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Evaluating Geotechnical Engineering Properties of Sandy soil using Granulate Waste Tires

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ABSTRACT

Used tires and scrap materials is environmental issue, cause and contribute to economic difficulties. It was required to find a safe ways to lower the harm. This study was to study the impact of granulate waste tires as additive on the mechanical properties of silty sand soils through laboratory tests. Different percentages of granulate waste tires mixed added in 5%, 10%, 15% and 20% by a dry weight and the change in index properties were examined. It was noticed that there was a decrease in specific gravity from 2.57 to 2.04 at 20% whereas the California Bearing Ratio values of soaked and unsoaked condition decreased from 27% to 12% and from 37% to 10%, respectively as the granulate waste tires increased to 20%. Direct shear test results indicated that adding of granulate waste tires increased friction angle from 30.34^{o} at 5% to 36.3^{o} at 20% and reduced the cohesion values from 2.94 kPa to 0 kPa at 0% and 20%, respectively. Modified Proctor and vibrating compaction tests reveal that a little reduction in the maximum dry density as the waste tires increased by limiting the content of up to 20%. It is recommended to use the materials in construction projects such as low traffic road, car parking, and lightweight fill material behind retaining wall, reduces its impact on environment disposal of this hazardous harm waste material.

Keywords: *Silty sand; granulate waste tires; waste material;*

1. Introduction

Solid waste tires and scrap materials are a significant environmental issue, cause and contribute to economic difficulties worldwide. To mitigate and reduce the harms on environmental, it is necessary to find a safe ways to reduce these harms on the economy and the environment. Many researchers recommend doing several investigation on this difficult task [1].

In the United States 1994, over 2 billion used tires were stockpiled and these stockpiles generation is continue increase at a rate of 200 to 250 million tires per year [2]. Approximately 250 million tires are discarded in the United States each year, and by 1998 five billion tires are stockpiled [3], and in another study since the automobile, scrap tire stockpiles have begun to grow and increasingly large amount of waste tires grow in the United States. That is probably one of the major environmental problem faced United State every year. Different methods used to reduce the wastes including burning, and recycling or reusing them. Some of the methods, such burial of wastes lead and affect a significant threat to our environment such as pollution and occupation of the lands suitable for agricultural and industrial activities [4].

Researchers are working and conducting various physical and chemical approaches such soil improvement methods to minimizing environmental hazards associated with grow up amount of waste. [5].

2. Objectives

This research was to evaluate the impact of crush discarded tires as additive on the mechanical properties of silty sand soils (SP-SM) through laboratory tests.

3. Properties of Materials

3.1 Sandy Soil

The sandy soil used in this study was collected from Janzour city, located at north-western of Libya at a depth of about 0.5 m below the ground level from the site as disturbed soils, and according to the USCS (Unified Soil Classification System), the soil type is classified as poorly graded sand with silt (SP-SM) and consists of 91.4% sand and 7.4% finer particles that yielded by sieve analysis (dry and washed) as shown in Figure 1. Some physical properties such as specific gravity, maximum dry density, optimum moisture content and shear strength of the soil were determined according to ASTM [7, 8, 9, 10, and 11]. The basic physical and mechanical properties of these soils are presented in Table 1. This soil was chosen so that the scrap materials will contribute to reducing the cost of construction with no effect on mechanical properties and solving disposal problems of these harm materials.

