ANALYSIS AND DESIGN OF RIGID PAVEMENT: A REVIEW

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Abstract: Because of a substantial volume of commercial vehicles likely to use facility, the pavement structure has to receive careful consideration in design and choice of materials forming the pavement. Pavement costs constitute a significant proportion of total cost of highway facility. Hence, great care is needed in selecting right type of pavement and specification for the various courses that make up the pavement. The choice of pavement type, whether flexible or cement concrete, therefore, has to be very carefully exercised. Pavement associated traffic safety factors include skid resistance, drainability against hydroplaning, and night visibility. Cement concrete pavement has distinct initial advantage over bitumen pavement in this regard, as surface texturing forms integral part of the normal construction practice for such pavements. They also have superior night visibility by virtue of their lighter colour. Poorly designed and constructed concrete pavements are known to have very long service life. The cement concrete road constructed in the country in the past, though extremely limited in length, have an excellent service track, having given good service under condition much sever than those for which they are originally intended.

Keywords: Rigid pavement; Traffic; Joints; Cement concrete.

1 INTRODUCTION

Cement concrete pavement has distinct initial advantage over bitumen pavement in this regard, as surface texturing forms integral part of the normal construction practice for such pavements. They also have superior night visibility by virtue of their lighter colour. In area of low rainfall intensity, hydroplaning not being the governing consideration, it a possible to design the concrete mix for adequate skid resistance even after the loss of textured surface finish, subject to availability of appropriate quality material. Poorly designed and constructed concrete pavements are known to have very long service life. The cement concrete road constructed in the country in the past, though extremely limited in length, have an excellent service track, having given good service under condition much sever than those for which they are originally intended. Cement concrete develops very fine, small, discontinuous micro-cracks in initial stages due to hydrothermal changes. Under increasing or repetitive loading, the micro-cracks tend to extend and join, resulting in fracture and failure. To minimize them inherent micro-cracking, only minimally essential water for ensuring full compaction of concrete should be used.

Construction of rigid pavement is also financially viable as rigid pavements require less thickness than the bituminous pavements when same and equal traffic load is applied to the pavement [1]. The main disadvantage is rigid pavement requires a high initial cost for rectification compare to bitumen roads as the entire concrete slab needs to be replaced when it damages. In addition the rigid pavement tends to fail across the construction joints provided between the adjacent slab panels as it acts as a weak plane across the section. Furthermore there is a delaying for allowing normal traffic to newly constructed rigid pavements since concrete requires 28 days for achieving utmost compressive strength [2]. Attention should be taken to design and construct of subgrade and subbase since it is essential to ensure the structural capacity and ride quality of all types of pavements. Pavement performances with respect to bearing strength, consolidation and moisture susceptibility are strongly influenced by subgrade and subbase [3]. During rain storm the damage to bituminous surfaced roads are faster than concrete roads, while gravel roads become very dusty in dry weather condition causing safety and health problems. Problems of dust formation and wet weather damage to roads can be easily overcome by constructing concrete roads [4]. Rigid pavements have a life span of more than 40 years compared to the bituminous which has 10 years life span [5]. Rigid pavements require little maintenance; whereas bituminous roads need frequent repairs due to damage occurred by traffic and weather, high surface resistant to automobile fuel spillage and environmental friendly since concrete is 100% recyclable [6].

2 MATERIALS

Various material used in rigid pavement are cement, fine aggregate, coarse aggregate, water, reinforcing steel, dowel bars and tie bars.

OPC grade 43 conforming to IS 8112 is mainly used in rigid pavements. The minimum fineness requirement of this cement should be 225 m^2/kg. Soundness of the cement should be 10 mm maximum. Initial setting time of cement should be 60 minutes (minimum). Compressive strength of cement at 7 days should be minimum 33 MPa and maximum 37.5 MPa. The specific gravity of cement should be in between 2.6 to 3.8. Sand is used in the rigid pavement as a fine aggregate. Mainly river sand and crushed stone are used. The specific gravity of sand should be near to 2.7. Main requirement of coarse aggregate in rigid pavement is the gradation of the material. Maximum size of coarse aggregate used in pavement is 20 mm and the material used is of well graded. Typically aggregate used in rigid pavement will have a specific gravity between 2.5 and 3.2 with 2.7 being fairly typical of most the aggregate. Water used in a cement concrete rigid pavement should be suitable for drinking and as far as possible always avoid water from sea. Reinforcing steel used in cement concrete rigid pavement to reduce cracking. Dowel bars are used as a load transfer mechanism across joints. They gives shearing, flexural and bearing resistance. 25-38 mm diameter and 610 – 915 mm length of dowel bars generally used at a spacing of 300 mm centers across the slab width. To tie two sections of the cement concrete rigid pavement together tie bars are used. Tie bars are smaller in diameter than the dowel bars.

