Scrapt Waste Tire as an Additive in Asphalt Pavement for Road Construction

Tomas Ucol-Ganiron Jr
Departement of Architecture, Planning and Design, Qassim University, Buraidah, Saudi Arabia

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ABSTRACT

This experiment study aimed to use of the waste tires in asphalt mixture as additive. Research has shown that scrap waste tire can be partial replacement by 2% total weight of aggregate retained in No. 4 sieve has an average performance. Characteristics compared to the standard eequirements conformable code. Moreover, the use of scrap waste tire would result in the reduction of waste. High stability of asphalt mixture can be made and the incorporation of admixture or substitute to improve the properties of the mixture. Test result of specimens indicates the stability, and bonding strength of properties, and different reaction when gradation and scrap tire contents have varied. Marshall test having an appropriate workable mixing and right temperature gave sufficient compressive strength and lessen its flow or it deformation under a certain loads.

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Corresponding Author:

Tomas Ucol-Ganiron Jr.,
Departement of Architecture, Planning and Design,
Qassim University,
P.O. Box 6677, Buraidah, Saudi Arabia
Email: tomas@qec.edu.sa

1. INTRODUCTION

Waste tire has been a one of the major problem in the country, properly handled scrap tires or waste tires do not present any major environmental problems. If improperly handled however, scrap tires can be a threat to the environment. Tires exposed to the elements can hold water and be a breeding space for mosquitoes that carry disease. Tire piles can be set on fire through arson or accident. These fires are difficult to put out, and produce heavy smoke and toxic run off to waterways. Tire piles can also harbor other vermin, such as rats and snakes.

Due to the increasing number of scrap waste tires some foreign countries came up with the idea of using it again and luckily several uses discover including in construction matter [1]. Approximately 280 million tires are discarded each year by American motorists, approximately one tire for every person in the United States [1],[2]. Around 30 million of these tires are retreaded or reused, leaving roughly 250 million scrap tires to be managed annually [2]. About 85 percent of these scrap tires are automobile tires, the remainder being truck tires [1]. Besides the needs to manage these scrap tires, it has been estimated that there may be as many as 2 to 3 billion tires that have accumulated over the years and are contained in numerous stockpiles [2].

However,the primary use of recycled tire materials has been as fuel (cogeneration plants), as rubberized asphalt concrete (rubber content in asphalt roads), for surfacing (playgrounds and tracks), or for Civil engineering applications In the Philippines, waste tire is used as an artificial coral reef [2]. At least 9 million scrap tires are processed into ground rubber annually. Ground tire rubber is used in rubber products (such as floor mats, carpet padding, and vehicle mud guards), plastic products, and as a fine aggregate addition (dry process) in asphalt friction courses [3]. Crumb rubber has been used as an asphalt binder modifier (wet process) in hot mix asphalt pavements [3].

Currently, the largest single use for scrap tires is as a fuel in power plants, cement plants, pulp and paper mill boilers, utility boilers, and other industrial boilers. At least 100 million scrap tires were used in 1994 as an alternative fuel either in whole or chipped form [3].

Scrap tire can be used to modify the asphalt binder (e.g., increase its viscosity) in a process in which the rubber is blended with asphalt binder (usually in the range of 18 to 25 percent rubber) [1],[3]. This process, commonly referred to as the wet process, blends and partially reacts crumb rubber with asphalt cement at high temperatures to produce a rubberized asphalt binder [2]. Most of the wet processes require crumb rubber particles between 0.6 mm (No. 30 sieve) and 0.15 mm (No. 100 sieve) in size [2]. The modified binder is commonly referred to as asphalt-rubber.

The history of adding recycled tire rubber to asphalt paving material can be traced back to the 1940's when the U.S. Rubber Reclaiming Company began marketing a devulcanized recycled rubber product, called Ramflex TM, as a dry particle additive to asphalt paving mixture.In the mid-1960's,Charles McDonald began developing a modified asphalt binder using crumb rubber.

