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An Experimental Study on Use of Road Demolition Wastes as Recycled Materials in Pavement Construction

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Abstract – *In the Roads and Highway construction the granular course layer such as GSB (Granular Sub Base) and WMM (Wet mix macadam) are the most important layer. With the use of these layers in Flexible Payment Road a stable surface can be formed. The constructions of roads consume natural valuable resources like aggregate which is costlier. The use of recycled aggregate instead of virgin aggregate helps in reducing the demand of extraction. If a new Road is formed over the existing road or if bridge is constructed over the existing road due to increasing in day to day traffic demand than for the construction of newly road the valuable aggregate of existing road can be utilized as secondary aggregate in the replacement of virgin aggregate. In present study the granular course layer of flexible pavement such as GSB and WMM are investigated experimentally to form with excavated aggregate material produced from existing road to construct fresh road. In this study it also believed that magnificent preservation of natural and valuable resources would be attained from the inclusion of secondary and tertiary materials in road construction.*

***Key Words*: GSB (Granular Sub Base), WMM (Wet mix macadam), Recycled Aggregate, Road Demolition Wastes, Road Dismantling Materials, Road Granular Waste.**

1. INTRODUCTION

Recycling of aggregate as Road Demolition Wastes is a process in which existing road aggregate is reused for new road construction. Use of secondary (recycled) aggregate in road construction is not very usual in India and other developing nations. The aggregate is valuable material and there is huge requirement of the aggregate as the traffic is increasing day to day with fast development in the infrastructure area. It is required to reduce the usage of virgin aggregate. In continuation of this step the RD aggregate could be used in the replacement of new material. If there is a provision of new construction of road over the existing road or if there is requirement of bridge at the existing junction then in such case the requirement of aggregate can be full filled with the dismantling of existing roadway cutting in the form of aggregate.

In this paper the secondary aggregate is contracted from the granular of dismantled roads. For a developing nation the highways and road infrastructure is an constitutive requirement for economic growth. The road network system is a way to joint other transport modes like rail-ways, air-ways etc. The growth of a country depends on a well synchronized road system. For construction of road there are multiple types of material which includes different grade of aggregate and binding material.

Among this Aggregate is an important part of pavement structure. This should be of appropriate physical property as define in IRC codes. In the road construction and it's design the important role of the pavement layer is to forward wheel load of vehicles to the sub grade. In this load transfer process, the aggregates have to take stresses coming reason to the vehicles wheel load of the traffic. Therefore it is required to use aggregate that has significance properties to the highway engineers. The aggregates are further divide based on their physical characteristics such as-gradation, size, shape and texture. For designing of different pavement mixes like B.C., D.B.M., semi dense bituminous macadam and bituminous concrete it is important separate gradation as has been denoted by various parties like A. S. T. M, B. S. I, I.S.I & I.R.C.

Pavement layer like Granular Layer and Bituminous Layer can be constructed by using road demolition material as recycled material.

2. REVIEW OF LITERATURE

Recycled Aggregate

2.1 Wilmot and Vorobieff (1997) – the use of RD aggregates to build and mending local polity roads has improved significantly over the former five years they also prime that the Australian road industry has been using RD aggregates for the former 100 years. The report also states that Europe's recycling industry has been established since the end of World War II. Fact files from the C & D recycling industry point out that, from the Roman era, the stones on previous roads were reused when rebuilding their boasted roads. RD aggregate is widely used in the road construction part. Many tests based on recycled aggregates have been performed around the world.

2.2 Hanson and Torben (1986) – The main cause of testing RD aggregates is to find out the results of their strength characteristics and to analyze whether the RD aggregates are suitable to replace new granular in road construction. It is noted that research on RD aggregates has been conducted in many countries. In few cases, the compressive-strength of RD (secondary) aggregates is the same as that of new aggregates.

2.3 Limbachiya and Leelawat (2000) – Ethically to their test results, superseding 30% of the coarser RD aggregate has no impression on the strength of the newer aggregate. It was underlay that the ρ (relative) of the RD aggregate was lower and the water absorption capacity was lesser than that of the newer aggregate.

2.4 Sagoe, Brown and Taylor (2002) – It is indicated that difference between the characteristic of RD aggregate and new aggregate (unified from natural ways like from mountain) is relatively parochial than indirect for laboratory crush RD aggregate mixture.

2.5 Mandal, Chakaborty and Gupta (2002) – They adduced that the characteristics and characteristics of RD (secondary) aggregates were insufficient compared to new (virgin) aggregates. It appeared that as the replacement amount recovered increased similarly the strength of compressive increased. There must be some effects that conduct to a reduction in the compressive strength of the RD (secondary) aggregate.

2.6 According to Tavakoli (1996) – There are various tract that can be utilized to increase the strength of the RD aggregate. From the results obtained, the RD aggregate has the same engineering and durability performance as new aggregate. The characteristics strength of the RD aggregate are affected by some inorganic pastiche, the ratio of coarser aggregate to finer aggregate, and the ratio of the top size of the aggregate in the RD aggregate.

2.7 Florida Division of Transportation (FDOT) – The amount of wear in Los Angeles required to be lower than 45%, and the stability of the sodium sulfate test need to be inferior to 15%. The code recommends that for RD aggregates to be used as a base material for flexible pavements.

3. RESEARCH OBJECTIVES

When there is a provision of any structure like VUP/PUP/CUP or MNB/MJB over existing road then the main layer of existing road layer is required to dismantle for this new proposed project. In such case the valuable layer of existing road like Bituminous Course and Granular Course extracted from dismantling process. These valuable layers can be reuse for construction of approaches of proposed VUP/PUP/CUP or MNB/MJB or can be reuse for its proposed service road.

