INTERNATIONAL JOURNAL OF ADVANCED RESEARCH IN ENGINEERING, SCIENCE & MANAGEMENT

GAINFULL UTILIZATION OF TYRE WASTE CRUMB RUBBER FOR THE CONSTRUCTION OF PAVEMENT

Prof. Reshmaben L. Patel[1], Dr. Jayeshkumar Pitroda[2]
Associate Professor, Civil Engineering Department, B.V.M.Engineering College, V.V.Nagar[1]
Assistant Professor, Civil Engineering Department, B.V.M.Engineering College, V.V.Nagar[2]

Abstract: Municipal solid waste (MSW) management is a major problem in world today. The collection and disposal of MSW is one of the pressing problems of city life, which has assumed great importance in the recent past. Current global MSW generation levels are approximately 1.7-1.9 billion metric tonnes per year, and are expected to increase to approximately 2.8 billion tonnes per year by 2025. This represents a significant increase in per capita waste generation rates, from 1.2 to 1.42 kg per person per day in the next fifteen years. However, global averages are broad estimates only as rates vary considerably by region, country, city, and even within cities. MSW generation rates are influenced by economic development, the degree of industrialization, public habits, and local climate. Crumb rubber is a term usually applied to recycled rubber from automotive and truck scrap tyres. During the recycling process steel and fluff is removed leaving Tyre rubber with a granular consistency. Continued processing with a granulator and/or cracker mill, possibly with the aid of cryogenics or mechanical means, reduces the size of the particles further. It is not possible to discharge the rubbers in the environment because they decompose very slowly and cause lots of pollution. So, it is necessary to have a relevant use of these wastages. This paper will help in effective use of these MSW in construction of road pavements thus solving a major problem of MSW disposal.

Key words: **tyre waste, crumb rubber, pavement,**

INTRODUCTION

Presently in India, about 960 million tonnes of solid waste is being generated annually as byproducts during industrial, mining, municipal, agricultural and other processes. Of this 350 million tonnes are organic wastes from agricultural sources; 290 million tonnes inorganic waste of industrial and mining sectors and 4.5 million tonnes are hazardous in nature.

Currently, the transportation industry is under increasing pressure to use alternate or secondary materials because of its high-volume consumption of bulk materials (such as natural fine and coarse aggregates) in road construction. Materials including industrial byproducts, concrete aggregates, old asphalt pavement, scrap tyres, fly ash, steel slag, and plastics are often used as alternate materials for natural aggregates. A significant amount of debris resulting from various activities is currently disposed of in landfills. Landfilling of this debris results in a large burden on the world's natural resources and an increasingly expensive problem for solid waste management.

Over the years, there has been a continuous migration of people from rural and semi-urban areas to towns and cities. The proportion of population residing in urban areas has increased from 25.70% in 2001 to 36.83% in 2011. The uncontrolled growth in urban areas has left many Indian cities deficient in infrastructural services such as water supply, sewerage and municipal solid waste management.

Fig. 1.1.1: Solid waste collection

Most urban areas in the country are plagued by acute problems related to solid waste. Due to lack of serious efforts by town/city authorities, garbage and its management has become a tenacious problem and this notwithstanding the fact that the largest part of municipal expenditure is allotted to it. It is not uncommon to find 30-50% of staff and resources being utilized by Urban Local Bodies for these operations. Despite this, there has been a progressive decline in the standard of services with respect to collection and disposal of municipal solid waste including hospital and industrial wastes, as well as measures for ensuring adequacy of environmental sanitation and public hygiene. In many cities nearly half of solid waste generated remains unattended, giving rise to insanitary conditions especially in densely populated slums which in turn results in an increase in morbidity especially due to microbial and parasitic infections and infestations in all segments of population, with the urban slum dwellers and the waste handlers being the worst affected.

PROBLEM STATEMENT

Production of synthetic and processed materials is vital for the growth of modern societies. Such production results in the creation of large quantities of solid waste materials (SWMs). Many of these SWMs remain in the environment for long periods of time and cause waste disposal problems. Existing landfills are reaching maximum capacity and new regulations have made the establishment of new landfills difficult. Disposal cost continues to increase while the number of accepted wastes at landfills continues to decrease.

