Development of Robust Grout for Cement Grout Bituminous Macadam

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***Abstract*—Grouted macadam combines the advantage of bituminous macadam with cement concrete. Cement grouted bituminous macadam is made up of single sized aggregates with cement grout poured into it. Grouted bituminous macadam constitutes a poorly understood branch of pavement technology and has generally been relegated to a role in certain specialist pavements whose performance is predicted on purely empirical evidence. Literature suggests that some of the individual limitations of bituminous mix and cement concrete mix will overcome by cement grouted bituminous mix. And also no mix design approach has been suggested based on laboratory performance. Thus, in the present work a systematic approach has been developed for design of cement grouted bituminous macadam using volumetric, strength and other performance related parameters.**

The main conclusion drawn from this project is that adding of grouted macadam is likely to provide an economical solution in many pavement designs owing to superior strength and serviceability.

Keywords— Grouted macadam, flexible, rigid, bitumen, concrete, grout, porous aggregate skeleton mould.

I. INTRODUCTION

Cement Grouted Bituminous Macadam is pavement that consists of voided bituminous surface which is then filled with highly flowable cementitious grout. The grout is manually spread for achieving complete penetration and air voids content present is almost equal to zero [1].

The new type of Cement Grouted Bituminous Macadam (CGBM) pavement is also becoming popular due to green construction practices [2]. The composite system has the advantages of both the pavements to perform like concrete and also to be quickly constructed with asphalt concrete. This semi-flexible pavement or the cement grouted bituminous macadam have been constructed in areas where the pavement is being subjected to high wheel loads, mostly in parking and widely even in city traffics [3].

CGBM type of grouted material offers many benefits over a conventional bituminous material such as high resistant to permanent deformation, fuel spill resistance, higher stiffness modulus, resistance to abrasion, quick constructability and opening to traffic [4].

The main objectives of this paper is related to better understanding the properties of this type of material, in order to be able to predict its performance, to design pavements incorporating grouted macadam more accurately and to develop for more durable roads at affordable cost to reduce burden on recurring maintenance cost and initial capital cost.

As there is no enough data on design methods, material test procedures and real construction practices, there is a great demand to develop robust standard practice procedures on CGBM [5][6][7]. The performed trials were useful for studying properties of cementitious grout.

II. EXPERIMENTAL WORK AND ANALYSIS

A. *Preparation of cementitious grout.*

The cementitious grout mix consists of cement, fly ash, micro silica, crushed sand, water and admixtures. The cement grout used in the trials contained 43 grade ordinary Portland cement. In order to have a high initial strength, micro silica was incorporated in the grout. Also, fly ash was used for limiting the early-age shrinkage and temperature rise. They were used to get the required fluidity at the lower water contents for cement grout. The crushed sand used in the cement grout should pass through 2.36 mm size so that the grout can enter into the voids easily. Cement, fly ash, micro silica and crush sand were taken in required proportion and mixed thoroughly to prepare dry mix. Water was poured in dry mix as per the required water content. The water/binder ratio (w/b) was varied from 0.25 to 0.4. Tap water was used in the grouts as no differences were found in the water demand or initial setting time with distilled water. In order to increase the performance and reduce the amount of water necessary to make the grout flowable enough to penetrate the voids, chemical admixtures are used.

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B. Compositionof cementitious grout.

Several lab trials were done, and based on the trials in lab following important findings are drawn as shown in table 1.

Table 1. Proportions of flowable cementitious grout.

MATERIALS	QUANTITY (in %)				
	TRIAL 1	*TRIAL 2*	*TRIAL 3*	*TRIAL 4*	*TRIAL 5*
Cement	34.84	49.18	32.44	66.12	67.37
Fly ash	8.71	14.24	9.39	5.52	5.61
Micro silica	8.71	14.24	9.39	1.83	1.87
Crush sand	33.87	0	34.03	3.68	1.87
Water	13.4	21.57	14.24	22.04	22.45
Admixture	0.47	0.77	0.51	0.81	0.83

Trial 5 is selected as final trial. In earlier trials the composition of crush sand was higher to achieve economy in the design. The trials which were performed with higher percentage of crush sand had relatively low compressive strength as compared to trial 4 and 5. Due to more percentage of crush sand it causes segregation of grout. Cement content is increased to gain required compressive strength.

C. Laboratory testing of grout.

Following tests were conducted on cementitious grout:

i) Fluidity of grout.

The test on fluidity is performed to check the penetration of grout in aggregate. The grout is poured into the aggregate mix i.e. open graded friction course. The fluidity is checked by using Flow table test and Marsh cone test [8]. When efflux time exceeds 35 seconds, flowability is better determined by flow table [9] as shown in Fig. 1. As in trial 1, 2 and 3 the efflux time exceed more than 35 seconds so flow table test was performed.

The Marsh cone test is used with grout having an efflux time of 35 seconds or less [10]. The marsh cone was used to determine the flow time for a certain volume of paste i.e 1500 ml to flow through a metal funnel as shown in Fig. 2. The marsh cone was calibrated by using water and the time required to empty the cone was 7.35 seconds. Marsh cone test was performed on trial 4 and 5 as the efflux time was less than 35 seconds. The results of flow table and marsh cone are shown in table 2 and 3 respectively.