The principal chemical component of tires is a blend of natural and synthetic rubber, but additional components include carbon black, sulfur, polymers, oil, paraffins, pigments, fabrics, and bead or belt materials [3]. Other properties of scrap tires are, heating value ranges from 28,000 kJ/kg (12,000 Btu/lb) to 35,000 kJ/kg (15,000 Btu/lb) [2],[3]. As a result, given appropriate conditions, scrap tire combustion is possible and must be considered in any application.

Advantages include decreased rutting, reflective and thermal cracking, and better de-icing properties and reduced traffic noise [3],[4]. Lower maintenance costs and significantly increased service life translate to a lower lifecycle cost for RMA [4].

It will greatly help the world to recycle the bulk or hundred of tons of abandoned waste tires. From this, it also reduces the possible dwellings of mosquitoes and rats which cause harmful diseases.

This material makes a new break through for modern construction materials and methodology due to the impact of scarce resources and economical constraints. According to technical surveys, there is an increasing rate of adopting this kind of material as a modifier for roads construction in different parts of the world [5].

The studies made from United States and India that the rubber asphalt road can minimize the noise from 4 decibels up to 10 decibels [6]. Therefore, it is better to apply this on roads for the benefits and convenience of numerous motorists and communities nearly located along this type of road.

Somehow, the Philippines make this scrap rubber tires still as an option to be an additional material in asphalt pavement for road construction.

Nevertheless, since waste tire has been used in other countries as modifier the researchers focus on the process of cutting it manually before mixing to the mixture of asphalt concrete [7]. The aim of the study is to release an appropriate mix design of waste tires as an additive in asphalt pavement for road construction. The need of this study is base from the availability of the material which is mainly the waste tires and to minimize their existence as purely garbage materials and to show its advantages as replacement material for aggregates in asphalt pavement.

2. RESEARCH METHOD

The design of the project started from the gradation of aggregates before batching shown in figure 1. The scrap waste tire and hot asphalt were mixed with batch aggregates. Tampering was necessary during molding process. The molded sample was cooled as a requirement for compaction then testing like Marshall and Immersion to determine whether the design is adequate or not.

The aggregate fractions for selected gradation were combined in pre-calculated quantities. These were dried and batch before thoroughly mix together with hot asphalt and scrap tire fraction which was the replacement for a specific aggregate fraction under the required temperature during mixing.

This study come up with the use of 2% of scrap waste tire which was express in terms of the total cumulative weight of aggregates in grading E passing through sieve no. 3/8 and retain in sieve no. 4. The scrap waste tire was in cubical form which retains in sieve no. 4.

Whenever the smallest percent of scrap tire as an additive for the asphalt mixture does not comply with the standards and specifications then the study should try other size of this material.

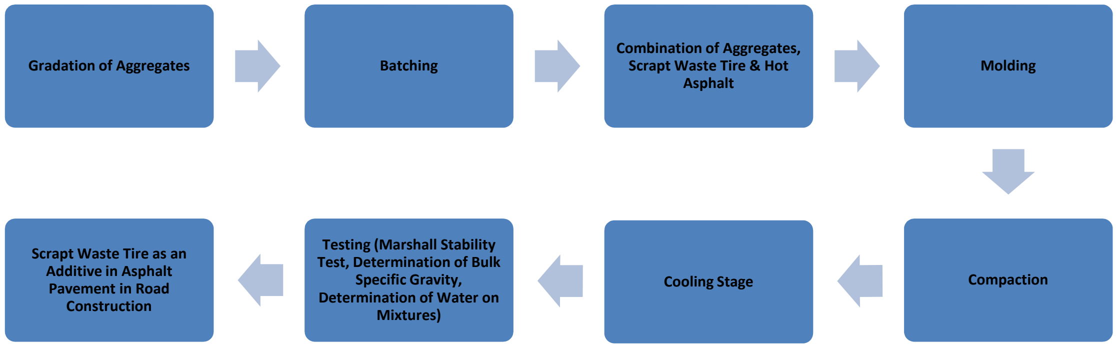


Figure 1. Project Design

The developments of the project concentrate on the waste tire which was the main concern of the study is to maximize its value for another beneficial purpose. It started on gathering or collection of waste tires from landfills shown in figure 2.

