International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 7 (2018) pp. 198-202

PREVENTION OF MUD PUMPING IN RIGID PAVEMENT BASE COURSE DUE TO CHANGE IN MOISTURE CONTENT ALONG THE JOINTS

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Abstract
In current practice dry lean concrete (DLC) is used as base course above which pavement quality concrete (PQC) slab is rested in the construction of cement concrete road in India for highways. Dry lean concrete base course is even used by Municipal's concrete roads and for low volume roads. Ordinary Portland cement (OPC) is mostly used for the construction of DLC according to Indian Road Congress specification SP – 49 : 1998, which advocates the usage of ordinary Portland cement (OPC) with change in water and cement ratio for DLC. Increase in percentage of cement and water content can change the strength of pavement by laboratory tests with the proportion of M40 grade of pavement quality concrete (PQC) satisfy the compressive, flexural and split tensile strength more than normal DLC. Increased percentage of cement content in a material is called as rigid lean concrete (RLC). Combination of both DLC and RLC below PQC can give high strength and may finally lead to reduction in failure on PQC and mud pumping and also variation in age factor.

Keywords: Dry lean concrete, Pavement quality concrete, Rigid lean concrete, Mud pumping.

Introduction
The total length of road network in India is about 4.70 million kilometers. In which 54.2% (2.55 million kilometers) are completely paved. About 2.5% pavements are made up of cement concrete. With overall economy, long life advantages and least maintenance cost thousands of kilometers of cement concrete pavements are already constructed and are being constructed in India. At the rural level, construction of cement concrete pavement is being encouraged by government of Karnataka and India.

The pavement wearing surface is under laid by several materials in terms of layers, which is known as base course. Concrete cement of Portland, soil stabilized by fly ash, aggregate mixtures of soil, slag and stone fragments are used in the construction of base course. When the base course is subjected to deformation under high pressure, it must withstand it as the pavement surface seems to be very close to it.

The base course's functions depend on the pavement types. When the load is distributed up to certain thickness, to support its capacity, initially, flexible pavement uses the base course under it to enhance the supporting capacity of load. The purposes for which rigid pavements use base course under it are:-

- Prevention of mud pumping.
- Construction expedition.
- Increase in the structure capacity.
- Drainage.
- To prevent volume change of sub grade.
- Frost action protection.

Lean cement fly ash, concrete of lean cement, wet mix macadam, mixture of soil and cement, water bound macadam,

macadam of bitumen, granular material etc. have been used as base course over two centuries. The IRC: SP: 49-1998 has signified to use Dry lean concrete (DLC) as a material of base course recently for concrete pavements. The use of DLC under the pavements as base has been very advantageous. Now a days in India DLC is very needful for the construction of cement concrete pavement. Some of them are increasing the performance of pavement under cold conditions, prevention of pumping and availability of firm structural support for construction equipment. The base course thickness reduction, improvement of pavement joint load transfer, volume change control of expansive soils, highly resistive to deformation and strong and uniform support are included in the other benefits of using DLC. The areas which yield higher quality of stones over long distance for base course are suitable for DLC.

Dry lean concrete acts as one of the best suitable materials for cement treated bases to obtain higher support value. But the most important requirement for evaluation and rational design is to determine the property of several materials of pavements. Fatigue and strength characteristics, modulus of Elasticity (E), Poisson's ratio (μ) constitute the fundamental properties. It is very essential to estimate these properties accurately in order to make use of DLC as a material for base course. A present study says that both destructive and non destructive methods are employed to study the fundamentals of DLC.

Low volume roads are defined as the roads with volume of traffic is below 1000 vehicles per day. It however giver the enormous impact on social interaction, economics and communication. These rods give connectivity for minor places like farm to market, between places to major roads, parkland. Pavement quality concrete is a high quality types which is used to build Cement Concrete roads or rigid pavements and it should possess the following.

