IMPACT OF POLYMERIC CONCRETE IN RIGID PAVEMENT DURABILITY: A REVIEW

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Abstract - A Polymeric concrete is useful to enhance extravagant properties of normal paving quality matrix concrete to desired strength and quality concrete. Now a days intensified motive is to construct quality-based pavement roads with higher construction rate per given length (say; km). This is best achievable by using constructing Rigid pavement instead of Flexible pavement and as Rigid pavement is laid by using concrete mass. Here efforts have been done to modify the physical properties of pavement concrete for best possible outcome.)

Key Words: Rigid Pavement, Flexible Pavement, Polymeric Concrete & Physical Properties.

1.INTRODUCTION

The Construction of Rigid pavement is completely different in all contexts from Flexible pavement, as basic method and materials utilization are non-concurrent. These types of casted rigid pavements were basically constructed by using concrete matrix, as concrete reflects high rigidity and stiffness after being set or attains hardness. Concrete rigid pavement can be reinforced suitably if needed by using reinforcement materials like steel bar for better stress divergence and load carrying capacity. The rigid pavements is measured, framed, checked and designed by exploitation the elastic theory, during which the surface layer is taken into account because the elastic layer, that is supported by another elastic plate known as the sub grade. The rigid pavement won't distort just like the versatile pavements if the undulating surface is there at the bottom.

1.1. Construction of Rigid Pavement

The durable behavior of rigid pavement hangs not merely to the appropriate pavement design and materials assortment, but on skilled construction procedures too. Poor construction procedures have got ensued in untimely disasters of laid rigid pavement. The construction of a rigid pavement is a complex process. It involves many processes, which can be summarized as suitable preparation of bed with subgrade and sub-base, placing reinforcement bars or dowels, optimal management of aggregates and additional materials, development of concrete mix design, production and conveyance of the concrete, and placing, finishing, curing, and un-jointing long slabs of the concrete.

As per IRC 58: 2002, IRC Method of Rigid Pavement Design: This method is based on mechanistic-empirical principles.

The motives in designing a rigid pavement are:

a) Defining and Fixing of the thickness of pavements.

If $$SR < 0.45, N_f = \infty \qquad (7.32\,a)$$

If $$0.45 \le SR \le 0.55, N_f = \left[\frac{4.2577}{(SR - 0.4325)}\right]^{3.268} \qquad (7.32b)$$

If $$SR > 0.55, \log_{10} N_f = \left[\frac{0.9718 - SR}{0.0828}\right] \qquad (7.32c)$$

b) The specifying of constructional discontinuity.

c) The designing of load-transferring devices such as dowel bars and tie bars.

1.2. Defining and Fixing of the thickness of pavements slab

1. Just fix a trial value of depth for the rigid concrete slab.
2. Evaluate the stresses due to load [σ_e and σ_c from Eq. 7.23 and 7.24] and those due to warping (σ_{txi}, σ_{tyi}, σ_{txe} and σ_{tye} from Eqs. 7.27 to 7.30)
3. Calculate the stress ratio (SR) by dividing the edge stress due to load by the flexural strength of the concrete (modulus of rupture, MR)
4. Obtain the anticipated add up to standard axle load repetitions (N) for each stress ratio by the subsequent standard relations for each group of axle loads (or fatigue life, Nf):

5. Calculate the collective fatigue damage framed by different groups of axle load and sum up.

6. The summed-up value of the increasing wearing & fatigue distortion for all the expected axle loads must be under limit of accord unit. If this criterion is satisfied, proceed to the later steps. The adequacy of flexural strength of the slab must be checked for –

(i) total most stress at the edge activated by wheel load and warping, and

(ii) utmost stress at the corner pressed by wheel load. The assumed depth is considered tolerable if the maximum stresses are lower than the modulus of rupture of the concrete.

If above mentioned criteria are not pleased, revise the assumed depth to higher side and follow the similar system all over again to make certain the competence of the slab depth. (As per IRC guidelines warping stress at the corner is not considered as it is less than the stresses in the other locations of the concrete slab. Also, the effect of moisture changes is ignored for instant.)

