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A DETAIL STUDY ON RIGID PAVEMENTS CONSTRUCTION METHODOLOGY WITH EMPHASIS ON JOINT'S AND FORMATION OF CRACK'S

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***ABSTRACT**– A pavement consists of superimposed crusts of chosen and processed materials which are compacted on the base soil or sub-grade. Pavements are made to carry traffic loads and to provide a comfortable surface for vehicles to ply. The main role function of a structure of pavement is to absorb the wheel stress/loads coming on the top crust of the pavement surface and to further distribute that stress on the underlying sub-grade. Generally, there are two kinds of pavements depending on the materials of construction used: Flexible and rigid pavements. Flexible pavements are constructed using asphalt as binder whereas the binder used in rigid pavements is cement. The usage of these two different materials as a binder changes the overall characteristics of the two pavement types. The age, rigidity, load distributing characteristic, and riding quality of the pavements differ exceedingly based on the kind of binder used.*
The various kinds of cracks formed on rigid pavement and how these cracks occurs on rigid pavement and how they can be avoided has been discussed in this study. Recommendation has been given keeping in mind IRC 15 2011 and IRC 62 2014 and also for joints.

Keywords- Pavement, Rigid Pavement, Flexible Pavement, Flexural Strength.

1. INTRODUCTION

Modern design of structure of pavement revolve around the mechanics of providing the solution for development of cost effective pavements that will ensure that the loads distributed from the carriageway do not exceed the total bearing capacity of each layers, or of the sub-grade, during the entire span of life of the road. Major parameters affecting the design criteria of the surface of pavement are therefore the quantum and type of traffic, the sub-grade environment and strength. The stress sharing phenomenon of a pavement layers is greatly varies as per its modulus of elasticity. The modulus of elasticity of cement concrete is very high as compared to that of asphalt concrete. As a result, the stress dividing phenomenons of the two pavements are different. In flexible pavements, the traffic load is distributed using the help of many layers ultimately bringing down the stress within the stress absorbing capabilities of the sub-grade soil. Taking of the study of the rigid pavements the load is almost evenly distributed into a larger area under the pavement quality concrete layer (PQC layer). The two pavements surface differs in their ages. Life of pavement is 15 to 20 years; a PQC pavement carries a life of 30 years. Concrete/PQC pavements surfaces are generally known as rigid pavements. They may or may not have a base course between the pavement top surface and sub-grade. The rigid pavement surface, due of its rigidness and high modulus of elasticity, distribute the load coming over it in extended portion of soil; thus, the slab on which load is coming itself becomes the prominent part for the stress taking of the structure. This is in contrast to the flexible pavement, wherein building up relatively thick layers of sub base, base, and wearing course brings the load bearing strength of the pavement. Rigid pavements have various advantages over bituminous pavement. Few of them are as follows: it has more useful life, low cost of maintenance, provide good visibility for night driving, it requires lesser amount of aggregates and no flame thereby more environmental friendly, can be constructed under unfavorable soil condition, practically unaffected by weather and temperature etc. Most importantly for flooding potential areas it offers better performance than that of flexible pavement.

Primarily the drawback of concrete pavement is the high initial cost of constructions. But in consideration of several functional and operational advantages and above all from the viewpoint of life cycle cost, the cement concrete roads are becoming popular around the world. Advent of modern techniques in the production of durable concrete, price escalation of petrol and above all participation of private sector in road infrastructure development made the selection of rigid pavement in many high standard road projects particularly built under BOT concept. Literature obtained from the Internet **[**Thomas, 1999**]** reveals that the advantage of long life is widely favourable to private sector projects where the lease period is up to 30 years, since a careful investor would expect that his project should last for the full period of franchise without the need for major repairs, overhauls or rehabilitation. A bituminous pavement, however carefully constructed, requires significant periodic renewals when the pavement deteriorates functionally and structurally, and this can happen once in every 7 years on an average as found in actual care **[**David at el., 2000**]**. Now-a-days reduction of maintenance works particularly on busy roads is one the main concerns of traffic management measures.
A PQC pavement is amenable to a much more precise structural analysis than flexible pavement. The fact is that the flexural strength of concrete, which is considered to be as the main basis for design, is well understood. The most

common design method for rigid pavement is Portland Cement Association method (PCA, 1984). AASHTO design method considers the following factors:-

