Study on Fly Ash Based Grout in Cement Grouted Bituminous Mix

Mohit Sodani
[1]*M.Tech - Transportation Engineering, Mewar University, Chittorgarh, Rajasthan, India*

Abstract - ***A Cement Grouted Bituminous Mix (CGBM) is a composite pavement made up of an open graded porous type bituminous mix having 25% to 35% of air void content and different proportions of fly ash based cementitious grout was introduced in this study. The main objective of this research is to find out the best proportion of cement and fly ash to fit for the CGBM. In this experimental study CGBM mix prepared with replacement of fly ash by 0%, 20%, 25%, 30% and 50%. Experiments on different proportions of cement and fly ash were done to know the impact of partial substitution of cement by fly ash on the characteristics of CGBM. In this research three types of experiments were carried out. They are compressive strength, Marshal Stability and Modulus of Rupture test. Based on the outcome from these experimental study found that, 75:25 mix proportion of cement and fly ash gave satisfactory results. By using fly ash in CGBM leads to decrease in cost of construction and also the CGBM pavement becomes environmental friendly as the disposal of fly ash decreases.***

Key Words*: *Fly ash based cementitious grout, open graded, air void, environmentally friendly

1. INTRODUCTION

India has the second largest road network with heterogeneous traffic conditions. Although the road construction in India has improved a lot in the last two decades, at times, it is observed that the pavements, especially in urban areas, are unable to last for the desired life and are subjected to premature distresses. One of the major forms of such distresses is moisture induced damages, which occur due to poor drainage conditions in the city roads and sensitivity of bituminous pavements to the water. Keeping this in mind, CSIR-Central Road Research Institute (CRRI) has developed and demonstrated a composite surfacing wearing course for pavements called Cement Grouted Bituminous Mix (CGBM). It is a different type of composite surface course that consists of an open graded high voids bituminous mix as core structure, grouted with a proper cementitious material. Technically, it is a designed amalgamation of concrete pavement and bituminous pavement, thus, consequently and desirably having the nature of both rigidity and flexibility. Need of such new kind of pavement material was being felt for a long time to overcome the deficiencies of the conventional surfacing layer (Bituminous Concrete) while retaining its advantages and benefits. The rutting in bituminous pavements and 'provision of joints' in concrete pavements giving poor riding quality are likely to be completely eliminated in future by this new 'Cement Grouted Bituminous Mix'.

One of the technologies to yield improved surfacing against Moisture induced damages and Rutting is Cement Grouted Bituminous Mix. In case of rigid pavement we will provide joints in between pavement. Because of these joint there is a chances of mud pumping failure of rigid pavement. And these joint give discomfort to passengers. This problem in rigid pavement is completely eliminated by CGBM pavement.

The Cement Grouted Bituminous Mix (CGBM) is a combination of both flexible and rigid pavement qualities. The CGBM layer is a bituminous concrete mixture (Aggregate + Bitumen) with a high void content (25% to 35% as per IRC SP 125 2019) that is filled with fly ash based Cementitious Grout slurry prepared with Cement + Sand + Fly ash + water combination. It is important that the bituminous mix be designed accurately to have enough air voids (25% to 35%) and that grout can be easily penetrate the voids into the skeleton structure of bituminous mix upto bottom level of Cement Grouted Bituminous Mix.

1.1 Objective of Purposed work

The objective of this research is to show by using different proportion of fly ash (shown in below table) in place of cement to decreases the cost of CGBM construction.

Table 1.1 Cement and fly ash proportion in this research study

S No.	Cement: Fly Ash
1	100:0
2	80:20
3	75:25
4	70:30
5	50:50

2. LITRATURE REVIEW

Lokesh Gupta et. al. (2021) attempted to prepare grouting material and develop the mix design consideration first. Further, CGBM characteristics as an alternative recarpeting and/or wearing course material in the Indian scenario based on laboratory and field evaluation in comparison with bituminous concrete mix that is conventional wearing course was explored. In this regard, a trial stretch of CGBM was constructed in the urban area, and field performance is ensured with the laboratory results. Test results revealed that the CGBM mix possesses higher Marshall stability, compressive strength, tensile strength, resilient modulus, better resistance against the moisture damage and oil spillage condition, and less temperature susceptible than the conventional bituminous concrete mix. This case study of CGBM overlay was substantially increasing the remaining service life of the pavement in terms of fatigue and rutting life.