While using recycled aggregate like road demolition wastes for the making of new road layer, it is important to design its proportion so it may sustain under the heavy loads of vehicle. It is also important to find the percentage of recycled aggregate that can be reuse which will define the MORT&H specification limits. The main cause of this research include-

(1) To collect the material for study.

(2) Investigate various characteristics of selected materials, such as grade, water absorption, M.D.D., A.I.V., F.I. & E.I. property to determine their suitability in G.S.B. and W.M.M. structures.

(3) Design of JMF for G.S.B. by adding Road demolition wastes as recycled aggregate in various proportions.

(4) Design of JMF for W.M.M. by adding Road demolition wastes as recycled aggregate in various proportions.

4. MATERIALS USED

The materials used for developing the road layers of fresh G.S.B. and W.M.M. after addition of recycled aggregate of road demolition have been described this way.

4.1 *Road Aggregate –*

In Road construction, Aggregate is a grainy material, such as sand, gravel, and crushed stone which is a expanded category of coarser-to-medium-grained materials that is used in construction of sub base course and base course layer. Mainly road aggregate are further categorized in Fine Aggregate and Course Aggregate. Here in this experimental programme we use course aggregate as fresh aggregate that will use with recycled aggregate.

4.2 Recycled Aggregate –

Recycled aggregate is formed by dismantling / excavation of granular layer of existing road. In the present investigation, the recycled aggregates of G.S.B. and W.M.M. are use for construction of new road. The study includes the use of RD granular aggregate with addition of fresh 40 mm courser aggregate and stone dust in various proportions.

Recycled aggregate use in this study are further described as below :

4.2.1 Granular Course

In existing road pavement structure the granular course is available in base / sub base layer. It is further find in two proportions of G.S.B. and W.M.M..

4.2.1.1 Granular Sub Base (G.S.B.) – G.S.B. is a type of drainage layer and it is also type of good sub base to laid base layer on it. The materials used for this work should be natural sand, crushed stone or a combination of them, depending on the grade required by the grade.

4.2.1.2 Wet Mix Macadam (W.M.M.) – W.M.M. serves as the base layer which is laid on sub base layer and just below to BC. It forwards the receiving load from BC to sub base layer.

5. TEST RESULT AND DISCUSSION

Road demolition waste in form of granular courser were taken for gradation test and other physical tests such as water absorption test, Atterberg limits test, combined F.I. and E.I, A.I.V., M.D.D. & O.M.C. and C.B.R. test for the conformation of specification required for construction of new G.S.B. and W.M.M. layer.

5.1 For Granular Sub Base –

5.1.1 Gradation Test result for Improved GSB Material after addition of 20% of 40mm fresh aggregate with acquired road demolition wastes has been shown below-

Sieve Size 'mm'	% Passing	Mid Range	MORT&H Limits	
			Lower	Upper
75.00	100.00%	100.00	100	100
53.00	100.00%	90.00	80	100
26.50	72.51%	72.50	55	90
9.50	48.43%	50.00	35	65
4.75	39.69%	40.00	25	55
2.36	28.80%	30.00	20	40
0.425	12.31%	12.50	10	15
0.075	2.60%	2.50	0	5

Table 5.1: Sieve Analysis of modified G.S.B. Material

5.1.2 Water Absorption Test performed to find the porous property of amended / modified G.S.B. material. The procedure was followed by IS code 2386 (Part 3) : 1963 and testes for three samples and the results of these sample has been shown in table no. 5.2. Water Absorption Test Result of amended / modified G.S.B. material

Sr. No.	Description	Sample 1	Sample 2	Sample 3	Average %
A	Wt. of SSD Material in gm	2037	2084	2055	0.68
B	Wt. of Oven Dry material in gm	2022	2069	2043	
C	Absorption (A-B)/B x 100 (%)	0.74	0.72	0.59	

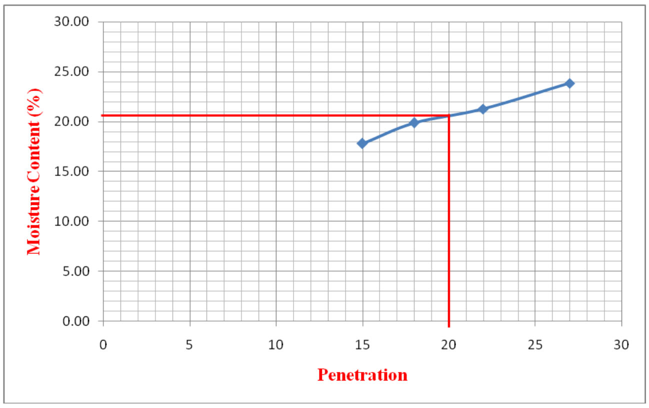
Table 5.2: Water Absorption Test Result of amended / modified G.S.B. material

5.1.3 Atterberg Limits (L.L., P.L., & P.I.) - For determining the L.L of amended / modified G.S.B. material the Cone Penetrometer Method was adopted accordance with IS code 2720 (Part 5) – 1985. The two samples were taken for testing and the results derived from test of sample no. 1 has been shown in Table 5.3

S. No.	Determination Detail	L.L.			
		1	2	3	4
1	Penetration Depth	15	18	22	27
2	Vessel Identification No.	B13	B6	B8	B3
3	Wt. of Blank Vessel, gm (A)	20	20.30	20.30	18.10
4	Wt. of Moist Soil + Vessel, gm (B)	50.31	53.28	47.44	49.99
5	Wt. of Dry Soil + Vessel, gm (C)	45.73	47.81	42.68	43.85
6	Wt. of Water, gm D = (C-B)	4.58	5.47	4.76	6.14
7	Wt. of Dry Soil, gm E = (C-A)	25.73	27.51	22.38	25.75
8	% M.C. = (D/E)x100	17.80	19.88	21.27	23.84

Table 5.3: Atterberg Limits by Cone Penetrometer of G.S.B. Material for Sample – 1

With the help of obtained result a graph was prepared showing the W.C. on the Y-axis and the cone penetration on the X-axis. With the obtained data most suitable line was drawn in Graph.