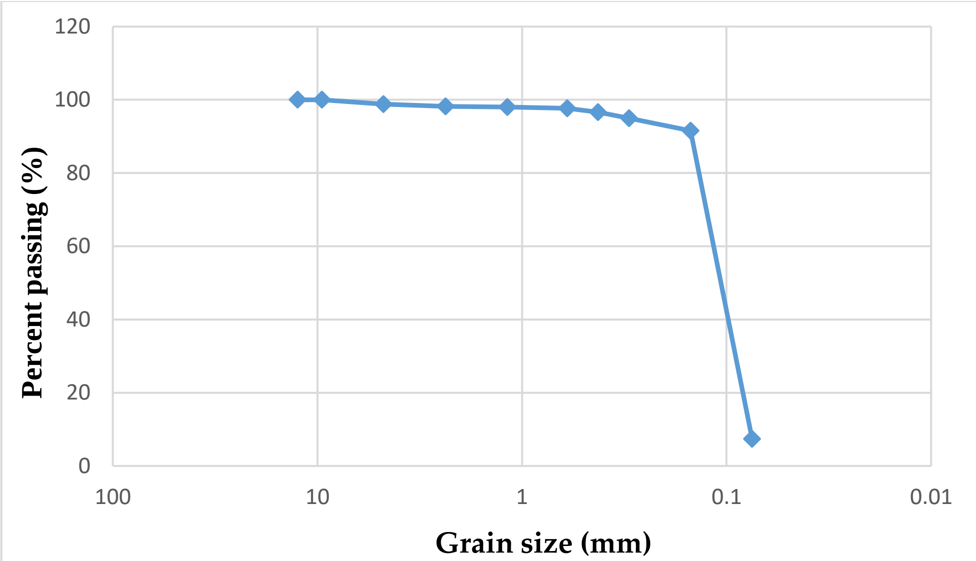

Figure 1. Grain-size distribution of used sand (SP-SM)

Table 1. Physical and Mechanical Properties

Soil Property	Value
Specific Gravity	2.57
Gravel %	1.2
Fine Sand %	89.2
Coarse to medium Sand %	2.2
Silt and Clay %	7.4
Cu	1.41
Cc	0.92
Effective size, D10 (mm)	0.0763
USCS Classification	SP-SM
AASHTO Classification	A-3
Natural Moisture Content %	3.99
Maximum Dry Density (g/cm3)	1.67
OMC %	14.6
Cohesion (kPa)	2.93
Angle of Internal Friction (deg)	30.34°
Unsoaked CBR Value %	36.8

3.2 Granulate Waste Tires

The waste tires used in this research are erratically shaped, differs from 1.18 mm to 2.36 mm in diameter. The granulate waste tires is a recycled rubber from automotive scrap tire. The average specific gravity found to be 1.009 based on two replicate tests.

The result of the sieve analysis (dry) is shown in Figure 2.

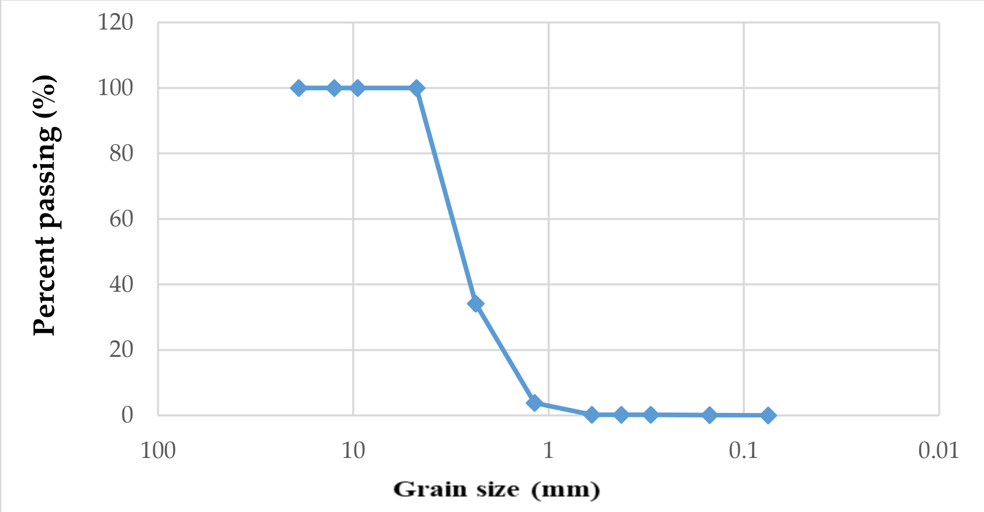

Figure 2. Grain-size distribution of granulate waste tires

3.3 Soil-Granulate Waste Tires Mixture

All samples were prepared at the same way; mixing the samples manually in dry condition (air-dried method) to prepare an appropriate combination of sand-granulate mixture, then the additive was added in 5%, 10%, 15% and 20% by dry weight of the soil. The samples were dried at 100 ± 5 °C for 24 hours.

4. Experiments Methods

The mixture of each sample was used for series of laboratory tests. Table 2 shows the weight structure of sand-granulate. The laboratory tests were conducted according to ASTM procedure. Modified Proctor tests were performed to evaluate the compaction characteristics of the sand-granulate waste tires mixture.

