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Experimental Analysis on modified concrete pavements

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Abstract:The rigid pavement is composed of concrete slabs, which are connected by joints and reinforced by dowel bars and tie bars. It also includes a dry lean coat, as well as a subbase and subgrade soil. The entire pavement cannot be erected as a single unit; therefore, there will be opportunities for the formation of multiple inevitable cold joints. Avoiding the establishment of cold joints during the building of rigid pavement projects is extremely difficult. The formation of cold joints is a result of the delay between the preparation and placement of concrete. Nevertheless, it isrecognised that when subjected to dynamic loads from vehicles, such as impacts and rolling loads, as well as the effects of temperature profiles and warping, traditional concrete used for pavements can experience failures such as cracking at panel joints, and the failure of dowel bars and tie bars. The purpose of this study is to investigate the development of cold joints and their negative impact on the quality of pavement concrete (PQC). To address the issue, one can utilise remixed concrete and implement the Selfing and Crossing technique in pavement construction. The concrete, which was remixed with a precisely measured quantity of water, did not exhibit any improvement inits strength. However, in specific cases, the concrete is prepared by remixing it within a time frame of zero to ninety minutes, which enhances the durability of the concrete pavement. Remixed concrete is a composite material consisting of newly mixed concrete that has been blended with partially solidified older concrete. Several researchers have attempted to utilise this partially cured concrete by blending it with freshly poured concrete to get the necessary level of strength. It has been observed that the compressive strength of any mixture decreases significantly with time. This study examines the influence of several conditions on the strength of partly concrete combined with either the same grade (selfing) or a higher grade (crossing) of fresh concrete. When designing and preparing remixed concrete for rigid pavement, several factors are taken into account, including the cement contents, water-to-cement ratio (w/c ratio), proportions of fine aggregate (FA) and coarse aggregate (CA), as well as other parameters such as time lag, blend ratio, and deflection. These factors have an impact on the modulus of subgrade reaction (K in Kg/cm3) of the pavement. The study examines the impact of intermittent curing sequences on the strength of remixed concrete for rigid pavement. It emphasises the importance of proper curing to achieve the desired qualities and acceptable durability of hardened concrete. While it is not possible to carry out the precise laboratory curing technique in the field, the recommended methods can nevertheless be employed to a restricted degree. Additionally, it is crucial to determine the impact of cold joints on the bond tension and bond-slip between dowel bars and tie bars. By implementing the process of selfing and crossing, the bond strength of the partially set concrete was significantly enhanced as compared to traditional concrete. The FEM and mathematical modelling are used to compare the outcomes of the evaluation of the prepared field trial patches and laboratory cast specimens. The laboratory fabricated pavement specimens were produced and subjected to testing on a loading frame utilising a hydraulic jack to apply static loading. This was done to determine the deflection, strength, and strain of the joints. A falling weight deflectometer (FWD) is utilised for conducting full-scale tests on rigid pavement slab panels composed of conventional concrete, self-consolidating concrete, and roller- compacted concrete. The deflection caused by the weight drop is directly linked to the subgrade response modulus. The modulus of subgrade reaction is a crucial factor in the construction of stiff pavements. The quality of concrete is determined by its strength and the deflection of the pavement slab. The deflections and modulus of subgrade reaction produced from the entire scaling testing are utilised to evaluate the accuracy of the finite element model through FWD test results. Mathematical modelling is utilised to create Scheffe's second-degree polynomial-based model, which optimises the deflection and modulus of subgrade reaction in stiff pavement. The modulus of subgrade reaction of new and partially set concrete was determined for several parameters such as water-to- cement ratio (W/C), fine aggregate (FA), coarse aggregate (CA), blend ratio (r), time lag (t), and deflection (δ). The adequacy of the model was assessed using the student's t-test and Fisher's test. The test results establish a strong correlation between the model and control domains. The model can be used to compute the modulus of subgrade reaction for all control points in the simplex. The models developed by Osadebe and Scheffe in 2013 are utilised for the purpose of forecasting factors that are not known. Nevertheless, they are demonstrated to possess certain limitations. In order to surpass the limitations, Ibearugbulem developed a novel framework for approximating the value of an unknown variable using the value of a known variable. This model utilised the measured outcomes ofthe control concrete pavement section as specified experimental values in order to generate new anticipated results. This model rectifies the deficiencies seen in the previous iterations of Osadebe's and Scheffe's models from 2013. Ibearugbulem's approach utilised traditional selfing and crossing processes to determine the modulus of subgrade response (K) for stiff pavement sections.