1.3. Design of Reinforcements for Pavement Slab

Concrete slab resists cracks and bears all stresses falling or diverted to its face also, it counteracts the tensile force due to shrinkage and contraction due to temperature as well as moisture changes.

(i) The maximum tension in the steel across the crack is the force needed to overcome friction between the slab and the layers below, from the crack to the nearest joint and free edge.

(ii) Maximum force occurs for a crack at the mid-span of the slab; therefore, the greater the spacing of joints, the greater is the required reinforcement.

(iii) Major portion of the reinforcement should be parallel to the greater dimension.

The below mentioned formula is prevalently used for the area, As, in cm^2, of the length and lateral steel per metre width or length of the slab-

$$A_s = \frac{L_j \cdot f \cdot h \cdot \gamma_c}{2\sigma_s} \quad (7.33)$$

Here,

L_j = Spacing in metres between lateral joints (for length ward joints), or free longitudinal joints (for lateral steel).

f = coefficient of friction between slab and subgrade (usually, maximum 1.5)

h = thickness of slab in meters

Υ_c = unit weight of concrete (kg/m^3, usually 2400)

σ_s = allowable stress in steel in kg/cm2 (Usually taken as 50 to 60% of yield stress-1400).

The reinforcing steel in the slab is placed below 50 mm of the top surface because larger tensile stresses are anticipated near the top, where the cracks tend to open.

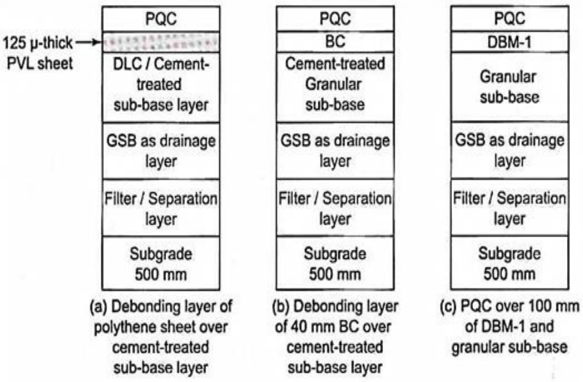

Figure – 1. Different Cross-sections of Concrete Rigid Pavement Layers (*Source-IRC: 58*).

IRC: 58-2002 specifies joints in cement concrete pavements based on their function as given below:

(a) Expansion joints
(b) Contraction joints
(c) Warping joints
(d) Longitudinal joints
(e) Construction joints

The current viewpoint rigid pavement construction strategy is centered on warping stresses established in the slabs due to temperature alterations and bending of the slabs due to vehicle or say, axle weight. The stress ratio model is treated to balance the falling axle load recurrences by which actual reverberations of axle load and admissible duplications of axle load are compared as per the suggested in design methods presented in IRC: 58-2002 and IRC: 15-2002.

Updated advice in specifications for designing of roads with lower traffic loads or volume were as per clauses of code IRC: SP: 62-2004. In the design of concrete pavement for low volume roads also temperature stresses and load stresses are required to be considered in combination so that the unified effect of said two stresses might not surpass the concrete flexural strength. As the traffic density at the ending pre-assumed or formulated life is low in non-urban roads the stress ratio concept had been not measured in the drawing of the PQC slab of the pavement. The guidelines for construction of Roller Compacted Concrete Pavement which makes use of zero slump concrete were also reported in IRC: SP: 62-2004.

1.4. Issue of Mix Design for Rigid Pavement.

The concrete mix design for rigid pavement is processed as put forward by IRC: 44-2017 is outdated. At the time of formulation of this code usage of super plasticizers was not common. High strength concrete can now be produced using various new additives and high strength cement. Cements with 43 and 53 Grade are commonly available in market now a day's which were not available at the time of formulation of this code. So, a new mix design procedure must be evolved in the light of the developments in cement industries and allied admixtures.

