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Experimental Analysis Of Plastic Cell Filled Self Curing Concrete Pavement: A Review

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ABSTRACT— *Form work of plastic cells is laid across the compacted sub base and put under tension with iron spike so that cells are close to square in plane. The nylon thread is passed through the plastic cells so that collapse would not be happened during the filling of concrete in the cell. Uniformity of level should be checked before the compaction and the iron spikes should be taken out after the cells are filled up with concrete. Premix method is adopted and the concrete mix 1:1.5:3 i.e. M20 grade with Polyethylene glycol (PEG-400) as an admixture is used. The cell-filled concrete blocks behave as flexible layers and confirm to the deformed shape of the sub-base, if there is any additional compaction or settlement of the sub-grade. This type of construction is likely to be cost effective for pavements of low volume roads and may have better riding surface than a concrete block pavement.*

As a result of such huge maintenance cost pavement is reduced by the use of plastic cell field concrete pavement i.e. are increasingly used in rural roads connectivity in India because of their durability and addition of polyethylene glycol leads to perfect curing of concrete without maintaining external moisture throughout up to achieving its mean strength.

Keywords — *Plastic cell, Cell filled concrete, Polyethylene glycol, Waste Degradation, Eco-friendly.*

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I. Introduction

A road pavement is a hard durable surface laid on any area that is used to carry loads of vehicular traffic or food traffic. Its purpose is to distribute the vehicular loads and to transfer normal stresses to the underlying ground. Generally they are of two types:

1. Flexible – Pavements with asphalt or bitumen bonded surface.
2. Rigid – Pavements with concrete slab resting on prepared sub-base.

Normally for rural roads, conventional flexible pavement with a thin layer of bituminous adopted which needs frequent maintenance due to damages caused by various overloaded traffic conditions, poor drainage systems, etc. The damaged pavement causes huge maintenance cost so because of their durability; concrete pavements are increasingly being adopted in rural road connectivity in India to tackle this problem and expenditure.

A unique pavement technology known as plastic cell filed concrete pavement (PCCP) has been developed for enhanced structural performance and low maintenance by IIT Kharagpur, which has proved to be a very promising solution for overloaded traffic conditions, poor drainage systems, water logging complications of the roads, bullock carts etc. PCCP are cast in situ concrete blocks in which there are interlocking between individual blocks with plastic between the blocks. The method involves overlaying the compacted sub-grade or sub-base with form work of stretched plastic cell and the irons spikes are driven at cell's corner to make formwork firm in its original place. To prevent collapse of the cells nylon ropes passed through the cell walls before pouring of concrete into the cells. PCCP cells needs labour at more numbers which may be utilized making it labor intensive with possibility of generating employment opportunity for the rural inhabitants.

Only a few studies on PCCP technology have been reported in India such as Piyush Madke and Prof. Shrikant harle (2012), Shivaprakash (2011), Roy et. al., (2009, 2010), Ryntathiang et. al., (2005), and Pandey (2006) on the feasibility and cost-effectiveness of rural roads. Despite the fact that their research was limited to a few PCCP thicknesses, i.e. for 40mm, 75mm, 100mm, 120mm etc. PCCP was shown to be capable of offering a sufficiently high elastic modulus at a lower initial and maintenance cost. It should also be noted that, because most reported PCCP experiments were not conducted under real-world traffic situations, their applicability for actual field settings must be assessed. The lack of the relevant data has hindered the creation of design standards, at least in the context of Indian rural roads.

As an admixture polyethylene glycol (PEG-400) is used to make the concrete pavement self curing. The curing of concrete should be done properly to meet the desirable properties and to achieve its target mean

strength. Normal conventional concrete hydration is carried out by external process of curing i.e. by providing water on the prepared concrete bed surface. Generally PEG-400 is used as it is good in water retention capacity with increasing durability. Self curing technique can minimize rate of evaporation as well as self desiccation of the concrete and it also offers increased compressive and tensile strengths.

From various research studies based on polyethylene glycol for self curing such as (M.V. Jagannadha Kumar et al. IRJET Vol.1 Issue.1), (M.Poovizhiselvi, D.kartik IRJET Vol.04 Issue.01, 2017) it is observed that at most the optimum dosage of PEG-400 is 1.0% by weight of cement for M20 grade to get maximum compressive, tensile as well as modulus of rupture strengths for the concrete. So in this work 1.0% of PEG-400 by weight of cement is used to obtain targeted mean strength.

Evaluation of PCCP vis-a-vis for concrete pavements and study is done on making the most of use of plastic cells weather on the concrete or as retaining wall replacement on the sideways of road pavement so as to prevent soil erosion when required.