These were cleaned and dried to eliminate undesirable particles before cutting it manually in to smaller pieces using G.I. cutter. Aggregates undergo in wet sieve analysis articularly in coarse aggregates before proceeding on the dry sieve analysis. The mixture required the presence of fine aggregates and fillers.

After the gradation of aggregates, it was turn over for batching. The batched aggregates were added by scrap waste tire and hot asphalt. The specimens were molded and tampered before giving it 75 blows in its both face for compaction.

Within the testing and curing of the mix design, two results will be occurred. It is either adequate or not. If the first one takes place then it will be the advisable mix design of scrap waste tire for asphalt pavement. If the latter one, return on the batching process and try another percent of scrap waste tire to be added in hot mix asphalt. The accepted mixture design was tested using the Laboratory Testing Procedures Manual made by the DPWH for Bituminous Materials and Bituminous Mixtures in accordance with AASHTO and ASTM. These testing are Determination of Bulk Specific Gravity, Immersion Compression test, and Determination of the Effect of Water on Cohesion of Compacted Bituminous Mixtures [8],[9].

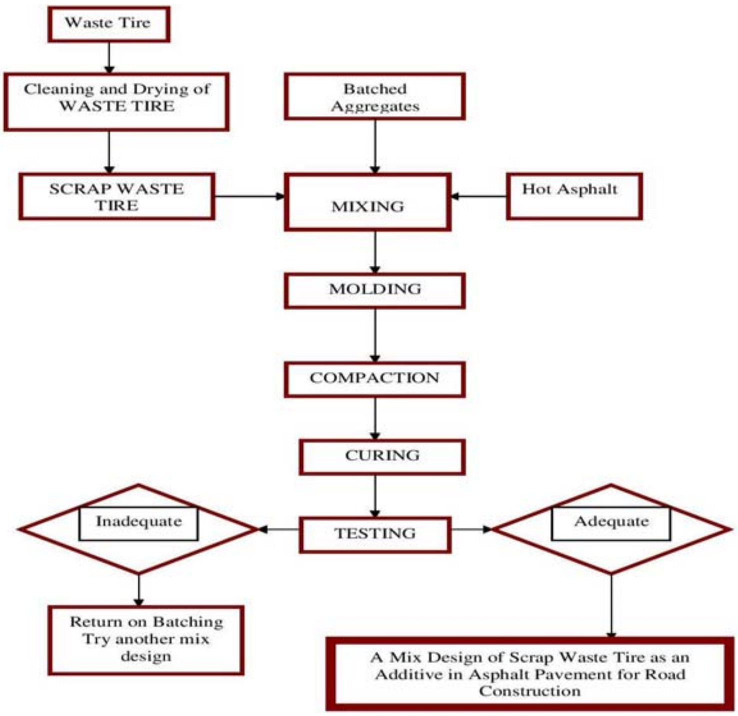


Figure 2. Project Development

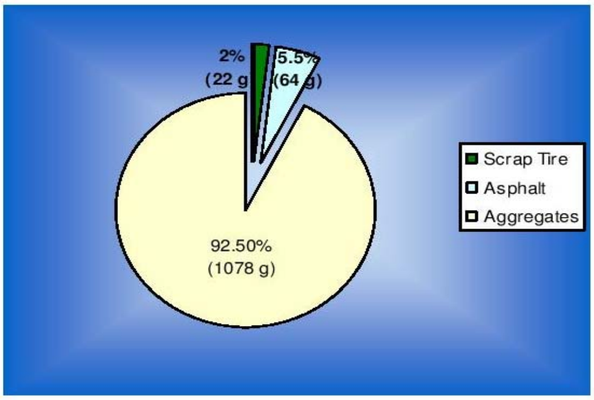
3. RESULTS AND ANALYSIS

The method of experiment was used to specify the factors that may constitutes a big effect in the mixture such as gradation of fine and coarse aggregates as well as the properties of bituminous mixture such as specific gravity, marshall stability and flow, maximum theoretical density, and air voids by performing the following tests: determination of bulk specific gravity, marshall test, immersion compression test, and determination of effect of water on the mixture.

