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Study of RCC Pavement as a Sustainable Option for Village Road in Expansive Soil

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ABSTRACT

Expensive soil is mostly found in arid and semi-arid regions and it covers very large area of the world. It covers nearly 20% of the land mass in India and includes almost the entire ocean plateau western Madhya Pradesh, Parts of Gujarat, Andhra Pradesh, Uttar Pradesh especially Bundelkhand belt, Karnataka & Maharashtra the swelling soil is commonly known by the name of black cotton soils swelling to occur, these soil initially unsaturated at same water content. If the unsaturated soil gains water content, it swells on the other band it decrease in Water content occur occurs the soil shrinks the presence of mantmorllonite clay in these soil imparts them high swell – shrink potentials. One of the major indicators of a country's prosperity is its road length and vehicle Ownership India is a country where a large population lives in villages with their livelihood depending upon agriculture. Industrial growth is also shifting towards villages. Both of these activities require a better means of communication which can be provided by good conditioned roads3% village roads have very low volume of traffic, consisting mostly of rural transport vehicles, like agricultural tractors/trailers, light goods vehicles, buses, animal drawn vehicles, motorized two-wheelers and cycles. Some of the village roads may also have light and medium trucks carrying sugarcane, timber, quarry materials, etc. Flexible pavements are in use for village connectivity program because of low initial cost of construction to high cost of maintenance, being very sensitive to water logging and lack of institutional set up for their maintenance, the village roads deteriorate very fast, especially in expensive soil regions. Every year several kilometers of village roads are washed away by floods and water logging Thus, the planners and engineers are bound to think about the option of rigid pavement as a substitute of flexible pavement for village roads. Rigid pavement is an alternative to flexible pavement where the soil strength is poor, aggregate are costly and the drainage conditions are bad (as in portions of the roads passing through villages and water logged areas). However, they demand a high degree of professional expertise at the design stage, construction and maintenance besides high initial cost.

Key words: RCC Pavements, Expansive soil, Flexible Pavements, Rigid Pavements, Village roads

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INTRODUCTION

The guidelines have been developed by Indian Road Congress (1RC) for the design and construction of cement concrete pavements for village roads in year 2004, named as IRC: SP : 62 – 2004 which is now revised on 2015. SP: 62-2004. For low traffic volume roads i.e. village roads and street rural road manual has been introduced by IRC where cement concrete roads are preferred in populated areas/streets to meet the problems of maintenance due to poor drainage etc. As most of – ocean plateau of India belong to expensive region having clay soil and poor drainage Conditions, lot of expenditure is being incurred every year to maintain the flexible pavements in their congenial condition and this necessitates the use of cement concrete road, a better option from climatic and environmental considerations. The village roads have a very low volume of traffic consisting of tractors, animal drawn vehicles, light goods carriers, buses etc. The maintenance of village roads is constrained due to shortage of funds and poor institutional set up. These roads normally face problems of poor drainage condition, i.e. water logging besides poor strength of soil. Mostly flexible pavements with granular sub-base and base having thin bituminous carpet as wearing course are adopted, which deteriorate during long monsoon season leading to costly annual maintenance. This necessitates the exploration of other alternative pavements. Rigid pavements are one of the answers to this pertinent problem. However, they demand a high degree of professional expertise at the design stage, construction and maintenance besides high initial cost. In the present chapter a review of the rigid pavements along with the practices followed by Indian Roads Congress is presented.

