Florida's Approach Using Ground Tire Rubber in Asphalt Concrete Mixtures

GALE C. PAGE, BYRON E. RUTH, AND RANDY C. WEST

In 1988, under a legislative mandate, the Florida Department of Transportation (FDOT) began a concentrated effort to evaluate the potential uses for reclaimed tire rubber in asphalt pavement construction. FDOT indicated that the most advantageous use of rubber would be as a binder modifier to improve the performance of friction course mixtures. Three demonstration projects were constructed. The field construction operations with the rubber-modified mixtures were essentially the same as those with conventional friction course mixtures. Currently all of the test sections are performing well. The optimum rubber content for dense-graded friction course mixtures has been identified as 5 percent (by weight of asphalt cement) using a maximum nominal 80-mesh ground tire rubber. It is believed that the rubber will provide improved elasticity to the binder and therefore greater resilience for these mixtures in recovery from high strains at intersections. The optimum rubber content for open-graded friction course mixtures was determined to be 12 percent (by weight of asphalt cement) using a maximum nominal 40-mesh ground tire rubber. In open-graded mixtures, the rubber has allowed a significant increase in the total binder content, which increased in the film thickness on the aggregate particles resulting in improved durability. On the basis of these demonstration projects, specifications have been developed for using ground tire rubber in friction course mixtures as a standard practice.

The provisions of Section 336.044(3) of the Florida statutes created by Senate Bill 1192 in 1988 directed the Florida Department of Transportation (FDOT) to expand, where feasible, its use of recovered (waste) materials for highway construction. Specifically, the bill directed that an investigation be conducted to determine how ground tire rubber (GTR) from recycled waste tires could be used in quality asphalt concrete mixtures for highway construction by undertaking demonstration projects as part of currently scheduled construction projects. It further stipulated that within 1 year after the conclusion of the demonstration projects the FDOT should report to the governor and the legislature on the maximum percentage of GTR that can be effectively used in road construction projects. Concurrently with this report, the FDOT should review and modify its standard road and bridge construction specifications to allow and encourage the use of GTR consistent with the findings of the demonstration projects.

The purpose of this report is to provide a concise overview of all FDOT and University of Florida activities pertaining to the development of the use of GTR in asphalt-rubber binders for specific asphalt concrete mixtures and other highway construction applications, and to document the steps taken by the FDOT to facilitate the use and quality control of this material. The term asphalt-rubber in this report is defined as a binder with GTR blended in a paving-grade asphalt cement.

G. C. Page and R. C. West, Florida Department of Transportation, P.O. Box 1029, Gainesville, Fla. 32602. B. E. Ruth, Department of Civil Engineering, University of Florida, Gainesville, Fla. 32611.

BACKGROUND INFORMATION

The first investigation conducted by the FDOT in the use of asphalt-rubber for highway construction was performed nearly 10 years before the passage of Senate Bill 1192. That project was to evaluate asphalt-rubber as a stress-absorbing interlayer and a binder for seal coat construction. A demonstration project constructed on SR 60, Hillsborough County, was used to evaluate the performance of asphalt-rubber in these applications. The results of this study are documented in an August 1980 report prepared by the FDOT for the U.S. Department of Transportation (*1*). As a result of this demonstration project, the FDOT has permitted the use of GTR in selected surface treatment and interlayer construction. In addition, FDOT currently permits the use of GTR in certain joint sealers and in railroad crossing pads.

Upon passage of Senate Bill 1192 by the 1988 Florida Legislature, FDOT personnel, in cooperation with University of Florida researchers, established and implemented a detailed plan to address the legislative mandate. The relatively short time period allocated for this investigation required concurrent activities. One primary activity was to document pertinent information from technical literature on asphalt-rubber and its application in asphalt concrete mixtures. The National Center for Asphalt Technology (NCAT) at Auburn University was selected to conduct this investigation because of the knowledge and experience of the investigators with asphalt-rubber, paving mixtures, and construction processes. Their report, dated August 1989, provided a comprehensive documentation of material properties, benefits, limitations, and recommendations for the use of GTR and asphalt-rubber binders for asphalt concrete mixtures (*2*). This state-of-the-art overview of asphalt-rubber in an asphalt concrete application confirmed and validated the direction of FDOT in the development of the subsequently constructed demonstration projects.