- Modulus of sub grade reaction
- Concrete elastic modulus
- Concrete modulus of rupture
- Load-transfer coefficient
- Drainage coefficient
- Reliability and standard deviation
- Traffic load applications
- Serviceability loss

Thus aim of this study is to understand rigid pavements, its joints and the reasons for cracks.

II. CONSTRUCTION OF RIGID PAVEMENT (Acceptance criteria: Ret. Sec. 600 of MORT&H)

The construction of the rigid pavement is very unique. A rigid pavement comprises is a cement concrete slab on upper part of a sub-base. The pavement structure is described as being rigid because the slab is composed of pavement-quality concrete (PQC) with considerable flexural strength which enables it to act like a beam and bridge over any minor differences in the surface underneath. The concrete surface provides a smooth comfortable riding surface for the traffic that runs of it. Concrete slabs in rigid pavement are either jointed unreinforced (i.e. plain), or reinforced. Reinforced concrete slabs are usually described as being jointed reinforced or continuously reinforced.

The material and equipment used has been described. These are also helpful in using rigid pavement for the construction of rigid pavement.

This methodology shall be applicable for construction of 340 mm thick Pavement Quality Concrete (PQC) with M40 grade concrete pavement in accordance with the lines, grades, camber and thickness as shown in the drawings using fixed forms.

2.1 Materials:

Cementatious materials:. Cement shall be as per IRC 21 from approved source. The minimum cementations content shall be 350Kg/cum and maximum 425Kg/cum.

Admixtures: The admixtures shall confirm to IS 6925 and IS 9103 shall improve the workability of concrete or extension of time and they will not have any effect on the properties of concrete. The performance of these admixtures will be proved both on laboratory trials and in trial paving works. The admixtures containing calcium chloride shall not be used.

Aggregates: The aggregates shall be of crushed stone or naturally available confirming to IS 383. The coarse aggregate shall be clean, hard, strong, dense and durable of crushed stone the fine aggregate shall be of clean natural sand or crushed stone sand or combination of both. These shall be free from clay, shale, loam, mica and other organic matter.

Water:
Water used for mixing and curing of concrete shall be free from oil, salt, acid and other substances, which are harmful to concrete.

Mild steel bars for dowel and tie bars: Dowel bars shall be mild steel bars and tie bars shall be deformed bars of Fe 415 as per IS 1786.

Pre-Molded joint filler: This shall be used for expansion joints abutting structures like bridges, culverts and at end of the day's work. These shall be of 20-25mm thickness or as shown in drawings, complying to IS 1838. It shall be 25mm less in depth than the thickness of slab provided in suitable lengths, which shall not be less than lane width. Holes shall be made to accommodate dowel bars.

Joint sealing compound: This shall be hot poured Electrometric type as per AASHTO M282 or cold poured Polysulphide type as per BS 5212-part2 having flexibility, resistance to age hardening and durability.

Separation membrane: A separation membrane of impermeable plastic sheeting 125 microns thick shall be laid between the concrete slab and sub-base by nailing with concrete nails to the lower layer. Where overlap is necessary the same shall be laid by at least 300mm.

2.2. Construction Procedure:

Mix: The mix shall be designed as per IRC 44-2008 and MORT&H. And the design shall be based on the flexural strength of concrete. The water content shall be minimum required to provide workability for full compaction of the concrete to the required density. The maximum free water cement ratio shall be 0.5. The mix shall be proportioned to give an average strength at 28 days exceeding the specified strength (4.5Mpa) by 2.33 times the standard deviation calculated from the flexural strength of the first 30 beams first during the trial length and then the job control test beams (during the actual execution). The workability requirements at the batching plant and at site shall be established by slump tests while doing trial length. A slump value of 30±15mm is reasonable for slip form paving and 50±15mm for fixed form paving. The ratio of 7 days strength to 28 days strength shall be maintained, by testing pairs of beams and cubes batch wise for at least six batches of trial mix.