One answer to these problems lies in the ability to develop beneficial and sustainable uses for these wastes by recycling complex SWMs into useful products. The reuse of industrial byproducts in lieu of virgin traditional materials would relieve some of the burden associated with-disposal, and may provide inexpensive substitutes.

SOLID WASTE GENERATION SCENARIO

(a) Solid Waste Generation on a World Scenario

The estimated quantity of Municipal Solid Waste (MSW) generated worldwide is 1.7 - 1.9 billion metric tons. Waste generation varies as a function of affluence, however, regional and country variations can be significant as can generation rates within the same city.

All rights reserved by www.ijaresm.net

- Waste generation in sub-Saharan Africa is approximately 62 million tonnes per year.
- Waste generation in East Asp and the Pacific Region is approximately 270 million tonnes per year.
- Eastern and Central Asia, the waste generated per year is at least 93 million tonnes.
- Latin America and the Caribbean, the waste generated per year are at least 160 million tonnes.
- In the Middle East and North Africa, solid waste generation is 63 million tonnes per year.
- In South Asia, approximately 70 million tonnes of waste is generated per year.

(b) **Solid waste generation on an Indian scenario**

Urban India generates 188,500 tonnes per day (68.8 million tonnes per year) of municipal solid waste (MSW) at a per capita waste generation rate of 500 grams/person/day. The total waste generation figure is achieved by extrapolating the total tonnage of wastes documented for 366 cities (70% of India's urban population). The composition of urban MSW in India is 51% organics, 17.5% recyclables (paper, plastic, metal, and glass) and 31 % of inerts. The moisture content of urban MSW is 47% and the average calorific value is 7.3 MJ/kg (1745 kcal/kg). Although the collection, transportation and scientific disposal of MSW in about 26 cities were covered in Service Level Benchmarking (SLB)" conducted by the Ministry of Urban Development (MOUD), the quantum of wastes generated in other cities has never been addressed. The waste generated in urban India at 136,000 TPD, at an average per capita generation of 500 grams/day. It presents the approximate waste generation values and per capita waste generation rates in 366 Indian cities for 2011 to be the largest of such compilations yet.

REVIEW OF LITERATURE

This literature review deals with the experimental work carried out by researchers in developing the gainfull utilization of tyre waste crumb rubber for the construction of pavement.

Tatlisoz et.al (1997) decrypted soil-tyre chip mixtures are unique fill materials with high compressibility and ductility. Soil-tyre chip mixtures also have unique mechanical properties that are primarily governed by the tyre chip content, not by soil type. **(13)**

Zornberg et.al (2000) conducted a field investigation to assess the mechanical behaviour of an experimental embankment fill built with tyre shreds and cohesive soil. Immediately after construction, the embankment was submitted to heavy truck traffic and settlements were monitored for over two years. The results indicate that the embankment sections built with tyre shreds and cohesive soil showed satisfactory long term performances during traffic exposure. **(18)**

Tatlisoz et.al (2001) assessed the shear strength and geosynthetic interaction of tyre chip and soil-tyre chip backfills that may be used for geosynthetic reinforced walls and embankments and concluded that Soil-tyre chip mixtures have significantly higher shear strength than the soil used in the mixture. **(12)**

Carolyn et.al (2002) they stated that the educated use of recycled materials can result in reduced cost potentials and may enhance performance; however, not all recycled materials are well suited for highway applications due to limited or compromised performance-based benefits and/or high cost. **(3)**

Daniel J et.al (2004) they represented an effort to develop an automated computer-based system that can effectively evaluate industrial solid waste and their potential use in road construction applications. **(4)**

Hassona et.al (2005) based on their tests involving triaxial test and CBR test on shred tyre reinforced soil, concluded that The presence of shredded waste tyres in sand improves the stress-strain properties for all different sizes and contents of shreds waste tyre over that pure sand. The maximum deviator stress of randomly reinforced sand occurs at a higher axial strain compared to sand alone. CBR values increases with the increase of shreds tyre content up to 3 % content. After this content the increasing of CBR value decreases with the increase of shreds tyre content in both soaked and unsoaked specimens. **(7)**

Michael Heitzman et.al (2005) He gave a concise overview of the terminology, processes, products, and applications of crumb rubber modifier (CRM) technology. **(8)**