DEMONSTRATION PROJECT DEVELOPMENT

The purpose of the demonstration projects is to evaluate the constructibility and short-term field performance of different amounts and sizes of GTR in a number of plant-produced FDOT asphalt concrete mixtures in order to develop specifications and procedures for its use.

Current standard specifications for gradation and mixture properties would continue to be used to determine acceptable characteristics. This is a conservative approach believed to be warranted at this time, and is consistent with the legislative requirements for this investigation.

A number of decisions were made about the demonstration projects that were based on the relatively short time frame (approximately 2 years) for the development of specifications and procedures imposed by the legislation. The FDOT mixtures for the demonstration projects were limited to the friction course mixtures both dense-graded (FC-1 and FC-4) and open-graded (FC-2). This was based on two considerations:

1. Improvement in the properties of these mixtures had previously been identified as desirable: improved durability and resistance to shoving at intersections for the dense-graded mixtures, and increased binder film thickness for improved durability and aggregate retention, with improved resistance to binder drainage for the open-graded mixtures.
2. The compatibility of the GTR with the efficacy of a recycling agent (soft asphalt) to rejuvenate the existing asphalt cement in reclaimed asphalt pavement (RAP) was an unknown. Therefore only mixtures using virgin components would be included.

It was decided to concentrate on the use of fine (−80 mesh) GTR at relatively low percentages in the demonstration projects based on previous experience in the laboratory in obtaining acceptable mix properties. These initial laboratory results are not included in this report.

It was also decided to concentrate on the process under which the GTR was preblended or dispersed in the asphalt cement before mixing with the aggregates. This was done on the basis of a "common sense" approach assuming that if the GTR "reacts" or "swells" in the asphalt cement, then that process should take place under controlled conditions before mixing with aggregates in the asphalt plant.

DEMONSTRATION PROJECT CONSTRUCTION

From 1989 through 1990, three demonstration projects were constructed to evaluate the use of GTR in asphalt concrete friction course mixtures. A summary of key information for the three demonstration projects is presented in Table 1. The specification requirements for both the dense-graded friction course (FC-4) and open-graded friction course (FC-2) are shown in Table 2. Each project required a substantial preliminary effort to ensure the best possible operational conditions for production, construction, and testing of materials evaluation. This involved development of work plans, special provisions, mix designs, laboratory testing, and considerable interaction with the prime asphalt contractor and the subcontractor providing the blending of GTR with the asphalt cement. During construction, extra sampling and specialized tests were performed in addition to the standard quality-control and quality-assurance tests. A concentrated effort was required to furnish a sufficient number of qualified personnel to conduct these tests and to observe construction procedures for assessment of any problems or deficiencies.

TABLE 1 SUMMARY OF ASPHALT-RUBBER DEMONSTRATION PROJECTS

	1st Project	2nd Project	3rd Project
Date:	March 1989	June 1989	September 1990
Location:	N.E. 23 Ave. Gainesville, FL	State Road 16 Starke, FL	I-95 St. Johns Cty
Mix Type:	Dense-Graded (FC-4)	Open-Graded (FC-2)	Open-Graded (FC-2)
Test Section GTR Size/% (a)	(1) 80 mesh/3.1% (2) 80 mesh/5.3% (3) 40 mesh/11.1% (4) control/0%	(1) 80 mesh/5.3% (2) 80 mesh/11.1% (3) 80 mesh/17.7% (4) 24 mesh/20.5% (5) control/0% (6) 80 mesh/11.1%(b)	(1) 80 mesh/10% (2) 80 mesh/10% (3) 80 mesh/10% (4) 80 mesh/10% (5) Control/ 0% (6) Control/ 0% (7) Control/ 0% (8) Control/ 0%
Total Binder Content	(1) 7.1% (2) 7.3% (3) 8.2% (4) 7.0%	(1) 8.0% (2) 8.4% (3) 11.4% (4) 10.3% (5) 6.3% (6) 6.9%	(1) 7.78% (2) 7.78% (3) 7.78% (4) 7.78% (5) 6.30% (6) 6.30% (7) 6.30% (8) 6.30%
Test Section Length - ft.	(1) 3520 (2) 3656 (3) 2460 (4) 2640	(1) 2100 (2) 2532 (3) 1818 (4) 2880 (5) 1761 (6) 263	(1) 5260 (2) 5655 (3) 5513 (4) 5937 (5) 5280 (6) 5280 (7) 5280 (8) 5280