Mixing: The materials shall be mixed in a mechanized batching plant consisting air- conditioned centralized control cabin, minimum 4bins, weigh hoppers, separate scales for cement, fine and coarse aggregate with weighing balances calibrated, aggregates being proportioned by automatic weighing devices using load cells. The concrete ingredients shall be mixed thoroughly by a mixer with automatic timing/alarm device to mix and discharge (in case of failure of timing/alarm device concrete shall be mixed as per Manufacturer's recommendations) capable of mixing to get a homogenous mix without being segregated while discharge.

2.3. PLANT AND EQUIPMENT

- Concrete mixture
- Batching device
- Internal vibrators
- Edging tools
- Vibrating screed.

III. JOINTS AND JOINTING ARRANGEMENT

Joints are designed to control cracks, prevent entry of unwanted materials in to joints, to afford load which are transfer across the joints. Joints helps to release stresses due to temperature variation, shrinkage of cracks etc. without joints most concrete pavement would be comes in contact with cracks within 1 or 2 years after placement. The various joints provided in rigid pavement are:

- Expansion joint.
- Contraction joint.
- Warping joint.
- Longitudinal joint.

3.1. Contraction Joints

Transverse joints shall be contraction and expansion joints, cut with mechanical saw, could start as early as 6-8 hours, i.e. initial hardening of concrete, after paving. The contraction joints shall consist of mechanical sawn joint groove, 3 to 5mm wide and 1/4 to 1/3 depth of the slab. The expansion joints shall consist of a joint filler board positioned vertically with the prefabricated assemblies along the line of joint.

The dowel bars shall mild steel with details and dimensions as indicated in the drawings. Unless otherwise shown in the drawings the dowel bars shall be positioned at the mid depths of the slab with suitable tools/means within +/-20mm tolerances. The dowel bars shall be covered with plastic sheath for at least 2/3rd from one end for contraction joint, and '/z length +50mm for expansion joint. For expansion joints, a closely fitting cap of 1 00mm long shall be provided at the sheath end. To block the entry of cement slurry between dowels and cap a compressible sponge may be used.

The dowel bars shall be supported on cradles / chairs in pre-fabricated joint assemblies positioned prior to the construction of slab or mechanically inserted with vibration into the plastic concrete by a method which ensures correct placement of the bars besides full re-compaction of the concrete around the dowel bars.

3.2. Longitudinal Joints

The longitudinal joints shall be saw cut as shown in the drawings. A groove of 1/3rd the depth of the slab may be cut after the final set of the concrete. The tie bars shall be deformed steel bars of 415 Mpa complying to IS 1786. Tie bars shall be painted with bituminous paint for 75mm at the both ends and positioned with suitable tools/means. Tie bars shall be placed within the middle third of the slab depth. Tie bars in the longitudinal joints shall be made up into rigid assemblies with adequate supports to remain firmly in position during the construction of slab.

3.3. Construction Joints

Transverse construction joints shall be place whenever concreting is completed for the day's work on is suspended for more than 30 minutes. These shall be provided at regular location of contraction joints using dowel bars as stated above. Using sealants, not before 14days after construction of slab shall seal all transverse and longitudinal joints, but prior to allowing the traffic ply on the new construction.

3.4. Separation membrane:

A separation membrane of impermeable plastic sheeting 125 microns thick shall lay between the concrete slab and the sub base by nailing with concrete nails to the lower layer. Wherever overlap is necessary, the same shall be laid by at least 300mm. Before placing the separation membrane the sub-base shall be swept clean of all extraneous materials using high pressure water jetting or compressed air.