RIGID PAVEMENTS

Considerable work has been carried out for the analysis, design and construction of rigid pavements by various researchers and design engineers. The guidelines have been developed by Indian Roads Congress for the design and construction of cement concrete pavements for village roads in year 2004, named as IRC: SP: 62-2004 which is further revised on 2014. For low traffic volume roads, i.e. village roads and streets, a rural road manual has been introduced by IRC, wherein it is mentioned to prefer cement concrete roads in populated areas/streets to meet out the problems of maintenance due to poor drainage etc. Cement Manufacturer Association of India and Prasad [20] have shown that cement concrete rigid pavements are cheaper in terms of life cycle cost than flexible pavements. However, the initial construction cost of rigid pavements is much higher than the flexible pavements. Prasad carried out life cycle cost analysis of the two types of pavements and concluded that the cost difference between flexible and rigid pavement is negligible considering the savings for the cost of maintenance, vehicle operating cost and fuel. Further, rigid pavement is a better option from climatic and environmental considerations. Also, cement concrete pavement is the best option for locations having cement and fly ash in close proximity when sub-grade soils have low CBR values. A number of joints are provided in rigid pavements to reduce the stress due to change in temperature. A comparative study of economics of rigid and flexible pavements and observed that the rigid pavement is far more economical than flexible one based on overall economic consideration. This generalization is valid for all zones of the country and is independent of the sub-grade characteristics. Due to the Submergence/during the cyclones, CC Pavements which are constructed on the expansive soils sub grades are getting damaged due to the sub-grade soils are expansive nature. During the submerged condition/at the time of cyclones, Swell pressure develops in the sub-grade expansive soils, If this Swell pressure is more than the combined surcharge weight of Sub base and CC Pavement, Uplift takes place. The swell pressure varies from 0 - 2000 KN/sqm (for Bentonite) under the surcharge of 6.9KN/Sqm. The surcharge weight of Granular sub base is 3.0 kN/sqm and CC Pavement is 4.80 KN/sqm resulting total surcharge weight is 7.80 KN/sqm over the sub grade. Due to confined edges of both Sub base and CC Pavement with the shoulder soils, the net uplift due to Swell pressure will be more in the middle of the pavement when compared at the edges. The rate of wetting and drying of the expansive sub grade soils always starts at edges to middle of the pavement. This leads the difference in the swell pressure more in the middle than the edges. Due to the high swell pressure at the centre of the pavement and early drying of the expansive sub grade soils at the edge of the road, longitudinal cracks will be formed almost in the middle of the road. When the expansive soil dries, due to the shrinkage in the sub grade, the pavement tries to settle down. Among both CC Pavement and Sub base, the sub-base over the sub grade will settle first leaving gaps in between CC Pavement and Sub base. At this stage, during the traffic flow, transverse cracks I crocodile cracks occurs. Also, after the formation of longitudinal cracks, the length to breadth ration of CC pavement panel will be double and influence the design of CC Pavement. The failure in the CC Pavement is due rigid and also weak in tension. Construction of flexible pavements by raising the existing expansive sub grade 0.30m to 0.50m thick with non swelling soils as embankment is most reliable and economical when compared to the CC Pavements. It has been observed the flexible pavement under submergence during floods / during cyclones, only minor part of the road is damaged due to formation of undulations. Up to some range of swell pressure, the undulations are being carried by the flexible pavement without damaging the road; this is due to flexible nature of flexible pavement. IRC: SP: 62-2004and IRC: 62-2014 provides guidelines regarding design and construction of cement concrete pavement for village roads. It specifies the necessity of expansion joints, where concrete slabs abut with bridges and culverts. Since village roads have low volume of traffic with small wheel