Sang Luo et. al. (2018) carried out comprehensive performance evaluation to study the viability of the GOAC with latex modified cement mortar. The asphalt skeleton gradation was determined by adopting the GOAC experience in Japan. The asphalt skeleton was designed based on porosity, strength and runoff resistance, while the latex modified cement mortar was designed based on fluidity, flexural strength and compressive strength. The results showed that the addition of the latex can significantly improve the 7-day flexural strength while only slightly compromise the fluidity. A grouting saturation degree of higher than 96% was found for the GOAC-13 and GOAC16. The performance of the latex modified GOAC was compared with conventional asphalt concrete. It was found that the GOAC has significantly better rutting resistance, but the moisture susceptibility, low-temperature crack resistance and fatigue performance were weaker. However, the results also showed that the moisture susceptibility and the low-temperature performance for the latex modified GOAC were at acceptable levels. In addition, it was found that the Marshall Immersion test is not suitable for evaluating the moisture susceptibility of GOAC in comparison with the freeze–thaw conditioning method.

Supratim Kaushik & Anjan Kumar Siddagangaiah (2020) conducted laboratory study to evaluate the properties of cement grouted bituminous mixes (CGBM) prepared with marginal aggregates. A conventional dense-graded bituminous concrete mix was also considered for the purpose of comparison. The CGBM specimens prepared were then evaluated in terms of its strength (Stability and Indirect Tensile strength), Elastic properties (Resilient modulus and Indirect Tensile Stiffness Modulus), Durability (Tensile strength ratio) and raveling resistance (Cantabro Abrasion Test). Testing was conducted at two different curing periods (7 and 28 days) to consider the long-term strength gain of cement. Two test temperatures (25°C and 40°C) were considered to simulate the average and high-temperature properties. Further, both moisture conditioned and unconditioned states were examined to evaluate the susceptibility to moisture. Obtained results were statistically analyzed to determine the critical effects of the curing period, temperature and moisture conditioning on the CGBM properties. An example of a low volume road was used to assess the cost related to the use of CGBM as a structural layer. Overall, laboratory results showed CGBM to be an effective method for the utilization of marginal aggregates in routine road construction with enhanced material properties as compared to the control mix. Statistical analysis showed a significant influence of curing, temperature and moisture on the properties of CGBM. Further, the replacement of the conventional bituminous layer with CGBM resulted in a substantial reduction in material use, indicating that the use of marginal materials in CGBM could lead to sustainable road assets.

G. Manikantha Raju, D. Sita Rami Reddy et al (2014) performed. Rutting performance test, Compressive strength test, and flexural strength and Marshal Stability test to evaluate the Performance of Cement Grouted Bituminous mixes. They concluded that Rutting in CGBM Pavement is very less compared to flexible and rigid pavement. The marshal stability value of CGBM is higher than results obtained with normal mix. Also the quantity of grout requirement is directly proportional to percentage of air void content in the bituminous mix.

G. Bharath et. al. (2019) evaluated CGBM in the laboratory and field. A conventional dense graded Bituminous Concrete (BC) mix was also considered for comparison. They presented the details of different investigations carried out for evaluation of CGBM mix for properties such as Indirect Tensile Strength (ITS), Resilient Modulus and Dynamic Modulus at different temperatures. Performance characteristics such as rutting, fracture energy, moisture resistance, oil spillage and durability were also evaluated for the mixes. A CGBM test section has been laid on site and is being monitored for its performance. Results showed that CGBM has better ITS, Resilient Modulus, Dynamic Modulus, and Rutting performance than a conventional bituminous mix. It showed a slight reduction in durability and crack resistance due to the relative brittleness of the hardened cement constituent but within acceptable limits. The material was also more resistant to damage by moisture and diesel. CGBM mixes are less temperature susceptible compared to conventional bituminous mix. Dynamic Modulus and Phase Angle master curves for CGBM mixes have been developed in the study. Full depth grouting was observed in field core samples and Micro Computed Tomography (Micro-CT) tests were carried out to check the air voids connectivity and their content in the CGBM mix.

3. RESEARCH METHODOLOGY

Bitumen is a Visco-elastic material which performs like an elastic solid at low service temperature and high rate of loading and while at high service temperature and slow rate of loading it acts like a viscous fluid.