3 CONSIDERATIONS RELEVANT TO STRUCTURAL AND FUNCTIONAL ASPECT OF RIGID PAVEMENTS

3.1 Pavement design

While concrete pavement makes more efficient use of constructional material, particularly aggregates, as compared to bituminous pavement, they are much more sensitive to overloading in terms of damage to the pavement structural strength. The concept of equivalent standard axel loads (ESALs), which is based on functional criteria, does not adequately their structural response and is not the appropriate criteria for their design.

3.2 Concrete mix design

Concrete mix design should base on both the structural and functional requirements of pavements. It should not have the requisites flexural strength, but should also provide needed wear resistance and skid resistance. While kid resistance of new pavement would mainly depend upon the texturing of the surface, the materials – particularly the aggregate would be so selected as to ensure adequate skid resistance even after the initial texture wears off. Where such materials are not readily available, two layer bonded construction may be considered, with the more wear and skid resistant mix design adopted for upper layer.

3.3 Quality control of construction

For expeditious construction of substantial length of pavement, highly mechanized construction technology would need to be adopted. Central mixing and batching plant, transit mixtures, and paving and finishing trains can obviate much of the variability associated with manual or semi-mechanized construction. However constant check on the supplies of fresh material, and the strength and workability of concrete would need to be ensured.

3.4 Maintenance and rehabilitation

Cement concrete need very little routine maintenance, while confined practically renewal of the joint seal. Any joint spalls or contraction cracks are best maintained using resin repair technology. For surfacing OF concrete pavements to improve their riding quality or enhance their structural strength, bonded concrete technology is available.

4 CONSTRUCTION OF CEMENT CONCRETE PAVEMENT

4.1 Construction of Pavement slab

Various specifications for construction of cement concrete pavement are: cement grouted layer, rolled concrete layer, and cement concrete slab. In cement grouted layer open graded aggregate mix with minimum size of aggregate as 18 to 25 mm is laid on the prepared subgrade and the aggregate are dry rolled. The loose thickness is compacted to provide 80% of rolled thickness. The grout made of course sand, cement, water is prepared. The proportion of cement to sand is taken as 1:1.5 to 1:2.5. In rolled concrete layer, lean mix concrete is used. Lean mix of aggregate, sand, cement and water is prepared and laid on prepared subgrade and sub base course. The rolling is done similar to WBM construction. The loose thickness of concrete is 20% more than the compacted or finished thickness.

There are two modes of construction of cement concrete slab: Alternate bay method and continuous bay method. Alternate bay construction method of construction means constructing bay or one slab in alternation succession leaving the next or intermediate bay to follow up after a gap of one week or so. As shown in fig.1 in alternate bay construction the slabs constructed are in sequence of x, y, z etc. leaving the gaps of bay x', y', z' etc. This technique provides additional working convenience for laying of slabs. The construction of joints is easier. In continuous bay method all the slab or bay are laid in sequence i.e. x', y', z'.

