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INVESTIGATION FOR POTENTIAL USE OF COAL REJECT IN FLEXIBLE PAVEMENT

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Abstract- ***The paper describes an investigation into the coal reject waste available abundantly in the thermal power station, composed of rocks mixed with a small fraction of fine coal extracted during mining and is separated in the thermal plant during pulverization of coal. The coal reject has been investigated to evaluate its feasibility to be used in road construction in the Bituminous Concrete mix when coal reject aggregates are used as a replacement for coarse aggregate in the Bituminous Concrete mix. X-ray diffraction test shows that quartz, chlorite and muscovite are main constituents present in coal reject waste. Engineering test carried shows that it is porous in nature with an average water absorption value of 3.22% and 2.23 % loss in weight when subjected to freeze and thaw cycles in sodium sulphate while the impact test, crushing test and Los Angeles abrasion test gave a value of 20.2%, 34 %, and 35 %, respectively. Stability and flow value satisfy as per MoRT&H (Vth Revision) specification when tested for Bituminous Concrete mix by Marshall Mix. The optimum bitumen content for coal reject Bituminous Concrete mix comes out at 6.25%, whereas for the Conventional Bituminous Concrete mix, optimum bitumen content comes out 5.88%.***
Although the material is porous, the test results suggest that it can be used in bituminous pavement construction.

Keywords- Marshall Mix design, Coal rejects aggregates, Bituminous concrete mix, Aggregate tests, XRD test

I. INTRODUCTION

The growing need for physical connectivity of rural area with urban areas has intensified the growth in road sector and which further had exerted pressure on the use of natural resources for road construction and its maintenance. Some states in India are experiencing scarcity of aggregate supply for road construction due to the ban on quarrying and river mining, which has halted many undergoing projects. So in order to fill this gap, it is required to find need alternative to conventional aggregates to overcome the scarcity of aggregates and exploitation of natural resources. One of the promising solutions to the problem could be the use of coal reject waste in pavement construction. With the advent of green technology concept and need for effective utilization of waste material, India has already put its leg forward by successful utilization of fly ash, waste plastic, bottom ash and other waste material in road construction. So there is a need to look forward to other sources of waste material which can be used in road construction. In this study various mechanical and physical properties of coal reject are evaluated by various laboratory tests such as specific gravity test, water absorption test, impact test, etc and stability –flow and volumetric characteristics of Bituminous Concrete (BC) mix are evaluated when coal reject is used as replacement of coarse aggregates in the mix. Based on the test results for several physical and stability parameters of coal reject the utilization of the coal reject in pavement construction is asserted.

II. MATERIAL USED

A. Coal Reject Aggregate

Throughout India, the coal from coal mines, which is supplied to coal-fired thermal power plants, contains both coal and stones as the mining of coal are done at the interface of the coal seam. The material building the roof and floor of the coal seam which consists of sedimentary and igneous rocks also gets mined along with coal. When this mined coal is transferred to the coal handling plant in thermal power stations the differentiation of pure coal from waste coal is carried out. When the coal is ground in a bowl mill for pulverization, heavy mineral matters are separated which are mixed with a small fraction of coal therefore known as coal reject waste. These rejects cannot be used for combustion because of their calorific value is as low as 800-900 kJ/kg and on the whole, contains rocks and slates. Since the coal rejects has no value to thermal plant and neither the plant authorities can sell it to outside parties, as a result, it is accumulated and form piles of reject within the plant and occupies the limited and prime land of a thermal power plant.

A single bowl mill produces about 200-300 kg of reject per hour and if assumed that 25000 kg coal is feed into a single bowl mill and of that 0.7% of is reject produced in one hour it would produce about (24x365x175) 1533 tons of rejects per year. The coal mixed reject contains sulphur and metals which can pollute nearby streams and can leach into groundwater thus poses threat to the environment. The present study is conducted for the Guru Gobind Singh Super Thermal Power Station GGSSTPS) Rupnagar, Punjab where it has six coal-fired (PC) boilers with installed generating capacities of 6 X 210MW and an estimated of 6132 tonnes of reject produced per year. The size of the coal reject waste obtained from the thermal plant was greater than 100 mm so the coal reject was crushed manually to get the varying sizes of aggregates from 26 mm to 2.36mm to be used in the present investigation

B. X-Ray Diffraction Test on Coal Reject Aggregate

X-ray diffraction test was conducted to do mineralogical analysis of the coal reject procured from thermal power plant, Rupnagar. From the XRD graph shown in Fig. 1 following minerals were identified Muscovite $KAl_3Si_3O_{10}(OH)_2$, Chlorite $Al_2Mg_5Si_3O_{10}(OH)_5$ and quartz(SiO_2). X-Ray diffractogram of coal reject shows that the chlorite and Muscovite are present in lesser amounts and quartz seems to be the major constituent of coal reject and no mineral of coal is identified.