CHAPTER 1 INTRODUCTION

Concrete roads are of great importance in the contemporary field of civil engineering, namely in the realm of roadway construction, since they play a crucial part in the transportation infrastructure of a nation. The Indian government's Ministry of Road Transport and Highways (MORTH) has decided to adopt the mass building of cement concrete pavement (rigid pavement) as the preferred approach for developing public roadways. After conducting a comprehensive analysis of many aspects such as road durability, lifespan, weathering effects on road materials, operational considerations, maintenance and repair costs, and environmental impact assessment, the ministry has made the decision to undertake extensive construction of rigid pavement for national highways, state highways, and motorways. Opting for concrete pavement addresses the shortcomings observed in flexible pavements, such as premature deterioration, water infiltration leading to moisture-induced damage caused by inadequate drainage conditions, and the need for frequent maintenance. Rigid pavement construction incurs a high initial cost, but its repair and maintenance expenses are modest, and its lifespan exceeds that of bituminous pavement. The main aim of this research is to examine and analyse the partially formed cold joints in rigid pavement caused by delays in time, variations in mix ratio, and certain unavoidable site limitations. The concrete pavement system comprises concrete panels, dowel bars, tie bars, transverse and longitudinal connections connecting the panels, construction joints, sub- base, and sub-grade dirt. The rigid pavement slabs can experience failure due to different load cases such as dynamic load, impact load, rolling load, and uniformly distributed load. This failure can manifest as cracking of the concrete slab at edges or joints, sliding of the subgrade or sub-base, temperature-induced stresses (warping stresses), and misalignment of dowel bars or tie bars. Tensile failure in the rigid pavement, specifically at joints, is a significantfactor leading to the deterioration and failure of the pavement. Both the impact of static and dynamic loads must be taken into account when designing pavements. The static and dynamic loading conditions are accountable for diverse failure reasons and for attaining a cost-effective design. A study is undertaken to elucidate the issues surrounding the creation of cold joints and its detrimental impact on the quality of road pavement (PQC). The problem can be resolved by employing recycled concrete and the process of selfing and crossing in concrete.

Chapter 2 Literature Review

2.1 Background This study has constructed the general selfing idea as a logical extension of the pure selfing concept, based on a certain set of assumptions. The assumptions hold true for the circumstances where self- fertilization occurs exclusively. The basic selfing formulas only take into account the equivalent blend ratio 'r' in relation to the individual mixtures. r1, r2, and so on. This achievement has been facilitated by embracing the principles of equal strength and equivalent time. By evaluating the potency of a mixture, whether it is pre-stiffened or freshly-prepared, or a combination of both, using the variables r and t, it is feasible to classify it as Art, which plays a crucial role in the suggested formulas. The pure selfing theory, which has been confirmed for pre-stiffened mortars by Bairagi, shows that the discrepancy between experimental and analytical results is insignificant. The theory will be highly valuable for field engineers who encounter the challenges of pre-stiffened mixes. The study offers vital insights by demonstrating that the strength of a mixture may be optimised for accurate and precise measurements, even when there is a delay in its final setting time. However, it is necessary to determine the impact of the intermittent curing method on the strength of concrete for both selfing and crossing theories. This can be achieved by constructing a suitable model, which is a realistic requirement in the present day. When it comes to concreting operations, it is common to encounter situations where the mixed concrete solidifies unexpectedly before it is placed in the formwork. Assume that the time delay t, measured from when water is added till the moulding process, is significantly longer than the initial period of stiffening t. Under those circumstances, the partially stiffened or pre- stiffened mixture begins to solidify and is frequently deemed unusable. However, in order to save unnecessary waste, a specific amount of pre-stiffened compound is frequently repurposed by blending it with another recently mixed concrete or cement slurry, rather than being completely discarded. While blending different materials is not considered a healthy practice, it does not significantly compromise the overall strength of the composite combination as long as the time lag (referred to as time t) of the pre-stiffened mixture is roughly equal to or slightly more than the time t. In his 1978 paper, N. Bairagi introduced the concept of pure selfing theory to determine the final strength of a composite mortar mix. The mix consists of two different mortars: one that is pre-set and has a known strength, and another that is freshly prepared. By applying a system approach, Bairagi demonstrated how the final strength can be determined by mixing the two mortars in a specific ratio. The theory has been theoretically calculated, and the compressive and tensile strengths, as well as the modulus of elasticity, have been compared with experimental data obtained from 1:2 and 1:3 mortars. These mortars had water-cement ratios of 0.4 and 0.5 and were cured for 28 days. He demonstrated that mortar weakens when the pre-set mortar mix is kept uncovered after the water has been added to the dry mixture. By introducing a predetermined amount of pre-mixed mortar at a specific moment t, the likelihood of recovering a certain level of strength was increased. This concept was encompassed within the purview of observation. This study introduces the innovative notion of "pure selfing" involving the combination of two mixtures. This study was performed on a 1:3 mortar mixture with a water-to- cement ratio (w/c ratio) of 0.45. The curing duration for the mortar was 3 days and 7 days. This study introduces a novel notion known as "pure selfing" of two mixtures. The idea aligns with the broader framework of the previous works of 'Bairagi and Kar' and also provides predictions for the variations in strength with respect to any time t, where ti< t ≤ tf, for the desired variation. In this context, ti represents the intermediate setting time, and r represents the ratio of the weight of the pre-set (old) mix at time t to the weight of the freshly prepared (fresh) mix at the same time t. Yu T. Chou (1983) utilised the finite element method to examine stress conditions in concrete pavements with slabs placed on liquid and elastic sub-grades. The analysis considers the sites where the load transmits across the joints, identifying the loading positions that result in the most critical stress and deflection situations in the pavement. The study conducted by Larralde et al. (1987) presents an estimation of the mechanical deterioration of rigid highway pavements resulting from repeated traffic loading. Erosion, fatigue, and joint faulting are identified as distinct modes of failure in rigid highway pavements within the system. A finite element analysis is utilised to investigate the non-linear behaviour of traffic-induced stresses and strains. Micro-fissures within the stiff pavement slab are noticed, leading to the eventual formation of massive localised cracks.