Relationship between Cube Strength and Core Strength: In the case of pavement concrete, where the requirements are not met with, or the eminence of concrete or its compaction is uncertain, the actual strength of the concrete in the slab shall be ascertained by carrying out tests on cores cut from the hardened concrete at such locations." The equivalent cube strength of concrete shall be obtained by multiplying the corrected cylinder strength by a factor 1.25., where height to diameter ratio of the core is two, IS: 516 – 1959/2018. As per article 17 of IS: 456-2000, the concrete shall be accepted if the average equivalent cube strength of cores is equal to at least 85% of the cube strength for the corresponding age and that no individual core has a strength less than 75%. It is very hard to achieve this target in fields.

1.5. Theory of Polymer Based Amendment in Concrete.

Admixtures were applied in the form of, polymer latexes, water-soluble polymers, and liquid polymers, applied to a filling composite such as concrete. Crucial stage to be remarked is that parallel formation of polymer film and cement hydration advances highly to crop a monolithic matrix phase with network structure in which the cement hydrated and polymeric phase mingles. Such polymer- modified concrete structures, possess better properties than traditional cementations composite. Polymers thin skinned layer is established by cement compound hydration activity and by the melding of polymer particles in polymerlatexes.

Polymer concrete: is made by adding ingredient as in form of admixture likely; a chemical compound or an organic compound raised of resins with aggregate mixture. Smaller fillers also are utilized on an average to fill the free space within the mixture. Chemical compound resins that are ordinarily utilized in chemical compound concrete area unit methacrylate, polyester organic compound, epoxy, vinyl organic compound organic compound, and organic compound resins. Polymer-modified concrete is usually utilized in several applications. You ought to apprehend what polymers you're applying and their strengths and weaknesses. Creating the proper alternative may verify the achievement or disappointment of associate installation— and the resultant liabilities.

The Polymer impregnated concrete can overcome many restraints or lags in the plain or ordinary cement concrete without any admixture. Polymer modified concrete were well reckoned to strengthen the durability and stress-strain capacity in all constructional fields and hence, shall be handsomely induced to cast rigid pavements. They have demonstrated superior stress dissemination, lower cracks, and surficial fatigues under various loading conditions. The impact of utilization of numerous polymers and the quantity in regard of flow ability and strength characteristics are found. A relative research has been conceded to highlight the effect of two different polymers on fresh and hardened properties of polymer modified concrete. Established upon these findings, suggestions remain put together with respect to its dosage, chemical characteristics, and suitability. The Polymer based concrete based on continuous reaches are attributed for their following behaviors:

1. Reduction in Cement Volume
2. Impermeability
3. Durability
4. Stringent to weathering agents
5. Stress – Strain Resistant
6. Water retentivity
7. Shrinkage resistant
8. Thermal stability
9. Enhanced

Concrete having polymers has a much stronger resemblance to the concrete matrix along with which we all are almost certainly aware. In the due course of curing the polymer concrete, fewer used polymer's molecules in matrix raise to the exterior of the concrete and there it forms a protective thin-skinned shielded film that helps to retain water as the concrete cures or up to hydration is complete. This shielded film also provides an extra layer of surface protection once the concrete has fully cured and attained stiffness and rigidity. It also reflects that no special or only minimum curing is required for this type of graded concrete. The treated concrete will have a decrease water-cement ratio. This generally shows that a better electricity concrete may be produced without growing the quantity of cement. Latest improvements in admixture technology have caused the development of mid-variety water reducers.

2. *REVIEW: TO EXISTING RESEARCH WORKS*

1. **S. K Gupta** et. Al. [2] **"Use of polymer concrete in construction"** Polymer concrete (PC) is a composite material in which the binder consists entirely of a synthetic/organic polymer. It is globally known as synthetic resin concrete, plastic resin concrete or simply resin concrete. Because the use of a polymer instead of Portland cement represents a substantial increase in cost, polymers should be used only in applications in which the higher cost can be justified by superior properties, low labor cost or low energy requirements during processing and handling.