Graph 5.1: Moisture Content (M.C.) Vs Cone Penetration of G.S.B. Material for Sample – 1

In the graph M.C. (%) corresponding to 20 mm Cone Penetration was taken as L.L. of sample no. 1 of amended / modified G.S.B. material. The test result for sample 1 corresponding to above Table 5.3 and Graph 5.1 are mentioned below –

L.L. to be determine at 20mm Penetration (L.L.) = 20.08%

Average P.L. = Nil

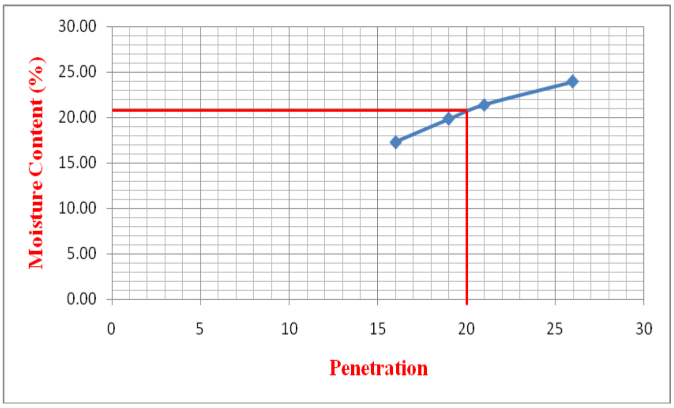
P.I. % = Non - Plastic

Similarly the test was performed for sample no. 2 and results obtained are shown in Table no. 5.4.

S. No.	Determination Detail	L.L			
		1	2	3	4
1	Penetration Depth	16	19	21	26
2	Vessel Identification No.	B21	B22	B23	B24
3	Wt. of Blank Vessel, gm (A)	23.8	23.9	23.9	23.9
4	Wt. of Moist Soil + Vessel, gm (B)	50.08	54.71	54.88	58.23
5	Wt. of Dry Soil + Vessel, gm (C)	46.21	49.61	49.42	51.6
6	Wt. of Water, gm D = (C-B)	3.87	5.1	5.46	6.63
7	Wt. of Dry Soil, gm E = (C-A)	22.41	25.71	25.52	27.7
8	% M.C. = (D/E) x 100	17.27	19.84	21.39	23.94

Table 5.4: Atterberg Limits by Cone Penetrometer of G.S.B. Material for Sample – 2

With the help of obtained result of sample no. 2 a graph was plotted showing the W.C. and the cone penetration and the most suitable line was drawn which shown in Graph 5.2.



Graph 5.2: Moisture Content (M.C.) Vs Cone Penetration of G.S.B. Material for Sample – 2

In the graph M.C. (%) corresponding to 20 mm Cone Penetration was taken as L.L of sample no. 2 of amended / modified G.S.B. material. The test result for sample 2 corresponding to above Table 5.4 and Graph 5.2 are mentioned below –

L.L. to be determine at 20mm Penetration (L.L.) = 20.09%

Average P.L. = Nil

P.I. % = Non –Plastic

The average values of sample no. 1 & sample no. 2 shows the Atterberg Limit of amended / modified G.S.B. material. For L.L it found 20.85% (Avg. of 20.08% and 20.09%). The value of P.L. was not found in both samples hence the value of P.I. considered as Non - Plastic. According to MORT&H the value of L.L. should not be more than 25% and in test result it was found 20.85% which is less than specified limit.

5.1.4 Aggregate Impact Value shows the behavior of aggregate under impact load. It also represents the strength property of material which helps to maintain its uniformity under vehicle loads. For performing the test three sample were taken and the process was followed according to IS Code: 2386 Part IV – 1963. The result obtained for these samples are shown in Table 5.5.

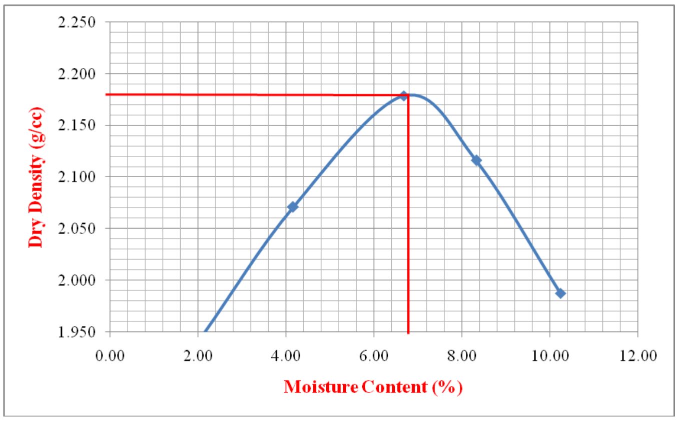
S. No.	Description	Units	Trail 1	Trail 2	Trail 3	Avg.
1	Wt. of Oven Dry Sample (12.5 mm Passing and 10mm Retained)(X) gm	gm	365.5	366.7	363.3	365.17
2	After Impact Test - Wt. of 2.36mm Sieve Retained Fraction (Y) gm	gm	270.4	268.2	265.4	268.00
3	After Impact Test - Wt. of 2.36mm Sieve Passing Fraction (Z) gm	gm	95.1	98.5	97.9	97.17
4	A.I.V. = (Z/X)x 100	%	26.02	26.86	26.95	26.61

Table 5.5: Test Result of Aggregate Impact Value of G.S.B. Material

The AIV should not be more than 40% as defined by MORT&H. In average test results of three sample of amended / modified G.S.B. material it is found 26.61% which is less than specified limit.

