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A Study on Impact of Industrial Wastes Utilization as Granular Sub Base (GSB) Material in Flexible Pavement Construction

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Abstract: *Nations economy is invariably a dependent factor of infrastructure and industrialization advancement as both the parameters goes hand in hand. Development of roads are part and parcel of infrastructure development as they play a major role in making more vibrant economy. In the process of constructing road projects, pavement engineers often face acute paucity of good soil with much required geotechnical characteristics. But for the structural safety of flexible pavements it is indispensable to modify the quality of ground soil. This modification stimulates a wide variety of index and engineering properties of poor soil though it shoots up the overall project cost. However on the flipside, this very rapid industrialization also results in the accumulation of industrial wastes and subsequent problems associated with their disposal. The judicious usage of these industrial wastes with conventional materials in pavement construction may help in overcoming some of the above mentioned constraints. In order to suggest a viable solution and to extract maximum benefit from the industrial wastes in the light of MoRT&H specifications an attempt has been made in this study by making use of Crusher Dust, Aggregate and Ground granular waste tyres in bulk quantities in granular sub base course (GSB).*
Keywords: *Aggregates, CBR, Compaction, Crusher Dust, Ground granular waste tyres, GSB, MDD, OMC*

I. Introduction

In a flexible road pavement component structure, the granular sub base (GSB) is a densely packed aggregate layer between the base course and the underlying sub grade layer. As the sub base is placed below the base it serves as a foundation for the entire pavement structure and functionally involves in transmitting heavy traffic loads to the sub grade. This sub base layer is formed by spreading the conventional materials in thin layers and then compacting them till they form a dense layer with better interlocking ability with the subsequent layers to be constructed over it. For improved structural performance the materials used in the sub base course should meet gradation requirements as per MoRT&H specifications so that they are adequately strong and durable throughout the design period.

Generally, soil and aggregates used for sub base constructions are composed of sand, gravel and other natural mineral materials which offers the necessary strength and durability. Natural aggregates are still the prime materials used for sub base construction. Ground granulated waste tyre usually mixed with different proportions helps in providing the much required elastic property at the sub base level. But the intrinsic deficiencies exhibited by all these conventional materials coerced the researchers to continue pioneering efforts in recommending sustainable solution in the form of bulk utilization of industrial wastes which may otherwise proves to be cost-effective in the long run with definite value addition.

Soosan T.G. et.al (2001)[1] studied the effect of quarry dust in Highway construction as embankment and sub base material. P.V.V. Satyanarayana et al (2013)[2] studied the CBR characteristics of Crusher dust and identified that crusher dust attained high CBR values(10%) at high moisture contents compared to sand and red soils. Sridharan A, et.al (2005,2006)[3,4] studied strength characteristics of soil and quarry dust mixtures in highway pavement construction. Praveen Kumar. et.al (2006)[5] carried out study on quarry dust as a sub-base material. Chi sun poon et.al (2006)[6] studied the effect of recycled aggregates in sub base constructions. Kumar P Rateesh (2007)[7] studied the effect of demolished waste products in concrete for improving strength. H.Venkateswarlu et.al (2015)[8] studied the Quarry dust effect on behavior of expansive soil with regard to strength aspects in pavement construction. R.A.Khan et al (2002)[9] studied the performance of a road base constructed with shredded rubber tires. Suat Akbulut et al (2007)[10] studied the modification of clayey soils using scrap tire rubber and synthetic fibres. Heeralal M et al (2009)[11] studied the recycled aggregate performance in the rigid pavements. Lee, J.H et al (1999)[12] studied the shredded tires and rubber-sand effect in back filling. K V Subramanyam (2014)[13] studied on utilization of waste materials and concluded that the CBR increase is from 4.71% to 7.7% with waste tyres in flexible pavement system. Nagraj et al (1996)[14] studied the rock dust, pebbles and aggregate utilization as promising one in stabilizing the cement concrete.

