

# **Center for By-Products Utilization**

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Report No. CBU-1991-02  
January 1991

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# Utilization of Discarded Tires as Construction Materials for Transportation Facilities<sup>1</sup>

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## ABSTRACT

Several technologies established for tire utilization were reviewed in order to determine the best use of discarded tires. The technologies reviewed were retreading, reclaiming, splitting, combustion, pyrolysis, use in breakwaters, erosion control structures, reefs, pavements, general construction materials, etc. Based on the information collected, it was concluded that the use of discarded tires in construction of pavements, erosion control structures, reefs, impact absorbing products, etc. were viable alternatives to dumping of discarded tires. In addition, the use of tire rubber in the construction of rubberized pavements is extensively reviewed. A recommendation is also made for use of tire rubber in new construction materials suitable for highway construction applications.

## 1.0 INTRODUCTION

Scrapped tires are produced in the U.S. at an annual rate of 300 million, approximately one tire per year for each person in the country. Less than 30% of these tires are utilized for resource and energy recovery [1]. The remaining tires are either land filled, added to the tire piles, discarded or destroyed in an environmentally unacceptable manner. At the present time, landfilling is the major technique for scrap tire disposal in the country.

Scrap tires used as landfills pose health, safety, and handling problems. Since tires do not degrade biochemically, they tend to rise up through the landfill and become uncovered as the fill settles. This provides an excellent breeding environment for vermin and mosquitoes. Therefore it has become highly essential to develop technologies for large-scale volume utilization of discarded tires in order to derive both ecological as well as economic advantages.

Scrap tires are primarily composed of natural rubber, steel, synthetic rubber, and other materials such as carbon black, fabrics, and inert filler. Scrap tire components are given in Table 1 and their chemical composition is presented in Table 2.

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<sup>1</sup> For presentation at the 70th Annual Meeting of Transportation Research Board, Washington, D.C., January 1991.

Table 1: Scrap tire components [2]

Component	Weight Percent
Rubber	50
Carbon Black	27.5
Oil	17.5
Ash	5

\* Average heating value of tire is 15,000 Btu/lb. (35kJ/g)

Table 2: Scrap tire chemical composition [2]

Element	Weight Percent
Carbon	83
Hydrogen	7
Oxygen	2.5
Sulfur	1.2
Nitrogen	0.3
Ash	6

## 2.0 COLLECTION AND PROCESSING OF TIRES

Most post-discard utilizations require collecting and transporting tires to the site of storage, disposal, use, or processing. Several types of uses of discarded tires require size reduction to make the material easier to handle. Size reduction can be accomplished by either mechanical or cryogenic devices. The latter technique generates a relatively small particle, whereas the former technique produces a range of shredded sizes. Mechanical shredders can reduce whole tires to pieces varying in sizes up to 100 mesh powders. In the cryogenic shredding process, whole scrap tires or coarse shreds are cooled below the glass transition temperature of rubber  $-62^{\circ}\text{C}$  ( $-80^{\circ}\text{F}$ ). As a result, the tire or coarse shreds become brittle, and are easily shattered in a hammermill to 16 - 24 mesh pieces (2).

## 3.0 TECHNOLOGIES FOR TIRE UTILIZATION

Various technologies are used to derive resource and energy from discarded tires. These include (1) retreading, (2) splitting (3.) combustion, (4) pyrolysis, (6) reuse of tires as rubber, (6) reuse of tires in pavements, and (7) miscellaneous uses.

In retreading, tire carcasses are passed through a recapping system in order to install new treads on them. Tire splitting involves removal of the bead wire by cutting or stamping, and the tread is cut and peeled off the tire carcass [3]. The remaining carcass, which is a tough, durable, fabric reinforced rubber sheet, is divided into three sections, the crown or tread and two sides. These carcass sections are planed to uniform thickness. They are then placed in a press, which can be die cast into desired shapes. The products derived from splitting industries include gaskets, seals, automotive tailpipe insulators, doormats, etc. Both retreading and splitting consume a low-volume of tires.

