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EXPERIMENTAL AND ANALYTICAL STUDY OF RESULTS OF BLENDED PAVEMENT CONCRETE MODELS TESTED IN LABORATORY AND FINITE ELEMENT METHOD

Vishal B Shinde[1]
Rakesh Kumar

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A B S T R A C T

To investigate the deflection, maximum stress, maximum strain, and failure of pavement joints of conventional and remix concrete pavement models. Nine model pavement slab specimens has been cast and statically loaded using hydraulic jack, load cell on loading frame assembly. Two concrete mix design grades and three concrete remixing procedures were chosen and fixed. This work checks the effect of remix concrete on rigid pavements, taking into account time lag (t in hr.) of Concrete (THC) and the blend ratio (r). The methods were a regular mixed with traditional procedures and a remix mixture with selfing and crossing methods. The results of a 3D finite element analysis with ANSYS simulation are compared to experimental trials. By adding a higher graded fresh concrete to the old and partially set concrete, there is improvement in the compressive strength, quality of the concrete, and modulus subgrade reaction, according to this study.

1. INTRODUCTION

Cement concrete pavements are recently used in many road projects in India, because they have a longer service life, require less maintenance, and provide a smooth riding surface. The current technique for laying concrete pavement on Indian roads is to place a granular base on top of the base, fill it with a dry concrete base, and then laid in concrete slab on top, known as 'rigid pavement'. Stresses in concrete pavements are not transferred from grain to grain to sub layers as they are in flexible pavement layers. The rigid pavements are built from plain, reinforced, or pre-stressed Portland cement concrete. The flexural stress on the plain cement concrete slabs is predicted to be around 40kg/cm^2. M35 and above concrete grade is used in rigid pavement for which thorough mix design is necessary. Joined plain concrete pavement, jointed reinforced concrete pavement, and continuously reinforced concrete pavements are the three varieties of rigid pavement. In recent years, ready-mix concrete (RMC) has been used in large-scale pavement construction. Due to numerous field work constraints such as transfer of concrete from RMC to specific site location taking a significant amount of time, time lag t-hr. concrete (THC > 30Min.) has passed for concrete placement, incorrect site management, work breakdown due to various reasons, and so on, Due to the delay (time t-hour) in the concreting placement on site, at a single time construction of the complete pavement stretch is

[1] Corresponding author: Vishal B Shinde
Email: shindevishal747@gmail.com

impossible. To solve this problem, the procedure of remixing concrete is employed, as well as the addition of a tiny extra amount of water if necessary, known as blend concrete, which is done on the field. Road slabs are formed by successive lugs of concrete new "cold joints" and old "cold joints". Cold joints create an unfavourable situation in concrete pavement and adversely affect compressive strength, elastic modulus, stress and strain of rigid pavement joints. The strength of concrete, elastic modulus and other qualities of concrete determine time lag (t) by Bairagi (1977). Selfing and Crossing are two remixing techniques for addressing this issue by incorporating new concrete of the same or higher grade into existing concrete. (Bairagi and ELFrnsawy 1995; Bairagi, 2009).

1.1 Effect of selfing method and crossing method of remixing of pavement quality concrete on the mechanical behaviour of cold joint.

The conventional typical concrete method is the first way of concreting that is commonly utilised in the field. The second and third techniques of remix concreting are produced, the second of which involves combining two pre-mixed concrete mixes of the same grade, a process called as ‘selfing’ concrete. The third form, which involves the mixing of two predetermined mixes, is referred to as a crossing T joint by Shinde and Kumar (2020). The pre-stiffened mixes in the composite mass under inspection have different mix quantities, water-cement ratios, and time delays as experimental variables by Bidkar and Jadhao (2019). Selfing theory and crossing theory were used to forecast the theoretical strength values, which were then compared to the actual values.