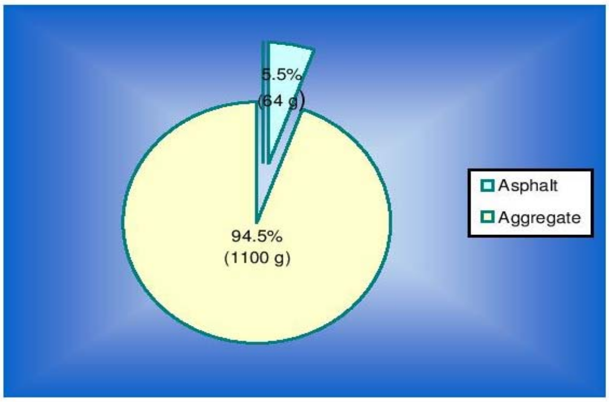
Table 1. Sample for Marshall Test (1100g of Aggregates)

Sieve Size	Grading Requirement	% Passing	Asphalt Mixture with Scrap Tire			Conventional		
			% Retained	Wt. Retained	Cu. Wt.	% Retained	Wt. Retained	Cu. Wt.
12.5 mm (½ in)	100	100	0	0	0	0	0	0
9.5 mm (⅜ in)	95-100	97.5	2.5	27.5	27.5	2.5	27.5	27.5
4.75 mm# 4	75-90	82.5	**13**	**143**	**172**	**15**	**165**	**192.5**
2.36 mm # 8	62-82	72	10.5	115.5	287	10.5	115.5	308.5
1.18 mm # 16	38-58	48	24	264	551	24	26.4	572.5
0.60 mm# 30	22-42	32	16	176	727	16	176	748.5
0.30 mm# 50	11-28	19.5	12.5	138	865	12.5	138	886
.0.075 mm# 200	2-10	6	13.5	148.5	1014	13.5	148.5	1035
Filler	0	0	6	66	1078	6	66	1100

Table 1 show that the conventional sample for marshall tests has the total weight of 1100 g of aggregates with 5.5 % of asphalt. However, the asphalt mixture with scrap tire has 1078 g of aggregates and 22 g of scrap tire and has the same amount of asphalt. The grading requirement was conformed in AASHTO T-11 and T-27 under grading E.



Mixture with Scrap Tire



Conventional Mixture

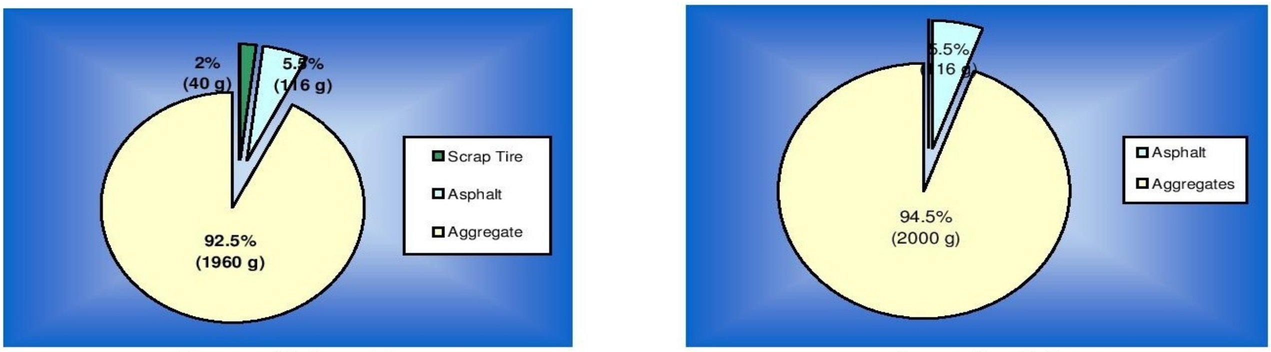
Figure 3. Asphalt Mixture for Marshall Test