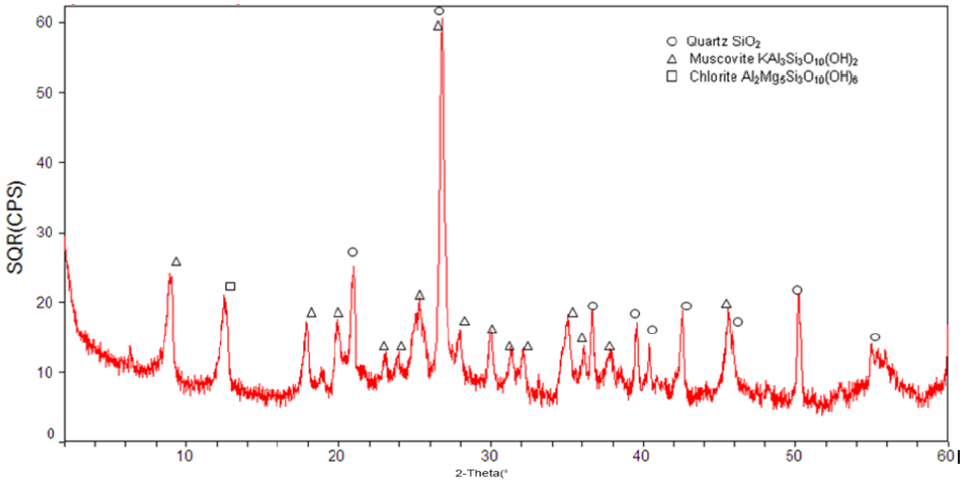

Fig. 1 X-Ray Diffractogram of Coal Reject

C. Conventional Aggregates

Conventional aggregates were procured from local suppliers in Dhanas, Punjab,and varies between the 4.75 mm to 20 mm sieve sizes. Crushed local sand is used as fine aggregate. The conventional aggregates are considered as base material to compare the properties of coal reject aggregates when tested under same experimental conditions.

C. Bitumen VG-30

The binder used in the study is VG-30 grade bitumen .The bitumen has been tested in the laboratory. The physical properties such as Softening Point, Ductility, Viscosity, Flash Point and Specific Gravity were evaluated. The results satisfy the requirement of binder to be used in bituminous mix as per IS: 73-2013 are shown in Table I.

TABLE I PROPERTIES OF BITUMEN

Methods for testing Binder	Test Results	Requirement as per IS:73-2013
Penetration at 25˚C, 100g, 5 sec,0.1mm	69	50-70
Ductility value@ 27˚C,cm	125	Min 75
Softening Point (R&B), ˚C	52	Min 47
Specific Gravity	1.02	Min 0.99
Flash point, ˚C	273	Min 220
Fire point, ˚C	292	Min 220

D. Mineral Filler

Mineral fillers have significant impact over the properties of mix design. Filler used for the study is hydrated lime, 3% by weight of bituminous mix sample. Fillers tend to increase the stiffness of the asphalt and mortar matrix. It improves resistance to moisture, improves workability, maintains adequate amount of void in the mix and enhances the durability of mix.

III. RESULTS AND DISCUSSION

A. Aggregate Gradation for Conventional Aggregates Bituminous Concrete Grade I.

The conventional aggregates were sieve analysed to determine the proportion of course aggregate, fine aggregate and filler and is ensured the aggregates are well blended within the gradation limit as specified in MoRT&H (V^{th} revision) for BC Grade I mix as shown in Table II.