Tarek A. et.al (2005) their study showed that highway construction industry can effectively use large quantities of diverse materials. The use of waste by-products in lieu of virgin materials for instance, would relieve some of the burden associated with disposal and may provide an inexpensive and advantageous construction product. Current research on the beneficial use of waste byproducts as highway construction materials has identified several promising uses for these materials. **(17)**

F.A. Aisien et.al (2006) decrypted that for various rubber particle sizes, the tensile strength and elastic modulus of rubber-modified asphalt aggregate increased and then decreased with increasing rubber/asphalt ratio with optimum properties shown at a rubber asphalt ratio of 0.3. **(6)**

Eric J. McGarrah et.al (2007) decrypted that reusing non-renewable resources and decreasing the size of the stockpiles of RAP can both be accomplished by using RAP as base course and are both beneficial to sustainable construction. **(5)**

P Paige-Green et.al (2007) decrypted that by-product phosphogypsum has been shown to be a potentially useful road construction material, particularly when stabilized with cement. **(15)**

Narantuya Batmunkh et.al (2008) decrypted that the optimum moisture content for recycled crushed demolition road base (CDRB) materials is higher than for crushed granite road base (CGRB). It has also been determined by repeat load triaxial testing (RLTT) that the resilient modulus of the CDRB is superior to that of CGRB by a factor of two or more. The RLTT also showed that the source of material strongly influences the modulus of the recycled material. **(14)**

Asokan Pappu et.al (2009) they focused on effectively utilizing wastes as a raw material, filler, binder and additive in developing alternative building materials. **(2)**

M Wayman et.al (2009) they decrypted process of turning waste container glass into aggregate has lower impacts than the quarrying of primary aggregate in 7 out of the 10 impact categories examined. These benefits, with contribution to climate change being the sole exception, are counteracted when used in a binder course. **(9)**

Mohammed Muazu Abdulahi et.al (2009) he decrypted from the study that Bottom ash from municipal solid waste incinerator plants in Minna metropolis was characterized to investigate some alternatives for its utilization in road construction and their potential environmental impact. **(11)**

All rights reserved by www.ijaresm.net

R. M. Subramanian et.al (2009) decrypted that waste tyre pieces be effectively used in subgrade to improve its CBR value. An increase in CBR value of 2% can significantly reduce the total thickness of the pavement and hence the total cost involved in the project. **(16)**

Mohammad M. Khabiri et.al (2010) He decrypted from this study that by increase in waste construction material (WCM) percent, the specific weight increases too; but unconfined compressive strength decreases. By increase in lime percent, the compressive strength of samples against dry specific weight increases quicker. The best percent for lime and WCM for fine grained is about 20% of WCM and 6% limes. For average grain is in this maimer about 20% and 4% and for coarse grain is about 30% and 4%. **(10)**

Audrey Copeland et.al (2011) decrypted that RAP is a valuable, high-quality material that can replace more expensive virgin aggregates and binders. The most economical use of RAP is in asphalt mixtures. **(1)**

CRUMB RUBBER MIX DESIGN

Crumb rubber mix design tests conducted for finding the optimum value of crumb rubber, are as follows:

(a) Crumb* rubber *in binder course:

Crumb rubber pieces passing IS 2.36mm sieve were taken for the mix design. Crumb rubber was being mixed in various proportions with bitumen to find the optimum percentage of crumb rubber that can be used to obtain the desired strength. Marshal stability test was being conducted on the crumb rubber mixed with 5% bitumen. The test results for various percentage of crumb rubber mixed with bitumen is shown in see table 1 and figure 1:

TABLE 1

Marshal Stability Test On Aggregates+Crumb Rubber+5% Bitumen

Particular	Aggregates + 2% Crumb rubber	Aggregates + 4% Crumb rubber	Aggregates + 6% Crumb rubber	Aggregates + 8% Crumb rubber
Diameter of specimen (cm)	10.3	10.5	10.1	10.3
Height of speciman (cm)	6.38	6.4	6.37	6.42
Weight of speciman in air, WT (gm)	1223	1240	1221	1229
Weight of speciman in water, WT **(gm)**	702	723	700	710
Load of failure = Marshal stability value (kg)	1102	1068	1029	936
Deformation at failure = Flow value	3.1	2.7	2.7	2.45
Bulk density, Vm (g/cm^3)	2.3	2.22	2.39	2.29
Theoretical Sp.Gravity, Gt	2.455	2.49	2.45	2.467
Actual Sp.Gravity, Ga	2.347	2.1	2.343	2.368
Percent air voids, Vv (%)	3.31%	3.12%	2.86%	2.75%
Percent voids filled with bitumin, VFB (%)	86%	86%	87%	88.24%
Percent air voids mineral aggregates, VMA (%)	13.42%	13.80%	13.56%	13.38%
Volume of voids (cm^3)	10.18	12.16	12.43	11.42