1.1 COMPONENTS OF PAVEMENT:

1. SUB-GRADE: Sub-grade or formation refers to the finished and compacted earthwork surface on which a road pavement lies. Depending on the topography and the decided formation level, a road's sub-grade might be built on an embankment, in cutting, or on current ground level. It's made up of well-compacted natural soil that's been shaped to the desired camber and gradient. The thickness and pavement structure depends on resisting capacity of the sub-grade because the entire load of the pavement, including the load of traffic will eventually transferred through the pavement.

2. SUB-BASE: The term "sub-base" refers to the granular material that sits between the sub-grade and the base course of a road surface. When the sub-grade is of poor quality, it is provided as an additional layer. It consists of a layer of material which is comparatively less expensive, such as slag, natural gravel and burnt clinker etc.

3. BASE COURSE: Base course, also known as soling or foundation course, is a layer of stones or bricks placed over the sub-base or directly over the sub-grade in the lack of a sub-base in a road pavement. Because this course bears the impact of traffic conveyed through the wearing course, it is regarded the most significant and major component of the road structure. It is made out of a stable material such as stones, gravel, and one or two layers of well-burnt bricks, among other things. This course is not available if the sub-grade is rocky.

4. SURFACE COURSE OR WEARING COURSE: Wearing course or surfacing refers to the topmost layer of the road pavement that is directly exposed to traffic. In the case of flexible pavements, it may be made up of one or more layers. A good wearing course should be weather resistant and impenetrable to water. It should be capable of withstanding the abrasive effects of traffic.

1.2 ADVANTAGES AND DISADVANTAGES OF CEMENT CONCRETE ROAD:

Rigid pavements are those types of pavements that cannot change their shape without rupturing. Cement concrete roads are the best example of rigid pavements.

The advantages and disadvantages of cement concrete road are as follows:-

Advantages of Cement Concrete Road-

a) Cement concrete road have a longer life and offer great riding surface in all types of weather.
b) Concrete roads are weather resistant i.e. they are practically unaffected by weather conditions as well as temperatures.
c) Concrete roads are resistant to traction and are dustless, impervious, and non-slippery.

Disadvantages of Cement Concrete Road-

a) The initial construction cost of cement concrete road is very high and it requires skilled labor and supervisory.
b) Cement concrete road cannot be available to traffic instantly after its construction as well as after its maintenance.
c) These types of roads are liable to cracking and warping stresses because of change in temperatures.
d) Under iron-tyred traffic, concrete roads are noisy.

1.3 FAILURES OF CONCRETE PAVEMENT:

Pavement failure is caused due to contraction and expansion joint, heavy vehicular loadings, changes in chemical properties such as shrinkage, hydration effects etc. It needs proper maintenance like crack and asphalt sealing to prevent cracks from spreading or forming.

Asphalt Cracking: Normally asphalt cracking happens because of settling of the soil particles beneath the bed surface and also due to weather exposure of the surface of concrete. An improper mix design also tends to cracking of the cement concrete road. Repeated loads of the vehicles at the pavement leads to crack if not proper maintained.

Joint Spalling: Spalling is the deterioration or damage of the joints due to excess compressive stresses at the joints by high traffic loads. Joint spalling also caused due to weak concrete mix designs as well as due to freezing and thawing effects.

Pumping: Pumping is the process of expulsion of water beneath the bed surface of the pavement. The active vehicular loads coming over the pavement in a repetitive manner generate this pumping effect. As a result, the fine materials contained in the sub base will flow with the water and be flushed along with it. Repeated expulsion creates larger spaces beneath the pavement.

Alligator Cracking: It is common distress in asphalt cracking and also known as crocodile cracking. If proper maintenance is not done on these cracks it leads to potholes formation. It is caused due constant transfer to heavy loadings into the bed surface, water drainage problems, etc.

Corner Cracking: Excess pumping leads to the cracking of the corners of concrete pavement. Generally corner cracking or edge cracking caused by improper material proportioning, heavy vehicular loads, excess water expulsion i.e. pumping etc.

Block Cracking: Block cracking is observed when the cement concrete grade mix is not up to required proportions or due to various temperature variations etc. It is basically the crack which is observed in whole block of concrete bed surface which at the time of maintenance is replaced by the whole concrete block and due to which traffic on the road is stopped.

Pot Holes: Pot holes are developed when water seeps through existing cracks in the surface for an extended period of time. Water will start eroding the surface down to the sub-base, if the formed cracks in the concrete bed surface are not properly treated.