Table 2. Flow table test results.

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Flow in mm	970	1050	980	-	-

Table 3. Marsh cone test results.

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Flow in sec	-	-	-	34	20

Fig. 1. Flow table test.

Fig. 2. Marsh cone test.

The porous aggregate skeleton mould was prepared of 40 mm and 50 mm thickness by using the aggregate passing through 20mm and retaining on 16 mm (80%) and aggregate passing through 12.5 mm and retaining on 10 mm (20%), to maintain the void ratio of 25-30% [11]. The prepared grout was then poured into the porous aggregate skeleton mould to check the penetration of grout as shown in Fig. 3.

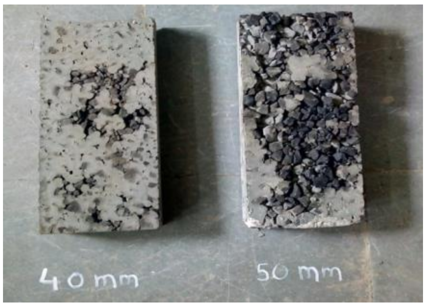

Fig. 3. Penetration of grout of trial 5.

ii) Compressive strength of grout.

The compressive strength of the grout was determined by casting the cubes of size 150*150*150 mm [12]. The compressive strength of grout was checked on 1 day, 7 days and 28 days. The results are as shown in table 4 and Fig. 4 and Fig. 5 shows cube failure pattern and compressive strength results respectively.

Table 4. Compressive strength results.

	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4	TRIAL 5
1 day(in Mpa)	32	19.77	19.11	24.26	19.55
7 day(in Mpa)	42.67	32.44	49.33	55.13	49.58
28 day(in Mpa)	48.44	40.88	53.33	73.51	59.44

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Fig. 4. Cube failure pattern.

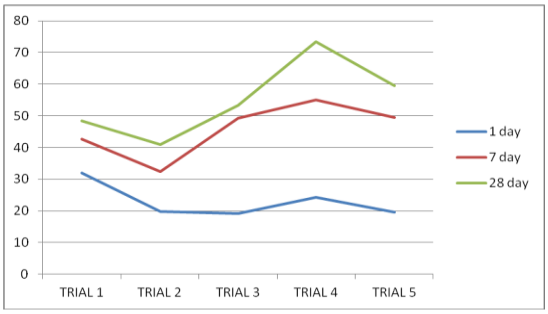

Fig. 5. Compressive strength results.

iii) Flexural strength of grout.

The flexural strength of the cementitious grout was determined on 700*150*150 mm beam specimen [12]. The flexural strength of grout was checked on 28th day. The results are as shown in table 5.

Table 5. Flexural strength results.

	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4	TRIAL 5
28 day (in Mpa)	1.44	1.73	1.73	2.7	2.3

Fig. 6 and Fig. 7 shows flexural beam specimen and flexural strength results respectively.

Fig. 6. Flexural beam specimen

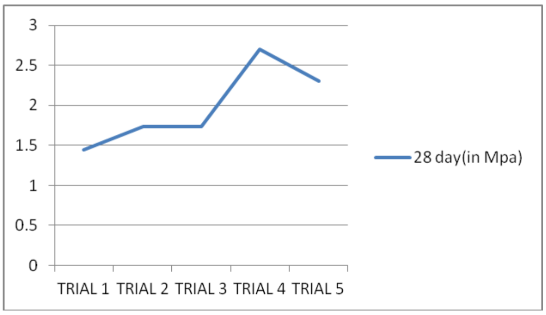

Fig. 7. Flexural strength results.

D. Testing of Aggregate.

Coarse aggregate were used for preparing laboratory model of porous aggregate skeleton. Various test were performed on the aggregate of size 10mm and 20mm such as Sp. Gravity, Bulk Density, Flakiness Index, Elongation Index, Aggregate Crushing value, Aggregate Impact value, Los Angles Abrasion value as shown in table 6.

Table 6. Test results on aggregate.

Test Particular	Test method	10mm aggregate	20mm aggregate
Sp. Gravity	IS 2386 [P 3]-1963	2.96	2.96
Bulk Density	IS 2386 [P 3]-1963	1.58 Kg/lit	1.59 Kg/lit
Flakiness Index	IS 2386 [P 1]-1963	3.92%	4.19%
Elongation Index	IS 2386[P 1]-1963	2.66%	3.44%
Aggregate Crushing value	IS 2386 [P 4]-1963	15%	16%
Aggregate Impact value	IS 2386 [P 4]-1963	11.38%	10.53%
Los Angles Abrasion value	IS 2386 [P 4]-1963	18.14%	18.40%

CONCLUSIONS

Preliminary results obtained from ongoing work on the development of optimum cement-grout for cement grouted bituminous macadam are reported. The research paper study showed the different tests performed on the cementitious grout. The material seems to have good applications, so more investigations are needed for this material on several grounds such as optimizing the constituents for getting good strength parameters. The gradation of aggregate and the different test are studied in this paper. As per trial 5 the compressive strength for 28 day is 59.44 Mpa and flexural strength is 2.3 Mpa. The cement grouted macadam is economical solution in the construction of roads in villages or low volume roads. It is very necessary to make such study for the construction of economical roads.

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