(a) By weight of asphalt cement. GTR contents originally specified as a percent of total binder.
(b) Not preblended - mixed in pugmill

The first demonstration project was constructed in Gainesville during March 1989 using a dense-graded friction course (FC-4) containing 3.1, 5.3, and 11.1 percent GTR by weight of asphalt cement. (Note: Rubber contents were originally specified as a percentage of total binder. As such, these sections contain 3, 5, and 10 percent GTR by weight of total binder. A decision was made later to specify GTR as a percentage of asphalt cement to simplify calculations. All amounts of GTR in this report are shown as a percentage of asphalt cement.) Dense-graded friction course mixtures were found to be generally more susceptible to change in binder content and particle size of GTR than open-graded mixtures. Tests conducted on the hot-mix samples with different levels of GTR indicated that the mix from Test Section 2 with 5.3 percent GTR appeared to be the mix for which the standard

TABLE 2 FRICTION COURSE MIX REQUIREMENTS

Requirements	Mix Type: Dense-graded (FC-4)	Mix Type: Open graded (FC-2)
Gradation (% passing)		
1/2	100	100
3/8	—	85-100
No. 4	---	10-40
No. 10	75-90	4-12
No. 200	2-8	2-8
Marshall Properties		
Min. Stability	500 lbs.	---
Max. Flow	8-16	---
Void Criteria		
Min. VMA	15%	---
Air Voids	12-16	---
Asphalt Content		
Min. Effective	5.0%	---

specification requirements were met, and in addition had increased resistance to shear as measured in the Corps of Engineers Gyratory Test Machine. Although all of the asphalt-rubber mixtures exhibited some degree of sticking to the pavers' screed, it was only considered excessive during paving of Test Section 3, which had 11.1 percent GTR. Otherwise, no major problems were encountered during construction of these asphalt-rubber friction courses. The data, discussion, and conclusions for this first demonstration project are contained in a separate report (*3*).

The second demonstration project was constructed on SR 16 near Starke in June 1989 with 4 sections using 5.3 to 20.5 percent GTR in an open-graded friction course (FC-2). Construction was accomplished without any significant difficulty or observable problems. Test Sections 3 and 4 with 17.7 and 20.5 percent GTR, respectively, had high total binder contents that could result in long-term performance and hydroplaning problems. The results obtained from construction of this demonstration project indicated that about 10 to 15 percent GTR can effectively be used in open-graded friction course mixtures, but the total binder content for mixtures with this rubber content should probably be less than that used in mixtures on this project. The evaluation of binder content relied to a large extent on subjective visual determinations in the field. The data, discussion, and conclusions for this second demonstration project are contained in a separate report (*4*).

The University of Florida provided technical assistance and documentation of these demonstration projects (*3,4*). A report prepared by the FDOT Materials Office (*5*) also provides a general overview and summary of FDOT involvement through the construction of the first two demonstration projects. Of primary importance to the development of draft specifications were the preliminary laboratory investigations for each of the demonstration projects conducted by the FDOT to establish asphalt-rubber blends, verify blend times, and develop mix designs. Other special studies were conducted to evaluate asphalt-rubber blending requirements and the effectiveness of extraction testing (*6*).

The third and last demonstration project was constructed on Interstate 95 during September 1990 using 10 percent GTR. The purpose of this project was to determine whether asphalt-rubber could be blended and incorporated into an open-graded friction course mixture using a prototype continuous production blending unit on a conventional construction project without encountering any problems that would contribute to construction defects or delays. The information collected on this demonstration project is documented in a technical report from the University of Florida (*7*). This demonstration project was constructed without any major technical problems. However, the blending time required to provide adequate reaction of GTR with the asphalt cement had to be increased with this prototype blending unit because of the lower-than-anticipated temperature (275°F instead of 310°F) of the asphalt cement. This indicated the need either to increase the blending unit capacity or provide additional heating for the unit to assure adequate blending to maintain hot-mix production rate at the desired 100 tons/hr.

The constructibility and short-term performance of these asphalt-rubber test pavements indicates that it is feasible to use GTR in a modified binder for friction course construction without any major change in construction operations. These projects also verified that current standard specified criteria for friction course mixtures (as shown in Table 2) could be met at design and during production for mixtures with an asphalt-rubber binder. In addition, current standard acceptance tests and criteria could be applied and met with the exception of modifying the method of measurement for the asphalt-rubber binder.