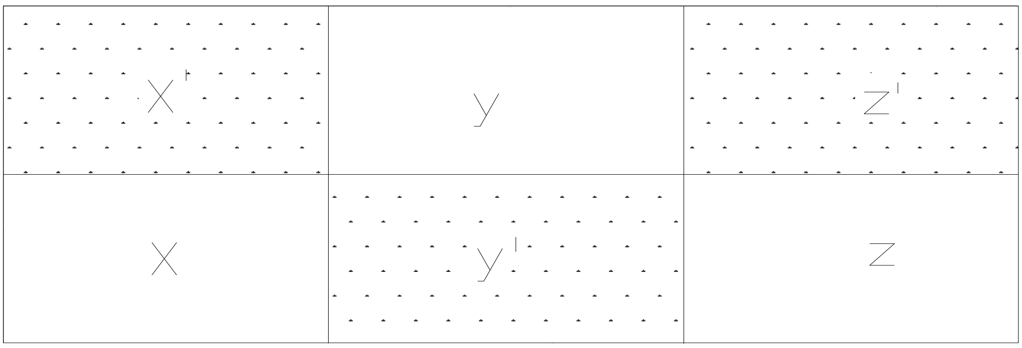

Fig.1 Construction method of cement concrete road

5 CONSTRUCTION STEPS FOR CEMENT CONCRETE PAVMENT SLAB

5.1 Preparation of sub grade and sub-base

The sub grade or sub base for laying of concrete slab should comply with the following requirements; that no soft spots are present in the sub grade or sub base; that the uniformly compacted sub grade or sub base extends at least 30 cm on either side of the width to be concreted; that the sub grade is properly drained; that the minimum modulus of sub grade reaction obtained with a plate bearing test is 5.54 kg/cm^2. The sub grade is prepared and checked at least two days in advance of concreting. The sub grade or sub base is kept in moist condition at the time when the cement concrete is placed. If necessary, it should be saturated with water for 6 to 20 hours in advance of placing concrete.

5.2 Placing of forms

The steel or wooden forms are used for the purpose. The steel forms are of M.S channel sections and their depth is equal to the thickness of pavements. The section has a length of at least 3 m except on curves less than 45.0 m radius, where shorter section is used.

5.3 Batching of material and mixing

After determining proportions of ingredients for the field mix, the fine aggregate and coarse aggregate are proportioned by weight in a weigh-batching plant and placed in to the hopper along with the necessary quantity of cement. All batching of material is done on the basis of one or more whole bag of cement. The mixing of each batch is commenced within one and half minute after all the materials are placed in mixture.

5.4 Compaction and finishing

The surface of pavement is compacted either by means of a power driven finishing machine or by a vibrating hand screed. For areas where the width of slab is very small as at the corner of road junctions etc. hand consolidation and finishing may be adopted.

5.5 Floating and straight edging

The concrete is further compacted by means of the longitudinal float. The longitudinal float is held in a position parallel to carriageway center line and passed gradually from one side of pavement to the other. After the longitudinal floating is done and excess water gets disappeared, the slab surface is tested for its grade and level with the straight edge.

5.6 Belting, brooming and edging

Just before the concrete become hard, the surface is belted with a two ply canvas belt. The short strokes are applied transversely to the carriage way. After belting, the pavement is given a broom finish with fiber broom brush. The broom is pulled gently over the surface of the pavement transversely from edge to edge. Brooming is done perpendicular to the centre line of pavement. Before concrete develop initial set, the edge of the slab are carefully finished with an edging tool.

5.7 Curing of cement concrete

The entire pavement of the newly laid cement concrete is cured in accordance with the following method: Initial curing; the surface of the pavement is entirely covered with cotton or jute mats. Prior or being placed, they are thoroughly saturated with water and are placed with the wet side down to remain in intimate contact with the surface. Final curing; is done with the any one of the following method: Curing with wet soil exposed edges of the slab are banked with a soil free from stone is placed. The soil is thoroughly kept saturated with water for 14 days. Impervious membrane method; use of an impervious membrane which does not impart a slippery surface to the pavement is used. Liquid is applied under pressure with a spray nozzle to cover the entire surface with a uniform film.

6 TYPES OF JOINTS:

Joints are the discontinuities in the concrete pavement slab, and help to release stresses due to temperature variation, subgrade moisture variation, shrinkage of concrete etc. There are various types of joints in concrete pavement, e.g. expansion joint, contraction joint, warping joint, and construction joint. Fig. 2 schematically shows position of various joints.

