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A Detailed Case Study on Construction and Maintenance of Rigid Pavement

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Abstract - *A Pavement is generally a structure which has numerous layers bounded together and placed on top of the soil sub-grade so that it provides a smooth surface for riding the vehicles. The chief purpose of the pavement is to distribute the loads coming onto it in a way that the bearing capacity of sub-grade on which the pavement rests is not exceeded. A pavement is designed to transfer the traffic load economically & safely, consequently it is designed cautiously with appropriate study, examination of material to be used and natural soil condition. Investigation of roads comprises of various surveys afterwards alignment is marked on the based on economy and determined application of all the natural aspects, after that geometric design is taken into account which contains, providing of camber, gradient, design speed etc. Design of pavement plays a significant role in big projects. The satisfactory performance of the pavement will result in higher savings in terms of travel time and operating cost of the vehicle, which has a bearing on the overall economic project feasibility. Though rigid pavement is expensive but requires less maintenance and have really good design period. The financial part is carried out for the design pavement of a section by using the result obtain by design method and their equivalent component layer thickness. It can be done by drawing judgments with the standard way and practical way. This total work includes detailed case study on rigid pavement construction, maintenance various materials used for the construction drainage system of the rigid pavement and collection of data for various rigid pavement designs based on rigid pavement construction site situated in Nagpur, Maharashtra, India.*

Key Words: **Rigid Pavement, Rigid Pavement Layers, Materials of Construction, Pavement Maintenance, Pavement Drainage**

1.INTRODUCTION

A pavement is an important structure consisting numerous structural elements whose main purpose is to protect the natural subgrade and to appropriately carry away the traffic safely and economically and safely. A pavement is a structure consisting of various overlying layers of treated materials above the natural soil sub-grade, whose chief function is to distribute and transmit the loads of vehicle to the sub-grade beneath. The pavement structure should be able to deliver a good quality surface for riding, should provide acceptable resistance to skid, low noise pollution and favorable light reflecting characteristics. The chief aim of the pavement is to guarantee that the stresses transmitted due to the wheel load of vehicle are adequately reduced to a certain extent, resulting in not surpassing the overall bearing capacity of the subgrade. Generally, two types of pavements are known to serve the above purpose, which are rigid pavements and flexible pavements. This study gives an overview of importance of pavement, various layers of pavement, their functions, materials used maintenance of pavement and joints of pavement. Inappropriate design of pavements may lead to premature failure of pavements affecting the overall riding quality.

1.1 IMPORTANCE OF PAVEMENT

Pavement, in India, perform a variety of roles in achieving speedy economic development. The importance of roads in India can be easily judged from the following purpose or advantages of roads:

1. Connection to villages: Accessibility to villages is possible only with a good system of roads. Roads facilitate conveyance of people, goods, raw materials, manufactured articles etc. speedily and easily in the different parts of a country. Thus, social uplift, health and education of the village population are aided by roads.

2. Communication in hilly terrain: For the hill states located along the Himalayan Range, communication facility is possible only by roads because of the steep terrain involved. Jammu and Kashmir, Himachal Pradesh, Sikkim, Assam, Meghalaya, Manipur, Mizoram, Tripura and Arunachal Pradesh depend heavily on roads for their very survival.

3. Strategic Importance: The defense of the northern, north- eastern and western borders of the country is dependent to a large extent on the road system.

4. Helps agricultural development: Roads have fostered quicker agricultural development facilitating movement of modern inputs such as fertilizers and high yielding seeds. Haryana and Punjab, which have connected all their villages by a road, are examples of agricultural prosperity aided by roads.

5. Helps dairy development: Since the cattle wealth of the nation is concentrated in innumerable small villages, the

collection and processing of surplus milk is possible only because of roads.

6. Forestry development: The forest wealth of the country is being exploited mainly because of the roads, which penetrate into the thick jungles.

7. Employment: Since road construction employs still labour intensive techniques in India, the large unemployed labour force gets gainful employment.

2. MATERIALS USED IN CONSTRUCTION

2.1. CEMENT

Ordinary Portland cement: - Ordinary Portland cement and High Strength Ordinary Portland Cement are most widely used for concrete pavements.

Rapid Hardening Portland Cement: - In general, this cement would be used only where time is a critical factor and the road is required to be opened to traffic at an earlier date than would be possible if Ordinary Portland Cement or High Strength Ordinary Portland Cement is used.

2.2. AGGREGATE

There are two types of Aggregate are used during construction of road i.e. Fine and Course Aggregate depending on requirements.