Chapter 3 Evaluation of Compressive Strength of Fresh Concrete and BlendedConcrete for pavement

3.1 Synopsis The addition of water to the dry concrete mixture resulted in a dramatic increase in the material's strength. Fresh concrete with complete workability is mixed at this initial time, which is referred to as 0-hr or tie at t = 0. In order to obtain the most strength out of the concrete, it needs to be prepared and placed at the proper spot without delay. The growth of the strength of the concrete mix is greatly affected by the time lag, shown as t in minutes. It is the time that elapses between the beginning of concrete preparation (at t=0) and the end of concrete placement in structural elements (at t). This type of concrete is called time lag concrete, t-hr concrete, or THC, and itwill definitely have less strength and less workability than fresh or OHC concrete. The compressive strength of setup concrete mixing with the same or higher grade of concrete, taking into account the concrete's initial and final setting time in the practical range, is well-documented in this study. Additionally, a suitable model is required to investigate the impact of intermittent curing on concrete's compressive strength and the effectiveness of pavement joints in relation to selfing and crossing theories. This is an urgent matter that has to be addressed today. By utilising theories of remix concrete, we can assess how different blend ratios and time lags affect both new and existing concrete. Also, under various time lags (e.g., 30 minutes, 60 minutes, 90 minutes, and 120 minutes), find the pavement's compressive strength, split tensile strength, flexural strength, and transverse strength. 3.2 Research Methodology Employed Below in fig 3-2 is a flow diagram depicting the process of calculating strengths for variousmix kinds, blend ratios, and curing sequences. Analytical computations are contrasted with experimental and laboratory strengths.