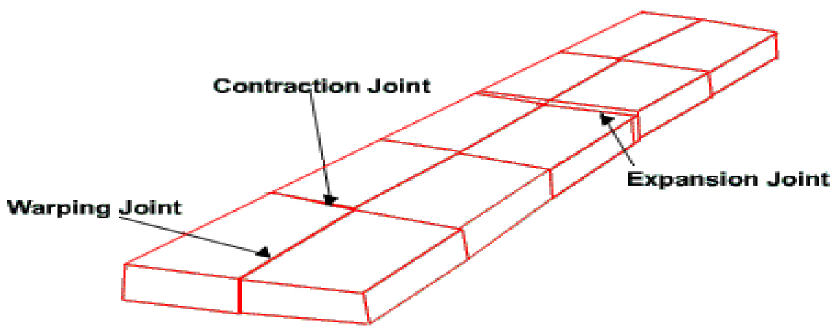

Fig. 2 Location of joints in cement concrete pavement

6.1 Expansion joints:

Expansion joints, as the name itself signifies, are intended to provide space in the pavement for expansion of the slabs. Expansion takes place when the temperature of the slab rises above the value when it was laid. It is normally a transverse joint. Expansion joints also relive stresses caused by contraction and warping. Fig. 3 shows expansion joint in cement concrete pavement.

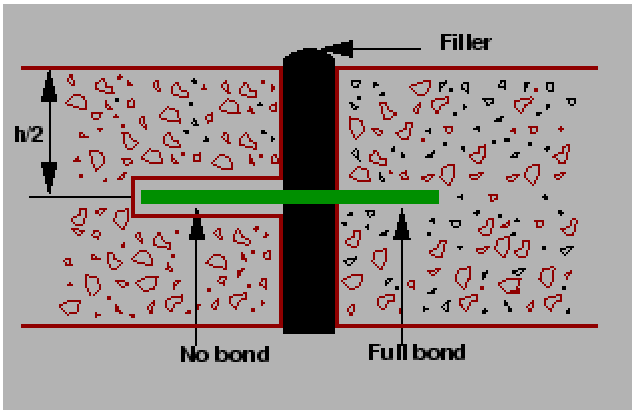

Fig. 3 Expansion joint in cement concrete pavement

6.2 Contraction joints

When the temperature of concrete falls below the laying temperature the slab contracts. If a long length of slab is laid, the contraction induces tensile stresses and the slab cracks. If joints are provided at suitable intervals transversely, the appearance of cracks at places other than the joints can be eliminated. Fig. 4 shows contraction joint in cement concrete pavement.

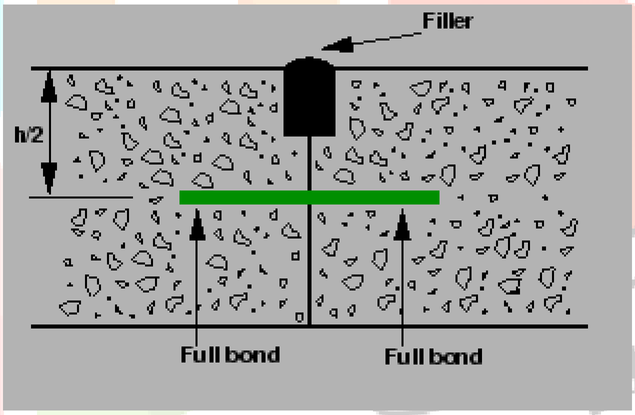

Fig. 4 Contraction joint in cement concrete pavement

6.3 Warping joints

Warping joints, also known as hinge joints, are joints which are intended to relieve warping stresses. They permit hinge action but no appreciable separation of adjacent slabs. Warping joints can be longitudinal or transverse. A major difference between the warping joints and the expansion or contraction joints is that in the former appreciable changes in the joints width are prevented.

6.4 Construction joint

A construction joint becomes necessary when work has to be stopped at a point where there would be otherwise no other joint. Such joints should be regular in shape, by placing a cross-form in position. The reinforcement should be continued across the joint.

7 CONCLUSION

Cement concrete have number of advantages over flexible pavement. Adequately design and properly constructed concrete pavement have good functional stability, long service life and very little maintenance needs. The special requirement viz. structural mechanism of concrete, environmental mechanism of paving concrete and rigidity of paving concrete needs to be adequately meet to realize the full service potential of concrete pavement for expressways. As regards cost, they compare very favorably with bituminous pavements even in initial cost. When whole life-cycle costs are considered, their cost advantages is very attractive. As an added benefit, they give fuel economy.

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