By introducing an internal source of water in lightweight aggregate, the internally cured concrete (ICC) approach is also utilised to give strengthen to concrete joints and decrease shrinkage cracking by Subgranon, T et al. (2016; 2018). By raising the workability of concrete and reducing the pre stiffening effect, the selfing and crossing methods might produce improved performance in strength at pavement joints. It is reasonable to anticipate that this will help in improving the performance of concrete at the joint location, as well as improving the strength of pavement grade concrete (PQC). However, the time lags t - hr concrete (THC) is longer than the cement first setting time and, the concrete's strength may be compromised. According to several studies, there has been a significant development in the strength.

However, because the time lag t-hr. concrete (THC) is longer than the cement's first setting time, the concrete's strength may be compromised. According to some studies, mixing existing Using a reasonable amount of fresh concrete of equal or better quality to the mortar or concrete will greatly improve the strength of the mortar or concrete. By providing a proper blend ratio, a significant number of research on hardened and fresh concrete mixes have been carried out, including the investigation of young’s modulus, compressive and tensile strength, using the idea of selfing and crossing (Shinde and Kumar, 2020). The selfing and crossing methods of a concrete remix allow a lot of flexibility in terms of preventing pre-stiffened concrete waste and are suited for using this newly prepared remix concrete to building operations.

2. OBJECTIVE

The goal of this investigation is to undertake a experimental and field testing programme to calculate the performance and check usage of remix concrete cast pavement joints under Maharashtra (India) circumstances utilising time lag and blend ratio parameters. The model pavement specimen was built and tested utilising a hydraulic jack and loading frame to apply static loading. To examine the prospective performance and functionality of joints, 3D FEA method was used. When non-linear temperature distribution is used, the temperature stresses are larger than when a linear temperature distribution is used. The performance of recycled aggregate in rigid pavement was examined for stresses and deflection induced by repeated traffic loading using the ANSYS software by Khope and Mohod (2016). Remixing technique is applied on partially set concrete, fresh concrete (Alnaki et al. 2014) and analysis of rigid pavement is carried out using ANSYS simulation tool.

The resulting results are compared to the real model that was cast. Using traditional approaches, it was extremely difficult to appropriately forecast stresses in a pavement system with discontinuities and complex support conditions. Patil et al. (2013) used ANSYS (finite element software) for the analysis (Daniel and Chairuddin, F., (2017). In this analysis solely considers the vehicle's impact load (not the moving load).The temperature varies across the thickness of the pavement slab, so the temperature effect is not taken into account in this study analysed the linear distribution of temperature across the thickness of the slab (Harle and Pajgade., 2018). The deflection seen when applying static loading is used to compute corner and interior stresses. These stresses are useful in pavement design. When compared to corner stress, edge deflection is more prominent, and it is not taken into account.The exploiting of corotational method, which uses minor deformations and elements’s big rotations, was used to account for considerable displacement. Loading conditions were validated for static ramp and step loads, sinusoidal loads, specified ground acceleration inputs, and plastic inputs by Nilaward et al. (1998) and her colleagues When compared to those generated by ANSYS by Mohd. Imran Khan et al. (2014; 2021), Westergaards equation underestimates edge wheel load stresses.

3. METHODOLOGY

We completed the project using the technique and steps outlined below.

Step 1: For conventional concrete and a combination of multiple concrete grades, analyse the stiff pavement using ANSYS software.

Step 2: Testing will be done on a casted slab specimen and a beam that has been manufactured using selfing, crossing procedures, and mix ratios.

Step 3: Experiment to determine compressive, tensile, and flexural strengths, as well as varied stress and strain values, modulus of elasticity, and strains, and compare the results with analytical results (Ansys Result).

4. FINITE ELEMENT ANALYSIS

4.1 Finite Element Failure Analysis

The Finite Element Analysis technique generates and solves a large number of simultaneous algebraic equations on a digital computer. The goal of failure analysis is to identify causes of failures so that modifications can be taken to avoid them. During the material selection, design, and processing, failure analysis addresses many of the same contributing causes to failure as product development does. Correct diagnosis requires knowledge of failure history as well as underlying causes rather than relying on a process of elimination, the reason must be found based on positive supporting evidence. Unexpected or unintentional causes or conditions are as common in the construction industry as they are in other industries. The models are prepared by mixing M40 and M50 grade concrete together to create a time lag. Two loads are applied in the centre of the long span, the centre of the short span, and 1125 mm from the centre and edge of the span of the load at various locations on the span surface. The Indian Road Congress has set a maximum legal axle wheel load of 8170kg. As a result, UDL over a shorter span is 2335kg/m, while UDL over a longer span is 3632kg/m as a result of the numerous parameter combinations, we generated 30 experiments, FEA used to validate all 30 experiments.