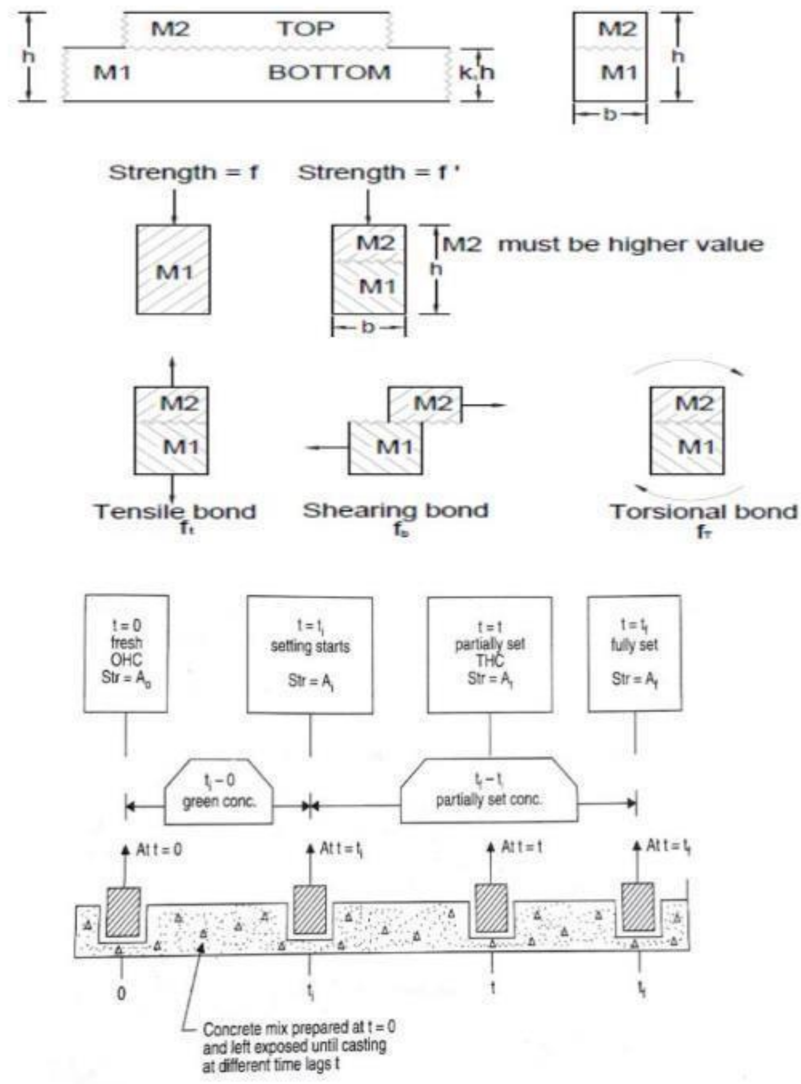

Fig. 3-1 Concept of Selfing and Crossing

3.2.1 Methodology- On a micro-scale, I Research involving experiments Concrete cube, cylinder, and beam specimens were subjected to laboratory testing for this investigation. In addition, the following tasks were supposed to be carried out. Section of concrete pavement panel tested in a controlled environment (Model Specimen) The FEM ANSYS model is covered in Section 3.2.2. Constructed an ANSYS finite element model of a stiff pavement joint section under different situations based on blend ratio and time lag. For the purpose of conducting case-specific parametric studies anddetermining model deflection and stress