Objectives

- Strengthening of base coarse by changing the behavior of DLC.
- Study on mud pumping characteristics due to variation in moisture content in base course.
- To provide adequate support to control corner faulting.
- To avoid cavity by using Shear keys between the layers

Proposed Methodology

Dry Lean Concrete Mix Proportions

The minimum cement content in dry lean concrete shall not be less than 180 kg/m3 of concrete As per IRC SP-49, 1988. The concrete mixture can be made proportionate with maximum aggregates ratio of cement of 15:1 in which OPC is used and ratio of 13:1 in which PSC or PPC is used. The minimum content of cement in any material must not exceed 150kg/cum of concrete. if this content does not satisfy the production of a suitable strength concrete, it can be changed accordingly. The GBPS or fly ash must be 25-50 or 15-30 percent by cementations materials weight. The Central Road Research Institute (CRRI) sets standards for the test results. For full rolling under compaction, the optimum content of water is decided. Too much content of water shall cause heaving before the pickup of vehicle under the roller wheels. Presence of too less water would result in inadequate segregation and compaction, open texture surface and lower in-situ strength. The trial mixtures of DLC are prepared with water content containing 5.0, 6.0, 6.5 and 7.0 percent of material's total weight. Optimum density and moisture are established by cubes that are prepared with moisture that varies for which the density-moisture curve can be drawn. To compact the specimens special vibratory type of hammer is used. During transportation, to compensate with the loss in evaporation, DLC with 1 percent of moisture is used while laying its sub-base layer. A drainage layer (GSB) is provided throughout the width of the road in order to facilitate quick disposal of water that is to enter the layer of subgrade.The sub grade layer gives confirmation to all the cross-sections and grades which are drawn and are compactly uniformly to the Proctor density that is modified must not be less than 97 percent which is specified. The lean, after its final preparation is softened by rain water is not laid on the layer of sub grade. The trenches on the surface, the soft spots if any are present, must be compacted and back-filled so that weak spots are avoided. The construction traffic is avoided on the sub grade as far as possible. In order to stabilize looser surfaces, the sub grade is given a fine water spray and is rolled with passes of one or two smooth wheeled roller with 2-3 hour time lapse. This is done a day before the sub-base is placed. Another fine water spray can be done before the placement of sub-base if necessary.

The trial mixtures of DLC with moisture contents can be 5.0, 5.5, 6.0, 6.5, and 7.0 percent of required cement content of aggregate-cement ratio. Cubes which have different moisture contents are used to establish optimum density and moisture. A vibratory hammer fitted with a rectangular or square foot can be used for compaction which is carried out in three layers. When the optimum moisture is set, 6 cubes are used to cast moisture that determines the strength of compression in a span of 3-7 days. If the strength dissatisfies, the trial mixtures are repeated by either increasing the content of cement or using a higher cement grade. When the design is approved, a section of trial is constructed. If the trail length during construction is found dissatisfactory, there can be changes made in the content of moisture so that it satisfies the requirement mixture. The specimens of cube with the changed content of moisture have to satisfy the required strength. The content of moisture in aggregates must be determined every day before the mix is produced in order to adjust the moisture content. The finally designed mixture should neither become too dry nor stick to rollers which results in the surface revelation.

Table.1-Gradation of aggregates for Dry lean concrete

Sieve Designation	**Percentage Passing (By Weight)**
26.50 mm	**100**
19.00 mm	**85**
9.50 mm	**60**
4.75 mm	**42.5**
2.36 mm	**29.5**
600 micron	**15**
300 micron	**12**
150 micron	**6**
75 micron	**5**

Replacing DLC with RLC

The mix design for RLC is not similar to conventional concrete mix. Increase in the water to- cement ratio is the criteria for RLC mix design but its optimum moisture content (OMC) to ensure full compaction of concrete under the rolling. The mix should not be too little bit wet. Hence, it is important to determine mix proportions and optimum moisture content for adequate compaction i.e. aggregate-to-cement ratio to yield required for compaction and compressive strength for the rigid lean concrete. The concrete mixture can be made proportionate with maximum aggregate ratio of cement of 10:1 in which ORG is used and ratio of 9:1 in which PPC or PSC is used. The trial mixtures of RLC rigid lean concrete are prepared with water content containing 5.0, 5.5, 6.0, 6.5, 7.0, 7.5 and so on percent of material's total weight. Optimum moisture and density are established by cubes that are prepared with moisture that varies for which the density-moisture curve can be plotted. To compact the specimen's vibratory type of hammer are used. During transportation, to compensate with the loss in evaporation, RLC with 1 percent of moisture is used while laying its sub-base layer.