Table 2. Weight composition mixture of sand-granulate

Granulate waste tires (%)	Soil type	Granulate waste tires (%)				
		Grain-size distribution	Specific gravity	Compaction characteristics	Shear properties	Strength properties
0		√	√	√	√	√
5			√	√	√	√
10	SP-		√	√	√	√

SM					
15		√	√	√	√
20		√	√	√	√

In this research, a number of tests were performed to determine the geotechnical engineering properties of sands in accordance with relevant ASTM which included sieve analysis tests (dry/wet), specific gravity tests, modified Proctor tests, vibrating compaction tests, Californian Bearing Ratio tests, and direct shear tests. The standard designation of the tests are summarized in Table 3.

Table 3. Standard Designation of the tests

Test	**Sieve Analysis**	**Specific Gravity**	**Modified Proctor**	**Vibrating Compaction**	**Californian Bearing Ratio**	**Direct Shear**
Standard Designation	ASTM [7] D-421	ASTM [8] D-854	ASTM [9] D-1557	/	ASTM [10] D-1883	ASTM [11] D-3080

5. Results and Discussion

5.1 *Effect of Granulate Waste Tires on Specific Gravity*

As shown in Table 4, a decrease in specific gravity with increase granulate-waste tire content from 2.57 at 0% granulate-waste tire to 2.04 at 20% granulate-waste tire additive. The reductions are considered as a material with low specific gravity. Other researchers agreed and reported a similar change in specific gravity of sand-granulate waste tires mixtures [12].

Table 4. Specific gravity of sand-granulate waste tires mixtures

Granulate tires	**0%**	**5%**	**10%**	**15%**	**20%**
G_s	2.57	2.39	2.25	2.13	2.04

5.2 Effect of Granulate Waste Tires on Modified Proctor

The findings of modified Proctor test are presented in Table 5. It can be noticed from Figure 3 that the max dry density of the sand-granulate waste tires mixture decreases with an increase of percentage of sand-granulate waste tires, the percentage decrease was about 8.38%. This can be attributed to low specific gravity of granulate waste tires.

Table 5. Proctor Compaction characteristics of sand-granulate waste tires mixture

Granulate tires %	Max Dry Density (g/cm³)	Optimum moisture Content (%)
0	1.67	14.6
5	1.62	13.8
10	1.57	13.2
15	1.57	12.2
20	1.53	12

On the other hand as shown in Figure 3, the OMC of the sand reduced about of 17.8% when granulate waste tires increased up to 20. That is due to low water absorption capacity of rubber. Al-Neami [12] also reported reductions in compaction characteristics of poorly graded sand with the inclusion of granulate tires.

