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Utilization of Coal Mixed Waste Aggregates available at Thermal Power Plants for GSB and Asphalt Mixtures

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Abstract
During the last two decades the infrastructure and construction sector has put its leg forward towards growing economy of country. The road and transportation sector are one of the most valuable and important amongst all others. The road sector provides connectivity of the growing cities and villages with the developed cities. For the road sector it costs minimum about a crores rupee for construction and maintaining a section of one kilometer road during its life span. India has about 4.6million kilometers of roads and still the infrastructure of roads is yet to be constructed and maintained. One of the problems in our country is to have quality roads in cities and villages to have better connectivity. Some of the villages have no roads and for that the inefficiency of the system prevailing including the engineers is blamed. The growing scarcity of natural aggregates, due to banning of quarries, leading to slowing down the rate of road construction is also a problem. An alternate for this problem is Coal Mixed Reject. The coal from coal mines is supplied to the thermal power plants for electricity production which contains both coal and stones. The material which contains less percentage of coal content in them is rejected. We have utilized this waste aggregate as a replacement of natural aggregate in Granular Sub-Base (GSB) and bituminous layers in road construction. Based on laboratory studies like proctor test, CBR test for GSB layer and mechanical strength parameters like rutting, fatigue, stability for bituminous layers, it is recommended for its use as an alternative to natural aggregate in road construction works.

Keywords: Coal mixed waste aggregates, GSB, alternate material

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1 Introduction

In terms of our modern civilization, it is a fact that there are more people alive on our planet today (more than 6billion), than have ever perished in the history of humankind. Development of the global road infrastructure is equivalent to this situation with the majority of the necessary capacity of roads being presently in place. For this reason, road maintenance, rehabilitation and upgrading have become gradually important to pavement engineers. The road and transportation sector are one of the most valuable and important amongst all others. The road sector provides connectivity of the growing cities and villages with the developed cities.

In India most of the rural roads are based on hot mix technology which consumes a lot of natural aggregates and energy and causing pollution. To save these two natural resources Green Technologies are need of the hour. These Green Technologies are warm mix, cold mix and to explore and use alternative aggregates to save the natural resources.

Rural roads need locally available suitable aggregates to save transportation cost. As quarrying of natural sand is causing river pollution that due to more and more river quarrying the bank of river gets destroyed which affects the flowing stream. The machinery used for quarrying emits large amount of fumes which increases carbon footprint. An alternate called as coal mixed waste aggregate has been found for the reason. This coal mixed waste aggregate as an alternate for natural aggregate taken for the study from National Thermal Power Plant (NTPC Badarpur) and tested for the specific properties which are necessarily required by aggregate as a road building material found to be good and indirectly tells us for its use not as a dump but as gold in road construction. In this research work the natural aggregate has been replaced 100% by alternate material and found to be suitable for the road construction works.

2 Materials Used

To carry out the experimental work materials: coal mixed waste aggregates, (procured from National Thermal Power Plant (NTPC), Badarpur (New Delhi, India)), viscosity grade 30 bitumen and slow setting grade 2 emulsion from Hincol Industries are used.

2.1 Coal Mixed Waste Aggregates

All over India the coal from coal mines, which is supplied to the thermal power plants for electricity production, contains both coal and stones. The material which contains less than 40% fuel (pure coal) content is rejected because its containment of less coal percent and when it is feed in the machinery it causes harm to the machinery. This material is separated out at the thermal power plants due to which the power plants has to make a new arrangement of space to dump that material. As they have no ways to make use of it and no other agencies have authority to take away that material due to which heaps and heaps of this material (Figure 1) is lying and land is occupied.

There is a scarcity of the place to store this material in power plant premises. One example is at Badarpur (New Delhi, India) NTPC plant this waste is about 0.5 million tons and similarly at NTPC Dadri (New Delhi, India) the situation is 50 times worst and similar situation exists all over the India at different power plants. This is causing a huge loss of money and space to Government. As the coal is mined daily from mines due to which the waste is increasing day by day and new places are to be found out to dispose the material which will cause extra cost of transportation of the material. This material is a waste for power plants and they want the new ideas or ways for disposing off the aggregates as indicated in one of the meeting held between CRRI, New Delhi and NTPC, Badarpur, New Delhi.

As per the Newspaper report in “THE ECONOMICS TIMES (3, April 2013)” “Petty stones could cost crores at times” (The Economic Times, 2013) tells about the capital loss due to this waste aggregate.