All rights reserved by www.ijaresm.net

Figure 1: Marshal Stability Value against Crumb Rubber + 5% Bitumen

Thus the optimum value of crumb rubber that can be used binder course construction = 6%.

(b) Crumb rubber in sub-base course:

Crumb rubber pieces passing IS 2.36mm sieve were taken for the mix design. Crumb rubber was being mixed in various proportions with soil to find the optimum percentage of crumb rubber that can be used to obtain the desired strength. CBR test was being conducted on the crumb rubber mixed with soil. The test results for various percentage of crumb rubber mixed with soil are as follows is shown in see table 2 and figure 2:

TABLE 2

CBR TEST OF AGGREGATES + CRUMB RUBBER

Penetration (mm)	Proving Ring Factor: 1 Div = 0.4 Kg					
	Aggregates +2.5% CT		Aggregates + 5% CT		Aggregates + 7.5% Ct	
	Dial Reading of Proving Ring	Load (Kg)	Dial Reading of Proving Ring	Load (Kg)	Dial Reading of Proving Ring	Load (Kg)
0.0	0	0.0	0	0.0	0	0.0
0.5	7	2.8	6	2.4	6	2.4
1.0	18	7.2	16	6.4	13	5.2
1,;5	38	15.2	J3	13.2	28	11.2
2.0	75	30.0	67	26.8	55	22.0
2.5	118	47.2	94	39.6	84	33.6
4.0	154	61.6	118	47.2	102	40.8
5.0	161	64.4	130	52.0	114	45.6
7.5	182	72.8	148	59.2	130	52.0
10.0	197	78.8	159	63.6	148	59.2
12.5	212	84.8	178	71.2	165	66.0
	CBR of agg. at 2.5mm penetration= 3.445		**CBR of agg. at 2.5mm penetration= 2.89**		**CBR of agg. at 2.5mm penetration= 2.452**	

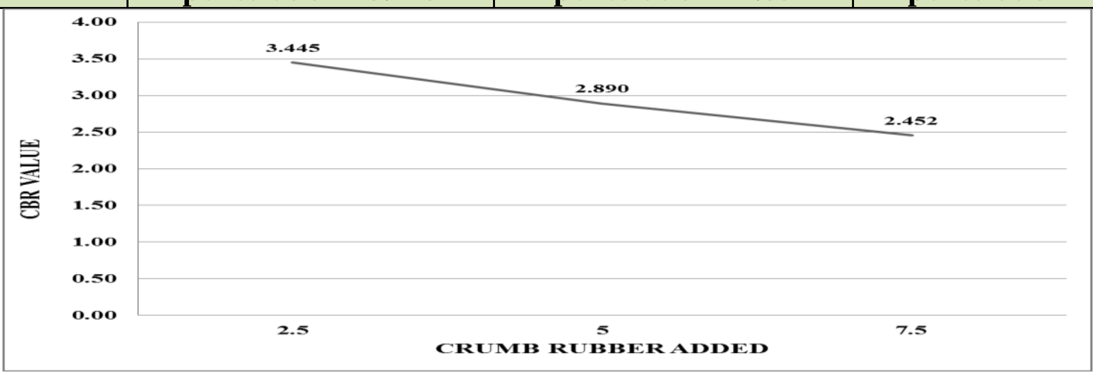

Figure 2: CBR Value against % Crumb rubber added

Thus the optimum value of crumb rubber that can be used sub-base course construction = 5%.