loads, the slab thickness is normally kept between 150—250 mm. The aggregate interlock at sawn joints is sufficient to transfer load itself and dowel bars are not required. However, at expansion joints where the width of joint is 20 mm or more, dowel bars should be provided. IRC: SP: 62-2004 further specifies that the minimum grade of concrete for rigid pavements should not be less than M 30. Such a high grade of concrete is not easy to achieve in the field because the village roads are usually small in length; deployment of heavy machinery and highly skilled workers are not economically feasible. Provisions given in IRC codes are on the basis of semi-empirical formulae which are conservative as well as non-realistic. The temperature variation between top and bottom layers is assumed to be linear and warping stress calculated on this basis is much higher than the actual. The variation of temperature between top and bottom layer is non-linear and warping stress calculated on the basis of Bradbury's formula adopted by IRC: 58-2002and IRC:58-2015 is quite high (Kumar et al. 2006)[**12].** Utilizing classical plate theory and modelling the concrete pavement as thin plate resting on Winkler foundation, a finding of the stresses and deflections in the rigid pavement, neglecting the combined effect of loading and thermal curling. A modelled the rigid pavement as plate resting on elastic solid and developed a finite difference programme (FIDIES) to analyze a plate resting on a Boussinesq half space. He investigated the effective slab size for each of the three fundamental loading conditions i.e. interior, edge, and corner and highlighted the differences in behaviour exhibited by the elastic solid sub-grade as compared to the dense liquid idealization. The problems of temperature and wheel load stresses in concrete pavements in Indian context have been the concern. The effect of temperature variation (linear/non-linear) across the thickness of concrete pavement dates back to as early as 1926 by Westergaard [17]. Thomlinson was first to examine the non-linear temperature variation in concrete pavement and Effect of non-linear temperature gradient on the rigid pavements using finite element approach [14]. Based on experimental and analytical observations it has been concluded by many researchers that temperature fluctuations produce a significant amount of stresses and strains in concrete pavements. Armaghani et al. [1] observed that the temperature gradient in a rigid pavement slab is related to fatigue damage. They also reported that a gradient of 1°F/in, in the slab increases the fatigue damage due to traffic by a factor 10 compared to that of a zero temperature gradient condition. An analysis was carried out field experiments for monitoring temperature variation of asphalt concrete and Portland cement concrete pavements in eastern Saudi Arabia and developed regression models for predicting temperatures in pavements. A proposed study of one dimensional heat transfer model to predict the temperature distribution across the rigid pavement. They used summer weather condition as input to simulate the temperature distribution through pavement in order to highlight the impact of daily temperature amplitude on a pavement temperature profile. A study of a model considering the combined effect wheel load and temperature distribution on the concrete pavement. Based on field observations A developed 3-D finite element pavement model for evaluating the temperature responses in the concrete pavement and concluded that temperature induced responses are more significant than traffic induced responses. A developed 3-D finite element model KGPSLABWH for analyzing individual and combined effect of wheel loads and linear temperature variation across the slab thickness. It was observed that there is a loss of sub-grade support due to curling, and the conventional practice of algebraic addition of wheel load and warping stresses was not correct. A non-linear temperature gradient results in lower tensile stresses during the day time and higher tensile stresses during the night hours. Effect of warping stresses in concrete pavement and observed that the effect is insignificant if the slab length is less than 4.5 m. Kumar et al [12] discussed the mechanistic design of concrete pavement considering the combined action of axle loads and non-linear temperature distribution and concluded that:

[1] Modulus of sub-grade reaction k of the foundation for pavement design should be carefully selected considering loss of sub-grade support due to erosion and permanent deformation and seasonal moisture changes during the service life of pavements. The maximum value of k is suggested as 200 MN/m3.
[2] Variation of tyre pressures has little effect on flexural stresses in pavements of thickness 200 mm or greater.
[3] Wheels tangential to the outer edge of a pavement cause highest flexural stresses but percentage of such vehicles is small.
[4] Cumulative fatigue damage due to combined action of axle load and warping should be computed for axle load between 10 am to 04 pm and between 00 am to 06 am, respectively. The average temperature differential (ATD) between 10 am to 04 pm is about 70 % of the day time peak temperature differential (PTD). Night time PTD is about 50 % of the day time PTD and the ATD between 00 am to 06 am is about 75% of the night time PTD.
[5] Temperature gradient across the depth of a concrete slab is non-linear and should be considered in the thickness design.
[6] Warping caused by moisture gradient is opposite to that of the temperature gradient and effect of moisture variation may be equivalent to a temperature gradient of 0.011°C/mm.
[7] Advantage of bonding of concrete slab and cement sub-base should also be considered to bring about the economy.

Seehra [11] investigated the design and construction aspects of cement concrete pavement and observed that IRC: 58-2002 guidelines for rigid pavement design are more realistic than any other pavement design method. Provisions of IRC: 58-2002 includes the vehicle load, temperature variation across the thickness of pavement, and fatigue which is a suitable combination for pavements of highways of large traffic intensity. Due to the above combination of loads and for the minimum grade of concrete prescribed is M 30 modernized equipments are most suitable. The equations for the stresses in the rigid pavement given in IRC: 58-2002 and IRC: SP: 62-2004 are based on plate on elastic foundation initially developed by Westergaards [17] and later modified by Teller and Sutherland. Sinha et al [12] presented the concept of white topping as a rehabilitation measure by strengthening of deteriorated bituminous pavements and observed that white topping will result in better and long performing roads at a much lesser cost. For curling/warping stress, Bradbury [2] developed the equation and coefficient for thermal stresses. The linear temperature gradient across the pavement thickness considered in IRC: SP: 62-2004 is conservative. From the literature it can be seen that the variation of temperature is not linear and the stress values calculated from Bradburry's formula are conservative. The stress value may be taken as 0.7 times the value given in IRC code (Kumar et al [12]).

DESIGN AND PROCEDURE

As per IRC58-2002and revised addition 2015 Plain concrete jointed slabs do not require reinforcement. Reinforcement, when provided in concrete pavements, is intended for holding the cracked faces tightly together, so as to prevent opening of the cracks and to maintain aggregate inter-lock required for load transfer. It does not increase the flexural strength of unbroken slab when used in quantities which are considered economical. Reinforcement in concrete slabs, when provided, is designed to counteract the tensile stresses caused by shrinkage and contraction due to temperature or moisture changes. The maximum tension in the steel across the crack equals the force required to overcome friction between the pavement and its foundation, from the crack to the nearest joint or free edge. This force is the greatest in the middle of the slab where the cracks occur first. Reinforcement is designed for this critical location. However, for practical reasons reinforcement is kept uniform throughout the length, for short slabs. The amount of longitudinal and transverse steel required per m width or length of slab is computed by the following IRC: 58-2002 and IRC: SP 58-2015

Formula:
$$A = \frac{LfW}{2S}$$

A = area of steel in cm2 required per m width or length of slab, W = weight of slab in kg/m^2
L =distance in m between free transverse joints (for longitudinal steel) or free longitudinal joints (for transverse steel), coefficient of friction between pavement and sub-base/base (usually taken as 1.5), and
S = allowable working stress in steel in kg/cm' (usually taken as 50 to 60 per cent of minimum yield stress of steel).

Since reinforcement in the concrete slabs is not indented to contribute towards its flexural strength, its position within the slab is not important except that it should be adequately protected from corrosion Since cracks starting from the top surface are more critical because of ingress of water when they open up, the general preference is for the placing of reinforcement about 50 mm below the surface. Reinforcement is often continued across longitudinal joints to serve the same purpose as tie bars, but it is kept at least 50 mm away from the face of the transverse joints and edge.

OBSERVATION, RESULT AND DISCUSSION

Village road in expensive soil have specific problems of poor sub grade soil every year many roads are flooded during rains maintenance of village roads are not carried out property due to lack of fund in U.P. there are very less fund for maintenance of village roads in fact government is not able to maintain O.D.R. and M.D.R. level roads. Rigid pavements are subjected to variety of stresses due to wheel load, curling stresses due to difference in temperature between top and bottom of the slab and frictional stresses developed due to overall change in temperature. In black cotton soil P.C.C. Pavement faces problem in dry seasons due to shrinkage and swelling in rainy season, swelling pressure and shrinkage create tension at the top of the surface and ultimately cracks develop to meet out such problems some of the observations are:

A. The condition of the damage surface of plan concrete pavement executed in past has been observed in district Chhatarpur, MP, India shown in Figure 1 (a & b)
B. The condition of the damage surface of plan concrete pavement executed in past has been observed in district Hamirpur and Jalaun , UP, India shown in Figure 2 (a & b)

IRC: SP: 72-2007 and IRC: SP: 72:2015 [21] provides guidelines for the design of flexible pavements for low volume rural roads considering and determination of equivalent standard axle load (ESAL) applications based on equivalency factors for different axial loads, vehicle damage factor calculation, traffic categories and sub grade strength classes. Such type of Flexible pavements is not successful in expansive soil region area.