TABLE II: COMBINED GRADATIONS FOR BITUMINOUS CONCRETE MIX GRADE II USING CONVENTIONAL AGGREGATE

Sieve Size (mm)	Percentage Passing				Blending Proportion A: B: C: D 40:25:32:3	Permissible Limits as per Grading 1
	20 mm (A)	10 mm (B)	Local Sand (C)	Hydrated Lime (D)		
26.5	100	100	100	100	100	100
19	86.25	100	100	100	94.50	90-100
13.2	20.95	100	100	100	68.38	59-79
9.5	5.2	87.92	100	100	59.06	52-72
4.75	0	19.01	100	100	39.75	35-55
2.36	0	0	92	100	32.44	28-44
1.18	0	0	70	100	25.4	20-34
0.6	0	0	55.45	100	20.74	15-27
0.3	0	0	36.54	90	14.47	10-20
0.15	0	0	20	75	8.69	5-13
0.075	0	0	4	60	3.4	2-8

B. Aggregate Gradation for Coal Reject Bituminous Concrete mix grade I

The coal reject aggregates were sieve analysed to determine the proportion of course aggregate, fine aggregate and filler and is ensured the aggregates are well blended within the gradation limit as specified in MoRT &H (V^{th} revision) for BC Grade I mix. The grading adopted for aggregates recovered from coal reject dump is as per MoRT &H and are shown in Table III.

TABLE III: COMBINED GRADATIONS FOR BITUMINOUS CONCRETE MIX GRADE I USING COAL REJECT AGGREGATE

Sieve Size (mm)	Percentage Passing				Blending Proportion A: B: C: D 40:25:32:3	Permissible Limits as per Grading 1
	20 mm (A)	10 mm (B)	Local Sand (C)	Hydrated Lime (D)		
26.5	100	100	100	100	100	100
19	98.20	100	100	100	99.2832	90-100
13.2	28.94	100	100	100	71.578	59-79
9.5	4	58.89	100	100	51.3225	52-72
4.75	0	19.01	100	100	39.7525	35-55
2.36	0	0	92	100	32.44	28-44
1.18	0	0	70	100	25.4	20-34
0.6	0	0	55.45	100	20.744	15-27
0.3	0	0	36.54	90	14.4678	10-20
0.15	0	0	20	75	8.6935	5-13
0.075	0	0	4	60	3.3995	2-8

C. Coal Reject and Conventional Aggregate Test Results

Coal Reject and Conventional Aggregate aggr*egat*es were tested for physical properties as per the procedure given in IS code for method of aggregate test. Test results were compared with permissible value for aggregates used in Bituminous Concrete (BC) mix as per MoRT&H (V^{th} revision) specifications, shown in Table IV.

The experimental results indicated that the specific gravity value, impact test value, soundness test value and adhesion to bitumen test value are well within the permissible limits and are relatively comparable to conventional aggregate. Coal reject aggregates stand well when tested for resistance to disintegration(Soundness test) when subjected to freeze and thaw cycles in sodium sulphate with a loss in weight value of 2.33% against maximum permissible value of 12%.So the aggregates fulfil the criteria for water absorption.

The aggregates should qualify either the impact test or the aggregate abrasion test to be used in Bituminous Concrete mix as given in MoRT&H (V^{th} revision), as the coal reject aggregate qualifies the impact test with a value of 20.20% .So coal reject aggregates qualifies the criteria for strength parameter. Results for conventional aggregate satisfy the requirement for BC mix as per specifications given in MoRT&H (V^{th} revision).

TABLE IV: AGGREGATE PHYSICAL PROPERTIES TEST RESULT AND COMPARISON

Test Performed	**Property**	**Test Result for Conventional Aggregates**	**Test Results for Coal Reject Aggregates**	**Specified Limit as per MoRT&H (V^{th} revision)**
Water Absorption test (IS: 2386 Part 3)	Porosity	0.5 %	3.22 %	Max 2%
Specific Gravity Test *Course aggregates *Fine aggregate *Filler	Specific Gravity	2.66 2.60 2.34	2.62 2.60 2.34	Min 2.5 Min 2.5
Crushing Test (IS : 2386 part 4)	Crushing Strength	21.20 %	34.40 %	Max 30%
Aggregate Impact Test (IS: 2386 Part 4)	Toughness	20 %	20.20 %	Max 24%
Los Angeles abrasion Test (IS : 2386 Part 5)	Hardness	23 %	36.40 %	Max 30%
Coating & Stripping of Bitumen Aggregate Mix (IS: 6241)	Adhesion to Bitumen	95.60 %	97.45 %	Minimum Retained Coating 95%
Soundness in Sodium Sulphate (IS: 2386 Part 5)	Durability	2.22 %	2.34 %	Max 12%

D. Comparison of Marshall Mixes design result for Conventional and Coal reject BC mix at Optimum Bitumen Content.

Marshall parameters like stability, flow, VFB, bulk density and air voids has been compared at optimum bitumen content obtained for conventional BC mix at 5.88 % and Coal reject BC mix at 6.25 % in accordance with specification given in MoRT&H(V^{th} revision) and has been shown in Table V and plotted graphically in Fig. 2.