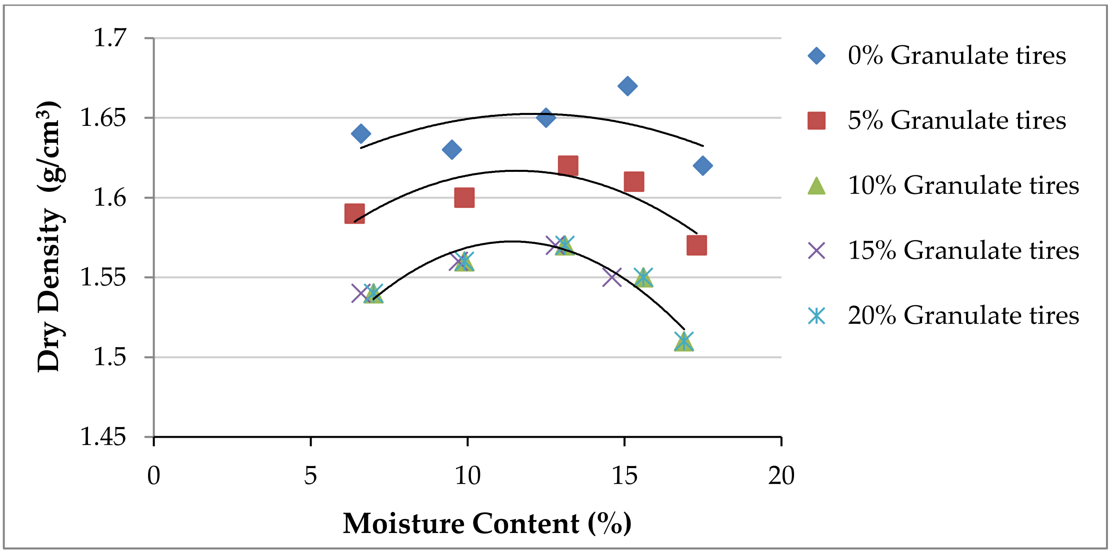

Figure 3. Proctor compaction curves of sand-granulate waste tires mixture

5.3 Effect of Granulate Waste Tires on Vibrating Compaction

Table 6 shows outcomes of the influence of waste tires on maximum dry density and optimum moisture content during vibration compaction. Through the results shown in Figure 4, when the granulate waste tires content increased in the sand mixture, the maximum dry density is reduced, the percentage decrease was about 9.95%. This reduction because of the nature of granulate waste tires, which considered as a lightweight fill material.

Table 6. Vibrating Compaction characteristics of sand-granulate waste tires mixture

Granulate tires %	Max Dry Density (g/cm³)	Optimum moisture Content (%)
0	1.58	17.1

5	1.50	17.25
10	1.48	17.56
15	1.45	17.6
20	1.43	17.8

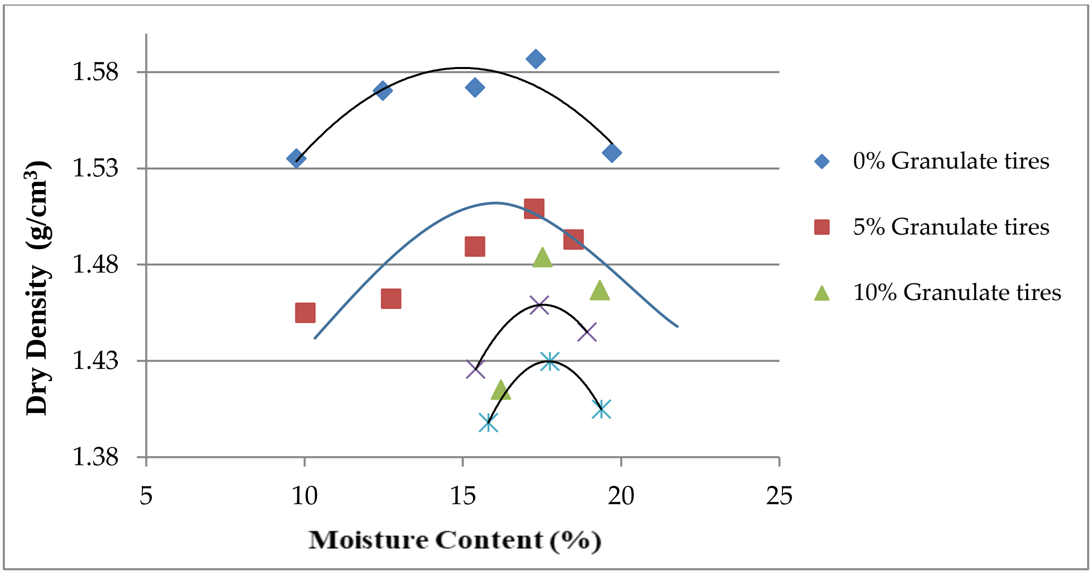

Figure 4. Vibration compaction curves of sand-granulate waste tires mixtures

Also, it was observed that the optimum moisture content is increased from 17.1% to 17.8% when the granulate waste tires increased to 20%, therefore; the granulate waste tires have a little influence on optimum moisture content. Similar results are founded from modified Proctor test.

5.4 Effect of Granulate Waste Tires on Direct Shear

Direct shear test was used to determine the angle of internal friction and cohesion of the soil. Table 7 shows the results of shear strength parameters verses granulate waste tires percentage. Findings of shear tests indicated that adding of granulate waste tires decreases friction angle from 30.34° to 28.94° when adding 5% of granulate waste tires, and then increases up to 36.3° at 20% of granulate waste tires as shown in Figure 5. As for the cohesion value, a slight increase when adding 5% granulate waste tires, and then it can be seen a major reduction with increase of percentage of granulate to almost zero at 15% of granulate waste tires (Figure 6). The increase of friction resistance between particles by granulate waste tires attributed to the frictional behaviour displayed between sand and mixture. These results are found like results reported by other investigators [13, 3, 14, 15].