5.1.5 M.D.D. & O.M.C. shows the physical characteristic of material. With the help of M.D.D. and O.M.C. G.S.B. layer can be laid with proper compaction. The % compaction value (F.D.D.) can be achieved with respect to M.D.D. The "Modified Proctor Test" was used followed by IS code 2720 (Part-8):1983 and two samples were tested and the different values of dry density were determined by adding different % of W.C.

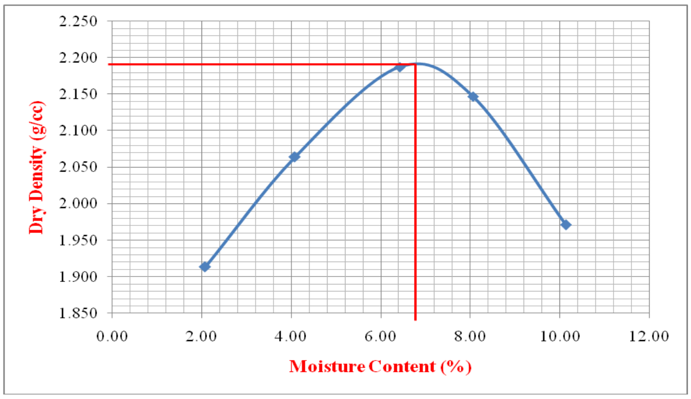
For finding M.D.D. & O.M.C. of sample no. 1 of amended / modified G.S.B. material a Graph was plotted between Dry Density (gm/cc) and % M.C.. The smooth curve obtained through the result points has been shown with Blue Line. In graph the position of maximum value of the curve has been indicated by Red Line. This value shows the M.D.D. The corresponding M.C. shows the O.M.C. for sample no. 1



Graph 5.3: Dry Density Vs M.C. of G.S.B. Material for Sample – 1

The values of M.D.D. and O.M.C. for sample – 1 obtained from graph 5.3 are 2.180 gm/cc and 6.80 % respectively shown by Red Line on the graph.

Similarly the tests of M.D.D. and O.M.C. were conducted for sample no. 2 and A Graph was plotted between Dry Density (gm/cc) and % M.C. with the help of obtained data.



Graph 5.4: Dry Density Vs M.C. of G.S.B. Material for Sample – 2

The smooth curve obtained through the result points of sample – 2 has been shown with Blue Line. In graph 5.4 the position of maximum value of the curve is indicated by Red Line. This value shows the M.D.D. The corresponding M.C. shows the O.M.C. for sample no. 2. The values of M.D.D. and O.M.C. for sample – 2 obtained from graph are 2.190 gm/cc and 6.80 % respectively shown by Red Line on the graph.

The average values of samples are taken as M.D.D. and O.M.C. value of amended / modified G.S.B. material which are found 2.185 gm/cc and 6.80% respectively.

5.1.6 C.B.R. Test is an important test for flexible pavement as it is used in the design part of pavement. The thickness of layer can be defined which required to wear the vehicle load without pavement failure. For finding C.B.R. value of amended / modified G.S.B. material, three samples were taken. The M.C. and Unit Wt. of three samples were obtained according to IS code – 2720 (Part – 16) : 1987 and the results are shown in table. The values of M.D.D. and O.M.C. will remain same as the result find in Para no. 5.1.5.

M.D.D. (gm/cc):	2.185	O.MC (%)	6.80	Proving Ring Constant	4.34

M.C. and Unit Wt. of Test Sample							
S. No	Description	Mold No. 1		Mold No. 2		Mold No. 3	
A.	No. of layers	5		5		5	
B.	No. of blows per layer	56		56		56	
C.	Socking Condition	Before	After	Before	After	Before	After
D.	Wt. of Mold (gm)	6942	6942	7338	7338	7401	7401
E.	Wt. of Moist soil + mold (gm)	12183	12234	12581	12591	12644	12656
F.	Wt. of Moist soil (E-D) (gm)	5241	5292	5243	5253	5243	5255
G.	Volume of Mold (cc)	2250	2250	2250	2250	2250	2250
H.	Wet Density = (F/G) (gm/cc)	2.329	2.352	2.330	2.335	2.330	2.336

J.	Moisture Assessment						
K.	Vessel no.	1	1	2	2	3	3
L.	Wt. of Vessel (gm)	75.7	75.7	77.6	77.6	77.5	77.5
M.	Wt. of moist soil + Vessel (gm)	345.2	325.5	290.45	265.52	270.52	295.45
N.	Wt. of dry soil + Vessel (gm)	328.04	307.23	276.90	253.14	258.23	281.02
P.`	Wt. of water (M-N) (gm)	17.16	18.27	13.55	12.38	12.29	14.43
Q.	Wt. of dry soil (N-L) (gm)	252.34	231.53	199.30	175.54	180.73	203.52
R.	W.C. = [(P/Q)x100] (%)	6.80	7.89	6.80	7.05	6.80	7.09
S.	Dry Density - {H/[1+(R/100)]} (gm/cc)	2.181	2.180	2.182	2.181	2.182	2.181