- Maximum size of aggregate should not exceed $1/4^{th}$ of the pavement slab thickness.
- Water used in mixing or curing of concrete shall be clean and free from injurious amounts of oil, salt, acid, vegetable matter or other substances harmful to the finished concrete.
- Portable water is generally considered satisfactory for mixing or curing.

2.3. REINFORCEMENT

Cement Concrete pavement is typically constructed with the help of plain reinforced cement concrete. Use of reinforcement for cement concrete pavement in the manner it is done for beam, slabs etc. The chief purpose of using steel as reinforcement is to grip the cracked pieces of the cement concrete pavement altogether. To a certain extent the reinforcement may be used as to hold up the tensile stresses occurring. Size of the reinforcement bars usually depends upon the thickness of slab of cement concrete pavement. These bars are tied together by the use of binding wires binding or may be welded to it.

Tie Bars: - Tie bars are distorted steel bars or connectors used to grip the different faces of adjoining slabs in contact with each other. Although they may deliver some minimum amount of load transfer, they are not at all designed to act as load transfer devices and should not be used for such purpose. Tie bars are characteristically used at longitudinal joints or between an edge joint and a curb or shoulder. Tie bars are generally of size length generally between 0.6 and 1.0 m (24 and 40 inches long and about 12.5 mm (0.5 inches) in diameter).

Dowel Bars: - Dowel bars are normally short-steel bars that deliver a particular mechanical assembly between two slabs without limiting any horizontal movement of the joint. They also help in increasing load transfer effectiveness by allowing the slab to assume a number of the load before the load actually comes over it. This reduces the deflection of joint to a specific amount and stress within the approach and slabs is additionally reduced. Dowel bars characteristically have size like, 460 mm (18 inches) long and spaced out at 305 mm (12 inches) and 32 to 38 mm (1.25 to 1.5 inches) in diameter. Precise locations and therefore the numbers of the dowel bars depend on various factors. so as to forestall corrosion of dowel bars, they're perfectly coated with stainless-steel or epoxy layer to scale back the corrosion effect which increases the sturdiness of the bars. Dowel bars are typically inserted at mid-slab depth and are finely coated with a bond-breaking material to avoid bonding to the plain cement concrete. Therefore, the dowel bars significantly help to transfer load uniformly but also allows the adjacent slabs to expand and contract independently which happens thanks to temperature variations.

2.4. ADMIXTURES

Air–entrained admixture: -Air-entrained concrete consists lots of minute air pockets in it. These air pockets within the concrete releases the inner pressure on the concrete by providing small cavities for water to expand it into when it freezes. Appropriate use of air-entraining admixtures guarantees the event of the proper size spacing, (usually measured in micrometers) and amount of those voids. These voids essentially absorb the pressure created by the expansion of the freezing water. Air-entrained concrete is manufactured with the assistance of using air-entraining hydraulic cement, or by the introducing air-entraining agents, under cautious engineering supervision. the number of entrained air is sometimes between 4% and 7%percent of the degree of the concrete, but may vary as needed by different conditions.
Water-reducing admixtures: -These admixtures usually reduces the specified water content for a concrete mixture by about 5 to 10 percent. Therefore, concrete comprising a water-reducing admixture needs less water to achieve a required slump than the untreated concrete. The treated concrete can have a lower water-cement ratio. This usually indicates that the next strength concrete is formed without increasing the number of cement content. Recent

developments in admixture technology have led to the expansion of mid-range water reducers. These admixtures reduce water content by a minimum of 8 percent and have a tendency to be more stable over the over a wider range of temperatures. Mid-range water reducers provide more consistent setting times than other standard water reducers.

Retarding admixtures: -These are those which impede the setting rate of the concrete and are used on counter the accelerating effect of atmospheric condition on setting of concrete. High temperatures frequently cause a rise within the rate of hardening which makes the method of placing and finishing the concrete difficult. Retarders here keeps the concrete in workable state during placement and help in delaying the initial setting of the concrete.

Accelerating admixtures: - These helps to extend the speed of initial development of strength of the concrete, also reduces the entire time required for correct curing and protection of concrete and significantly help in speeding up the beginning of finishing actions. Accelerating admixtures are particularly beneficial for amending the properties of the concrete in atmospheric condition conditions.

2.5. CONCRETE: - In general M40 grade of concrete are used in rigid pavement, which is in the ratio (1: 1.62:2.96) of cement, sand, aggregate.