Although the long-term performance of these pavements cannot be evaluated until some time in the future, sufficient test data and corroborating information suggest that asphalt-rubber friction courses, particularly open-graded, will have improved durability over conventional friction course mixtures. This improvement is related to (a) reduced age hardening because of anti-oxidants in the rubber and increased film thickness, and (b) improved retention of aggregate because of increased film thicknesses and greater resiliency of the binder. Greater binder contents and the retention of thicker binder films on the aggregate are possible because of the increase in viscosity produced by the addition of GTR.

TYPE AND AMOUNT OF GTR IN FRICTION COURSE MIXTURES

The type of rubber currently determined to be satisfactory for use in asphalt-rubber friction course mixtures is that produced by ambiently grinding tires to a suitable fineness (*2*). Cryogenically produced rubber is not currently acceptable because the effect of its smooth-faced particles on reaction time and the material properties of the modified binder has not been evaluated.

The amount and fineness (gradation) of the GTR to be used in asphalt-rubber blends is based on the application. In dense-graded friction course mixtures, 5 percent of GTR passing the No. 50 sieve (e.g., a maximum nominal 80 mesh) is recommended. In open-graded friction courses, 12 percent of GTR passing the No. 30 sieve (e.g., a maximum nominal 40 mesh) is recommended to be blended with the asphalt cement. Open-graded mixtures are more tolerant of larger rubber particulate size and greater GTR contents. From experience of these demonstration projects, it was found that the calculations for blending are simplified if the amount of GTR is specified as a percentage of the asphalt cement rather than of the total binder.

Another application of GTR is in the asphalt-rubber binder for an asphalt-rubber membrane interlayer. In this case about 0.6 gal/yd^2 of asphalt-rubber binder is sprayed over the prepared pavement surface and uniformly sized aggregates are spread and rolled into the membrane before placement of the asphalt concrete structural layers. This asphalt-rubber blend uses 20 percent of GTR passing the No. 10 sieve (e.g., a maximum nominal 20 mesh). This provides a membrane that should seal the pavement from intrusion of moisture and retard reflective cracks, particularly for asphalt overlays of portland cement concrete pavements.

Requirements for the GTR and asphalt-rubber binder for each application are presented in subsequent sections.

BLENDING REQUIREMENTS

GTR must be blended with asphalt cement for a sufficient period of time to achieve a uniform product with fairly stable consistency (usually determined by viscosity measurements). This "reaction" time is significantly reduced when using finer GTR, softer asphalt cements, and higher blending temperatures. This was identified in FDOT laboratory blending studies as part of the demonstration projects. Another advantage of fine GTR is that the resulting asphalt-rubber blend is more homogeneous and is better suited for viscosity testing and other quality control tests than blends containing coarser GTR (particle sizes retained on the No. 30 sieve). Although "reaction" time is reduced at higher blending temperatures, holding the blended asphalt-rubber at elevated temperatures for long periods will degrade the quality of asphalt-rubber binder because of volatile loss and accelerated hardening. Field and laboratory studies by FDOT have shown that holding the blended asphalt-rubber binder at normal asphalt cement storage temperatures (300° to 350°F) does not degrade the quality of the binder for typical storage periods. These recent data, which are to be published, show that viscosity and softening point increased slightly and resilience increased four-fold during storage. It is necessary, however, to provide periodic agitation of the blended binder to present separation of the GTR.

Conventionally, GTR is packaged in plastic bags that are opened and dumped into the hopper of a feeding unit. The feed of GTR and asphalt cement into a blending unit is adjusted to achieve the desired percent GTR in the asphalt-rubber binder. The size and operation of the blending unit may differ according to the approach selected by the asphalt-rubber blending contractor. Blending at the asphalt cement terminal and shipping to the project site appear technically and economically practical. The blending temperature and reaction time requirements are given in the developmental specification for asphalt-rubber binder presented in subsequent sections.

EFFECTS ON CONSTRUCTION AND PAVEMENT PERFORMANCE

Properly proportioned asphalt-rubber binders can be used in dense or open-graded friction course mixtures without any significant effect on conventional mix production operations. However, standard asphalt metering pumps on asphalt hot-mix plants may not be adequate to handle the higher viscosity binders. Plants with asphalt weigh buckets will generally operate without any problems provided that the spray bar orifices do not restrict flow.