1.4 PLASTIC CELL:

- Plastic cells are a type of geocells which are made up of recycled plastic of low density polyethylene (LDPE).
- Plastic cells are ecofriendly in nature i.e. are not harmful to the environment and can give increased compressive as well as tensile strengths.
- It is very effective in soil reinforcement, dams, retaining walls, concrete roads, as well as for foundation erosion control etc.

1.5 PLASTIC CELL FILLED CONCRETE PAVEMENT:

- PCCP are the pavements in which at centre, the cells are tensioned with the help of iron spikes.
- The formwork of plastic cells is spreaded over the bed surface and then concrete mix is poured compacted into those cells.
- PCCP are cast-in-situ concrete blocks with interlocking between individual blocks and plastic between the blocks to keep it confined.

1.6 POLYETHYLENE GLYCOL:

- Polyethylene glycol is very good in water retention (moisture) in the concrete which makes the concrete self curing.
- It also increases the tensile and compressive of the concrete pavement.
- It is used in about 1.0% as an admixture in concrete mix to attain its targeted mean strength.
- This admixture also reduces rate of evaporation and self desiccation of the concrete.

II. LITERATURE REVIEW

Ryntathiang, T.L., 2005. An Investigation on Precast and Cast In-Situ Concrete Block Pavements for Low Volume Roads, Unpublished PhD Thesis, Department of Civil Engineering, Indian Institute of Technology, Kharagpur-721302, India[4], In India, he made the first attempt on the study of PCCP by investigating its structural performance in the laboratory and adopted grouting technique for casting 75 mm thick PCCP and premix technique for casting 100 mm thick PCCP. It was observed that sufficient compressive

strength for resisting the damaging action of low volume traffic could be obtained after seven days of casting. using a mix of 1:1.5 cement: sand (by volume). The mix made up of premixed cement, sand and coarse aggregates was found to have higher seven days compressive cube strength than grouting cement sand mortar into the voids of coarse aggregates. Core sample from the test pavements showed that premixed concrete had less voids than the grouted concrete blocks. It was also observed that PCCP of thickness 100mm had better interlocked faces than the 75 mm blocks. Accelerated test on blocks have shown rutting as low as 3 mm after 11,000 repetitions of standard 80 kN for 75 mm thick blocks. The moduli for 75 mm and 100 mm PCCP layer were obtained as 2995 MPa and 2542 MPa respectively. Economic evaluation of PCCP vis-à-vis conventional flexible and pre-cast concrete block pavement shows that conventional flexible pavement is 1.22 times the cost of pre-cast concrete block pavement and 1.62 times PCCP.

Sahoo, U.C., Reddy, K.S. and Pandey, B.B., 2006. Structural Evaluation of Concrete Filled Cell Pavement, International Journal of Pavement Engineering and Asphalt Technology, U.K., 7 (1), pp. 27-37[5], Constructed 250 meter long PCCP pavement over 150 mm compacted thickness of moorum sub-base to test its feasibility on field for low volume roads. The premixed cement concrete mix used for filling the pockets of plastic cell was mixed in the proportion 1:1.5:3 (cement: fine aggregate: coarse aggregate) by volume. The result obtained from the investigation showed that the elastic modulus of cell filled concrete layer were in the range 2486 to 6850 MPa and that of foundation layer (sub-base and sub-grade) were in the range 123 to 161 MPa which are sufficiently high for low volume roads.

Visser, A.T. and Hall, S., 1999. Flexible Portland cement Concrete Pavement for Low-Volume Roads, Transportation Research Record, 1652, Washington D. C., pp. 121-127[1], For better structural performance and low maintenance, a new pavement technology called Cell Filled Concrete Block Pavement (PCCP) was developed in South Africa. In PCCP, diamond shaped heat welded plastic cells is used to make concrete blocks.

Visser, A.T., 1994. A Cast In-situ Block Pavement for Labour-Enhanced Construction, Concrete Beton, Journal of the Concrete Society of South Africa, (71),1-8[3], Initial investigations on PCCP (plastic cell concrete slab) directly on the compacted in-situ soil was attempted by Visser (1994) by studying the load transferring capability of a 1200 mm by 800 mm cell slab over 20 mm thick rubber mats, having different shore hardness of 38, 50 and 70. The load transferring capability of different thicknesses of slab of 50, 75, 100 and 150 mm were tested under an applied load of 40 kN load (legal dual wheel load) on a 300 mm diameter load plate. The slabs were cast in the plastic cell formwork and tested after three weeks.

M.V. Jagannadha Kumar, M. Shrikanth, Dr. K. Jagganadha Rao, Vol.01 Issue.01 2012, Strength Characteristics of Self Curing Concrete, International Journal Of Research In Engineering And Technology, Sep 2012, In the investigation of self curing admixture of concrete, it was calculated that for maximum strengths (compressive, tensile and modulus of rupture), the optimum dosage of PEG-400 is 1.0% for M20 grade of concrete and 1.50% for M40 grade of concrete. It is also observed that PEG-400 is the answer for lack of curing in the concrete. If the proportion of PEG-400 is increased, then the slujmp increases for both M20 and M40 grade of the concrete.