3. LAYERS OF RIGID PAVEMENT

Rigid pavements typically and most commonly use portland cement concrete as the main or important component for the rigid pavement construction. Engineers design the rigid pavement slab with various concrete type mainly plain concrete, lightly reinforced concrete, continuously reinforced concrete, pre-stressed concrete or fibrous concrete all depending upon the various conditions of site. The cement concrete slab typically lies above the effectively treated sub base and finely compacted granular which is greatly supported by the finely compacted subgrade. The sub-base usually provides an unvarying good stable support and provide good subsurface drainage. The cement concrete slab of rigid pavement has significant amount of strength (flexural strength and also helps in uniformly distributing the above loads over a considerable huge area. For good performance of the pavement it is important that support of the concrete should be fine and uniform.

a) Concrete Slab: - The concrete slab provides structural support to the aircraft, cars trucks and various other vehicle and also provides an honest surface resistance against skid and also helps in providing a decent, smooth riding surface and also prevents the infiltration of excess surface water.

b) Sub base: - The sub base typically provides good stable and quite uniform support to the cement concrete slab of the pavement which makes it a crucial element within the pavement. The sub base also helps lots in controlling the action of frost up to an excellent extent, bulge of the subgrade soils, also provides an honest stable stage for the development for of rigid pavement, provides good subsurface drainage and helps lots in stopping pumping of mud of fine-grained soils above. Rigid pavements generally have thickness minimum 4 inches i.e. 100mm as sub base thickness.

c) Stabilized Sub base: -All new rigid pavements are designed to lodge aircraft weighing up to 100,000 pounds (45,000 kg) or could also be more which have a stabilized sub base. the soundness advantage instructed to a pavement section by an honest sub base (stabilized) is mirrored within the subgrade reaction modulus assigned to the muse.

d) Frost Protection Layer: - within the areas where very cold temperatures occur and where soil is susceptible to effect of frost and where the bottom formation exits at greater height, in such situations usually engineers consider action of frost as a vital factor when designing the pavements. Heave of frost typically cause a component of the pavement to rise a small amount reason being the non-uniform formation of the crystals of ice during a frost-susceptible material. The defrosting of the soil which is frozen and crystals of ice cause damage to the pavement under loads. the most function of the frost protection layer is to figure as a barricade against the penetration of frost and frost action into the subordinate frost-susceptible layers.

e) Subgrade: - Subgrade is sometimes a soil layer compacted with the assistance of various equipment so on provide the inspiration of the entire rigid pavement system. Lower stresses typically come more on the subgrade soil as compared thereto of the surface and also the sub-base courses i.e. subgrade is more subjected to that. because the depth increases these stresses starts decreasing and also the regulatory subgrade stress is usually at the highest of the subgrade unless an unusual condition arises. Various unusual conditions cause changes within the locations of the regulatory stress like layered subgrade or sharply varying water densities content.

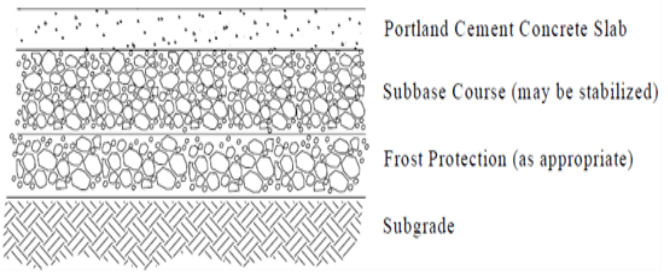

Fig No 1. Layers of Rigid Pavement

4. CONSTRUCTION PROCEDURE OF RIGID PAVEMENT

Preparation of sub-grade: - The subgrade is a natural ground where concrete slabs are placed. If an internal weakness is found, it should be eliminated as soon as

possible and new materials should be laid to strengthen it. If the concrete is applied directly to the substrate, the surface must be soaked with water 6-20 hours before the concrete is poured. This process is usually done so as to ensure that sub-grade does not absorb water from the concrete which may reduce the strength of the slab.

Provision of sub-base: When the natural sub-grade beneath is not that stable, a sub base over the sub-grade is provided so as to make it a bit stable. The decision of providing sub-base depends upon various factors like the type of soil, intensity of traffic design load, and economic consideration. The sub-base may consist of any one of the following layers:

(i)A layer of well graded soil-gravel mixture having maximum thickness of 15 mm.

(ii)Brick soling with one layer of water bound macadam of maximum total thickness of 10 mm.