   The following could be concluded from the results obtained in this study.

i. Strength of concrete in compression, tension and shear can be greatly improved by polymer modified concrete. The most remarkable increment is obtained in the tensile strength.
ii. Deformation capacity of polymer cements concrete under different kinds of loading

viz. compressive, tensile and is significantly higher.

iii. An improvement in the tensile and shear strength combined with a lower and delayed shrinkage makes the polymer modified concrete a viable and attractive alternative for concrete overlays and other similar constructions.

2. **Raman Bedi** et. Al. [3] **"Mechanical Properties of Polymer Concrete"** The polymerized monomer acts as binder for the aggregates and the resulting composite is called Concrete; because of its properties like high compressive strength, fast curing and resistance to chemical attacks polymer concrete has found ample applications.

This paper deals with the efforts of various researchers in selection of ingredients, processing parameters, curing conditions, and their effects on the mechanical properties of the resulting material. Research on characterization of mechanical properties of polymer concrete has been carried out and sufficient data has been generated regarding the effect of various parameters on the properties of polymer concrete.

The following could be concluded from the results obtained in this study.

i. Comparative studies between epoxy and polyester resins report that epoxy polymer concrete has far superior mechanical properties and durability.

ii. Various types of aggregate materials have been used by the researchers most of them based upon the choice of locally available materials to reduce the cost.

iii. The resin dosage reported mostly lies in the range of 10 to 20% by weight of polymer concrete. Higher resin dosage is recommended when using fine aggregate.

iv. Seven-day room temperature curing criterion has found widespread usage their research work and has been almost universally accepted.

3. **Jingjing Xiao** et. Al. [5] **"Effect of styrene–butadiene rubber latex on the properties of modified porous cement stabilized aggregate"** A laboratory experiments had been conducted herein study to improve the cracking properties of PCSA through the incorporation of styrene-butadiene rubber (SBR) latex. The property of SBR latex treatment on permeability, compressive strength, flexural strength and anti-freezing ability of PCSA were investigated.

The following could be concluded from the results obtained in this study.

i. Test outcome specify that the air voids and permeability coefficient subject falls with the augmentation of SBR latex dosages.

ii. The flexural strength and freezing resistant capability were modified when the SBR latex dosages is between 10% - 15%. While compressive strength after seven days has a slightly decrease while the 28 days compressive strength increased.

iii. The significant increase of flexural strength and freezing resistant can be attributed to the interpenetrating matrices formation, stretching effect as well as flexibility augmentation after accumulation SBR latex in concrete.

4. **Haoliang Huang** et. Al. [6] **"Improvement on microstructure of concrete by Polycarboxylate super-plasticizer and its influence on durability of concrete"** In this study, the influences of polycarboxylate super-plasticizers (PCE) on durability of concrete were investigated. Acidic affects due to oxides of carbon & Hydrocarbons, water impermeability and rapid chloride permeability of concrete with different types of polycarboxylate super-plasticizer and poly-naphthalene super plasticizer (PNS) were tested. According to test results, more hydration products in the cement pastes with PCE observed have been more than in the cement pastes with PNS.

The following could be concluded from the results obtained in this study.

i. Smaller carbonation depth, water penetration depth and chloride permeability of concretes show that concretes with PCE have better durability performances than concretes with PNS.

ii. Mortars with PCE have lower porosity and smaller critical pore diameters than that with PNS. Therefore, comparatively PCE best optimizes pore structure of concrete. PCE in Cement paste amplifies hydration products, i.e. C–S–H and CH than in the conventional cement pastes with PNS and, therefore, denser microstructures.

iii. The ratio of high density to low density C–S–H in cement paste with PCE are much higher than that in the cement paste with PNS, leading to a denser microstructure and better mechanical properties of the material.

5. **F. Puertas,** et. Al. [7] **“Polycarboxylate super plasticiser admixtures: effect on hydration, microstructure and rheological behavior in cement pastes”** research was conducted on the effect of a polycarboxylate (PC) admixture on the mechanical, mineralogical, micro-structural and rheological behaviour of Portland cement pastes. The existence ofPC polymer slows down the initial cements hydration reaction rate, although this effect may be offset by potential amplified diffusion in later stages. Furthermore, the PC admixtures produce a few alterations in the structure and composition of the formed C–S–H gel. T

   The addition of 1% PC admixture in the pastes generates a higher percentage of silicate bridge i.e. chain; mainly at 2 days. The admixture used induces atomic level modifications in the pastes which slightly reduced the porosity; however, the admixture did not affect the mechanical strength of the pastes at either 2 or 28 days of hydration.