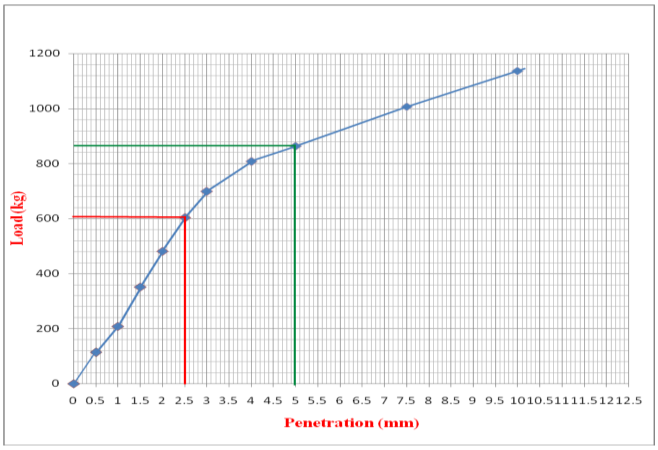
Table 5.6: Moisture Content and Unit Weight of Test Sample

The mould assembly of three sample with the surcharge weights were placed on the penetration test machine one by one and the rate of load was applied at 1.25mm / minute and at the penetrations value of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10 and 12.5 mm readings were recorded which have been shown in Table no. 5.7

Load Penetration Test Data						
Penetration (mm)	Mold No. 1		Mold No. 2		Mold No. 3	
	Proving Ring Reading	Corrected Load (kg)	Proving Ring Reading	Corrected Load (kg)	Proving Ring Reading	Corrected Load (kg)
0	0	0	0	0	0	0
0.5	26	112.84	26	112.84	24	104.16
1	48	208.32	49	212.66	48	208.32
1.5	81	351.54	85	368.9	84	364.56
2	111	481.74	125	542.5	111	481.74
2.5	139	603.26	144	624.96	141	611.94
3	161	698.74	162	703.98	158	685.72
4	186	807.24	190	824.6	191	828.94
5	199	863.66	211	915.74	205	889.7
7.5	232	1006.88	235	1019.9	232	1006.88
10	262	1137.08	250	1085	254	1102.36

Table 5.7: Load Penetration Test Data

For The C.B.R value a graph was plotted between Applied Load (Kg) and Penetration (mm) with the help of observation data derived for Mold no. 1 has been shown in Graph no. 5.5.



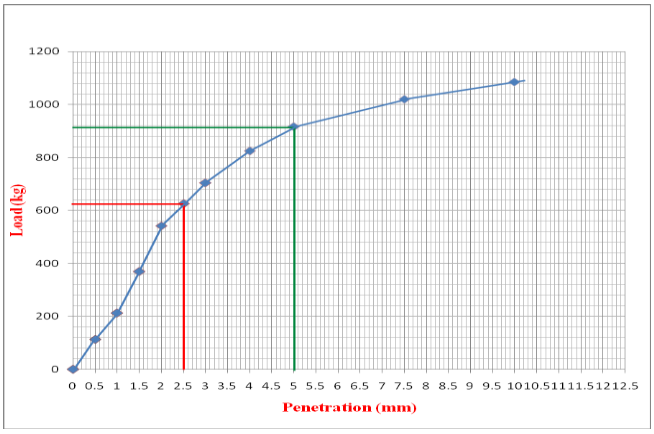
Graph 5.5: Applied Load (kg) Vs Penetration (mm) for Mould – 1

From Graph 5.5 the C.B.R. value for Mold – 1 @ 2.5mm (Shown by Green Color Line) and @ 5.0m (Shown by Red Color Line) are as below -

C.B.R. Value @ 2.5mm – (603.26 / 1370) x 100 = 44.03 %

C.B.R. Value @ 5.0mm = (863.66 / 2055) x 100 = 42.03 %

Similarly The C.B.R value a graph 5.6 was plotted between Applied Load (Kg) and Penetration (mm) with the help of observation data derived for Mold no. 2



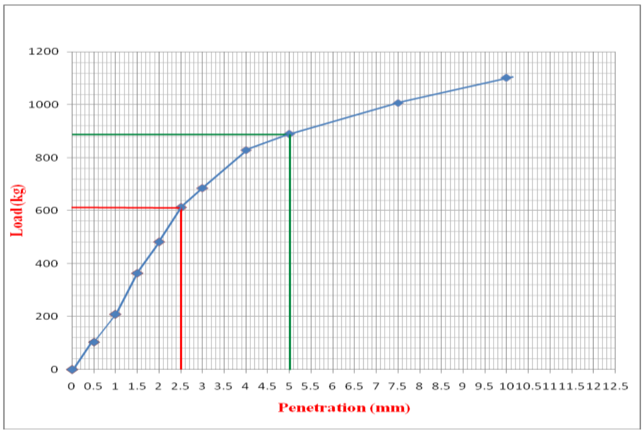
Graph 5.6: Applied Load (kg) Vs Penetration (mm) for Mould – 2

From Graph 5.6 the C.B.R. value for Mold – 2 @ 2.5mm (Shown by Green Color Line) and @ 5.0m (Shown by Red Color Line) are as below -

C.B.R. value @ 2.5mm – (624.96 / 1370) x 100 = 45.62 %

C.B.R. Value @ 5.0mm = (915.74 / 2055) x 100 = 44.56 %

Accordingly The C.B.R value a graph 5.7 was plotted between Applied Load (Kg) and Penetration (mm) with the help of observation data derived for Mold no. 3



Graph 5.7: Applied Load (kg) Vs Penetration (mm) for Mould – 3

From Graph 5.7 the C.B.R. value for Mold – 3 @ 2.5mm (Shown by Green Color Line) and @ 5.0m (Shown by Red Color Line) are as below -