3.1 Bituminous Mix Methodology

- As per selected gradation, take the required quantity of aggregate and keep in oven at a temperature of 150°C
- Heat the bitumen to 160°C.
- After reaching the required temperature, mix the both aggregate and bitumen at a mixing temperature range of 158°C to 162°C.
- Transfer this bituminous mixture into mould and give the compaction as per calculation.
- Keep the prepared mould in an ambient temperature for less than 24 hours.

3.2 Grout Methodology

- Take the required quantity of cement, sand, fly ash and water as per mix design.
- Mix the cement + sand + fly ash + water thoroughly at an ambient temperature. This mixture is called as grout.

3.3 Preparation of CGBM

- Pour the prepared grout into bituminous mix mould on vibration machine. Take care that grout should reach to bottom level of bituminous mix.
- Keep this mould in an ambient temperature for 24 hours. After that remove the CGBM sample from mould and keep the sample in a curing under gunny bag as per required days. After curing period the sample is ready for conducting experiments.

3.4 Bituminous mix design

Air Voids: With a compacted bituminous mixture, the pockets of air between the bitumen coated aggregate particles.

There are two types of bituminous mixes. They are

1. Dense bituminous mix
2. Open bituminous mix

In this experimental study, after compaction the minimum air void content is 25% as per

IRC SP 125 2019. So it comes under Open Bituminous mix.

The percentage of air voids in the design bituminous mix is used as one of the main criteria in the design methods and for evaluating the compaction imparted in bituminous paving projects.

Aggregate gradation selection: Aggregates play major role in CGBM Pavement. So selection of aggregate gradation is very important. So the first and foremost important thing in preparation of Skeleton structure of bituminous mix design is selection of aggregate gradation. In this experimental study I am using fly ash. So my aim is to find out the strength of CGBM Pavement by using fly ash. As per IS SP 125-2019 there are three type of aggregate gradation. I have selected Grade-III type of aggregate gradation as shown in below table. In grade-III type of aggregate the specific surface area is more compared to aggregate gradation type-I and II.

Determination of optimum binder content by using drain down test

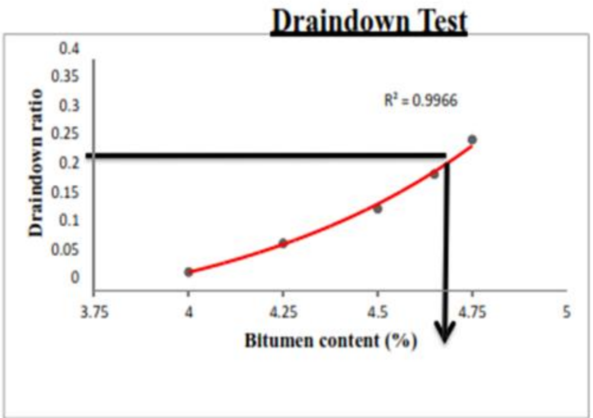

Fig.3.1 Optimum binder content by Drain down Test

Optimum Binder content based on drain down test = 4.7

Preparation of skeleton structure of Bituminous Mix as per IRC SP 125-2019:

- The required quantities of aggregate were proportioned as per the gradation selected (G-III).
- The aggregates were preheated to a temperature of 150°C.
- The required quantity of bitumen was added to the mixture of heated aggregate.
- Mix thoroughly for nearly two minutes for uniform mixing was achieved.
- The mix was transferred to the split mould when the temperature was in the required compaction temperature range of 142 °C to 146 °C.
- The mix was compacted using a 4.54 kg compaction hammer with a height of fall of 457 mm by applying 76 number of blows for mould size 180*60*60 (mm^3) and 37 number of blows for mould size 100mm dia and 60mm height.
- The specimens were allowed to cool down for 24 hours before grouting was done

Compaction Effort: For the compaction of high voids bituminous mix, there is no proper criteria for selecting the number of blows. The prepared bituminous mix is compacted using a Marshal Compactor with gradual variations in compaction effort to determine the optimum compaction effort.