The following could be concluded from the results obtained in this study.

i. PC admixture on cement hydration show that at very early ages an initial retardation of cement hydration is produced.

ii. Mineralogical analyses show that the same hydration products are formed in all pastes (mainly C–S–H gel), the amount of this product is similar after 28 days of hydration.

iii. Results from rheological studies it can be concluded that low dosage of PC leads to a substantial reduction (over 70%) in the yield stress.

6. **P Kumar Mehta**, et. Al. [8] **“Advancement in Concrete Technology”** carried research incorporating works relating to cement concrete until the date framing point to point in the history. His study states that there has been a considerable change from plain cement concrete out of Ordinary Portland cement or simply say, Portland cement to pozzolna, chemicals or admixtures entrained concretes. Admixtures can be of different origins and could be used to enhance or multiply any desired properties, such as slump value, flow-ability, hardening, self-curing and micro level reinforcement. All this can be achieved by adding or impregnating certain types of chemicals having polymeric configurations in basic frame form.

7. **Sapan Gupta,** et. Al. [9] **“Evaluation of Water Retaining Concrete Properties with Various Polymers”** Here in this research concentration has been focused to evaluate the water requirement and retentivity behavior of concrete properties by means of various types of polymers such as SBR-Latex, Polycarboxylate Ether and Polyethylene Glycol. For this study they have sampled M30 mix grade of concrete and carried; with dissimilar types of polymers and complete study on workability.

   The following might be concluded from the outcome of from these work.

i. A polymer addition induces addendum in workability and hence; greater usability of concrete due to increase in plasticity is obtained.

ii. Higher compaction is achieved by use of polymer; but conventional concrete compaction is higher in case of PCE & PEG.

iii. The series for compressive strength at later age is SBR
> PCE > PEG > Conventional Concrete.

iv. The series for flexural strength at later age is PCE>SBR> PEG > Conventional Concrete.
v. Modulus of elasticity is also increased after introduction of polymer concrete but it is higher for SBR concrete as compared to other polymer concrete.

8. **Shriram Marathe,** et. Al. [11] **"A Review on Strength and Durability Studies on Geopolymer concrete"** in this paper geopolymer concrete is studied, which includes inorganic alumino-silicate polymer gel synthesised from source materials rich in silicon and aluminium, such as low calcium (class F) fly ash, which binds the loose aggregates, and other un-reacted materials in the produced geo-polymer mix.

The following enlisted points have framed out through conclusion presented.

i. The studies on the effect of corrosion resistance, utilizing activated flyash indicated reduced corrosion of reinforcing steel. Also, Geopolymer materials do not generate any dangerous alkali aggregate reaction, even in the presence of high alkali content.
ii. The geopolymer concrete with greater discordance directed to higher strength loss during preeminent temperature.
iii. The creep and shrinkage of geopolymers are substantially lower than conventional Portland concrete.

9. **G. B. Ramesh Kumar,** et. Al. [12] **"Experimental Study on Polymer Concrete with Epoxy Resin"** To provide the knowledge required for its broad utilization. Hence; a comparison is done between the conventional concrete and polymer concrete along with resins and fibers of variant proportions. As per IS:10262-2009 the mix design of M25 grade concrete is calculated and Estimation of material quantity is done.

The following could be concluded from the results obtained in this study.

i. It is well elaborated that epoxy based polymer concrete showcases a flexural strength 10X times that in cement concrete, superb for structural engineering applications.
ii. Induction of Polymer increases compressive strength and toughness of concrete.
iii. It reduces cracks, also if fibers are added separately during mixing.
iv. Mechanical properties are enhanced in concrete due to polymeric characteristics.