TABLE V: COMPARISON OF MARSHALL PROPERTIES OF COAL REJECT AND CONVENTIONAL BITUMINOUS CONCRETE MIX GRADE I AT OBC

Properties Of Marshall Mix	Conventional Bituminous Concrete Mix	Coal Reject Bituminous Concrete Mix	Required as per MoRT&H(V^{th} revision)
Minimum stability (kN at 60˚C)	16.46	15.95	9
Marshall flow (mm)	3.45	2.79	2-4
% Air Voids	3.73	6.47	3-5
% Voids Filled with Bitumen(VFB)	67.28	63.10	65-75
% Voids in Mineral Aggregate (VMA)	15.90	21.37	14 %(for 19mm Nominal Maximum Aggregate size)
Bulk Density (g/cc)	2.36	2.30	-

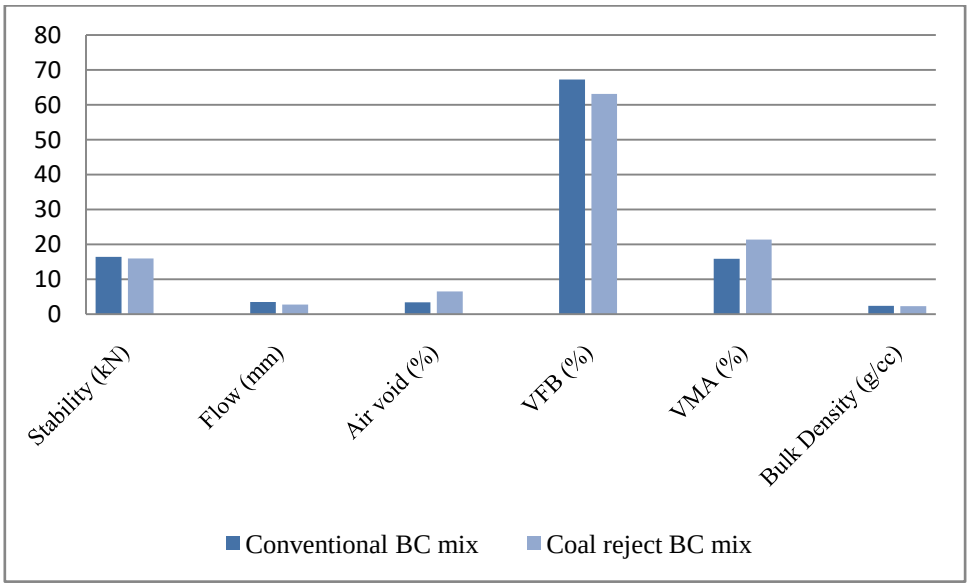

Fig. 2 Comparison of Conventional BC mix and Coal Reject BC Mix at Optimum Bitumen Content

IV. CONCLUSIONS AND RECOMMENDATIONS

[1] The water absorption value for coal reject aggregate comes out to be 3.22% whereas maximum permissible value is 2 % for a road aggregate. However it qualifies the soundness test which is a measure for resistance to disintegration due to weathering effect. So as mentioned in MoRT&H (V^{th} revision) that aggregates should qualify soundness test if failed in water absorption value, so the coal reject aggregates qualifies the water absorption criteria.

[2] Coal reject waste is porous in nature due to presence of clay minerals in it such as chlorite and muscovite as revealed in X-Ray diffraction test.

[3] The Marshall Mix design properties shows that the Bituminous Concrete mix prepared using coal reject aggregate require more bitumen than the conventional aggregate as reflected by its higher water absorption value.

[4] The physical test conducted on the coal reject aggregates shows the aggregates can also be used in Water Bound Macadam (WBM) and Wet Mix Macadam (WMM) for sub base/ base course, as the aggregate impact test values and abrasion test value fall below 30% and 40% respectively which satisfies the requirement for WBM and WMM as given in MoRT&H (V^{th} revision).

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