Reuse of tires as rubber is comprised of production of rubber by using a reclaiming process. The reclaiming process is referred to chemical or thermal devulcanization of the rubber resulting in rupturing the carbon-sulfur bonds that cross link the molecular chain [4]. The reclaimed rubber produced by this process can be blended with virgin rubber in production of tires and rubber products. The process is suitable with natural rubber or synthetic polyisoprene. However, this process is not well suited for styrene-butadiene rubber, which is the major component of most tires [4].

Scrap tires either as a whole or shreds have been burned to recover energy. Tires are a high Btu material, approximately three times the energy of municipal wastes and equivalent to the heat value of high-grade coals. Several combustion technologies are available to recover the heat energy from tires which meet emission requirements of coal fired boilers at present [2]. Under a more strict regulation, which is expected to be promulgated in the near future, combustion of tire may not meet the emission requirements. Therefore combustion of discarded tires is not a viable alternative.

Pyrolysis is a process of breaking organic chemical bonds by heating. It is also termed destructive distillation, thermal depolymerization, thermal cracking, carbonization, and cooking [4,5]. During the pyrolysis process, the organic polymers decompose to oil and gas, whereas inorganics such as fiberglass, Steel and carbon blacks remain unchanged. Tire pyrolysis is a well-established technology [4]. This technology has a great potential to utilize most of the scrap tires generated in this country. However, fluctuations in the oil, gas, crumb rubber, and char markets lead to uncertainty in future economic gains and planning for the industry. Unless a more economic pyrolysis process is developed in production of high-quality oil and char, there is not much hope that this technology will have an appreciable impact on tire recycling.

Scrap tires have been utilized in manufacture of artificial reefs, erosion control structure including breakwaters, etc. However, performance data on these uses are very limited. Further research efforts are needed to establish data for design and economical analysis purposes. Current research is also underway in Wisconsin. A great deal of research work has been done regarding the use of discarded tires in construction materials, especially in pavements. Since this paper is primarily concerned with the use of tires in pavements and construction on material, these topics are covered in detail in the following sections.

#### 4.0 USES OF TIRES IN PAVEMENTS

Various forms of rubber have been used in pavement construction. These include natural and synthetic latex and natural synthetic and reclaimed rubber powders. The quantity of rubber powder used in pavements has been found to vary between 5 to 30% of the asphalt used [6].

Numerous terms have been used to describe the rubber modified systems. The most commonly used terms are asphalt-rubber and rubber filled systems [7]. In asphalt-rubber system, asphalt is pre-blended with tire rubber, whereas in the case of rubber-filled systems the rubber is added dry to the asphalt concrete mixtures. In asphalt-rubber systems, the rubber is premixed with liquid asphalt at an elevated temperature. The new binder material can be used in the same fashion as conventional asphalt. When the binder is sprayed on to the surface and followed by distribution and rolling of cover aggregate, the resulting material is called a seal coat, chip seal or surface treatment. This treatment, when applied between layers of pavement to restrict the reflection cracking is termed an interlayer. When asphalt alone is used as a liquid binder and mixed with fine and coarse aggregate, it is called asphalt concrete. This concrete is called asphalt concrete friction course in the cases where it is used on the surface to increase friction. Rubber-filled systems are used in asphalt concrete and asphalt friction courses. This system causes substantial reduction in construction cost compared to asphalt-rubber systems, which involves pre-blending operations.

A special type of rubber-filled system, called Plus-Ride, was developed in Sweden in the 1960's. In this system relatively large shredded tire particles (1/16 - 1/4 inch) are in the mixture as a partial replacement of an aggregate, which requires preblending [7]. A typical mix incorporates 3 to 4% rubber by weight of the total mix. This requires the amount of asphalt used in the mix to be increased from 4 to 6% in a conventional mix to 7 to 9 percent for a Plus-Ride mix [7].

A large number of studies have been directed toward the evaluation of performance of rubberized materials and pavements. Research work related to the use of rubber in pavement has been done for a long time. The related work can be traced as early as 1884 [6]. Clinebell and Strank [6] reviewed extensively the early research work on rubberized pavements and materials. Based on the information collected, they reported that the use of rubber in asphalt material resulted in decreased softness at high temperatures and reduced brittleness at low temperatures. They also reported that a rubber road after an extremely severe winter in the Akron, Ohio area suffered less damage as compared to the non-rubberized pavements [6].