Experiments of RCC Pavement model:

1) **Model 1 –**Filling M40 grade of concrete in full c/s of slab and load of 2335kg/m along shorter span acting at center of longer span.

Similarly 30 nos. models were prepared at different load combinations and remixed techniques details of remixing given in figure 8 to figure 12.

4.2 Steps Carried in FEA

4.2.1. Material Data

Before starting modelling or Analysis this is very important step, in structural Analysis window, Material properties are feed in Engineering Data. Minimum required properties are Density, modulus of elasticity, and tensile yield, compressive and ultimate strength.

4.2.2. Geometric Modelling

4.2.2.1 Mesh Modelling

Geometric modelling is done using Ansys Design Modeler. First the single long member is modelled and patterned to required numbers, after that single short member is modelled and then it is patterned. In similar way dowel bars are modelled with suitable position and number shown in Figure 1.

4.2.2.2. Concrete Modeling

After mesh creation by selecting suitable plane Concrete is modeled around the mesh. As shown in following Figure 2.

4.2.3. Meshing of 3D Model

Finite element meshing of model is done shown in Figure 3.

4.2.4. Fixed Support

This is first step of applying Boundary conditions, where fixed support is applied at bottom surface shown in Figure 4.

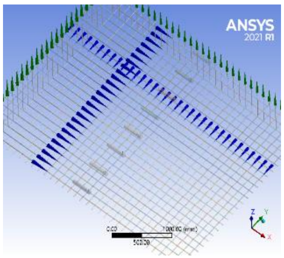

Figure 1. Mesh Modeling

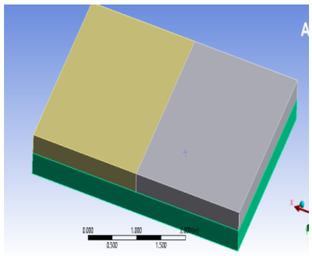

Figure 2. Concrete Modeling

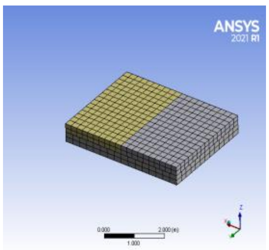

Figure 3. Finite Element Meshing

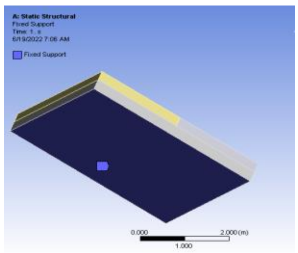

Figure 4. Fixed Support

4.2.5 Line Pressure

This is second boundary condition; the line pressure is applied at the required position shown in Figure 5.

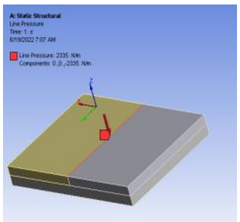

Figure 5. Line Pressure Applied

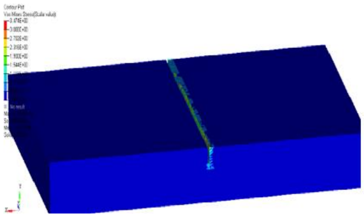

Figure 6. Equivalent Stress generated

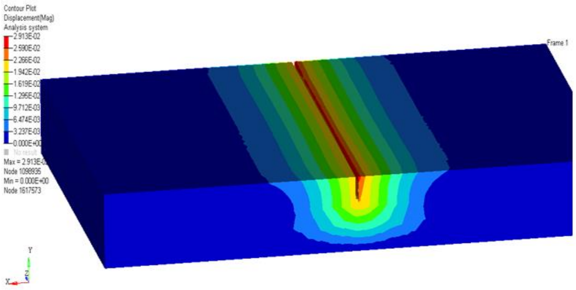

Figure 7. Total Deformation

4.2.6 Solution

After running the Ansys simulation, we get the two results as selected.