Conventional paving operations for friction course mixtures can be used for the paving of asphalt-rubber mixtures. Long-term performance data do not exist for asphalt-rubber mixtures, but the following performance effects are inferred. Dense-graded friction course mixtures with asphalt-rubber should tend to reduce pavement distortions at intersections in urban areas because of the improved resilient properties of the asphalt-rubber. Open-graded friction course mixtures with asphalt-rubber will tend to reduce or eliminate binder drainage from the aggregate in trucks even with increased binder contents. Increased binder in combination with the improved resilient properties of asphalt-rubber should provide improved aggregate retention and improved durability and life. Limited performance measurements of pavement friction (ASTM E 274) and rut depth have been made on the three demonstration projects and no differences have been identified attributable to the use of GTR.

The recycling of asphalt concrete pavements with asphalt-rubber friction course surfaces is not anticipated to be a problem because of the low rubber content present in the total amount of reclaimed asphalt pavement (RAP) for normal milling depths (*2*), and it is thought that the rubber has "absorbed" all the asphalt it can and asphalt demand has stabilized.

Issues of air quality and toxic fumes were not specifically addressed by FDOT in this evaluation, but data and reports from the Asphalt-Rubber Producers Group indicate that these issues are of no more concern than those for asphalt cement.

ESTIMATED GROUND-TIRE RUBBER USAGE AND COST

The estimated annual use of GTR is based on the total tonnage of open and dense-graded friction course mixtures normally used during one construction year. In addition, the asphalt-rubber membrane interlayer is included in the GTR use calculations, based on the estimated number of lane miles per year. These calculations and the yearly GTR usage projections are as follows:

	Tons Rubber/Year
Open-Graded Friction Course (FC-2)	
$640{,}000 \frac{\text{Tons}}{\text{Year}} \times 6.8\% \text{ Asphalt} = 43{,}520 \frac{\text{Tons Asphalt}}{\text{Year}}$	
$43{,}520 \frac{\text{Tons Asphalt}}{\text{Year}} \times 12\% \text{ Rubber}$	5,222
Dense-Graded Friction Course (FC-1 & 4)	
$160{,}000 \frac{\text{Tons}}{\text{Year}} \times 7.0\% \text{ Asphalt} = 11{,}200 \frac{\text{Tons Asphalt}}{\text{Year}}$	
$11{,}200 \frac{\text{Tons Asphalt}}{\text{Year}} \times 5\% \text{ Rubber}$	560
Asphalt-Rubber Membrane Interlayer	
$600 \frac{\text{Lane Miles}}{\text{Year}} \times 0.6 \frac{\text{Gal}}{\text{S.Y.}} \times 20\% \text{ Rubber}$	2,160
Pavement Marker Adhesive, Joint Filler, Railroad Crossing Pads, Guardrail Spacers	1,200
Total Estimated FDOT Usage Per Year	9,142

The total yearly generation of waste tires in Florida was estimated based on 0.75 tire/yr/capita and the 1990 population in Florida of 13,000,000. Approximately 10 lb of GTR is recovered from each tire, which results in 48,750 tons of rubber/yr.

On this basis, the FDOT can consume about 20 percent of the generated waste tire rubber in highway construction applications. Because the amount of road construction activity done by cities, counties, and developers exceeds that used by FDOT on an annual basis, it is assumed that their use of GTR would equal or exceed that of the FDOT. Therefore, the projected highway construction usage of GTR from waste tires in Florida is estimated at less than one half of the total generated per year. However, the amount of waste tires available is questionable because at the present time two major national suppliers of GTR already obtain some of their waste tire supply from Florida. Also, the roofing and tire manufacturing industry incorporate GTR in some of their products. Consequently, the exact status of usage cannot be determined unless a very detailed and comprehensive study and inventory is undertaken.