Studies have shown that addition of rubber affects the properties of bituminous mixtures considerably [1]. Among the various advantages claimed for rubber-bituminous mixture are better stability, moisture sealing, anti-skid properties, reduced maintenance expense, and dustless surface. The rubber powder added to bitumen reduces the influence of temperature and therefore the rubber bituminous mixture is less susceptible to temperature variations. It has been observed that a seal coat of the rubber-bituminous mix is particularly effective in preventing water from seeping down through the surface. Addition of rubber increases the friction between tires and a bituminous surface, which results in improved anti-skid properties, especially at high speeds.

Thompson [8] reported that the addition of a few percentage points of rubber caused marked increases in elasticity, reduction in temperature susceptibility, marked deviation from Newtonian flow and increased resistance to fracture. Full-scale road tests showed that inclusion of rubber to the road surface improved the performance considerably. The surface-dressing rubber prevented "fattening" up in hot weather conditions under heavy traffic, and cracking in mastic asphalt and rolled asphalt was reduced or eliminated entirely by the addition of the rubber.

A substantial amount of work has been done by the City of Phoenix and the Arizona Department of Transportation (ADOT) in the area of rubberized pavements [2,9]. In this work, mixtures of 25% crumb rubber of 25-40 mesh and 75% asphalt by weight is heated to 375 °F (190 °C) for 20 minutes. The rubber particles swell to approximately twice their original volume and become softer and highly elastic. A small amount of kerosene (5.5 - 7.5%) is added to temporarily reduce the mixtures viscosity. The resulting asphalt was used for road surfacing applications with little or no equipment modifications. The material can be utilized as a chip seal coat, stress-absorbing membrane (SAM) [2] in order to resist fatigue crack formation in the road surface. A thin layer of the material, less than 0.2 in., is sprayed over the road surface in which small rock chips can be added. In this application, 0.35-0.4 gallons (2.6-3.0 lb) of asphalt is replaced with 0.5-0.6 gal (3.8 - 4.5 lb) asphalt-rubber per square yard. The total cost increased from \$0.65/sq.yd. to \$1.10/sq.yd. However, the increased life span of asphalt-rubber pavement would result in substantial savings over the conventional asphalt roads. The roads treated with rubber-asphalt mixtures have been found to last 2 to 5 times as long as those treated with conventional asphalt sealer [2,9]. A road surfaced with a thin layer of asphalt-rubber 0.11 in. (0.6 gal. /sq.yd.) plus a 2 in. of asphalt concrete was found to be as durable as one with a 7 in. asphalt concrete overlay [2]. The use of asphalt-rubber has also been in sealing cracks and joints in pavements. A rubber-asphalt using 20% reclaim lasted two to three times as long as conventional asphalt sealers [9].

Chamberlin and Gupta [7] reviewed the previous studies related to performance of rubberized pavements constructed in U.S.A. during the period 1977 through 1984. They summarized the results of these studies as follows:

Out of 50 projects conducted, about one-half of the projects showed no significant differences between the performance of asphalt-rubber seal coats and convention asphalt materials. Less than 20% of experimental asphalt-rubber pavements outperformed conventional asphalt pavements. In remaining 30% projects, the rubberized systems showed worst performance.

Performance of asphalt-rubber interlayers were compared with conventional asphalt material in 90 different projects. About 50% of the projects showed identical results for both the materials. Nearly 20% of the projects showed better results in the case of asphalt- rubber pavements.

Of the total 54 projects considered, in about 30% of the projects rubber-filled asphalt concrete out-performed the conventional asphalt concrete pavements. Only three projects showed inferior results for the rubberized systems.

Since only a limited number of projects conducted were related to performance of asphalt-rubber friction courses, asphalt-rubber concrete, and rubber-filled friction course treatments, no general conclusions could be drawn in regard to their performance.

The poor performance of the rubberized pavements compared to conventional asphalt pavement was primarily attributed to deficient construction practices rather than to fundamental deficiencies of the rubber-modified materials. Performance of rubberized pavements is expected to improve with experience in use of rubber-modified materials.