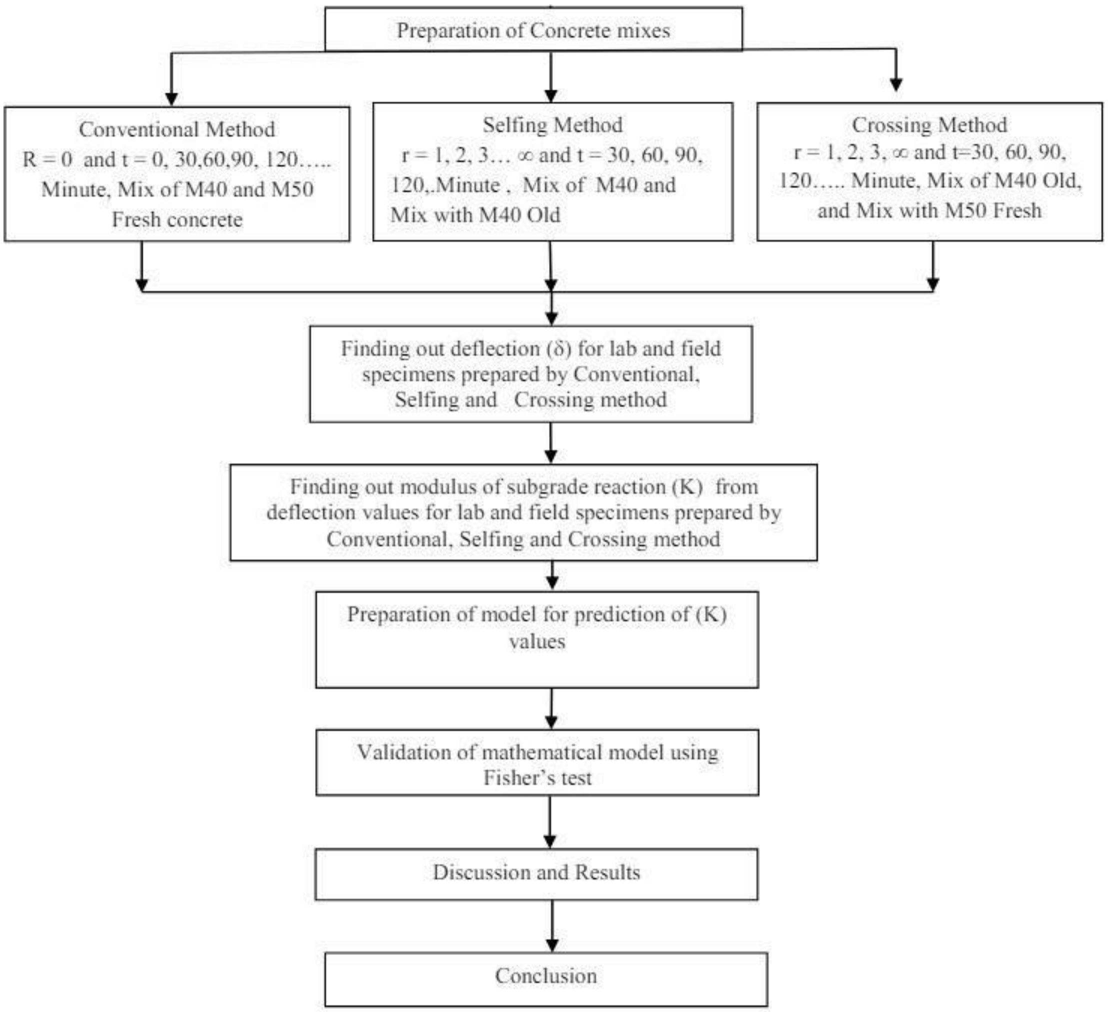

Fig 3-2 Flow chart of the methodology

3.2.3 Steps During Testing

The following were followed during testing

3.2.3.1 Testing of Materials (Cement, Fine and Coarse Aggregate, water)

Table 3-1 Characteristics of aggregates

Sr. No.	Properties of Aggregates	Normal value
1	Specific Gravity	2.78(CA) and 2.63(FA)
2	Bulk Density	1.487 kg/lit (CA)
3	Impact Value	17.64 % (CA)
4	Fineness Modulus	5.505 (CA)
5	Water Absorption	1.2 % (CA)
6	Moisture Content	37 %

Table 3-2 Characteristics of cement OPC (53 grade)

Sr. No.	Properties of cement	Normal Value
1	Standard consistency (% by weight)	29.0
2	Initial Setting Time (T_i) Minimum Final Setting Time (T_f) Maximum	58 min 420 min
3	Compressive Strength of Cement (MPa) 3 days 7 days 28 days	 28 39 56
4	Specific Gravity	3.15
5	Fineness in cm^2/gm	2673

3.2.3.2 Size and Form Are Important Characteristics of newly mixed concrete are dependent on particle size and surface roughness. In order to get high workability when working with concrete that contains elongated, rough- textured, and angular particles, more water must be added during the preparation process. Accordingly, a higher cement quantity is needed to maintain the water-cement ratio. The design of concrete grades M40 and M50 has a fineness modulus of 5.505. With the help of IS 10262 -2009 and IRC 44 -2017.

Table 3-3 Proportion of concrete mix design

	Water (Litres)	Cement (kg/m^3)	Fine Aggregates (kg/m^3)	Coarse Aggregates kg/m^3
Grade M40	155	387.5	707.84	1199.67
	0.40	1	1.82	3.09
Grade M50	165	471.42	672.55	1139.85
	0.35	1	1.43	2.42

3.2.3.4. Casting of Specimens At different time intervals (t = 0, 30, 60, 90, 120 minutes), cube, cylinder, and beam specimens made of M-40 grade concrete were mixed with M-50 grade concrete. First, there's the concrete that follows the standard, everyday procedure for making concrete. Two more varieties of concrete are ready to go; selfing concrete is the second variety, and it's made by mixing two pre-measured batches of the same grade. Thirdly, there's a variety of concrete mix types that use crossover, which involves blending two preset blends. The specimensof fresh and blended concrete joints are subjected to compressive and split tensile tests on concrete cubes, cylinders, and beams using a compressive testing machine. Also, put the beam specimen through its paces on the flexural testing machine to see how it affects flexural strength. In order to conduct this study, 124 specimens were created; the specifics of these specimens are displayed in tables 3-4. Concrete samples from the Pavement portion were tested in a laboratory setting using Cube, Cylinder, Beam, and Beam specimens. Tests on the Sample (3.3):Measurements of compressive, splitting tensile, and flexural strengths are performed on the specimens. 3.3.1 Chest Press Strength Evaluation Figure 3-3 shows the results of the compressive load test on cube samples taken using a compression testing machine with a capacity of 100 tonnes. Figures 3-6 display the average strength values obtained from testing three cube specimens cast per time lag. The goal of this study was to find out how strong concrete is employing selfing and crossing under different time lag parameters, all while keeping in mind the research area's gap. The concrete was tested at 7 and 28 days after hardening for this purpose. Figures 3-6 and 3-8 illustrate the ultimate compressive strength of cube specimens cast using the selfing process and conventionally prepared concrete, respectively, for the M40 grade of concrete.

Fig 3-3 Characteristic compressive strength test of the cube on the compressive testing machine

3.3.2 Split Tensile Strength Figures 3–4 show the results of the compressive testing machine used to measure the split tensile strength of the cylindrical specimens. We averaged the strength values of three samples at 0, 30, 60, 90, and 120 minute intervals. Figure 3.7 shows the ultimate splitting tensile strength of a cylinder specimen cast using the conventional way of casting concrete for M40 grade, while Figure 3.9 shows the same specimen formed using theselfing method.

Fig 3-4 Split tensile strength test of the cylinder on compressive testing machine

3.3.3 Strength under Flexure of a Plain Cement Concrete Beam The beam specimens were subjected to flexural strength tests utilising a flexural testing equipment with a capacity of 100 kN, as seen in figures 3-5. We averaged the strengths of three samples each batch and published the results. Figures 3-10 and 3-11 demonstrate the standard casting process for M40 grade concrete, while the flexural strength of beam specimens of each dimension is 100 mmx 100 mm x 500mm.