[1] IRC SP: 62-2004 and IRC SP: 2014 [8] provides guidelines for design, construction and maintenance of rigid pavements for village road. There are no specific provisions for expansive soil the recommended thickness is applicable to all type of subgrade soil such as clay, silt and silty clay.
[2] IRC SP: 62-2004 and IRC SP: 2014 provide provisions of sub-base below the concrete pavements to prevent mud pumping & acts as capillary cut of where the pavement designed for a wheel load of 51 KN a 150 mm thick sub-base of water bound macadam provided. Some provisions need to be reinvestigated and modified.
[3] The temperature variation assumed to be linear is not realistic and stresses calculated by using boundary's equations are much higher than the actual it needs rectifications.
[4] For sustainable option of rigid pavement in expansive regions, the field investigations regarding the performance of existing pavements need to be carried out in detail.
[5] The nature of subgrade soil, detail soil classifications, natural topography, environment conditions and traffic passing through village road needs to be observed in locations that fall in expansive soil.
[6] IRC : SP : 49-2014 provide guideline for the use of dry lean concrete as sub base for rigid pavements, a thickness of minimum 150 mm is recommended for all major projects 100 mm thick for village roads case study considering (GSB + PQC), (GSB + LC + PQC) & (LC + PQC) need to be carried out in detail.
[7] IRC: SP: 58-2002 and IRC SP: 58-2015 recommended reinforcement in concrete slab to counter cut the tensile stresses caused by shrinkage and contraction due to temp and moisture changes. This reinforcement in the concrete slab is not intended to contribute towards its flexural strength amount of steel used in pavement as

dowel bars, tie bars and for temp steel is sufficient in quantity and affect the cost of rigid pavement but such steel has no contribution for flexural strength. Hence this reinforcement can be saving when designing pavement for increasing flexural strength as per actual calculations of stresses.

[8] IRC: SP: 62-2004 and IRC SP: 62-2014 provides guidelines for transverse contraction and construction joints, expansion joints, longitudinal joints, and these closely spaced joints are cause of inconvenience to the traffic. Designed reinforcement concrete pavement can increase the spacing of joints to facilitate smooth and comfortable flow of traffic.

Fig. 1 (a) Shahpur village cc road Tahsil- chandala Dist – Chhatarpur, MP, India year of construction 11/2014

Fig. 1 (b) Sijai village cc road Tahsil- Launri Dist – Chhatarpur, MP, India year of construction 03/2014

Fig. 2 (a) Pateleshwar Temple cc road Dist – Hamirrpur, HP, India year of construction 02/2014

Fig. 2 (b) Soharapur village cc payment, Kalpi, Dist – Jalaun, UP, India year of construction 01/2011

CONCLUSIONS

The conclusions of this study are as follows:

1. In expansive soil shrinkage in summer and swelling in winter or rainy season may develop tension on the top surface of the pavement, ultimately causes cracks in pavement.
2. There is need for design of rigid pavement for village road in expansive soil with modification in existing provision and design the rigid pavement with structural consideration by providing reinforcement accordingly taking advantages of flexure.
3. IRC recommendations are common for all types of soil and there are no specific provisions for black cotton soil and the provision of reinforcement only for cracking due to shrinkage & temperature there is no advantage for flexure and no provision for catering tensile stress at the surfaces.
4. As per IS Code of Indian Road Congress. So there is severe need for special design of RCC pavement as a sustainable option for village road in expansive soil region.

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