Cost estimates performed by the FDOT State Materials Office indicate that an optimistic increase in cost of $4.80/ton of mix, or about a 15 percent increase in cost, would occur when using GTR in the binder (assuming $32.00/ton of conventional hot mix). This additional cost translates into an increase in binder cost of about 70 percent. This cost estimate is based on using asphalt rubber binders for all FDOT friction course mixtures on a continuing, not an experimental, basis. It includes reasonable costs for materials and processing. It should be noted that the third demonstration project (I-95) went through the normal bid process. The bid price (yd^2) for mix with GTR was 31 percent higher than mix without. This project contained 4 lane miles with GTR in the open-graded friction course (FC-2) compared with the remainder of the project with more than 30 lane miles of FC-2 without GTR. Others have experienced substantially higher costs for specific limited experimental construction (*2*). How, or whether, this increase in cost is funded is beyond the scope of this engineering investigation but is a definite area of concern. In addition, there may be other asphalt additives that can have the same effect in these mixtures. There is a concern that they should be able to compete economically, but the direction is to specify GTR exclusively.

APPROACH TO THE DEVELOPMENT OF SPECIFICATIONS

It was necessary to develop new specifications and to revise existing specifications before attempting to use asphalt-rubber friction course mixtures in construction on a conventional production basis. Therefore, the FDOT State Materials Office prepared tentative or developmental specifications for use on these construction projects. The current draft of these specifications was prepared using the compilation of information generated during the asphalt-rubber friction course demonstration projects.

The developmental specifications are presented in the following sections. The specification for GTR for use in asphalt-rubber binder was developed with input from tire recyclers and the ASTM specification being developed on this subject. This includes physical, chemical, packaging, and certification requirements for GTR use in dense-graded and open-graded friction courses and for asphalt-rubber membrane interlayers. A requirement that GTR be produced from Florida tires was dropped on the advice of legal counsel as being restraint of trade. The specification for the asphalt-rubber binder materials, blending requirements (temperature and time), and the method of measurement was developed for GTR and the asphalt-rubber blend based on the laboratory and field testing as a part of the demonstration projects in Florida. A specification was developed for an asphalt rubber membrane interlayer, but is not included in this report. Section 337 of the *Florida Department of Transportation Standard Specifications for Road and Bridge Construction*, which pertains to Asphaltic Concrete Friction Courses, was revised to require the use of asphalt-rubber binder in friction course construction.

It should be recognized that these developmental specifications may be further revised before actual implementation with input of additional data and review. Furthermore, as experience is gained on asphalt-rubber construction projects, it is probable that some modifications to the specification will be needed to improve their effectiveness.

These specifications are not meant to be the only approach to incorporating GTR into asphalt concrete mixtures. It is a documentation of the approach taken by FDOT in using GTR incorporated into asphalt cement as a modified binder to improve specific asphalt concrete mixtures currently used by FDOT.

FLORIDA DEVELOPMENTAL SPECIFICATION FOR GROUND TIRE RUBBER

Scope

The specification controls GTR for use in asphalt-rubber binders for use in a variety of road and paving applications. The specification does not address any safety or environmental concerns associated with its use.

General Requirements

The GTR should be produced by ambient grinding methods. It should be sufficiently dry so that it is free flowing and foaming is prevented when it is mixed with asphalt cement. The rubber should be substantially free from contaminants including fabric, metal, mineral, and other nonrubber substances. Up to 4 percent (by weight of rubber) of talc (such as magnesium silicate or calcium carbonate) may be added to prevent sticking and caking of the particles.

Physical Requirements

- Gradation: when tested in accordance with ASTM C-136 using a 50-g sample, the resulting rubber gradation should meet the gradation limits shown in Table 3 for the type of rubber specified.
- Specific gravity of the rubber as determined by ASTM D-297, pycnometer method, should be 1.15 ± 0.05.
- Moisture content: maximum 0.75 percent by weight as determined by AASHTO T 255 using a controlled oven temperature of 140°F and a 50-g sample.
- Mineral contaminants: maximum 0.25 percent by weight (test method to be developed).
- Metal contaminants: none (test method to be developed).

Chemical Requirements

- Acetone extract: maximum 25 percent
- Rubber hydrocarbon content: 40 to 55 percent
- Ash content: maximum 10 percent
- Carbon black content: 20 to 40 percent

TABLE 3 GRADATIONS OF GROUND TIRE RUBBER

SIEVE SIZE % PASSING	TYPE I	TYPE II	TYPE III
10	--	--	100
20	--	100	85-100
30	--	95-100	40- 65
40	100	85-100	20- 45
60	98-100	30- 60	--
80	90-100	15- 40	5- 20
100	70- 90	5- 25	--
200	35- 60	--	--

Packaging and Identification Requirements

The GTR shall be supplied in moisture-resistant packaging such as disposable bags or other appropriate containers. Each container or bag of GTR shall be labeled with the manufacturer designation for the rubber and the specific type, maximum nominal size, weight, and manufacturer batch or lot designation.