Fig 3-5 Flexural test of the beam on the compressive testing machine

Table 3-4 Specimen Details

<table>
<tr><th>Sr. No.</th><th>Specimens</th><th>Blend Ratio (r)= $\frac{\text{old concrete}}{\text{Fresh concrete}}$</th><th>Time Lag (in minutes)</th><th>Conventional concrete Specimens (Nos.)</th><th>Selfing Method (Nos.)</th></tr>
<tr><td>1</td><td>Cube (150mm x150mm)</td><td rowspan="3">0, 0.33, and 1</td><td rowspan="3">0, 30, 60, 90, and 120</td><td>15</td><td>36</td></tr>
<tr><td>2</td><td>Cylinder (150mm dia.)</td><td>15</td><td>36</td></tr>
<tr><td>3</td><td>Beam (100 mm x 100mm x 500mm)</td><td>15</td><td>36</td></tr>
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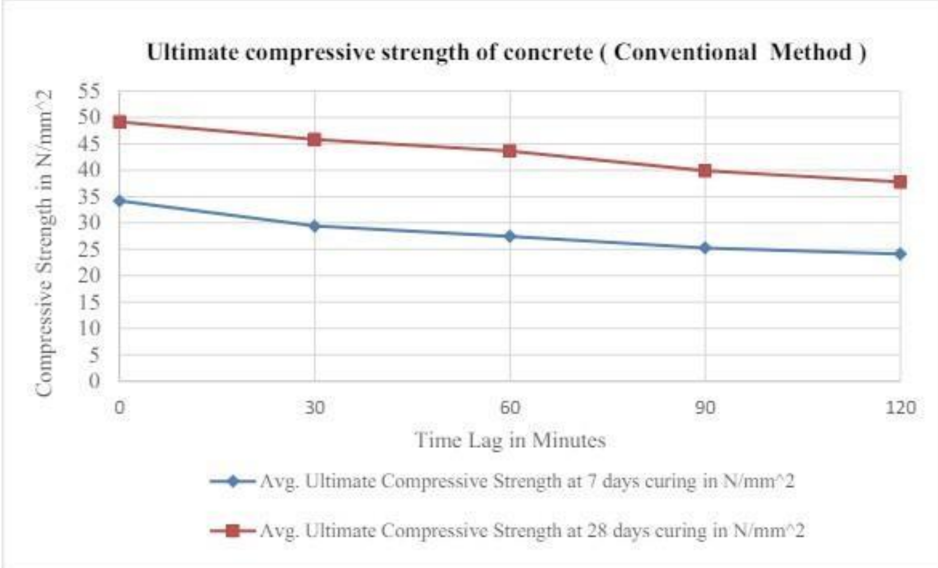

Fig. 3-6 Ultimate compressive strength of cube specimens (Type of casting: Conventional concrete).

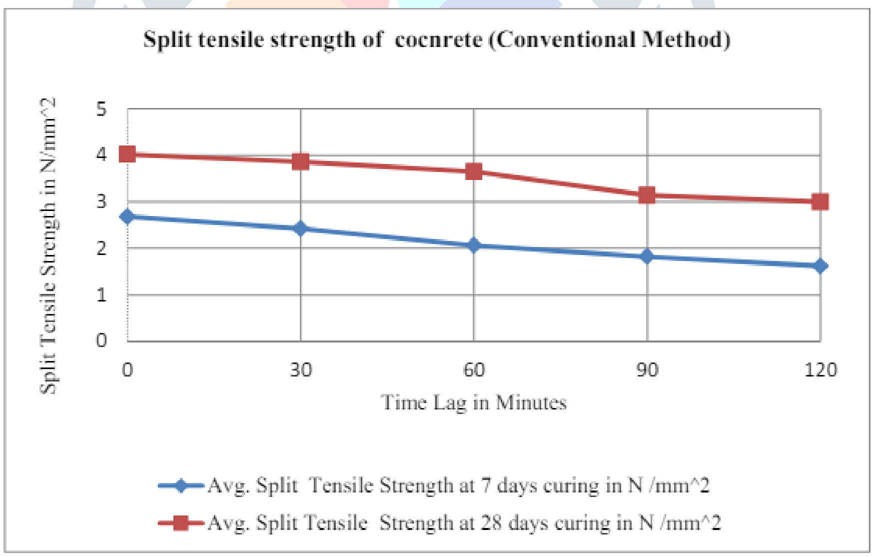

Fig. 3-7 Split tensile strength of cylinder specimens (Type of casting: Conventional concrete)