(c) Crumb rubber chips mix design

Crumb rubber pieces passing IS 25mm sieve and retained on IS 20mm sieve were taken for the mix design. Tyre chips were being mixed in various proportions with fine aggregates to find the optimum percentage of tyre chips that can be used to obtain the desired strength. CBR test was being conducted on the tyre chips mixed with fine aggregates. The test results for various percentages of tyres chips pieces mixed with fine aggregates is shown in see table 3 and figure 3:

TABLE 3

CBR TEST OF AGGREGATES + CRUMB RUBBER CHIPS

Penetration (mm)	Proving Ring Factor: 1 Div = 0.4 Kg							
	Aggregates +2.5% Crumb rubber chips		Aggregates + 5% Crumb rubber chips		Aggregates + 7.5% Crumb rubber chips		Aggregates + 10% Tyre Crumb rubber chips	
	Dial Reading Of Proving Ring	Load (Kg)	Dial Reading Of Proving Ring	Load (Kg)	Dial Reading Of Proving Ring	Load (Kg)	Dial Reading Of Proving Ring	Load (Kg)
0.0	0	0.0	0	0.0	0	0.0	0	0.0
0.5	21	8.4	24	9.6	30	12.0	23	9.6
1.0	47	18.8	53	21.2	65	26.0	50	20.0
1.5	81	32.4	91	36.4	118	47.2	87	34.8
2.0	110	44.0	139	55.6	166	66.4	134	53.6
2,5	163	65.2	192	76.8	217	86.8	175	70.0
4.0	199	79.6	313	125.2	377	150.8	280	1 12.0
5.0	321	128.4	371	148.4	435	174.0	339	135.6
7.5	395	158.0	450	180.0	496	198.4	430	172.0
10.0	430	173.0	504	201.6	546	218.4	478	191.2
12.5	487	194.8	545	218.0	598	239.2	515	206.0
	CBR of agg. at 2.5mm penetration = 4.76		CBR of agg. at 2.5mm penetration = 5.61		CBR of agg. at 2.5mm penetration = 6.33		CBR of agg. at 2.5mm penetration = 5.1	

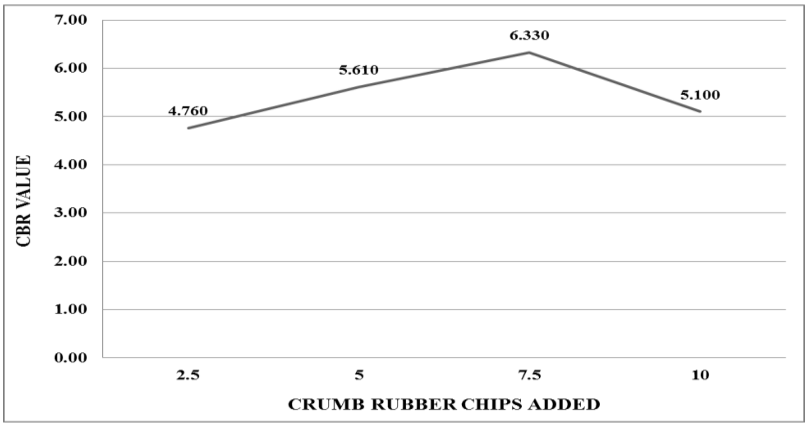

Figure 3: CBR Value against % Crumb rubber chips added

Thus the optimum value of tyre chips that can be used sub-base course construction = 7.5%.

All rights reserved by www.ijaresm.net ISSN : 2394-1766

CONCLUSIONS

Based on the experimental investigation and the results obtained the following conclusions are made:

a) The mix design test for waste tyre was carried out for various layers of pavement. Optimum value of crumb rubber to be used as bitumen substitute in binder course was found out to be 6%. Optimum value of crumb rubber to be used as soil substitute in sub-base course was found out to be 5%. Optimum value of crumb rubber chips to be used as aggregates substitute in sub-base course was found out to be 7.5%.
b) Crumb rubber waste material can be used in the construction of road pavement effectively and efficiently. Though not for the expressway and national highways but it can be used for the construction of district roads and rural roads. This would lead in saving of a lot of materials and also solve the problem of waste disposal that the world is facing today to some extent.

ACKNOWLEDGMENTS

The Authors thankfully acknowledge to Dr. C. L. Patel, Chairman, Charutar Vidya Mandal, Er. V. M. Patel, Hon. Jt. Secretary, Charutar Vidya Mandal, Mr. Yatinbhai Desai, Jay Maharaj Construction, Vallabh Vidyanagar, Gujarat, India for their motivational and infrastructural support to carry out this research.