Certification Requirements

The manufacturer of the ground rubber shall furnish the engineer with certified test results covering each shipment of material to each project. These reports shall indicate the results of tests required by this specification. They shall include a certification that the material conforms with the specification and be identified by project number and manufacturer's batch or lot number.

FLORIDA DEVELOPMENTAL SPECIFICATION FOR ASPHALT-RUBBER BINDER

Scope

This specification controls the production of asphalt-rubber binder for use in asphaltic concrete friction courses and asphalt-rubber membrane interlayers. This specification does not address any safety or environmental concerns associated with its use.

Materials

Asphalt cement: The particular grade of asphalt cement as specified in Table 4 for the respective uses shall meet the requirements of the standard specifications. The asphalt cement shall be fully compatible with the proposed GTR as determined by the State Materials Office.

Ground tire rubber: The type of GTR as specified in Table 3 shall meet the requirement of Developmental Specification on Ground Tire Rubber.

Asphalt-rubber binder: The asphalt cement and ground tire rubber shall be thoroughly mixed and reacted in accordance with the requirements of Table 4. The rubber type shall be in accordance with the approved design mix. The blending unit may be batch or continuous type and shall provide for sampling the blended and reacted asphalt-rubber binder material during normal production.

Equipment

The meter for the asphalt rubber binder shall meet the requirements for accuracy, condition, and so on, of the Bureau of Weights and measures of the Florida Department of Agriculture and such fact shall be recertified every 6 months either by the Bureau of Weights and measures or by a registered scale technician.

Method of Measurement

The GTR content in the asphalt-rubber binder shall be monitored by the department on the basis of the weight of ground rubber used versus the gallons of asphalt-rubber binder used. The weight/gal for the various types of asphalt-rubber binders included in Table 4 are to be used for these calculations.

The quantity of asphalt-rubber binder material used shall be determined by a certified meter meeting requirements as previously specified.

OTHER METHODS FOR USED TIRE RECYCLING

The use of GTR in asphalt concrete and other highway applications previously discussed will not solve the waste tire problem. Other uses for recycled tires have to be developed. A variety of products exist that can be constructed from whole tires. The U.S. Forest Service has used tire-faced retaining walls for construction of narrow mountain roads (*8*). However, this is not practical for major highway construction because of aesthetics and safety for off-road vehicular accidents. Tires have been used to control erosion along drainage channels and to stabilize highway slopes (*9*). Malaysia is currently seeking 35 million tires to use as a barrier reef (*10*). Other products such as crash barriers, playground equipment, breakwater, and installations to control soil and beach erosion can be constructed from whole used tires.

Whole tires are being used as the fuel in a power plant in Modesto, California (*11*). Tires are burned at a rate of 700/hr or about 4.5 million tires/yr to produce electrical energy. No preprocessing of the tire is apparently necessary in this operation.

TABLE 4 ASPHALT-RUBBER BINDER

USES	Dense-graded FC	Open-graded FC	Asphalt-Rubber Membrane Interlayer
Rubber Type	Type I	Type II (or I)[a]	Type III (or II or I)[a]
% GTR (by wt. of AC)	5	15	25
AC Grade	AC-30	AC-30	AC-20
Minimum Temp., °F	300	300	335
Maximum Temp., °F	335	350	375
Minimum Reaction Time	10 min.	15 min. (for Type II)	30 min. (for Type III)
Unit Weight lb/gal. *[b]	8.6 lbs	8.7 lbs	8.8 lbs

(a) Use of finer rubber could result in the reduction of the minimum reaction time.
(b) Conversions to standard 60° F are not necessary.

NOTE: The minimum reaction time may be adjusted if approved by the State Materials Office depending upon the temperature of the blend, size of the ground tire rubber and viscosity measurement determined from the asphalt-rubber binder material prior to or during production. Hold-over time of the asphalt-rubber binder material in excess of six hours will not be allowed. Any corrective action in hold over situations in excess of six hours will require the approval of the State Materials Office.