PMGSY, 2010. Pradhan Mantri Gram Sadak Yojna (online)[2], During the last few decades, road development have been given high priority by the government of India for rural areas the development process, the Ministry of Rural Development, Government of India, has launched a rural road development program called Pradhan Mantri Gram Sadak Yojna (PMGSY) for connecting unconnected rural area with all weather roads.

Gaurav Dhane1, Dhiraj Kumar2, Akash Priyadarshee3 Geocell; An Emerging Technique Of Soil Reinforcement In Civil Engineering Field, AETM'15 PP 59-63, IOSR Journal Of Mechanical And Civil Engineering, On investigation of study on soil reinforcement it was concluded that geocell reinforcement of soil provides all round confinement to the material i.e. it prevents lateral soil displacements on loading which reduces erosion of the soil. It is very versatile in cost efficiency based on the strength that obtained. It's applications in civil engineering is numerous such as earth support footing, Concrete roads, retaining walls, channel protection etc.

M. Poovizhiselvi1, D.Karthik2 Vol.04, Issue.01 2017, Experimental Investigation Of Self Curing Concrete, International Journal Of Research In Engineering And Technology, Sep 2017, It was observed that the maximum strength of concrete is obtain by adding 1.0% of PEG-400 by weight of the cement to the concrete mix. The strength and durability properties of internal curing i.e. by PEG-400 prove to be best alternatives percentage compared to external curing. It is also observed that strength of the self curing concrete is on par when in conventional type of concrete.

III. PROBLEM IDENTIFICATION

3.1 Requirement of Project:

i. The costs of various types of cell-filled pavements are compared to the costs of conventional flexible and rigid pavements designed for low traffic volumes, it is clear that cell-filled pavements are more cost-effective than conventional pavements, especially in rural areas.

ii. Under accelerating and stopping forces, the interlocking joint needs precautionary frequent maintenance that may not be feasible for rural roads.

iii. To study the various uses of plastic cells other than construction in road pavement so that plastic cell can be fully optimized which is eco-friendly towards the nature.

iv. To make use of wastes that are readily available in large quantities, such as plastics, which take a long time to degrade and are therefore considered naturally undegradable.

v. The reduction of wastage of water for the curing process of concrete through making the concrete self curing by addition of polyethylene glycol as an admixture.

3.2 Objective of Study:

a) Objective of the present study is to investigate the behavior of pavements constructed by filling the cells with concrete mix and polyethylene admixture for making concrete self curing.

b) To explore the possibility of laying PCCP as overlaying on existing old bituminous pavement.

c) Identifying the attributes of new technology over the old conventional technology.

d) To quantify the structural and functional parameters to be used for the further study on deterioration modeling in terms of Pavement Condition Index (PCI).

e) To study the various uses of plastic cells i.e. geocells for further use other than concrete pavement.

f) Economic assessment of PCCP vis-a-vis conventional flexible as well as rigid pavement.

g) The Performance of pavement is taken up to study the behavior of conventional concrete and to find out the economical construction of rural road for the economic and social development of the rural inhabitants.

IV. DISCUSSIONS AND CONCLUSIONS

- It is an individual block approach; so on a block failing only that particular block is replaced without much effort, which makes it economical and low maintenance work.
- There is no need of providing any expansion or contraction joints in this type of pavement.
- PCCP are the cast in situ concrete blocks where there is interlocking between individual blocks with plastic between the blocks hence it has good load spreading capacity and later provide better compressive and tensile strengths, and increased life span.
- PCCP leads to minimization of plastic wastes from the environment & by the use of recycled plastics in pavement, strength is also increasing.
- By using PEG-400 as an admixture, the pavement acts as self curing i.e. no additional water needed for curing up to targeted mean strength of concrete. So wastage of water is also not done and will reduce cost of water curing as well as workforce.
- PCCP is best suited for rural areas where low maintenance construction works are carried.

V. FUTURE SCOPE

- This new plastic cell filled pavement technology can be used for high volume roads to resist higher vehicular loadings.
- Replacement of the self curing admixture polyethylene glycol-400 can be done to make it more compelling with strength and workability.
- Measures on methods can be taken to make the initial costing of the plastic cell concrete pavement mush less as till now it is more as initial stages.
- These plastic cells can also be used at the sub-grade level of the foundation to make the soil erosion resistant beneath the concrete pavement.

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