C.B.R. value @ 2.5mm – (611.94 / 1370) x 100 = 44.67 %

C.B.R. Value @ 5.0mm = (889.70 / 2055) x 100 = 43.29 %

The average C.B.R. value of Mold - 1, Mold - 2 and Mold - 3 are shown in Table no. 5.8

Description	**Mold No. 1**	**Mold No. 2**	**Mold No. 3**
C.B.R. at 2.5mm Penetration	44.03	45.62	44.67
C.B.R. at 5.0mm Penetration	42.03	44.56	43.29
Corrected C.B.R at 2.5mm Penetration	44.35	45.41	43.51
Corrected C.B.R at 5.0mm Penetration	42.24	45.93	44.98
C.B.R. Reported (%) 2.5 mm	44.42%		

Table 5.8: C.B.R. Value of amended / modified GSB material

For construction of new G.S.B. layer the C.B.R. value of material should be Min. 30% as per IS Code : 2720 (Part-16). The C.B.R value obtained from tests of amended / modified GSB material was 44.42% which fulfill the minimum requirement of guideline; hence the modified material can be use for construction of new G.S.B layer.

5.2 For Wet Mix Macadam –

5.2.1 Gradation Test result for Improved WMM Material after addition of 10% of 40mm fresh aggregate and 1% Stone Dust with acquired road demolition wastes has been shown in Table no. 5.9 below-

Sieve Size 'mm'	% Passing	Mid Range	MORT&H Limits	
			Lower	Upper
53.00	100.00%	100	100	100
45.00	97.37%	97.50	95	100
22.40	70.65%	70.00	60	80
11.20	50.51%	50.00	40	60
4.75	32.99%	32.50	25	40
2.36	22.80%	22.50	15	30
0.600	15.22%	15.00	8	22
0.075	2.57%	2.50	0	5

Table 5.9: Sieve Analysis of modified W.M.M. Material

5.2.2 Water Absorption Test – The results of collected samples have been shown in table

Description	Sample 1	Sample 2	Average Value	Limit
Water Absorption Courser Agg. 40mm (%)	0.21	0.34	0.28	2% Max.
Water Absorption Courser Agg. 20mm (%)	0.94	1.02	0.98	
Water Absorption Courser Agg. 10mm (%)	0.56	0.91	0.74	
Water Absorption Stone Dust (%)	0.37	0.55	0.46	

Table 5.10: Water Absorption Test Result of amended / modified W.M.M. material

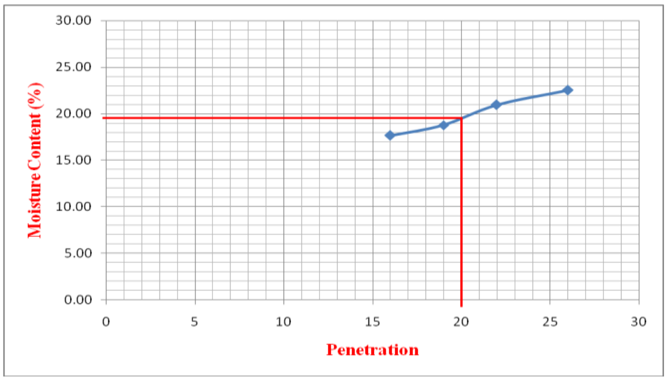
The results of average of collected samples were found under limit of Max. 2% specified by IS code 2386 (Part 3) : 1963. So, the amended / modified W.M.M material can be use.

5.2.3 Atterberg Limits (L.L., P.L. and P.I.) - For determining the L.L. of amended / modified W.M.M. material the Cone Penetrometer Method was adopted accordance with IS code 2720 (Part 5) – 1985. The two samples were taken for testing and the results derived from test of sample no. 1 has been shown in Table no. 5.11

S. No.	Assessment Detail	L.L.			
		1	2	3	4
1	Depth of Penetration	16	19	22	26
2	Vessel Identification No.	B21	B22	B23	B24
3	Wt. of Blank Vessel, gm (A)	23.8	23.9	23.9	23.9
4	Wt. of Moist Soil + Vessel, gm (B)	52.68	54.29	55.01	57.55
5	Wt. of Dry Soil + Vessel, gm (C)	48.35	49.49	49.62	51.37
6	Wt. of Water, gm D = (C-B)	4.33	4.8	5.39	6.18
7	Wt. of Dry Soil, gm E = (C-A)	24.55	25.59	25.72	27.47
8	% M.C. = (D/E)x100	17.64	18.76	20.96	22.50

Table 5.11 : Atterberg Limits by Cone Penetrometer of W.M.M. Material for Sample – 1

With the help of obtained result of Sample – 1 a graph was plotted showing the W.C. on the Y-axis and the cone penetration on the X-axis. With the help of data most suitable line was drawn, that has been shown in Graph no. 5.8.