Research being conducted by the University of Wisconsin is directed toward the use of shredded tires to replace sand and gravel fills (*12*). Potential benefits include reduced weight of fill constructed with rubber chips and soil, conservation of mineral aggregates, and elimination of some of the 20 million discarded tires in the state of Wisconsin. Small quantities of metals in the leachate from these fills apparently are too small to affect the groundwater.

Shredded tires have been successfully burned as a fuel in power plants, in cement kilns, in pulp and paper production, and by tire manufacturing facilities (*10*). Generally a "fluidized bed" burning system is required to achieve sufficiently high temperatures for combustion of the rubber. Often a combination of fuels is used that promotes efficient burning and reduced emissions. Although this is technically feasible, modern scrubber systems are necessary to remove particulate and undesirable emission such as sulfur dioxides and nitrous oxides.

Crumb rubber can be mixed with other materials and processed to make mud guards, floor mats, carpet padding, adhesives, new tires, or other rubber products (*10*). However, a Minnesota company established recently to produce rubber products from crumb rubber could not achieve the quality desired by its customers. Their inability to meet the purchaser's specifications apparently led to bankruptcy.

In summary, the solution to the waste tire problem needs to be a comprehensive one.

REFERENCES

1. K. H. Murphy and C. F. Potts. *Evaluation of Asphalt-Rubber as a Stress-Absorbing Interlayer and as a Binder for Seal Coat Construction (SR-60 Hillsborough County).* Demonstration Project 37, FHWA-DP-27-14, June 1980, pp. 1–28.
2. F. L. Roberts, P. S. Kandhal, E. R. Brown, and R. L. Dunning. *Investigation and Evaluation of Ground Tire Rubber in Hot-Mix Asphalt.* National Center for Asphalt Technology, Auburn University, Alabama, Aug. 1989, pp. 1–172.
3. B. E. Ruth, S. Sigurjonsson, and C. L. Wu. *Evaluation of Experimental Asphalt-Rubber, Dense-Graded, Friction Course Mixtures: Materials and Construction of Test Pavements on N.E. 23 Avenue, Gainesville, Florida.* Technical Report, U. F. Project 4910450426912, Department of Civil Engineering, University of Florida, May 1989, pp. 1–161.
4. B. E. Ruth. *Evaluation of Experimental Asphalt-Rubber, Open-Graded, Friction Course Mixtures: Materials and Construction of Test Pavements on State Road 16.* Technical Report, U.F. Project 4910450426912, Department of Civil Engineering, University of Florida, Nov. 1989, pp. 1–56.
5. G. C. Page. *Florida's Initial Experience Utilizing Ground Tire Rubber in Asphalt Concrete Mixes.* Research Report FL/DOT/M089-366, Florida Department of Transportation, Materials Office, Tallahassee, Sept. 1989, pp. 1–31.
6. R. C. West and J. A. Musselman. *Extraction Testing of Asphalt Concrete Mixtures Containing Ground Tire Rubber.* Bituminous Materials Study 89-4, Florida Department of Transportation, Materials Office, June 16, 1989, pp. 1–7.
7. B. E. Ruth. *Documentation of Open-Graded, Asphalt-Rubber Friction Course Demonstration Project on Interstate 95, St. Johns County.* Technical Report, U. F. Project 4910450429812, Department of Civil Engineering, University of Florida, Gainesville, Dec. 1990, pp. 1–28.
8. G. Keller. Retaining Forest Roads. *Civil Engineering*, American Society of Civil Engineers, Dec. 1990, pp. 50–53.
9. G. Berthelsen. Erosion Control. *AASHTO Quarterly*, April 1989, pp. 6–7.
10. R. A. Sapek. *National and International Industries Using Recycled Paper, Plastics, Used Oil, and Used Tires.* Report prepared for the Florida Department of Commerce, Department of Public Administration, University of Central Florida, Orlando, June 30, 1990, pp. 219–234.
11. Promotional Literature, The Oxford Energy Company, New York, N.Y., 1990.
12. T. B. Edil, P. J. Bosscher, and N. N. Eldin. *Development of Engineering Criteria for Shredded or Whole Tires in Highway Applications.* Interim Report to the Wisconsin Department of Transportation, The University of Wisconsin, Madison, June 1990, pp. 1–19.