Test results of coal mixed waste aggregates are given in Table 1. The results shown below in Table 1 verifies that the material is suitable to be used in place for natural aggregates.

Property	Test Performed	Specified limit as per MoRTH 2013	Test Results
Cleanliness (dust)	Grain Size Analysis (IS: 2386 Part 1)	Max. 5% passing 0.075mm sieve	2%
Particle Shape	Combined Flakiness and Elongation Test (IS: 2386 Part 1)	Max 35%	25%
Strength	Aggregate Impact Test (IS: 2386 Part 4)	Max 24%	18%
Soundness	Soundness in Sodium Sulphate (IS: 2386 Part 5)	Max 12%	7%
Water Absorption	Water Absorption test (IS: 2386 Part 3)	Max 2%	1.99%
Specific Gravity	Specific Gravity Test (IS: 2386 Part 3)	-	2.69 (20 mm) 2.64 (10mm) 2.2(dust)
Stripping	Coating & Stripping of Bitumen Aggregate Mix (IS: 6241)	Minimum Retained Coating 95%	98%

Table 1: Properties of Coal Mixed Waste Aggregates

Figure 1: Coal mixed waste aggregate at NTPC premises

2.2 Bitumen VG-30

The bitumen VG-30 used for the study is confirming to IS: 73-2013, the properties of which are shown in Table 2 below:

Property	Method of Test	Specified limit as per IS:73-2013	Test Results
Penetration @ 25˚C, 100g, 5 s, 0.1mm	IS:1203	Min 45	48
Kinematic Viscosity @ 135˚C, cSt	IS:1206 (Part 3)	Min 350	400
Softening Point (R&B), ˚C	IS: 1205	Min 47	52
Solubility in trichloroethylene, %	IS: 1216	Min 99	99.5
Test on residue from RTFOT, ductility @ 25˚C	IS:1208	Min 40	60

Table 2: Bitumen VG-30 test results

3 Laboratory Study

The dump of rejected coal mix aggregate has different size coarse and fine aggregates and the aggregates gradation corresponding to the specified gradation of different pavement layers are recovered from the rejected coal mix dump material.

3.1 Aggregate Gradation

The coal mixed waste aggregates has been used to make different layers of flexible pavement namely Granular Sub-base (GSB), Wet Mix Macadam (WMM), Dense Bituminous Macadam (DBM) and Bituminous Concrete (BC). The grading adopted for aggregates recovered from coal mixed dump for different layers is as per MoRTH 2013. In some layers, lime or stone dust has also been added to get desired grading. The grading obtained for GSB, WMM, BC and DBM layers and specified limits are as given in Table 3, Table 4, Table 5 and Table 6 below:

GSB:

Sieve Size, mm↓	Percentage of aggregates passing through sieve sizes		
	Percentage Passing of Coal Mix Waste Aggregate	Specified limits for GSB-II as per MoRTH 2013	
		Upper Limit↓	Lower Limit↓
53	100	100	-
26.5	100	100	70
9.5	76	80	50
4.75	43	65	40
2.36	40	50	30
0.425	10	15	10
0.075	3	5	-

Table 3: Grain Size Distribution of coal mix waste aggregates for GSB layer

WMM:

Sieve Size, mm↓	Percentage of aggregates passing through sieve sizes		
	Percentage Passing of Coal Mix Waste Aggregate	Specified limits for WMM as per MoRTH 2013	
		Upper Limit↓	Lower Limit↓
53	100	100	100
45	100	100	95
22.4	76	80	60
11.2	43	60	40
4.75	30	40	25
2.36	20	30	15
0.600	10	22	8
0.075	3	5	0

Table 4: Grain Size Distribution of coal mix waste aggregates for WMM layer

DBM:

Sieve Size, mm↓	Percentage of aggregates passing through sieve sizes		
	Percentage Passing of Coal Mix Waste Aggregate	Specified limits for 50mm DBM as per MoRTH 2013	
		Upper Limit↓	Lower Limit↓
37.5	100	100	100
26.5	91	100	90
19	84	95	71
13.2	76	80	56
4.75	53	54	38
2.36	32	42	28
0.3	11	21	7
0.075	4	8	2

Table 5: Grain Size Distribution of coal mix waste aggregates for DBM layer

BC:

Sieve Size, mm↓	Percentage of aggregates passing through sieve sizes				
	Nominal size of aggregates		Blending proportion Coal Mix Agg.:Stone Dust 80%:20% ↓	Specified limits for 50mm BC as per MoRTH 2013	
	NTPC↓	Stone Dust↓		Upper Limit↓	Lower Limit↓
26.50	100.00	100.00	100.00	100.00	100.00
19.00	90.45	100.00	92.36	100.00	90.00
13.20	72.46	100.00	77.97	79.00	59.00
9.50	55.48	100.00	64.38	72.00	52.00
4.75	26.63	100.00	41.31	55.00	35.00
2.36	16.68	83.29	30.00	44.00	28.00
1.18	15.60	54.32	23.34	34.00	20.00
0.60	8.84	42.09	15.49	27.00	15.00
0.30	6.23	28.43	10.67	20.00	10.00
0.15	4.12	18.48	6.99	13.00	5.00
0.08	2.71	12.58	4.69	8.00	2.00

Table 6: Grain Size Distribution of coal mix waste aggregates for BC layer

3.2 Performance Test

For the verification of the material suitability for the road construction purpose various performance evaluation tests: Proctor test, California Bearing Ratio (CBR), Atterberg's Limit for GSB and WMM; Marshall’s stability, indirect tensile strength (ITS), tensile strength ratio (TSR) for BC and DBM were done. The test results are given in subsequent sections.

3.2.1. For GSB:

Property	Method of Test	Specified limit as per MoRTH 2013	Test Results
Aggregate Impact Value	IS:2386 part 4	Max 40	23
Liquid Limit	IS:2720 part 5	Max 25	15.7
Plasticity Index	IS:2720 part 5	Max 6	1
CBR, %	IS:2720 part 5	Min. 30	43

Table 7: Test Results for GSB

3.2.2. For WMM:

Property	Method of Test	Specified limit as per MoRTH 2013	Test Results
Aggregate Impact Value	IS:2386 part 4	Max 30	23
Liquid Limit	IS:2720 part 5	Max 25	15.7
Plasticity Index	IS:2720 part 5	Max 6	1
Combines Flakiness & Elongation Index	IS:2386 part 1	Max. 35	15

Table 8: Test Results for WMM

3.2.3. For DBM:

For preparing samples for DBM, Marshall's method (ASTM D6931) of mix design was used. The samples were prepared and optimum binder (OBC) comes out to be 4.5%. After OBC samples were prepared at OBC and performance parameters were recorded which are shown in Table 9 below:

Property	Method of Test	Specified limit as per MoRTH 2013	Test Results
Marshall Stability, kN @ 60˚C	AASHTO T245	Min 9	10
Flow, mm	AASHTO T245	2-4	2.5
% Air Voids	-	3-5	4
Specific Gravity	-	-	2.6
Tensile Strength Ratio, %	AASHTO T283	Min 80	90
Retained Marshall Stability, %	AASHTO T245	Min 80	92

Table 9: Test Results for DBM

3.2.4. For BC:

Using Marshall Mix design method OBC for BC comes out to be 5.5%. Samples prepared at OBC were tested for performance parameters, results are shown in Table 10 below:

Property	Method of Test	Specified limit as per MoRTH 2013	Test Results
Marshall Stability, kN @ 60˚C	AASHTO T245	Min 9	12
Flow, mm	AASHTO T245	2-4	3
% Air Voids	-	3-5	4.1
Specific Gravity	-	-	2.63
Tensile Strength Ratio, %	AASHTO T283	Min 80	90
Retained Marshall Stability, %	AASHTO T245	Min 80	90

Table 10: Test Results for BC

4 Results and Discussions

The physical property of coal mixed waste aggregates lies within the limits specified in code of practice (MoRTH-2013) ensuring for its further use. The volumetric and mechanical properties of the material are found to be suitable for construction of GSB layer with CBR value of 43% with maximum dry density of 2.2 gm/cm^3 at 6.3% optimum moisture content and WMM layer. The volumetric and mechanical properties of bituminous mixes are also fulfilling the criteria of Marshall's stability, flow, air voids, Retained stability and Tensile strength ratio (TSR) as per the requirement of MoRTH 2013 for DBM and BC.

5 Conclusions

Based on the laboratory studies it can be concluded that:

1. The coal mixed waste aggregates are suitable as an alternate for natural aggregate in GSB, WMM and bituminous works.
2. Their use will not only offer the solution for conservation of natural aggregates but also offer a scientific approach to solve the problem for disposal of stored rejected coal in thermal power plant premises.
3. The cost of construction is also minimized for local areas as quarrying of aggregates and their transportation will be reduced.

It is also recommended the use of coal mixed waste aggregate as an alternate resource and replacement for natural aggregates for road works.

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