Pavement Quality Concrete

The pavements of concrete get into stress due to various factors and highest stress reducing condition must be considered for its analysis. Temperature gradient and traffic loads are the main factors. The moisture changes and shrinkage normally are opposed to temperature. These are of smaller values of magnitude and hence relieve the temperature effects and are not used to design as they are critical. The corner and the pavement slab are the two regions considered for analysis. The effect of temperature gradient is too high at edges, while it is too low at the corner. The pavements of concrete undergo a variety of period cyclic change of differing temperatures, the bottom being cooler than the top during the day and vice versa during the night. Curling stresses are defined as the tendency of the slabs to top curl (top convex) during the day and down curl (top concave) during the night and the induction of stress in the self-weighted pavements. The stress induced here are flexural, tensile, during the day being bottom and night being top. The curling's restraint is a function of weight of any section of slab leaving lesser restraint at the corners. This consequently reduces the restraint at the corners. An excel sheet which is programmed is given for the thickness computation of pavements. 200 mm is the minimum thickness of the slab to be considered. To design a pavement, totally three cases are studied which are as follows:

- The stresses because of 50 KN double load for wheel just for traffic which is less than 50 CVPD. This category has most of such lesser volume roads.
- The combined stresses that take place because of 50 KN double wheel load and traffic's temperature gradient that is greater than 50 is lesser than 150 CVPD.
- The analysis for fatigue stresses that take place because of 50 KN double wheel load and traffic's temperature gradient that is greater than 150 CVPD is lesser than 450 CVPD. This category comprises of very few roads of lower volume.

Table.2-Aggregate Gradation for pavement Quality concrete

Sieve Designation	**Percentage passing the sieve by weight**
26.50 mm	100
19.00 mm	90
9.50 mm	65
4.75 mm	47.5
600 micron	17.5
75 micron	4

Results

7-day and 28-day strength is the main acceptance criteria for the dry lean concrete mixes. Therefore, standard cubes, and cylinders prepared from dry lean concrete mixes were tested for strength development at 7-day and 28day.

Results for DLC

The compressive strength, split tensile, flexural strength tests were determined at 7-day and 28-day, aggregate to cement ratio and moisture content of different DLC mixes by taking OPC are shown in Figures 4 and 5, respectively.

An increasing reading for the compressive strength, split tensile and flexural strength with decrease in aggregate to cement ratio is also obvious (Figure 4) and it falls down at 1.2% of W/C ratio. It is to be noted that even at the same moisture content, DLC mix with lesser aggregate – to-cement ratio developed not the required strength. The requirement of compressive, split tensile and flexural strength at 7-day and 28-day age is partially satisfied at maximum aggregate-to-cement ratio 1:13. The maximum density of the fresh concrete was 2210 kg/m3. Figure 5 shows that 7-day compressive strength, aggregate to cement ratio and moisture content of DLC mixes manufactured with OPC. M-5 showed the maximum strength developed at 7-day followed by Mix-4. No other mixes developed a strength of 10 MPa at 7-day. The concrete mix M-5, which developed maximum compressive strength, had aggregate to cement ratio of 15:1 with a cement content of 200 kg/m3. The concrete Mix has developed a compressive strength (6.75 MPa), flexural strength (2.015 MPa) and split tensile strength (0.84 MPa) which is not that effective strength criteria for DLC i.e. 10 MPa for compressive strength, 1MPa for split tensile strength and 3MPa for flexural strength to be used for base course in concrete pavement construction. The moisture and cement contents for the mix are 1.1% and 180 kg/m3.