Graph 5.8: Moisture Content Vs Cone Penetration of W.M.M. Material for Sample – 1

In the graph M.C. (%) corresponding to 20 mm Cone Penetration was taken as L.L. of sample no. 1 of amended / modified W.M.M. material. The test result for sample 1 corresponding to above Table no. 5.11 and Graph no. 5.8 are mentioned below –
L.L. to be determine at 20mm Penetration (L.L.) = 19.55%

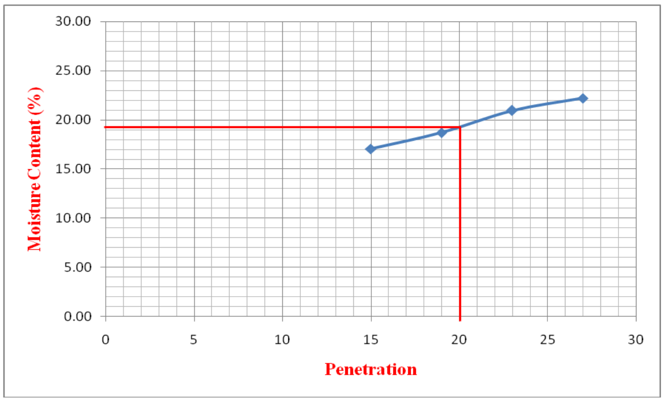
Average P.L. = Nil
P.I. % = Non – Plastic

Similarly the test was performed for sample no. 2 and results obtained are shown in Table no. 5.12

S. No.	Assessment Detail	L.L			
		1	2	3	4
1	Depth of Penetration	15	19	23	27
2	Vessel Identification No.	B25	B26	B27	B28
3	Wt. of Blank Vessel, gm (A)	24.5	24.1	23.9	23.4
4	Wt. of Moist Soil + Vessel, gm (B)	51.02	53.2	49.93	52.75
5	Wt. of Dry Soil + Vessel, gm (C)	47.16	48.62	45.42	47.42
6	Wt. of Water, gm D = (C-B)	3.86	4.58	4.51	5.33
7	Wt. of Dry Soil, gm E = (C-A)	22.66	24.52	21.52	24.02
8	% M.C. = (D/E) x 100	17.03	18.68	20.96	22.19

Table 5.12: Atterberg Limits by Cone Penetrometer of W.M.M. Material for Sample – 2

With the help of obtained result of Sample - 2, a graph was plotted between W.C. and cone penetration and the most suitable line was drawn which shown in Graph no. 5.9.



Graph 5.9: M.C. Vs Cone Penetration of W.M.M. Material for Sample – 2

In the graph M.C. (%) corresponding to 20 mm Cone Penetration was taken as L.L. of sample no. 2 of amended / modified W.M.M. material. The test result for sample 2 corresponding to above Table no. 5.12 and Graph no. 5.9 are mentioned below –

L.L. to be determine at 20mm Penetration (L.L.) = 19.20%

Average P.L. = Nil
P.I. % = Non - Plastic

The average values of sample -1 and sample - 2 shows the Atterberg Limit of amended / modified W.M.M. material. For L.L. it was found 19.38% (Avg. value of 19.55% and 19.20%). The value of P.L. was not found in both samples, hence the value of P.I. considered as Non - Plastic. According to MORT&H the value of L.L. for W.M.M. material should not be more than 25% and in test result it was found 19.38% which is less than specified limit.

5.2.4 Combined Flakiness and Elongation - F.I. and E.I. of aggregate were tested accordingly to IS Code - 2386 (Part -1) : 1963. It is an important test of W.M.M. aggregate that is required before laying W.M.M. layer. For finding FI & E.I of aggregate, the collected sample of amended / modified W.M.M. material was tested with Standard Thickness Gauge and Standard Length Gauge after passing sieves specified in IS Code. The outcome results of collected two samples have been shown in Table no. 5.13.

Combined Flakiness and Elongation As per IS 2386 (Part -1) : 1963				
Description	Sample 1	Sample 2	Average Value	Limit
FI & EI (%)	21.70	23.90	22.80	35% Max.

Table 5.13: F.I. & E.I. of amended / modified W.M.M. material

The combined F.I. & E.I. for amended / modified W.M.M. aggregates found 22.80 % which is less than specified limit i.e. 35%. So, we can say that the aggregate present in amended / modified W.M.M. material can be reuse.

5.2.5 Aggregate Impact Value – The result obtained for these samples are shown in Table no. 5.14.

S. No.	Description	Units	Trail 1	Trail 2	Trail 3	Avg.
1	Wt. of Oven Dry Sample (12.5mm Passing and 10mm Retained) (X) gm	gm	363.5	359.8	360.7	361.33
2	After Impact Test - Wt. of 2.36mm Sieve Fraction Retained (Y) gm	gm	280.4	272.6	277.3	276.77
3	After Impact Test - Wt. of 2.36mm	gm	83.1	87.2	83.4	84.57

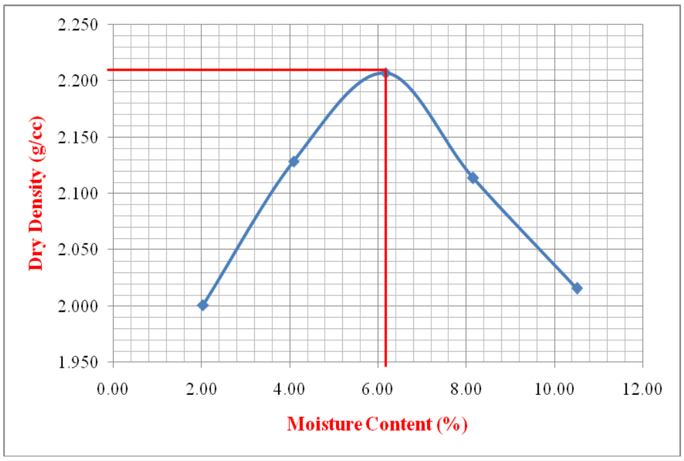
	Sieve Fraction Passing (Z) gm					
4	A.I.V. = (Z/X)x 100	%	22.86	24.24	23.12	23.41

Table 5.14: Test Result of A.I.V. of W.M.M. Material

The AIV should not be more than 30% as defined by MORT&H. In average test results of three sample of amended / modified W.M.M. material it is found 23.41% which is less than specified limit.