In this connection, industrial waste materials like Crusher Dust, Aggregate and Ground granular waste tyres are tried in the study. Crusher dust comprises both coarse and fine particles, aggregates usage in granular sub base already proved to be an established experimental procedure and tire chips usually mixed with other aggregate materials with different sizes provide good drainage while reducing the weight of the aggregate layer. The use of industrial waste materials in mass applications like GSB construction also reduces the need for quarrying of virgin aggregate and the associated use of water, fuel, CO_2 emissions, while saving the valuable landfill space.

Grading I of Table 400-1 of section 400 - MoRT&H specification strictly advocates about the minimum CBR requirement as 30% with a plasticity index less than 6 and a liquid limit less than 25, for natural soil and gavel. But this natural soil used in sub base course is subjected to undue development of plasticity characteristics over a period of time by effecting the CBR value and elasticity characteristics significantly. As a result the granular sub base course undergoes significant deformation leading to the settlement, and the ultimate disastrous failure of the pavement. In order to address MoRT&H specifications shortfall in GSB construction apart from conserving the green environments, an attempt has been made in this study to develop a new gradation and using the same gradation with the Crusher dust, aggregate and ground granulated waste tyre combined mix so that it will satisfy the MoRT&H stipulations. For the sake of convenience five different gradations namely GSB_{11}, GSB_{12}, GSB_{13}, GSB_{14} and GSB_{15} are designated by using a set of sieves of the order 12.5 mm to 0.075 mm as shown below.

II. Materials Used

Crusher Dust is obtained from local stone crushing plants nearer to Visakhapatnam City, Andhra Pradesh. The sample is subjected to various geotechnical characterizations. Crushed stone aggregate is collected from the same crushing unit from where crusher dust is collected. Ground granulated waste tyre (GGWT) is collected from a tyre re-retreading unit in Visakhapatnam city.

Table: 1

Property	**Values**
Grain size distribution:	
Gravel Sizes (%)	5
Sand Sizes (%)	88
Fines Sizes (%)	7
a. Silt Sizes (%)	7
b. Clay Sizes (%)	0
Consistency:	
Liquid Limit (%)	Non Plastic
Plastic Limit (%)	Non Plastic
I.S Classification	SWN
Specific gravity	2.65
Compaction characteristics:	
Optimum moisture content (OMC) (%)	11.5
Maximum dry density (MDD) (g/cc)	2.08
Shear parameters:	
Coefficient of uniformity (Cu)	6.25
Coefficient of curvature (Cc)	1.0
CBR:	
California bearing ratio CBR (%) (Soaked)	11