(iii)Two layers of water bound macadam having maximum total thickness of 15 mm.

(iv) A layer of lean concrete with a maximum thickness of 10 mm.

Placing of forms: - These figures can be made of different materials, such as steel or wood. The steel formwork is a structural steel channel with a depth equal to the thickness of the road surface. These shapes are correctly fixed together and fixed to the ground. Forms are fixed in position by three stakes at back of each of length 3-meter. When the forms are fixed, it is necessary to check their accuracy. For every 3 m of template length, the maximum allowable deviation in the vertical plane is about 3 mm, and the maximum allowable deviation in the horizontal plane is about 5 mm.

Watering the prepared sub-base: - Before pouring the concrete, the formwork must thoroughly have lubricated with oil. After the formwork is installed, the surface on which the concrete will be placed should be wetted with water. When the substrate is dry, spray as much water as possible. It is always recommended to wet the surface for at least 12 hours before pouring the concrete. If a waterproof foil insulation layer is provided, there is no need to wet the surface before pouring the concrete.

Batching of materials & mixing: - After determining all the quantities of the ingredient of the concrete mix, the fine and coarse aggregate are properly proportioned by weight in weight-batching plant. Material is then feed into the hopper along with essential quantity. The specific ingredients are dry mixed in an appropriate amount. It is recommended to mix concrete in a concrete mixer. Add measured amount of water to achieve the required water/cement ratio. (as per the design) ready mix concrete is generally used nowadays for the construction of rigid pavement. After mixing materials thoroughly, the concrete is then transported to the site in wheel barrows manually or is directly transported through the mixer. Mixed concrete is deposited quickly on the subfloor in layers no more than 50-80 mm or more than 2 to 3 times the aggregate size. Concrete should be poured continuously in batches across the mold.

Transporting and placing of concrete: - After mixing materials thoroughly, the concrete is then transported to the site in wheel barrows manually or is directly transported through the mixer. Mixed concrete is deposited quickly on the subfloor in layers no more than 50-80 mm or more than 2 to 3 times the aggregate size. Concrete should be poured continuously in batches across the mold. The top layer must be laid with the required curvature and slope, and suitable tools must be used to remove voids when pouring the concrete. Prevent concrete from peeling off during transportation and installation. If reinforcement is specified in the slab, the concrete is laid in 2 stages. In the first step, the concrete is poured and compacted to a depth corresponding to the level of the steel bars. The compacted concrete is then reinforced, and the remaining slab thickness is processed in the second step.

Compaction: After the concrete is placed in the correct position, use a heavy ruler or a rammer with a suitable handle to place it in the correct position. The wooden temper has size at least 75 mm width and its underside is shaped to the finished cross-section of the slab its weight is about 10 kg/m. It should have sufficient strength to retain its shaper under all the working conditions. Its length is equal to length of plus 60mm. Underneath tamper it is provided with a 5mm thickness of metal plate. The concrete is also compacted with an electric trimmer or vibrator. Upto12.5 cm5cm thickness of slab screed vibrator along immersion vibrator is used for the purpose.

Floating: - After compaction, the entire surface of the board is moved longitudinally by the floating board main purpose behind this process is to provide good even smooth and wave free surface. Belting: After the flotation process, the surface is trimmed shortly before the concrete hardens. The main purpose of this process is to make the road skid resistance and non-slippery. Sometimes this process is ignored.

Belting: - After belting process brooming is done, which involves drawing brushes from edge to edge at right angles to the centerline of the road surface. Brooming is done

shortly before the concrete becomes plastic. Sometimes this process is skipped.

Brooming: - Curing consist of loss of water from the concrete slab, and keeping the fresh concrete slab moist during hardening period. Initial curing is done for 24 hours. You can walk on the concrete at this time, then remove the wet pad, and the final hardening takes place within 2-3 weeks. Final curing is done by the methods like ponding by covering slab by 4 to 8cm thick layer of wet sand by using wet gunny bags.

Edging: - Before the concrete finally hardens, carefully process the edges of the panel with the edging tool.

Curing: - Curing consist of loss of water from the concrete slab, and keeping the fresh concrete slab moist during hardening period. Initial curing is done for 24 hours. By this time the concrete become hard enough to walk upon and then wet mats are removed and final curing is done for 2 to 3 weeks. Final curing is done by the methods like ponding by covering slab by 4 to 8cm thick layer of wet sand by using wet gunny bags.