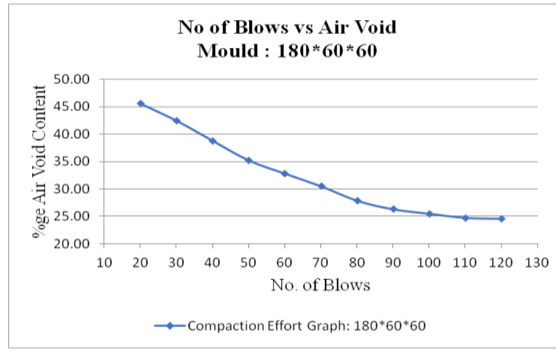

Fig.3.2 Compaction Effort: 180*60*60

From the above figure it was observed that for the mould size 180*60*60 the number of blows required are: 76

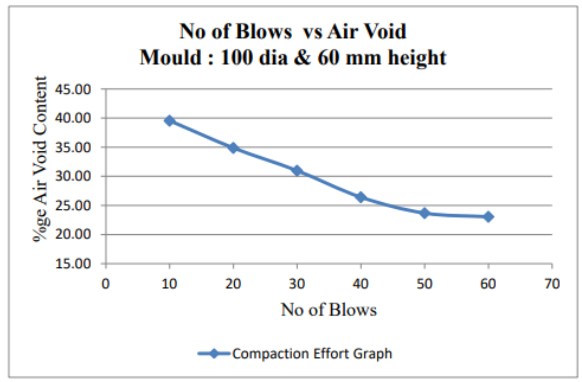

Fig.3.3 Compaction Effort: 100mm dia and 60mm height

From the above figure it is observed that for the mould size 100 mm dia and 60mm height the number of blows required are: 37

3.5 Preparation of cementitious grout

In this experimental study the grout is a mixture of cement, sand, fly ash (by different proportions of fly ash by replacing in place of cement) and water. The prepared grout should easily flow into the voids of the compacted a bituminous mix and meanwhile the grout should have good strength to withstand the vehicular load. The cementitious grout slurry needs to have a sufficient fluidity (flow value in seconds) so that it can be easily fill the air voids in the bituminous compacted mix up to bottom. The fluidity value is calculated based on Grout flow test (flow cone test) as shown in the below.

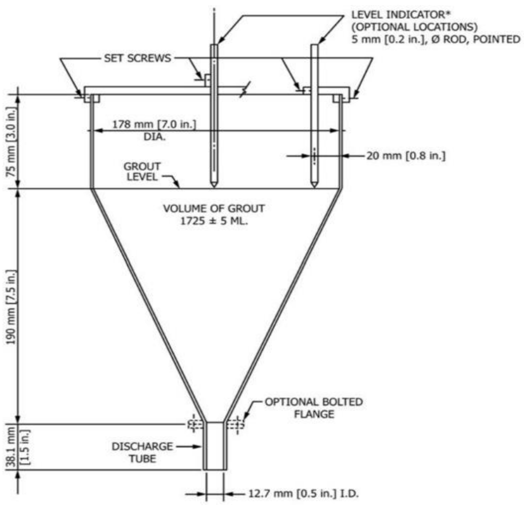

Fig.3.4 Flow cone cross-section

Fig.3.5 The flow cone is used to determine the flow value

Table 3.1 Determination of Optimum compaction effort for cylindrical sample

Mix No	Cement : Fly ash	Water requirement (Percentage of C+S+F)	Flow Value (Sec)
1	100 : 0	27	38
2	80 : 20	26	36
3	75 : 25	25.5	35
4	70 : 30	25	34
5	50 : 50	23.5	31

3.6 Preparation of CGBM Sample

Pour the prepared grout into bituminous mix mould on vibration machine. Take care that grout should reach to bottom level of bituminous mix. Keep this mould in an ambient temperature for 24 hours. After that remove the CGBM sample from mould and keep the sample in a curing under gunny bag as per required days. After curing period the sample is ready to conducting experiments.

3.7 Curing

To achieve design strength and maximum durability, CGBM must be properly cured. Direct curing is not recommended as per IRC SP: 125 – 2019. Prepared CGBM Samples curing is done by using Gunny bags. Now a days gunny bags curing is widely used method of curing. The advantage is covering the exposed pavement surface with gunny bags prevents it from drying out. These are wetted on a periodic basis. The length of time between wettings is determined by the rate of water evaporation. At night and on holidays, special arrangements must be taken to keep the pavement surface wet.

4. RESULTS

Before conducting experiments on prepared CGBM samples, all CGBM samples first checked their physical parameters like bulk specific gravity, bulk density and dimensions of CGBM samples. After that, the extracted samples are ready to conduct the experiments.