Fig: 1 grain size analysis

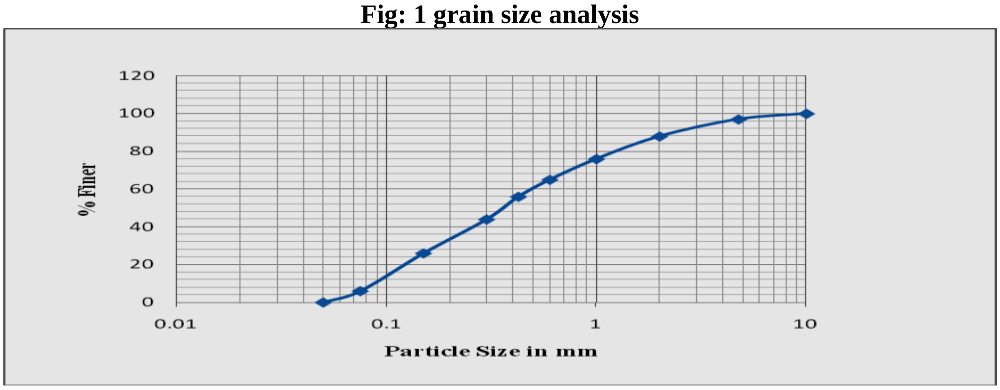


Table: 2

Water Content (%)	**Dry Density (g/cc)**
2	1.89
4.5	1.84
11.5	2.08
18	1.82

Fig: 2 compaction curve

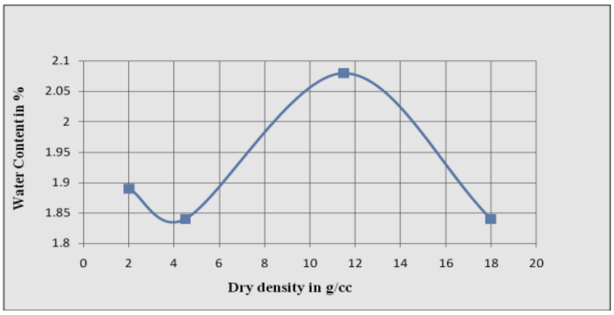


Fig: 3 crusher dust

Fig: 4 stone aggregate

Table: 3

Aggregate Properties	**Value**
Deval Abrasion Test Value	24%
Aggregate Impact Test Value	20.76%
Aggregate Crushing Value	23.82%
Water absorption	0.5%
Specific gravity	2.49

Fig: 5 GGWT

Table: 4

GGWT Properties	Value
Max. density g/cc	0.51
Min. Density g/cc	0.33
Specific gravity	1.06

III. Methodology

Typical strength parameters are appraised by conducting tests like Compaction and CBR on the mixes modified with the above mentioned industrial wastes with different proportions and the results are presented. Grain size analysis of crusher dust is done in accordance with IS 2720 Part IV-1985. A set of sieves of the order 12.5mm, 9.5mm, 4.75mm, 2.36 mm, 0.425 mm and 0.075 mm sizes were identified for the gradation of combined mix. Dry sieve analysis is conducted to obtain the grain size distribution. Coefficient of Uniformity (Cu) and Coefficient of Curvature (Cc) of crusher dust is determined from grain size distribution curves as shown in Table:1,2 and "Fig.1,2". Now in order to cater to the higher traffic cumulative standard axles load i.e for urban roads another combination in the form of Crusher dust, Aggregate mixed with Ground granulated waste tyre with 0,0.5,1.0,1.5,2.0 percent by weight of total weight of the crusher dust and aggregate is tried to get higher CBR. Table:3,4 shows the properties of Stone Aggregate, GGWT and "Fig.3,4,5" shows the pictures of Crusher dust, Stone Aggregate, GGWT respectively used in the study.

Table: 5 Gradation Table

Sieve Size in mm	GSB_{11}	GSB_{12}	GSB_{13}	GSB_{14}	GSB_{15}
12.5	100	100	100	100	100
9.5	75	67	60	52	65
4.75	25	33	40	48	55
2.36	20	25	30	35	40
0.425	10	11	12	14	15
0.075	5	5	5	5	5

IV. Results And Discussions

From the above newly developed gradation from GSB_{11} to GSB_{15} as shown in Table:5, strength tests like Compaction, CBR are carried out. IS Heavy compaction tests are carried out on modified mix as per IS:2720 (Part VIII)-1983 for finding the Optimum moisture content (OMC) and Maximum dry density (MDD). The collected modified mix is also subjected for California Bearing Ratio (CBR) test confirming IS: 2720- part 16- 1987. The results of the above tests are as listed below in Table:6 and" Fig. 6,7,8".

Table: 6

(Crusher Dust+Aggregate+GGWT)															
GGWT %	GSB_{11}			GSB_{12}			GSB_{13}			GSB_{14}			GSB_{15}		
	OMC %	MDD g/cc	CBR %	OMC %	MDD g/cc	CBR %	OMC %	MDD g/cc	CBR %	OMC %	MDD g/cc	CBR %	OMC %	MDD g/cc	CBR %
0	4.0	2.16	38	4.3	2.18	46	4.7	2.20	52	5.0	2.19	50	5.2	2.18	42
0.5	4.2	2.15	40	4.5	2.17	50	5.0	2.19	55	5.2	2.18	52	5.4	2.17	45
1.0	4.4	2.13	44	4.8	2.16	55	5.3	2.18	58	5.4	2.17	55	5.7	2.16	48
1.5	4.7	2.12	46	5.0	2.14	52	5.5	2.17	56	5.6	2.15	51	5.9	2.15	50
2.0	5.0	2.11	42	5.2	2.13	48	5.7	2.16	52	5.7	2.14	48	6.0	2.14	47

The OMC values increases with increase in the percentage of ground granulated waste tyre as well as with the five different gradations from GSB_{11} to GSB_{15}. The MDD values decreases with the increase in the percentage of ground granulated waste tyre and the value goes on increasing for the first three gradations of a given gradation and percentage i.e from GSB_{11} to GSB_{13} and it decreases from there onwards i.e from GSB_{14} to GSB_{15}. The CBR values increases with the increase in the percentage of ground granulated waste tyre up to 1.0% and beyond that it is getting decreased. The CBR value goes on increasing for the first three gradations of a given gradation and percentage i.e from GSB_{11} to GSB_{13} and it decreases from there onwards i.e from GSB_{14} to GSB_{15}.