Results on Semi Rigid Lean Concrete

The compressive strength, split tensile, flexural strength tests were determined at 7-day and 28-day for aggregate to cement ratio 10:1 and moisture content of different semi RLC mixes by taking OPC are shown in Figures 4 and 5, respectively. An increasing reading for the compressive strength, split tensile and flexural strength with decrease in aggregate to cement ratio is also obvious and it falls down at 1.2% of W/C ratio. It is to be noted that even at the same moisture content, semi RLC mix with lesser aggregate – to-cement ratio developed better required strength. The requirement of compressive, split tensile and flexural strength at 7-day and 28-day age is satisfied at maximum aggregate-to-cement ratio 10:1. The maximum density of the fresh concrete was 2310 kg/m3. Figure 5 shows that 7-day compressive strength, aggregate to cement ratio and moisture content of semi RLC mixes manufactured with OPC. M-10 showed the partial strength developed at 28-days. No other mixes developed a strength of 10 MPa at 28-day. The concrete mix M-10, which developed maximum compressive strength, had aggregate to cement ratio of 10:1 with a cement content of 210 kg/m3. The concrete Mix has developed a compressive strength (13.41 MPa), flexural strength (3.23 MPa) and split tensile strength (1.17 MPa) which is that effective strength criteria for semi RLC i.e. 13 MPa for compressive strength, 1.2MPa for split tensile strength and 3.1MPa for flexural strength to be used for base course in concrete pavement construction. The moisture and cement contents for the mix are 1.1% and 210 kg/m3.

Results on Rigid Lean Concrete

The compressive strength, split tensile, flexural strength tests were determined at 7-day and 28-day for aggregate to cement ratio 7:1 and moisture content of different RLC mixes by taking OPC are shown in Figures 4 and 5, respectively. An increasing reading for the compressive strength, split tensile and flexural strength with decrease in aggregate to cement ratio is also obvious and it falls down at 1.2% of W/C ratio. It is to be noted that even at the same moisture content, semi RLC mix with lesser aggregate – to-cement ratio developed better required strength. The requirement of compressive, split tensile and flexural strength at 7-day and 28-day age is satisfied at maximum aggregate-to-cement ratio 7:1. The maximum density of the fresh concrete was 2410 kg/m3. Figure 5 shows that 7-day compressive strength, aggregate to cement ratio and moisture content of RLC mixes manufactured with OPC. M-15 showed the good strength developed at 28-days. The concrete mix M-15, which developed maximum compressive strength, had aggregate to cement ratio of 7:1 with a cement content of 230 kg/m3. The concrete Mix has developed a compressive strength (15.12 MPa), flexural strength (3.23 MPa) and split tensile strength (1.61 MPa) which is that effective strength criteria for RLC i.e. 15 MPa for compressive strength, 1.5MPa for split tensile strength and 3.2MPa for flexural strength to be used for base course in concrete pavement construction. The moisture and cement contents for the mix are 1.1% and 230 kg/m3.

Conclusions

Experimental work carried out in the laboratory by preparing and testing on cubes for compression strength, cylinders for split tensile strength and beams for flexural strength mould for the construction of DLC, semi RLC and RLC base course for PQC layer which results on mud pumping at the joints, failures on PQC and age factor.

1. Comparing with all the results of compressive strength, flexural strength and split tensile strength, RLC gives the better performance compared to semi RLC and DLC. RLC has good strength and stability at the base course which avoids mud pumping as it is having good bonding ability due in increase in concrete grade. But in case of DLC which may lead to failure in base course for heavy wheel loads on PQC and also due to saturation areas in rainy season and finally it may lead to pumping at the expansion joints.
2. As there are failures in DLC base course because of saturation areas in rainy season may leads to uneven surface below PQC layers at the joints. The same happens even in the case on semi RLC mainly at the joints. But in RLC, it gives firm support at the base as it remains unsaturated and having high strength compared to DLC and semi RLC. Hence by providing firm surface

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 7 (2018) pp. 198-202

by RLC below PQC this finally reduces cracks and corner failures.

3. Among the tests, the layer RLC is 100mm and PQC is 200mm for low volume roads yield the similar load carrying capacity as that of PQC slab. Hence the load is distributed equally then it leads to increase in age of pavement.

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