REFERENCES

[01] Audrey Copeland (2011) “Reclaimed Asphalt Pavement in Asphalt Mixtures: State of the Practice”, Office of Infrastructure Research and Development Federal Highway Administration

[02] Asokan Pappu, Mohini Saxena and Shyam R. Asolekar (2009) “solid waste generation in India and their recycling potential in building materials” Regional Research Laboratory (CSIR), Habib Ganj Naka, Bhopa l – 462026, India CESE, Indian Institute of Technology, Bombay - 400076, India

[03] Carolyn T. Griffiths & James M. Krstulovich, Jr. (2002) “Utilization of Recycled Materials In Illinois Highway Construction” Illinois Department of Transportation Bureau of Materials and Physical Research Springfield, Illinois

[04] Daniel J. Fonseca, Gary P. Moynihan, Eric P. Richards (2004), “Expert System for Industrial Waste Recycling In Road Construction” University Transportation Center for Alabama The University of Alabama, The University of Alabama in Birmingham, and The University of Alabama at Huntsville

[05] Eric J. McGarrah (2007), “Evolution of current practices of reclaimed asphalt pavement/ virgin aggregate as base course material”, University of Washington

[06] F.A. Aisien, F.K. Hymore and R.O. Ebewele (2006), “Application of ground scrap tyre rubbers in asphalt concrete pavements”, Indian Journal of Engineering & Material Sciences, vol 13, August 2006, pp. 333-338

[07] Hassona, Hassan, Marei, Hashem, (2005), “Triaxial test and CBR test on shred tyre reinforced soil, concluded that The presence of shredded waste tyres”-2005.

[08] Michael Heitzman (2005), “Design and Construction of Asphalt Paving Materials with Crumb Rubber Modifier”, Transportation Research Record No. 1339, Recycled Tire Rubber in Asphalt Pavements.

[09] M Wayman, B Cordell & E Houghton (2009), "Life Cycle Assessment of the Use of Solid Waste Materials in Highway Construction" Transport Research Laboratory
[10] Mohammad M. Khabiri (2010), "The effect of stabilized subbase containing waste construction materials on reduction of pavement rutting depths", Electronic Journal of Geotechnical Engineering,Vol.15,Bund L.,2010,P1211-1219
[11] Mohammed Muazu Abdulahi (2009), "Municipal Solid Waste Incineration Bottom Ash as Road Construction Material", AU J.T. 13(2): 121-128 (Oct. 2009)
[12] N.Tatlisoz, C.Benson and T.Edil, "Effect of fines on mechanical properties of soil-tyre chip mixtures.", in ASTM STP 1275-1997
[13] N.Tatlisoz, C.Benson and T.Edil, "Interaction between reinforcing geosynthetics and soil tyre chip mixtures",Journal of geotechnical and geo environmental Engineering, 124(11),2001,psp.1109-1119.
[14] Narantuya Batmunkh, Komsun Siripun, Peerapong Jitsangiam and Hamid Nikraz (2008), "Sustainable Use of Crushed Concrete Waste as A Road Base Material" 4th International Conference on Sustainability Engineering and Science, Auckland, New Zealand: The New Zealand Society for Sustainability Engineering and Science (NZSSES).
[15] P Paige-Green and S Gerber (2007), "An Evaluation of The Use of by-Product Phosphor-gypsum as a Pavement Material for Roads, , Action In Transport For The New Millennium, Conference Papers, South African Transport Conference17 – 20 July, PP 1-10.
[16] R. M. Subramanian and S. P. Jeyapriya (2009), "Study on Effect of Waste Tyres In Flexible Pavement System, Indian Geotechnical Society Chennai Chapter, students Paper Competition, 2009.
[17] Tarek A. Kassim, Bernd R. T. Simoneit and Kenneth J.Williamson (2005), "Recycling Solid Wastes as Road Construction Materials: An Environmentally Sustainable Approach", The Handbook of Environmental Chemistry pp 59-181
[18] Zornberg, J. G., Costa, Y. D. and Vollenweider, B. 2004b. "Performance of prototype embankment built with tire shreds and nongranular soil". Transportation Research Record. 1874, National Research Council, Transportation Research Board, Washington, D.C. pp. 70–77.