3.5 Construction by fixed form:

This shall consist of straight side forms made of steel of thickness not less than 5mm and of minimum 3000mm length. These shall have a depth equal to the prescribed thickness of the pavement. These forms shall be straight and free from bends and warps. Side forms shall be of sufficient rigidity in the form and in the interlocking connection with adjoining form such that springing will not occur under the weight of the sub grade and paving equipment or from pressure of concrete.

The vibrators for concreting shall be either surface pan type or internal type with immersed tube or multiple spuds. The surface vibrators shall a frequency not less than 3500 impulse per minute and the internal type vibrators shall have frequency more than 5000 impulse per minute.

3.6. Trial length:

A trial length of 60m shall be made for the full width of the pavement and rolled, by involving at least one transverse construction joint involving hardened concrete and freshly lay concrete.

After the side forms are removed, edges of slabs shall be corrected wherever irregularities have occurred by using fine concrete consisting 1:3 ratio of cement to fine chips and aggregate.

After the final regulation of the slab and before the application of curing membrane, the surface of the concrete shall be brush-textured at right angles to the longitudinal axis. The wire brush used for this purpose shall be made of 32 gauge type wired grouped together in tufts at 1 0mm centers and of width not less than 450mm.

The total time taken from addition of water to the mix, until the completion of surface finishing and texturing shall not exceed 120minutes when the concrete temperature is less than 25°C and 90minutes when the temperature of concrete is between 25°C-30°C.

Immediately after the surface texturing, the surface and sides shall be cured by application of curing compound, which hardens in to impervious film with the help of mechanical sprayer. The curing compound shall have a water retention efficiency of 90%. After 3hours, the pavement shall be covered with moist Hessian cloth or pond with water for at least a period of 14 days.

3.7. Joints sealing:

When saw cuts joints are adopted in construction, they are not made to provide the minimum width specified in the drawings, they shall be widened subsequently by sawing before sealing, and the width and depth are controlled by gauges. When sealants are applied, an appropriate primer shall also be used, if recommended by the manufacturer and it shall be applied in accordance with their requirements. The sealant shall be applied within the minimum and maximum drying time of the primer recommended by the manufacturer. Before sealing, the temporary seal provided for blocking the ingress of dirt, soil, etc. should be removed. A highly compressible heat resistant paper-backed de-bonding strip as shown in drawing shall be inserted in the groove to serve the purpose of breaking the bond between sealant and the bottom of the groove and to plug the joint groove, so that the sealant may not leak through the cracks. The road may be opened for regular traffic after completion of curing period and after sealing of joints.

IV. Sand Patch Test (for measuring the texture depth)

The surface to be tested shall be dried; any extraneous mortar and loose material shall bear removed and swept clean, using a wire brush at right angles and parallel to the carriageway. A cylindrical container of 25ml capacity shall be filled with sand passing 300microns sieve and retained on 150microns sieve, compacted by tapping the base and excess sand stroked off to level with the top of cylinder. Then the sand shall be poured on the surface to be tested into a heap and spread with the help of flat wooden disc of 64mm diameter of 1.5mm thick, with its face kept flat, in a circular motion, so that the sand is spread into a circular patch, with the surface depressions filled with sand to the level of peaks.

The diameter of the patch shall be measured to the nearest 5mm. The texture depth of concrete shall be calculated as follows:

Texture depth in mm = 31000/ D2, Where D is the mean diameter of the patch.

Five such texture depth tests shall be taken along the diagonal line across the lane width at least 2m apart, between 50m points along the road. No measurement shall be taken within the 300mm of longitudinal edges of the slab constructed in one pass. The requirements of texture depth as per MORT&H table 600-2 are as follows:

Time of test	No. of measurements	Required texture depth (mm)	
		Specified	Tolerances
Between 24hrs and 7days after the construction of the slab	Average of 5 measurements	1.00	±0.25
Not later than 6 weeks before the road is opened to traffic	Average of 5 measurements	1.00	±0.25 -0.35