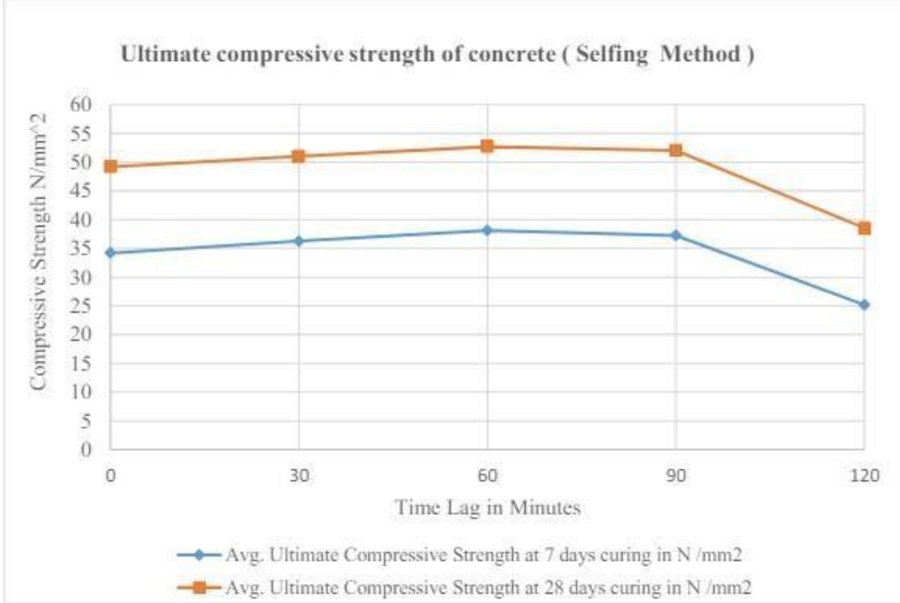

Fig 3-8 Ultimate compressive strength of cube specimens (Type of casting: Selfing method at r =1)

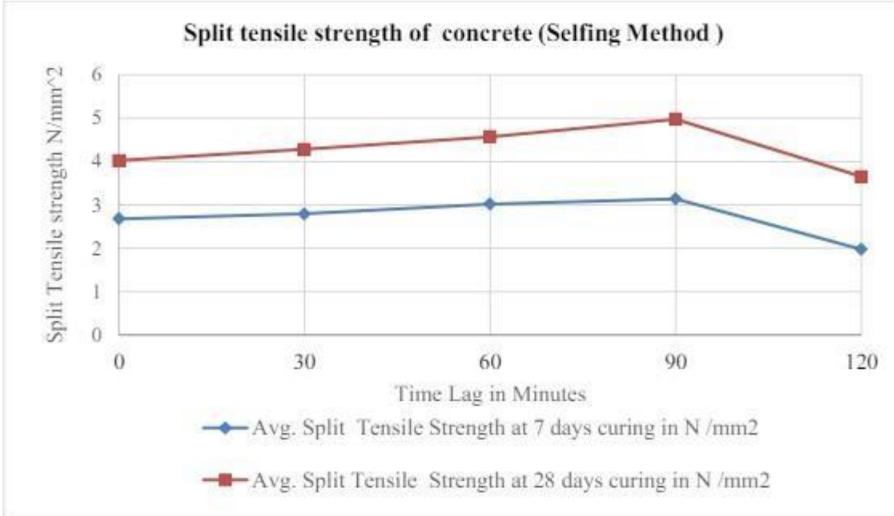

Fig. 3-9 Split tensile strength of cylinder specimens (Type of casting : Selfing method at r =1)

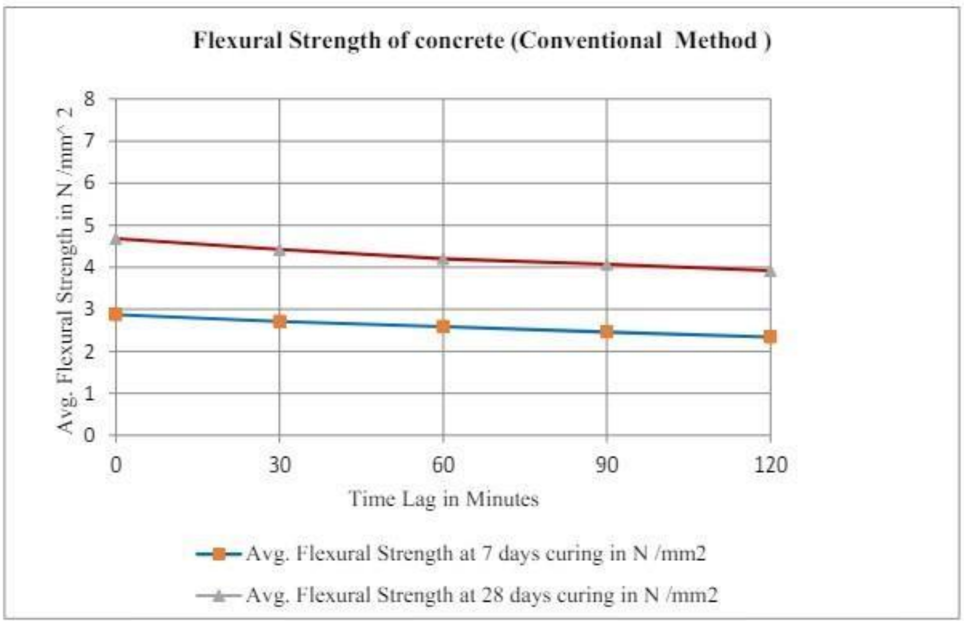

Fig. 3-10. Flexural strength of the beam specimens (Type of casting: Conventional concrete)