As shown in figure 3, the percentage of each material for both mixtures has been established for Marshall Test. The required weight of aggregate is 1100 g with 5.5 % or 64 g of asphalt for conventional mixture. Meanwhile, the mix design of scrap the total weight of aggregate is 1078 g with 22 g of scrap tire.

Table 2. Sample for Immersion-Compression (2000g of Aggregates)

Sieve Size	Grading Requirement	% Passing	Asphalt Mixture with Scrap Tire			Conventional		
			% Retained	Wt. Retained	Cu. Wt.	% Retained	Wt. Retained	Cu. Wt.
12.5 mm (½ in)	100	100	0	0	0	0	0	0
9.5 mm (⅜ in)	95-100	97.5	2.5	50	50	2.5	50	50
4.75 mm# 4	75-90	82.5	**13**	**260**	**310**	**15**	**300**	**350**
2.36 mm # 8	62-82	72	10.5	210	520	10.5	210	560
1.18 mm # 16	38-58	48	24	480	1000	24	480	1040
0.60 mm# 30	22-42	32	16	320	1320	16	320	1360
0.30 mm# 50	11-28	19.5	12.5	250	1570	12.5	250	1610
.0.075 mm# 200	2-10	6	13.5	270	1840	13.5	270	1880
Filler	0	0	6	120	1960	6	120	2000

Table 2 shows that the conventional sample for immersion has the total weight of 2000 g of aggregates with 5.5 % of asphalt. However, the asphalt mixture with scrap tire has 1960 g of aggregates and 40 g of scrap tire and has the same amount of asphalt. The grading requirement was conformed in AASHTO T-11 and T-27 under grading E.



Mixture with Scrap Tire Conventional Mixture

Figure 4. Asphalt Mixture for Immersion-Compression Test

Figure 4 shows the percentage of each material for both mixtures in immersion-compression test. The total weight of the aggregate is 2000 g with 5.5 % of asphalt for conventional mixture while the design mix with scrap tire has a total weight of the aggregate of 1960 g with a 40 g of scrap tire and same percentage of asphalt.

Table 3. Marshall Test of 2% Asphalt Mixture with Scrap Tire and Conventional Asphalt Mixture

	2 % Asphalt Mixture with Scrap Tire				Conventional Asphalt Mixture			
	1	2	3	**Ave.**	1	2	3	**Ave.**
I. Bulk Sp. Gravity, Gmb								
a. Wt. of Sample in air, g	1146.4	1155.7	1154.1	**1152.07**	1125.5	1248.5	1250	**1208**
b. Wt. of Sample in water, g	640.2	646.0	637.4	**641.2**	718.5	780	737.5	**728.67**
c. Wt. of Sample in SSD, g	1149.8	1159.8	1158.5	**1156.03**	1280	1250	1253	**1244.33**
Specific Gravity	2.250	2.249	2.215	**2.238**	2.396	2.401	2.425	**2.41**
II. Height of Specimen	63.9	65.8	66.6	**65.43**	63	64	63.5	**63.5**
III. Stability Value, lbs								
Reading	49	44	48	**47**	97	76	98	**90.33**
Equivalent load (R x 34.01)	1666.49	1496.44	1632.48	**1598.47**	3298.97	2584.76	3332.98	**3072.24**
Correlation Ratio	0.99	0.946875	0.9225	**0.953**	1.01	0.99	1	**1**
Stability Adjusted (E. L. x C.R),lbs	1649.83	1416.942	1505.963	**1524.25**	3331.96	2558.91	3332.98	**3074.62**
IV. Flow Value (0.25mm)								
Reading	53	38	44	**45**	51	50	45	**48.67**
Flow (R x 0.25)	13.25	9.5	11	**11.25**	12.75	12.5	11.254	**12.17**
V. Maximum Theoritical Density (Gmm)	2.49	2.49	2.49	**2.49**	2.625	2.625	2.625	**2.625**
VI. Air voids, %	9.639	9.639	11.245	**10.17**	8.7	8.5	7.6	**8.3**

Table 4 shows the result of Marshall Test for both 2% asphalt mixture with scrap tire and conventional asphalt mixture. Through this test the following properties of bituminous mixture were determine: specific gravity, stability, flow, maximum density and air void.