Economic analyses have shown that the installation cost of rubberized roads is higher than that for conventional asphalt pavements. The service life of rubberized roads has to be two to three times higher than that of conventional asphalt pavements in order to recover their higher first cost [7]. However, the cost is expected to decrease with improvement in processing and application techniques of the rubberized materials. The rubber-asphalt mixture using granulated and graded crumb has been used in the U.S. since the late 1970's. This type of mixture was used to improve various properties of pavements including noise reduction, fatigue properties, better skid resistance, and deicing ability resulting from increased flexibility [7,10]. Lundy et. al. [10] compared performance of rubber-modified asphalt mixtures with that of conventional asphaltic mixture. Both laboratory and field experiments were conducted. Analysis of test data showed that: (1) modulus of elasticity of both the rubber-modified and control mixtures was found to increase with time; (2) tensile strength tests indicated that the control had greater strength; (3) roughness of the rubber-modified pavements was slightly higher; and (4) laboratory tests showed that fatigue life of the rubber modified mixture exceeded those of the conventional mix by 25 to 75% depending upon strain levels.

Doty [11] described investigations concerning performance of rubberized pavements. The various systems investigated were: (1) dense graded asphalt- rubber blend marketed by the Arizona Refining Company, both with or without a stress absorbing membrane interlayer (SAMI); (2) PlusRide DGAC, both with or without a SAMI; (3) single and double absorbing membranes (SAM's) containing as described in (1); and, (4) a double stress absorbing membrane (SAM) containing the binder marketed by Sahuaro Petroleum in the early 1980's. Conventional dense graded concrete pavements were also constructed to compare their performance with the results obtained from the rubberized systems. This paper described the results of an ongoing research program. The long-term performance data are yet to be obtained. The results showed that initial stiffening effect of the asphalt-rubber overlays was equal to or greater than that of equivalent thickness of conventional dense graded asphalt concrete. Tolerable deflection of the asphalt-rubber was greater compared to DGAC. This revealed that life span of the asphalt-rubber overlay would be comparatively longer. The results obtained on a few thin overlays indicated that the asphalt- rubber overlays had higher resistance to crack in comparison to the conventional DGAC overlays. The results further showed that there is no significant advantage offered by double SAMs when compared to single SAMs.

More recently, in France, a weather-resistance base for gravel covered mountain roads has been developed [12]. In order to construct the base, the rolling surfaces, are removed from sides of the tires and clamped together in a subsurface layer over fill and the surface is finally covered with

gravel. This type of base can consume about 10,000 tires per kilometer of road. Such roads do not require frequent resurfacing.

## 5.0 USE OF TIRES IN CONSTRUCTION MATERIALS

Tire rubber is known to have good shock and vibration absorbing capacity. Therefore, inclusion of tire rubber in construction material would enhance their shock and vibration absorption capacities.

Asphalt containing rubber has been utilized in several types of asphaltic applications including tennis courts, basements, floors, tiles, roofs, adhesives, waterproofing, and expansion joints, etc. [6]. Tire rubber has a great potential for use in these applications. Tires have also been used as a protective barrier in highway bridges.

Tire chips can be used as an ingredient of various new materials for the following applications, which are investigated currently.

- (1) It can be used in manufacture of asphaltic blocks. These blocks can be used in construction of slope pavements under highway bridges and other similar applications. Also, asphaltic blocks can be used in construction of sidewalks.
- (2) Tire chips can be used in manufacture of crash barriers on highways.
- (3) Tire chips can be used in manufacture of railroad ties.
- (4) Tire chips can be used in elastic foundation to dampen vibrations. This includes the use of tires in soil base of railroads, highways, airport structures, etc.
- (5) Tire chips can be as a partial replacement of aggregates for low-strength concretes in manufacture of parking stops and other low-strength concrete materials.