4.1 Compressive strength

Compressive strength is an important experiment for designing CGBM structures. Compression testing is used to determine how a material behaves when subjected to a compressive vehicular load. CGBM Sample compressive strength is mainly depends on grout properties and it depends on many other parameters such as the water-cement ratio, cement strength, fly ash strength and quality control during the manufacturing process.

Fig.4.1 Compression Testing Machine

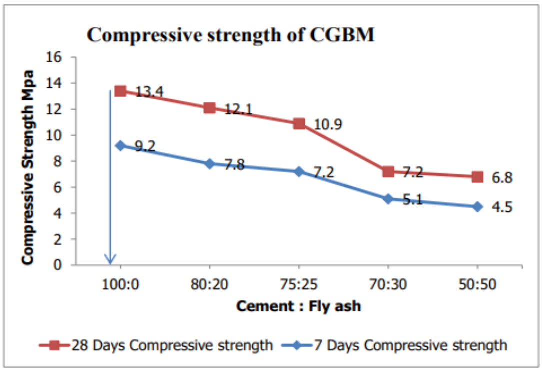

Fig.4.2 Compressive strength results

4.2 Marshal stability

The main objective of Marshall Stability test is to know the shear strength of materials. The Marshall stability is used to estimate how well the Marshall mix design procedure will perform in the real life. Procedure followed as per ASTM D 6927. Size of Specimen for testing: 100 mm diameter and 63 mm height cylindrical sample. Total Number of samples prepared under Marshal Stability test: 30 (15 for 7 days and rest 15 number for 2 days)

Fig.4.3 Bituminous Mix for testing

Fig.4.4 Marshal Stability set up

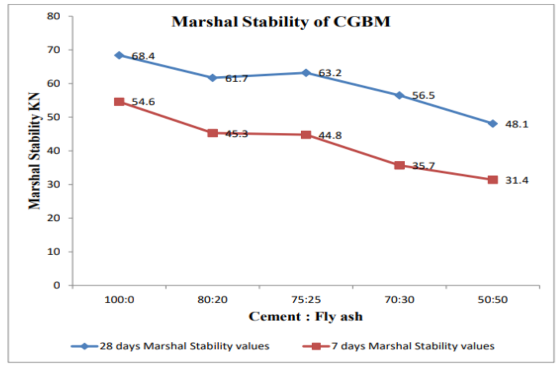

Fig.4.5 Marshal Stability Results

4.3 Flexural Strength of CGBM

(As per ASTM C 78)

Size of specimen for testing: 180*60*60

Total number of samples under this test: 30 (15 for 7 days and rest 15 for 30 days)

Fig.4.6 Beam Samples

Fig.4.7 Flexural test setup

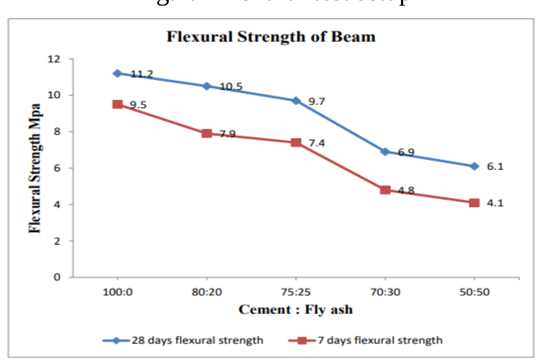

Fig.4.8 Flexural Strength results

5. CONCLUSIONS

The following specific observations can be drawn based on the research work in this study:

- From the Compressive strength and flexural strength of CGBM graph it is clearly visible that there is a sudden fall in the graph after 75:25 mix proportion of cement and fly ash.
- From the marshal stability of CGBM graph we can observe that there is a slight increase in the graph from 80:20 to 75:25 mix proportion of cement and fly ash.
- In this experimental investigation of CGBM study, from the above three test results we can observe that 75:25 mix proportion of cement and fly ash is gives best results compared to other mix proportion cement and fly ash.
- Day by day the fly ash wastage is increasing. It leads to Environmental and water pollution. By using this 75:25 mix proportion in CGBM, it gives following advantages.
- The Cost of CGBM Construction decreases.
- The CGBM Pavement becomes environmental friendly.

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