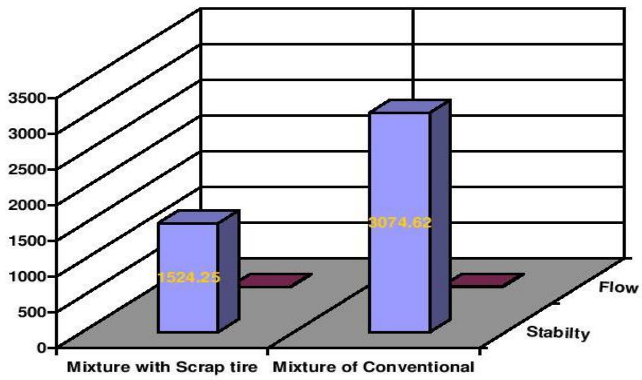


Figure 5. Marshall Stability Flow

As shown in figure 5, the mixture with scrap tire is only half of conventional with respect to stability, where the stability in marshall tests to measure the strength of the mixture.

Table 5.Immersion-CompressionTest

A. BILK SPECIFIC GRAVITY	1	2
DRY		
Mass in Air, g	1842.40	1858.00
Mass in Water, g	988.8	999.80
Mass in SSD, g	1863.4	1878.00
Specific Gravity	2.107	2.116
WET		
Mass in Air, g	1834.5	1848.4
Mass in Water, g	957.9	998.9
Mass in SSD, g	1859.2	1872.5
Specific Gravity	2.035	2.116
B. STABILITY		
Cross-sectional area, sq. m.	0.008107	0.008107
Dry: Loads, tons	0.97	0.99
KN/m²: 9.81/0.008107	1210	1210
KPa Load (tones) x KN/m²	1173.7	1197.9
Wet: Load, tons	0.74	0.88
KN/m²: 9.81/0.008107	1210	1210
KPa (tones) x KN/m²	895.4	1064.8
Index of Retained strength,%	76.29	88.89

Table 5 shows the result of bulk specific gravity and stability for both dry and wet specimen using compressive test to determine the quality of mix design. This test was used to check if the design has the capability to resist the effect of water.

Table 6.Cost Analysis

CONVENTIONAL ASPHALT MIXTURE				
I. Material	Qty.	Unit	Unit Cost	Material Cost
Asphalt	22542.3	lb	Php 11.628/lb	Php 262121.86
Aggregates	170.1	cu.m	Php 950/cu.m	Php 161595
Material Total Cost				**Php 423,716.86**
II. Labor	No of Days		Unit Cost	Labor Cost
2- Skilled laborer	3		Php 327/day	Php 981
5- Laborer	3		Php 250/day	Php 750
Labor Total Cost				**Php 1731**
TOTAL COST				**Php 425,447.86**

ASPHALT MIXTURE W/ 2% SCRAP WASTE TIRE				
I. Material	Qty.	Unit	Unit Cost	Material Cost
Asphalt	22542.3	lb	Php 11.628/lb	Php 262121.86
Aggregates	166.7	cu.m	Php 950/cu.m	Php 158365.00
Scrap Tires	3.4	cu m	Php 0	Php 0
Material Total Cost				**Php 420486.86**
II. Labor	No of Days		Unit Cost	Labor Cost
2- Skilled laborer	3		Php 327/day	Php 981.00
5- Laborer	3		Php 250/day	Php 750.00
5- Cutter	3		Php 300/day	Php 4500.00
Labor Total Cost				**Php 6231.00**
TOTAL COST				**Php 426717.86**

Table 6 shows the cost analysis of conventional asphalt mixture compares to the mixture with 2% scrap waste tire. The cost for the material and labor has changed for both mixtures, due to additional man power and using the scrap waste tire as substitute to aggregate. Conventional asphalt mixture has a total cost of Php 425,447.86 while the proposed mixture increased to Php 426,717.86 resulting to a difference of Php 1270.00.