V. CRACKS IN RIGID PAVEMENT

Surfaces are formed up of a PCC (Portland Cement Concrete)/PQC surface course. Such structures are relatively "harder" than flexible surfaces because of the high modulus of elasticity of the PCC/PQC material. Further, these pavements surfaces can have reinforced steel which are used to remove joints. A rigid pavement surface is a rigid structure that distributes the wheel stresses over a broad area to the sub-grade and is dependent on concrete slab strength for its stability. As concrete is a strong material, but it encompasses various cracks due to shrinkage, temperature and creep etc. The primarily reasons of cracks in rigid pavements are as under:

- Poor concrete mix
- Poor curing
- Improper joint filler material
- Improper spacing of joints
- Improper Sub-grade soil
- Pavement thickness is not adequate.
- Use of soft aggregate

But these inadequacies can be cured during the time of preparation which cannot lead these types of crack to be developed after the construction of pavement. Joints problem can be solved by placing it with help of IRC code 15 2004 and IRC 62 2014. It results in increasing the life span of rigid pavement.

5.1 TYPES OF FAILURES

With the rapid pace of globalisation vehicular traffic is increasing, thus the quality of pavement, quality of pavement material and other environmental changes will decrease the overall effectiveness of pavement which result in the failure of pavement and to enhance the use and life span of pavement we should understand the types of crack, its repairing procedure and further preventions .

5.2.1. FATIGUE CRACKING

Fatigue is a crumble of a material which is done by repeatedly applied load. Various factors affects the crumbling or fatigue cracking, these factors are heat of hydration, creep, shrinkage etc. At primary construction stage micro cracks are formed in concrete and after that it take shape of micro voids when large amount of water dynamically extend under the effect of loading. If there is no proper drainage it will result in cracking during raining season and hence the minor cracks will expand.

5.2.2. SHRINKAGE CRACKING

During setting and hardening of pavement of concrete at places away from joints leads to the formation of hair line cracks which are called as shrinkage cracks. These shrinkage cracks normally occur during curing operations. They are formed in longitudinal and as well as in transverse direction. Main causes of shrinkage cracks are delayed construction of contraction joint, improper design of reinforcement.

5.2.3. PUMPING

Removal of water and sub grade material through joints and cracks is called pumping. When free water accumulates under the slab, the deflection of pavement slab occur and hence cracks occurs.

5.2.4. SPALLING

Spalling is mechanism of breaking or crumbling of the edges of cracks and pavement. It occurs when large amount of stresses occur on pavement. This occurs due to poor alignment of dowel bar and also due to poor workmanship.

5.2.5. PUNCH OUT

Crumbling of small section of concrete slab in to several pieces is called punch out. Due to this roughness problem occurs and it also allows the infiltration of moisture which leads to the erosion of sub base. Punch out also occurs when compaction of sub-base is not done properly and it also create corrosion problem in steel.

VI. CONCLUSION

Concrete pavement surfaces are longer lasting and hence due to its nature of construction the PQC pavements are less pollution causing to the environment. The factors governing in their favour are as follows:-

- The rigid pavements do not require rehabilitation or reconstruction quite often.
- Lesser raw material being used on the rigid pavement both for construction or maintenance over the complete design life, hence causing less environmental hazards.
- Due to less maintenance fewer pollutants going in soil, air, and water.
- The rigid pavements structure requires less energy for construction purpose. In terms of machinery fuel used for maintenance purpose.
- As maintenance is low hence lesser quantum of traffic congestions thus reduction in wastage of fuel due to congestions.

Besides, there are many other advantages of concrete pavement over flexible pavement. Rigid pavement requires significantly less construction time; less number of heavy equipment consumes less fuel and lubricant and is environmentally safe. Also flexible asphalt pavement requires more aggregate materials than concrete pavement. Cement concrete pavement enhances protection of ecology and conservation. Concrete pavement provides better visibility, skid resistance, higher abrasion, and enhances cross drainage over pavement, better road environment and surface condition etc. Cement concrete pavement significantly improves the safety performance of road pavements and reduces road accidents risks.

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