5.2.6 M.D.D. & O.M.C. - To determine M.D.D. & O.M.C. for amended / modified W.M.M. material the "Modified Proctor Test" was used accordance with IS code 2720 (Part-8):1983. Two Trails were tested and the values of Dry Density were determined at different % of water content.

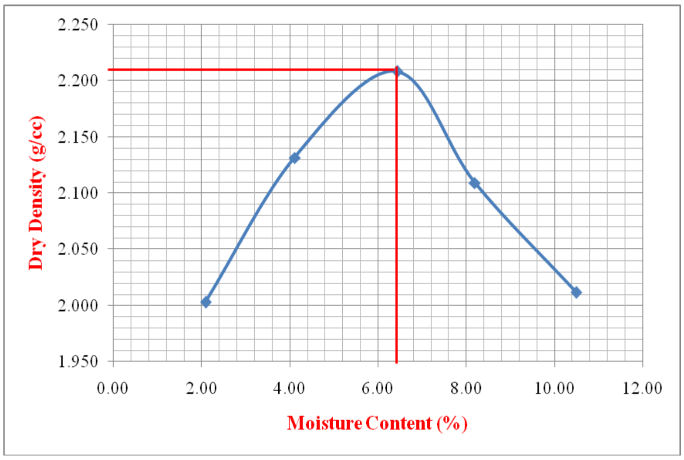
For finding M.D.D. & O.M.C. of Trail no. 1 of amended / modified W.M.M. material a Graph was plotted between Dry Density (gm/cc) and % M.C.. The smooth curve obtained through the result points of table (Shown with Blue Line). In graph the position of maximum value of the curve has been indicated by Red Line. This value shows the M.D.D. The corresponding M.C. shows the O.M.C. for Trail no. 1



Graph 5.10: Dry Density Vs M.C. of W.M.M. Material for Trail – 1

The values of M.D.D. and O.M.C. for Trail – 1 obtained from graph 5.10 are 2.210 gm/cc and 6.20 % respectively shown by Red Line on the graph.

Similarly the tests of M.D.D. and O.M.C. were conducted for Trail - 2 and A Graph was plotted between Dry Density (gm/cc) and % M.C.



Graph 5.11: Dry Density Vs M.C. of W.M.M. Material for Trail – 2

The smooth curve obtained through the result points of Trail – 2 has been shown with Blue Line. In graph the position of maximum value of the curve is indicated by Red Line. This value shows the M.D.D. The corresponding M.C. shows the value of O.M.C. for Trail no. 2. The values of M.D.D. and O.M.C. for Trail – 2 obtained from graph 5.11 are 2.210 gm/cc and 6.40 % respectively shown by Red Line on the graph.

The average values of Trail - 1 and Trail - 2 are taken as M.D.D. and O.M.C. value of amended / modified W.M.M. material which are found 2.210 gm/cc and 6.30% respectively.

6. CONCLUSIONS

The conclusive outcome of this experimental study for utilization of RD waste in construction of new granular layer is mentioned below –

6.1 Granular Sub Base –

RD waste of granular course was used for construction of new G.S.B. layer with addition of 20% 40mm course aggregate. The required physical tests were performed including sieve analysis and the results obtained from testes were found in specified limit.

The conclusive results of physical test of amended / modified G.S.B. material obtained from testes are as below –

- The sieve analysis of RD waste material was not found in limits of MORT&H but after addition of 20% of 40mm course aggregate, the test results shows the required limits.
- The water absorption percentage for amended / modified G.S.B. aggregate was obtained 0.68% which is under limit of Max. 2% specified by IS code 2386 (Part 3) : 1963

- For Atterberg Limits, the value of average liquid limit comes out 20.85% which was found below 25% specified by IS code 2720 (Part -5) : 1985.
- The plastic property was not shown during test. So, the Plasticity Index is denoted as Non – Plastic (NP).
- The A.I.V. of amended / modified G.S.B. material was found 26.61% which is less that 40% specified by IS code 2386 (Part -4) : 1963
- The Max. Dry Density (ρd) was found 2.185 gm/cc.
- The O.M.C. was found 6.80%
- The average value of C.B.R. were found 44.42% which shows that the amended / modified RD material can be use for construction of G.S.B. layer 30%

6.2 Wet Mix Macadam –

RD waste of granular course was used for construction of new W.M.M. layer with addition of 10% 40mm course aggregate and 1% stone dust. The required physical tests were performed including sieve analysis and the results obtained from testes were found in specified limit.

The conclusive results of physical test of amended / modified W.M.M. material obtained from testes are as below –

- The sieve analysis of RD waste material was not found in mid range limits of MORT&H but after addition of 10% of 40mm course aggregate and 1% stone dust, the test results shows the desired limits.
- The water absorption percentage for amended / modified W.M.M. material was found 0.28% for 40mm aggregate, 0.98% for 20mm aggregate, 0.74% for 10mm aggregate and 0.46% for stone dust which are under limit of Max. 2% specified by IS code 2386 (Part 3) : 1963
- For Atterberg Limits, the value of average liquid limit comes out 19.38% which was found below 25% specified by IS code 2720 (Part -5) : 1985.
- The plastic property was not shown during test. So, the Plasticity Index is denoted as Non – Plastic (NP).
- The value of Combined F.I. & E.I. was found 22.80% that is less than 35%, which specify IS Code 2386 (Part -1) : 1963
- The A.I.V. of amended / modified W.M.M. material was found 23.41% which is less that 30% specified by IS code 2386 (Part -4) : 1963
- The Max. Dry Density (ρd) was found 2.210 gm/cc.
- The O.M.C. was found 6.30%

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