4.2.6 .1. Stress Generated

Stress generated for **Model 1 –**Filling M40 grade of concrete in full c/s of slab and load of 2335kg/m along shorter span acting at center of longer span stresses shown in Figure 6.

4.2.6.2 Deformation

Total Deformation generated for Model 1 shown in Figure 7, similarly prepared 30 nos. models and found out stresses at various loading conditions.

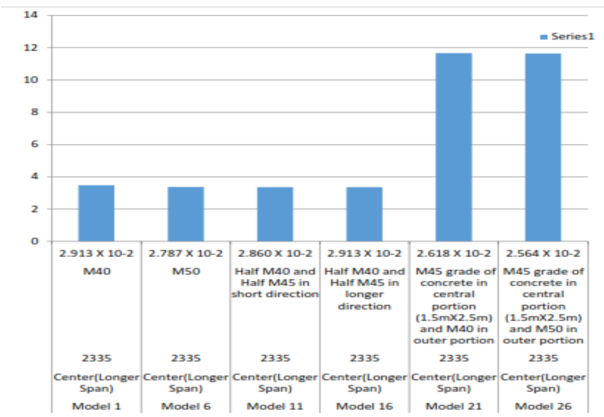

Figure 8. For models having load along shorter span acting at center of longer span

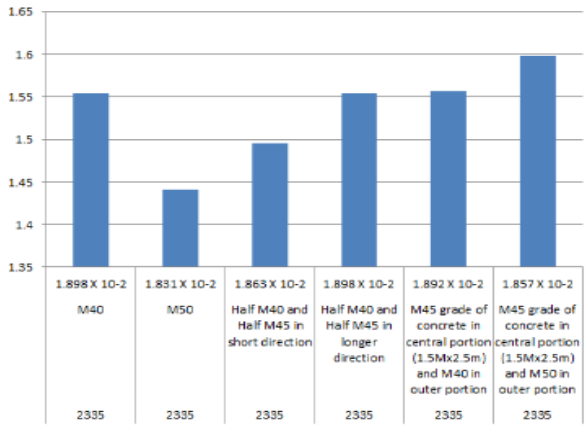

Figure 9. For models having load along shorter span acting at 1.125m from center of longer span

5. RESULT OF PAVEMENT MODELS AND VARIOUS REMIXING CONDITION AND LOADING POSITIONS

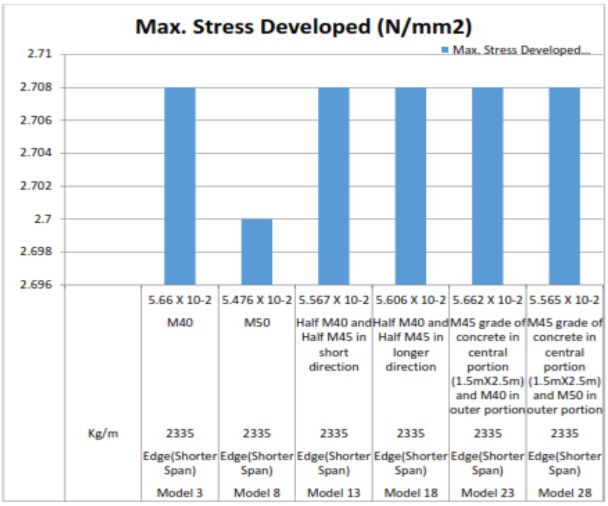

Figure 10. For models having load along shorter span acting at edge of shorter span