10. **Muthukumaran. S, Muralimohan. N, Sudha. P** et. Al [13] **"An Investigation on Strength and Durability Properties of Polymer Modified Cement Concrete"** Here in this study two varieties of polymers are used in concrete as an admixture to increase the properties of concrete. The objective of this study is to inspect the activities of polymer assorted cement concrete in both fresh and hardened state.

It has following out comes.

i. Partial addition of polymer with conventional cement concrete up to 10% which enhances the strength of concrete.
ii. The Compressive strength of concrete increases up to 26% for 28 days when compared with the conventional concrete.
iii. The split tensile strength of concrete increases up to 20% for 28 days when compared with the conventional concrete.
iv. The flexural strength of concrete increases up to 31% for 28 days when compared with the conventional concrete.

11. **S .Vijaya Bhaskar Reddy and Vadla Santhosha** et. Al. [14] **"Experimental Study on Fibre Reinforced Polymer Concrete"** It has been found that Polymer concrete has superior mechanical properties compared to conventional types of concrete. The investigational research concerning the polymer concrete acknowledges that mechanical characteristics of epoxy polymer concrete prepared with fly ash as filler.

The following could be concluded from the results obtained in this study.

i. The mix with 10% fly ash and 2% steel fibre gives maximum increase in the percentage of compressive strength i.e., 29.83% at 28 days over the control mix with 5% fly ash and 0% steel fibre

ii. Similarly, the same mix (10% fly ash + 2% steel fibre) gives maximum increase in the percentage of flexural strength i.e., 22.22% with respect to the control mix with 5% fly ash and 0% steel fibre.

iii. Coming to the split tensile strength similar to the previous two tests, the maximum value of split tensile obtained at 28 days is with the mix 10% fly ash and 2% steel fibre i.e., 16.18 MPa and so is the case with percentage increase in the strength i.e., 53.51%.

iv. The 7 days strength values are almost equal to the 28 days strength values in most of the cases, so that concludes polymer concrete gains strength very quickly.

12. G. Martínez - Barrera, E. Vigueras - Santiago, O. Genceland H.E. Hagg Lobland, et. Al. [16] **"Polymer Concretes: A Description and Methods For Modification And Improvement"** Polymer Concretes: A Description and Methods For Modification And Improvement" In this analysis work, care has been engrossed on concretes that has uninterrupted phase of some kind of polymeric resin and the discrete phase is some type of mineral aggregate. It has been shown that combining fiber reinforcements and the matrix curing effects of irradiation can provide significant improvements to the properties of polymer concrete. Additional strength is gained by adding supplement materials to catalyse flexural strength and split tensile strength such as; fibers.

Polymer Concrete properties depend on the interactions at the interface between the polymeric binder (i.e. thermoset resin) and the mineral aggregate. Therefore, improving its toughness and post peak stress-strain behaviours are compulsory; these parameters are also essential features to evaluate the presentation of the material for impact, earthquake, and fatigue anti action.

3. CONCLUSIONS

i. Polymeric compounds induce smooth workability, hence; stimulates greater usability of concrete due to enhancement of plasticity value.

ii. Required water-cement Ratio reduces noticeably with the polymers impregnation to concrete, upto 2.4% reduction for plasticity by 1-8%. of matrix mass.

iii. Self appraised compaction is viewed by impregnation with PEG & PCE but considerably PEG > PCE.

iv. Compressive strength is for conventional concrete is comparatively better then polymer-based concretes at early stages, such as SBR but less than PCE and PEG. However, at 28th day it is higher for polymer-based concretes.

v. The grading of compressive strength of polymeric concrete that polymer impregnation increases compressive strength of concrete considerably.

vi. Thermal stresses are better sustained by Polymeric concrete as it forms interlink macro structure within matrix.

vii. Modulus of elasticity shifts to better side after introduction of polymeric concrete, but it is higher for SBR concrete as compared to other polymer concrete.

viii. Water-retentively is best for polymer induced concrete as compared to conventional concrete as polymer forms thin protective laden used afterwards as internal curing support.

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