## 6.0 SUMMARY AND CONCLUSION

This study was carried out to determine constructive use options of discarded tires. Various technologies concerning use of discarded tires reviewed were retreading, splitting, reclaiming, combustion, pyrolysis, construction of breakwaters, erosion control structures, reefs, pavements, general construction material, etc. Analysis of the information gathered indicates that discarded tires have a great potential for being utilized in manufacture of pavements, erosion control structures, reefs, breakwaters, impact absorbing material, etc. This paper primarily describes the use of discarded tires in rubberized pavements and materials. Tire rubber can be used as an ingredient of construction materials, including impact absorbing materials. This includes use of tires in several asphaltic application such as roofs, basements, water proofing, expansion joints, etc., elastic foundations, railroad ties, crash barriers, etc.

A great deal of research work has been conducted in the design and performance of rubberized pavements. Studies conducted in several foreign countries as well as in U.S.A. have shown that addition of rubber improves the properties of bituminous mixtures considerably. Among the various advantages claimed for rubber bituminous mixture are better stability, moisture sealing, anti- skid properties, reduced maintenance expense, dustless surface, etc.

Tire rubber has been used extensively in construction of flexible pavements in several foreign countries. However, the use of rubberized roads is very limited in U.S.A. This is due to fact that the installation costs of rubberized roads are significantly higher than that of conventional asphalt pavements. Additionally, a large number of experimental pavements did not show appreciable improvement in the performance compared to convention asphalt materials, and in a few instances inadequate performance was obtained in the case of rubberized systems. Poor performance of rubberized roads was probably due to deficient construction practices and limited experience in the use of rubberized materials. It is anticipated that performance of rubberized roads will improve with additional research and increased experience in use of such materials under cold climate or other conditions. It is also expected that with further development and optimization of technical aspects and construction practices many, if not most, applications of rubber in pavements construction will become economical.

## 7.0 LIST OF REFERENCES

- (1) Naik, T.R. and Singh, S.S., "Utilization of Scrap Tires", Center for By- Products Utilization, Report No. CBU-1990-04, Department of Civil and Engineering Mechanics, University of Wisconsin-Milwaukee, April 1990.
- (2) Graines, L.L. and Wolsky, A.M., "Discarded Tires: Energy Conservation Through Alternative Uses", A technical report to the U.S. Department of Energy, December 1979. 1.
- (3) Environmental Protection Agency, "Rubber Reuse and Solid Waste Management", A technical report, Part 1, Part 11 and 111, U.S. Environmental Protection Agency, 1971.
- (4) Dodds, J., Domenico, W.F., Evans, D.R., Fish, L.W., and Toth, W.M., "Scrap Tires: A Resource and Technology Evaluations of Tire Pyrolysis and Other Selected Alternate Technology", A technical report, U.S. Department of Energy, Idaho, November 1983. -, Hazmatworld,
- (5) Roy, K.A., "The Less Traveled Roads to Scrap Tire Disposal" November 1988, pp. 41-44.
- (6) Clinebell, B.J. and Stranka, L.E., "A Survey on the Use of Rubber in Bituminous Pavements: 1945-1951", Rubber Age, October 1951.
- (7) Chamberlin, W.P., and Gupta, P.K., "Use of Scrap Automobile Tire Rubber in Highway Construction", Special Report 85, Engineering Research and Development Bureau, New York State DOT State Campus, Albany, New York, May 1986.
- (8) Thompson, P.D. "The Effects of Natural Rubber on Road Binders and Their Contribution to Improvements in Road Surfaces", Road International, Vol. 192, December 1964. 1.
- (9) Morris, G.R. and McDonald, C.H., "Asphalt-Rubber Stress Absorbing Membranes, Field Performance and State of the Art", Reprinted from Transportation Research Record #595, 1976. 0.
- (10) Lundy, J. R., Hicks, R.G., and Richardson, E., "Evaluation of Rubber- Modified Asphalt Pavement Performance - Mt. St. Helens Project", Presented at the Annual Meeting of the Association of Asphalt Paving Technologists, Reno, Nevada, February 1987.
- (11) Doty, R.N., "Flexible Pavement Rehabilitation Using Asphalt-Rubber Combinations", A Progress Report, California Department of Transportation, Sacramento, CA, January 1988. .2.
- (12) World Wastes, "Old Tire Makes Roads", April 1990, pp.34.