Table 7. Effect of cohesion and angle of internal friction on sand-granulate waste tires mixtures

Granulate tires %	c (KPa)	ϕ (Degree)
0	2.94	30.34
5	5.87	28.94
10	1.47	31.87
15	0	31.03
20	0	36.3

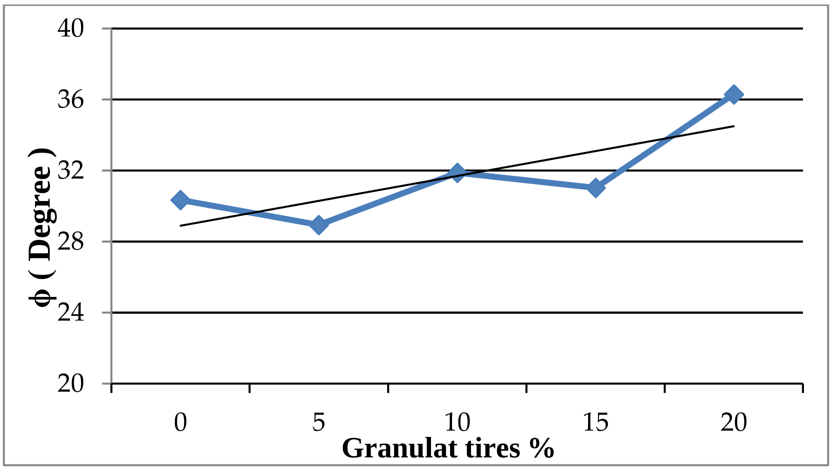

Figure 5. Angle of internal friction of sand vs. Granulate tires (%)

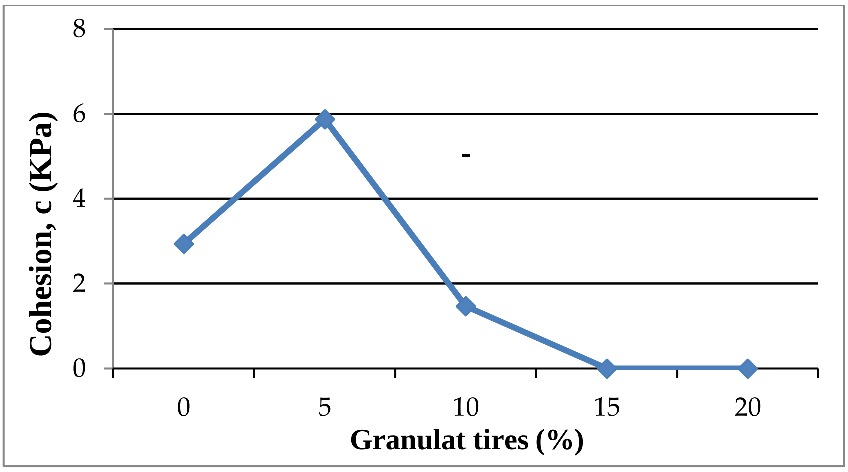

Figure 6. Cohesion of sand vs. Granulate waste tires (%)

5.5 Effect of Granulate Waste Tires on Strength Properties (CBR)

CBR tests were conducted on sand and sand- waste tires mixture, to establish the soaked and unsoaked CBR values. The sand is mixed with granulate waste tires of 5%, 10%, 15% and 20% by dry weight of soil, and then the tests were conducted at OMC and MDD.

Table8. Effect of granulate waste tires on CBR values of sand

Granulate tires (%)	Soaked CBR (%)	UnSoaked CBR (%)
0	27	37
5	19	31
10	14	19
15	13	10
20	12	10

The obtained results of soaked and unsoaked for sandy soil containing different contents of granulate waste tires are shown in Figure 7 and 8 respectively. It is assumed that the CBR value of soaked and unsoaked condition are 27% and 37%, respectively. It was observed that the values of sand in soaked condition decline as the content of granulate waste tires increases and are drop than the CBR value of the mixtures in unsoaked conditions.