Fig: 6

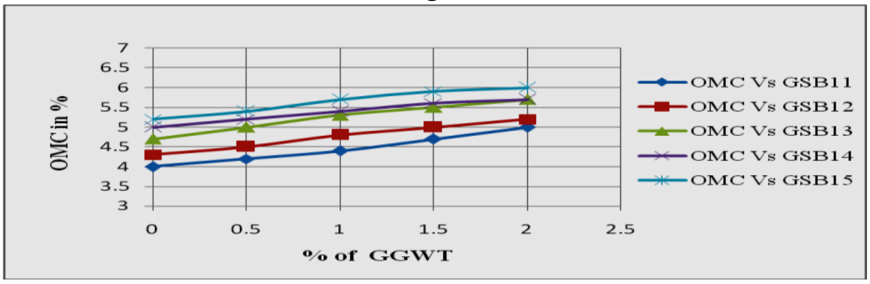


Fig: 7

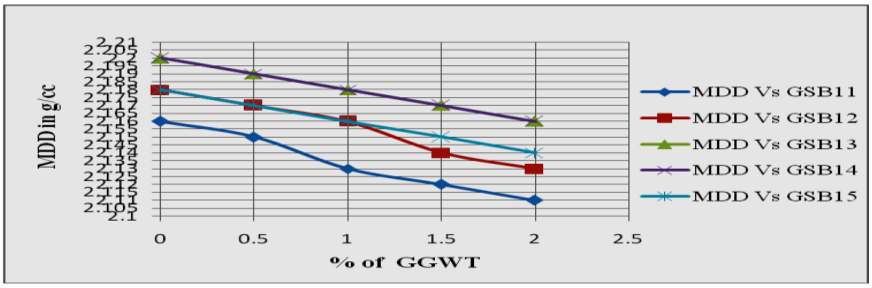
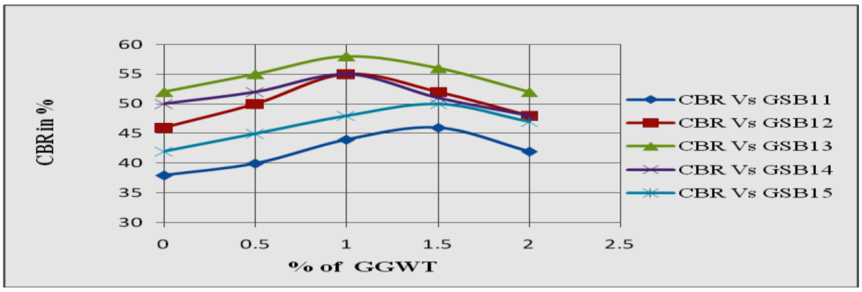


Fig: 8



V. Conclusions

- The increasing trend of optimum moisture content (OMC) and decreasing trend of maximum dry density (MDD) put forward a remarkable improvement of the modified mix in gaining the strength. As the ground granulated waste tyre is elastic in nature more amount of water is absorbed by the mix by offering much required flexibilty.
- Crusher dust grain sizes are similar to sand particles and when they are mixed with aggregates and ground granulated waste tyre, their combined effect results in attaining higher CBR value with much required elastic property due to the reduction in percentage of voids.
- GSB_{13} appears to be the more promising gradation as far as the CBR value is concerned with a CBR value of 58% at 1.5% of GGWT.
- As the CBR values are in the range of 42-58, these mixes could be used for heavier traffic roads where the expected cumulative standard axles load is greater than 10 MSA as per MoRT&H specifications.

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