Fig No 2. Placement of Concrete

Fig No 3. Brooming of Rigid Pavement Surface

Fig No 4. Placement of Dowel Bars in Concrete Slab

Fig 5. Frequent Visits to Case Study Site

5. DRAINAGE AND MAINTENANCE

5.1 ROAD DRAINAGE

Road drainage is the process of controlling and removing surplus surface and sub-soil water within the right of way as soon as possible. This mainly includes the seizure and diversion of water from the road surface and subgrade to the

appropriate place. The installation of appropriate surface and sub-surface drainage system is a very essential part of the design and construction of the rigid pavement. During rains some part of the rain water streams on and some part of rain water infiltrates through the soil mass as gravitational water flow until it reaches the ground water below the water table. The process of elimination and diversion of surface water from the roadway and adjoining land is generally called as surface drainage. The diversion or elimination of excess soil-water from the subgrade is generally called as sub-surface drainage. Some water is retained in the pores of the soil mass and on the Surface of soil particles by surface tension and adsorptive forces, which cannot be drained off by the normal gravitational methods and this particular water is termed as held water.

5.2 IMPORTANCE OF ROAD DRAINACE

An increase in moisture content causes decrease in strength or stability of a soil mass the variation in soil strength with moisture content also depend on the soil type mid: mode of stress application. Highway drainage is important because of the following reasons:

(i) Excess moisture in soil subgrade causes considerable lowering of its stability. The pavement is likely to fail due to subgrade failure.

(ii) Increase in moisture causes reduction in strength of many pavement materials like stabilized soil and water bound macadam.

(iii) In some clayey soils variation in moisture content causes considerable variation '51 volume of subgrade. This sometimes contributes to pavement failure.

(iv)One of the most important causes of pavement failure by the formation of waves and corrugations in flexible pavements is due to poor drainage.

5.3 MAINTENANCE OF PAVEMENT

Need for Road Maintenance

Road maintenance is one of the essential component of the entire road system. The maintenance operations involve various things like assessment of the condition of road, in depth analysis of the problem and implementing the utmost suitable maintenance steps. Even if the highways are well designed and constructed, they still may require proper timely maintenance; the extent of which will depend on several factors including the type of pavement, type of failure etc. There are numerous types of failures occurring in pavements extending from minor and localized failure to major failures that do take place on roads. The failures may occur due to one or amalgamation of several causes.

Maintenance Management System

The type and extent of maintenance requirement for a road depend on the various factors like serviceability standard laid -down, the maintenance needs funds available and the priorities for the maintenance operations. As several interlinked factors are involved in the maintenance works of road network consisting of different categories of roads, a system approach is appropriate for the road maintenance management. The various factors to be included in the maintenance management system are:

(i) Least acceptable serviceability standards for the maintenance of different categories of roads.

(ii) Field surveys for the assessment of maintenance requirements.

(iii) Availability of funds.

(iv) Type and extent of maintenance requirements and various possible alternatives and their economic evaluation.

(v) Estimation of rate of deterioration of the pavement under the prevailing set of conditions.

(vi) Various factors influencing the maintenance needs such as subgrade soil. drainage, climate, traffic, environmental condition, etc.

(vii) Need based allocation for optimum utilization of inputs and fixing maintenance priorities.

(viii) Maintenance cost, availability of materials, man power and equipment.

6. CONCLUSIONS

In this study, we did the feasible study of Rigid pavement adopted in & around Nagpur region, during this period we learnt lot about the various parameters involved in construction of rigid pavement like alignment of road, different surveys that are carried out before construction of the rigid pavement, various materials that are used, typical layers of rigid pavement, entire construction procedure of the rigid pavement, studied about various joints of rigid pavement and advantages of rigid pavement in complete detail. In this study we have observed that these techniques required advanced equipment & instrument, also it needs skilled operators & immense safety and care while using at site. We visited to Kalamna Road which was our case study site which gave us an overview of construction of rigid pavement on actual construction site, we observed lot things including laying of different layers in pavement, patch work and repairing work after the construction of project at different sites. Road Construction is really a very hard task. Road development shows the economy of the country. It can also be said from the study that the initial construction cost of rigid pavement is higher than flexible pavement but

considering the total life, maintenance, and durability aspect rigid pavement is far better, economical and durable than the flexible pavement, lifecycle cost of rigid pavement is lower than the flexible pavement, adding to that it can also be said that the initial cost of rigid pavement can be reduced to a certain extent by replacing cement with fly ash or other alternatives.

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