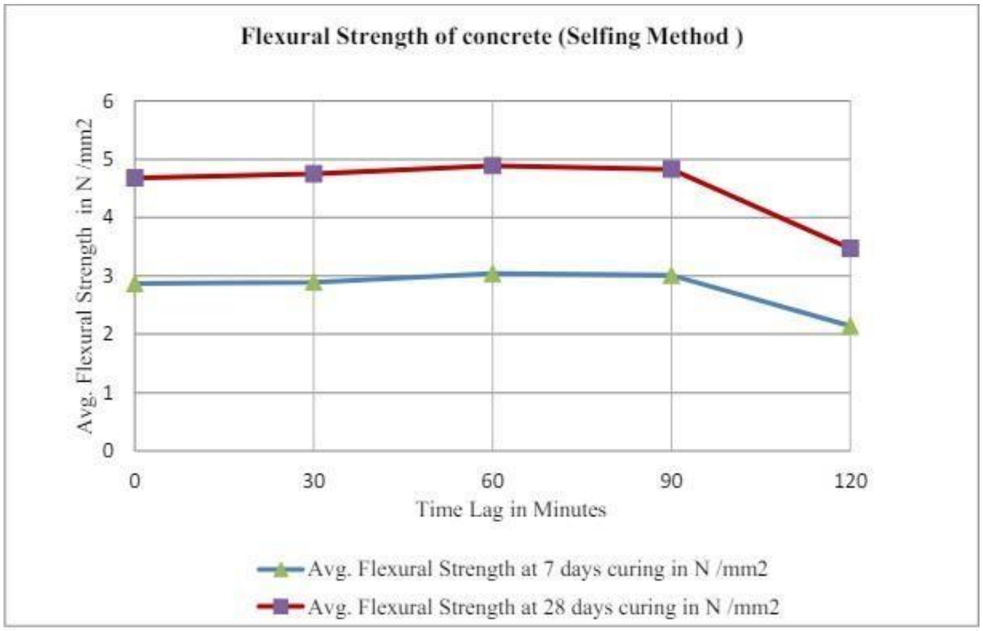

Fig. 3-11 Flexural strength of the beam specimens (Type of casting: Selfing method at r =1)

3.3.4 Effect of Selfing and Crossing Theory for Remix Concrete in a flexural component Samples of the beam were made with dimensions of 150 mm x 180 mm x 1000 mm. A 32 mm diameter dowel bar (Fe 500) with a length of 140 mm and a spacing of 300 mm c/c was supplied, and it was positioned 90 mm from the bottom. The specimens are subjected to two-point load testing on a 100-ton UTM, which measures the transverse strength and deflection of the joint pavement section. According to Hammons and Metcalf (2000), strain gauges and dial gauges can be used at joints in order to quantify deflection. section 3.3.4.1 Gauge for Strain One way to measure the amount of strain on an object is with a strain gauge. In 1938, Edward E. Simmons and Arthur C. Ruge came up with the idea. A metallic foil pattern is supported by a flexible insulating backing in the most popular type of strain gauge. Using an appropriate adhesive, like cyanoacrylate, the gauge is fastened to the item. The electrical resistance of the foil changes as the object's shape changes. A number called the gauge factor is used to link the strain to this resistance change, which is typically measured using a Wheatstone bridge.

Chapter 4.Findings and Analysis The selfing technique was used to partially set concrete at different time intervals. The results demonstrate that new concrete has higher compressive, split, tensile, and flexural strengths than old concrete (fig. 3.6 to fig. 3.11). Additionally, it has been noted that after 30 minutes, the strength of concrete that has been traditionally produced is lower than that of concrete that has been prepared utilising selfing theory, both in terms of time lag and grade. When comparing the selfing and crossing procedures to a normally cast concrete, the experimental work shows that the strength of the concrete increases as the time lag increases to 90 minutes. The typical strength of concrete in traditionally prepared concrete diminishes with increasing time lag. A crossing approach involves adding higher-grade fresh concrete to partially-set old concrete (M40 old+M50 fresh). This demonstrates that utilising the crossing approach while maintaining a constant blend ratio of r = 1 in R.C.C. increases the beam flexural strength.. When comparing concrete that is self-mixed with new concrete of the same grade with that that is made at t= 30 minutes, the strength of the latter is shown to be lower. It is possible to avoid wasting partially set concrete materials—unfit for high- quality building work—by using the selfing and crossing method to remix concrete.

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