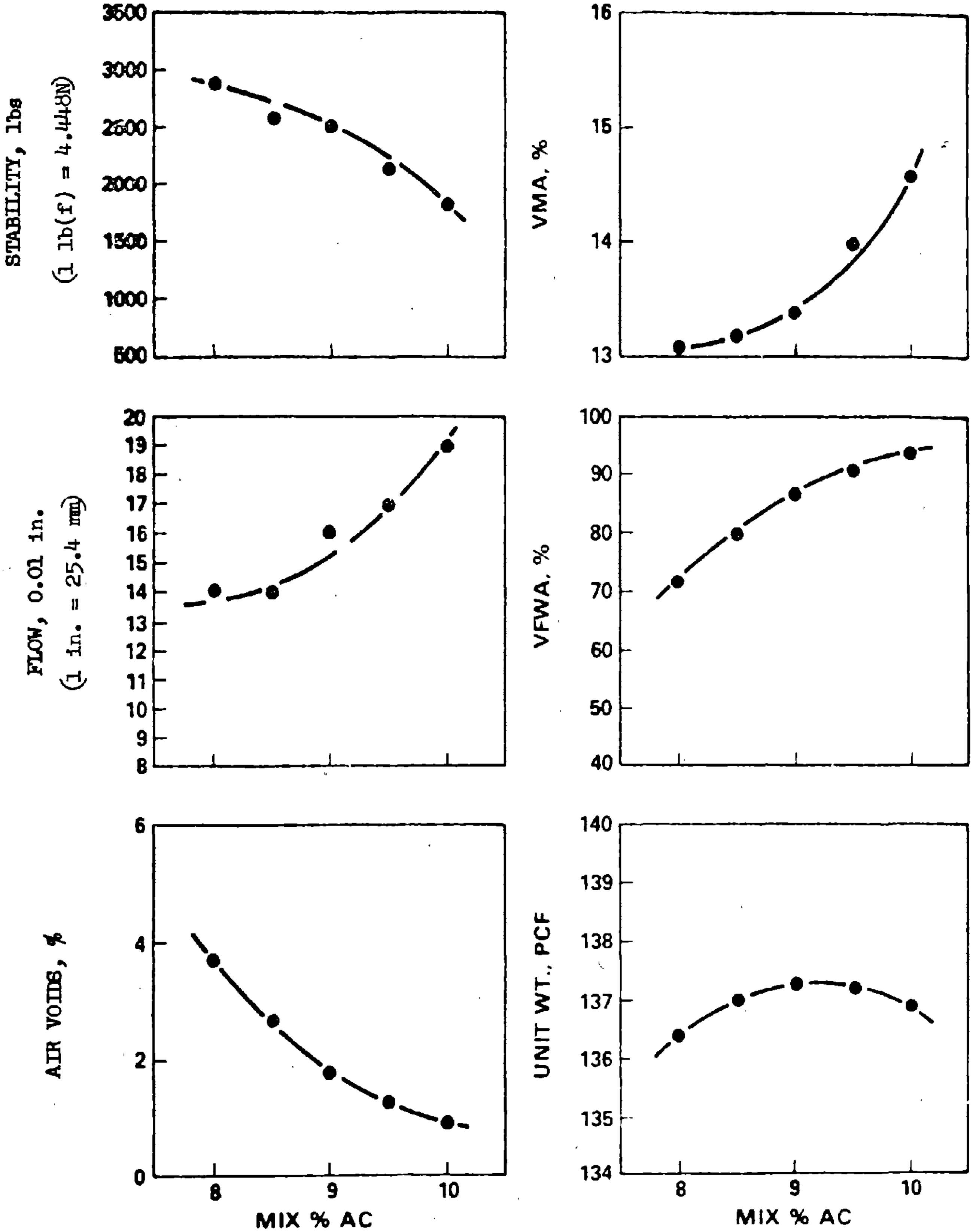


FIG. 2 68.5% RESIDUE (MIX B)



FEDERALLY COORDINATED PROGRAM OF HIGHWAY RESEARCH AND DEVELOPMENT (FCP)

The Offices of Research and Development of the Federal Highway Administration are responsible for a broad program of research with resources including its own staff, contract programs, and a Federal-Aid program which is conducted by or through the State highway departments and which also finances the National Cooperative Highway Research Program managed by the Transportation Research Board. The Federally Coordinated Program of Highway Research and Development (FCP) is a carefully selected group of projects aimed at urgent national problems, which concentrates these resources on these problems to obtain timely solutions. Virtually all of the available funds and staff resources are a part of the FCP, together with as much of the Federal-aid research funds of the States and the NCHRP resources as the States agree to devote to these projects.*

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems connected with the responsibilities of the Federal Highway Administration under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by keeping the demand-capacity relationship in better balance through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

*The complete 7 volumes are available from NTIS.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements which affect the quality of the human environment. The ultimate goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge of materials properties and technology to fully utilize available naturally occurring materials, to develop extender or substitute materials for materials in short supply, and to devise procedures for converting industrial and other wastes into useful highway products. These activities are all directed toward the common goals of lowering the cost of highway construction and extending the period of maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural designs, fabrication processes, and construction techniques, to provide safe, efficient highways at reasonable cost.

6. Prototype Development and Implementation of Research

This category is concerned with developing and transferring research and technology into practice, or, as it has been commonly identified, "technology transfer."

7. Improved Technology for Highway Maintenance

Maintenance R&D objectives include the development and application of new technology to improve management, to augment the utilization of resources, and to increase operational efficiency and safety in the maintenance of highway facilities.