In general, scrap tire replace the 2% of aggregates in no. 4 sievein terms of gradation with respect to Marshall and Immersion test.

The bulk specific gravity has an average value of 2.24 for asphalt mixture with scrap tire in Marshall Test. The stability of the design mixture has an average result of 1524 lbs., closely to the minimum required design criteria of 1800 lbs. under 75 blows of compaction.

The required flow in marshall mix design criteria ranges from 8mm-14mm,which the design mixture has a resulting average of 11.25 mm and maximum theoretical density of 2.49 and an air void of 10.17%.

Moreover, it has a bulk specific gravity of 2.12 for dry sample and 2.08 for wet in immersion-compression test. In terms of stability, for dry it has an average value of 1185.5 KPa, and 980 KPa for the wet sample.

4. CONCLUSION

Gradation of the asphalt mixture with scrap tire is lower in percentage retained No 4 sieve than the conventional one for both marshall and immersion- compression tests. Bulk specific gravity of the design mixture has a lower result than the conventional for Marshall Test.

Since scrap tire is not as hard as the crushed-stone aggregates, the Marshall stability values of the asphalt-aggregate-tire mixes were consistently lower than the control mixes without any scrap tire. It was also presumed that the tire which is cubical in shapes tend to absorb some of the energy imparted to compact a sample resulting in a weaker aggregate structure than a mix with no tire in it.

The stability of the design mixture is twice lower than the conventional one, and constitutes a lower value in terms of flow for Marshall Test. The density of the design mixture is lesser than the conventional. The stability of the mixture depends on the grading of the aggregates, temperature and size of scrap waste tire.

The advantages of scrapt waste tires are: it mitigates roads noise and lessen the number of waste tires.In terms of Marshall Test, the longer rate of curing, the higher stability acquires.

For Immersion-Compression test, the rate of curing by maximum 4 days will give the maximum value for water resistance.

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BIOGRAPHIES OF AUTHORS

Dr. Tomas Ucol-Ganiron Jr. This author obtained his Doctor of Philosophy in Construction Management at Adamson University (Philippines) in 2006, and subsequently earned his Master of Civil Engineering major in Highway and Transportation Engineering at Dela Salle University-Manila (Philippines) in 1997 and received Bachelor of Science in Civil Engineering major in Structural Engineering at University of the East (Philippines) in 1990. He is a registered Civil Engineer in the Philippines and Professional Engineer in New Zealand. His main areas of research interest are recycled waste materials, construction materials and project management.
He has been a resource person in various seminars in New Zealand (like in Auckland University of Technology, University of Auckland and University of Canterbury). He was connected with Advanced Pipeline System in New Zealand as Construction Manager wherein he supervised the sewerage and waterworks projects. He was the former Department Head of Civil Engineering in FEATI University (Manila) and former Department Head of Physics in Emilio Aguinaldo College (Manila). He also had teaching stints at the College of Engineering in Auckland University of Technology, New Zealand and at the MAPUA Institute of Technology (Manila). He is currently the Professor at Qassim University (KSA) College of Architecture and Engineering.

Dr. Ganiron Jr is a proud member of professional organizations like the Institution of Engineers-Australia and American Society of Civil Engineer. He is also very active in other professional groups like Railway Technical Society of Australasia and Australian Institute of Geoscientists where he became committee of Scientific Research. He has given invited or keynote lectures at a number of international conferences and has received the ASTM Award CA Hogentogler for 2008.