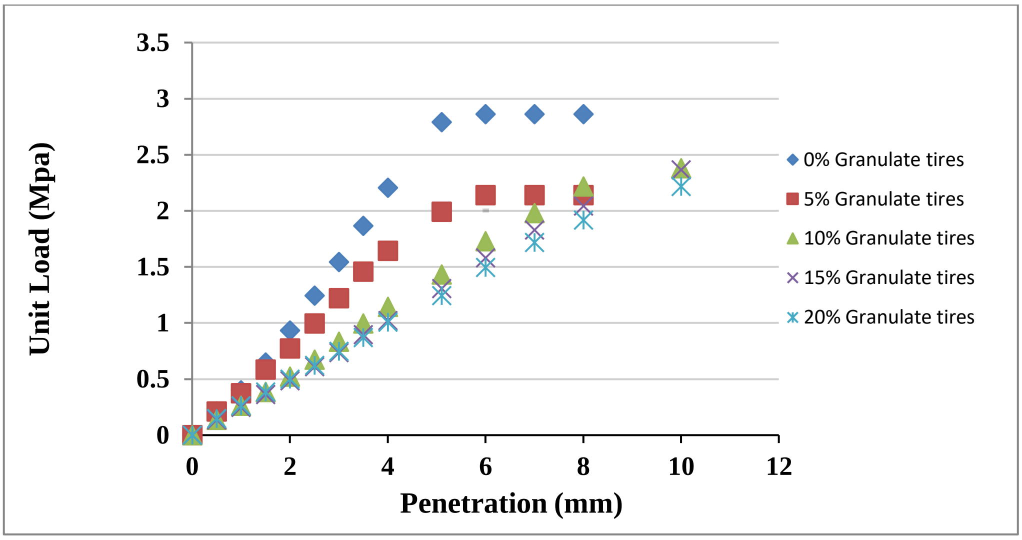

Figure 7. Unit Load-penetration curves of sand-granulate tires mixtures in soaked condition

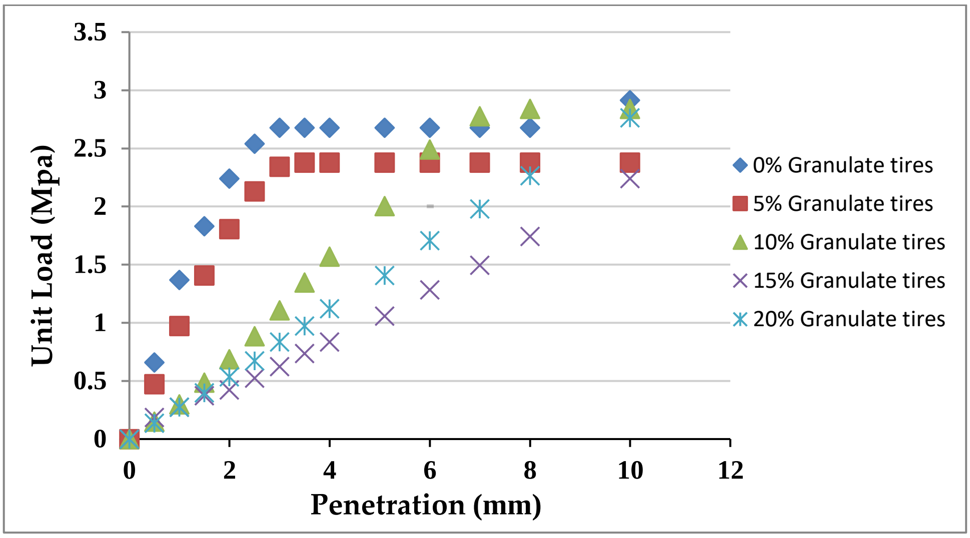

Figure 8. Unit Load-penetration curves of sand-granulate tires mixtures in unsoaked condition

6. Conclusion

Solid waste tires and scrap materials are a significant environmental issue, cause and contribute to economic difficulties worldwide. To eliminate and reduce the harms on environmental, it was needed to find a safe way to reduce these harms on the economy and the environment. Based on the present study, it can be concluded that granulate waste tire can effectively use in engineering applications. The study showed that adding of 20% of waste tires in case of reduction lateral stress on retaining walls. To improve the cohesion of poorly graded sandy soil, this research recommends adding 5% of granulate waste tires in construction projects such as light traffic roads, retaining walls and car parking. The use of the material up to 20% can provide a useful way of overwhelming huge stockpiles of scrap tires, decrease environmental contamination from all over the world.

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