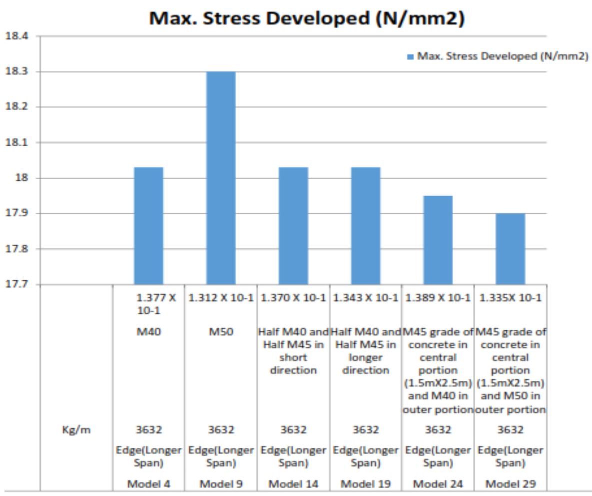

Figure 11. For models having load along longer span acting at edge of longer span

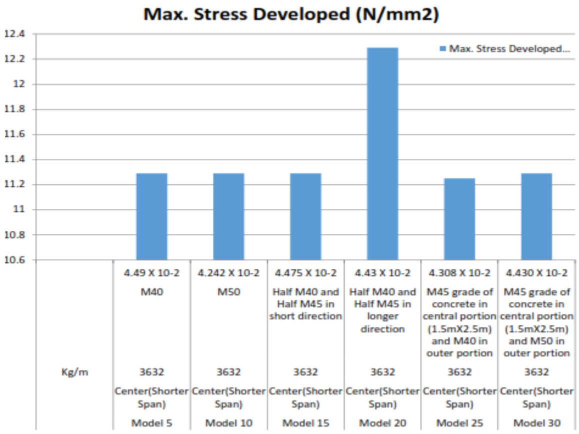

Figure 12. For models having load along longer span acting at the center of a longer span

6. LABORATORY TEST ON MODEL SPECIMENS

The laboratory work includes testing on pavement slab specimens of the size of 0.8m x1.2m x0.25m shown in figure 13 under static loading using a loading frame having a stacking edge of 1000kN limit pressure-driven jack. The 32 mm dowel bar at spacing 134mm is given at the joint location Shown in figure 14 Under bending moment and shear loading, the plate specimen forms a cold joint between the inserted dowel rods to acquire the stiffness of the dowel rods embedded in the plate. The load was applied to the shaft through a pressure-driven jack and steel plate of size distance of 300mm and thickness of 32mm shown in figure 15. Surface deflection of the substantial sections were recorded by various straight voltage removal transformers (LVDTs) shiwn in figure 16. These were on the shaft to record detours during testing. A stack outline was used to load the example with a limit of 1000 tons. Measure the strain due to stress with a strain gauge (ST).

5.1 The exploratory program

The exploratory program covers the rectangular model shaft lay on top of the compacted subgrade soil regulation box of size 1.28m × 1.3m × 1.25m.. In the static load test, the load (kN), deflection (mm), and strains are to be determined to utilize a load cell, LVDT, and strain gauges. Deflection and strain were observed and noted at the pavement specimens' centre, corner and edge.

5.2 Casting of Slab Specimens

Cast slab specimens M-40 and M-50 concrete grades at different time delay intervals. Placed strain gauges at regular intervals inner side and outer surface. The specimen numbers and sizes are given in table 1.

Table 1. Schedule of rigid pavement slab specimens for laboratory test.

Sr. No.	Specimens	Conventional	Selfing	Crossing	Total
1	3.5 m x 4.5 m x 0.25m (Full c/s of Rigid Pavement Slab model) (Model 0.8 m x 1.2 m x 0.2m)	3	3	3	9

5.3 Reinforcement details:

Reinforcement consists of dowel bars of 32mm dia., 450mm length at 250mm c/c in transverse joint and also provided tie bars of 12mm dia., 650mm length at 500mm c/c at longitudinal joints.

5.4 Laboratory Testing of PQC Pavement slab Specimen

For the slab testing events, consider pavement section to be tested at different joints condition. Prepared the M.S Square box model of size (1.10m × 1.25 m × 1 m). The box is filled with a different layer of subgrade, sub-base, and DLC& PQC.

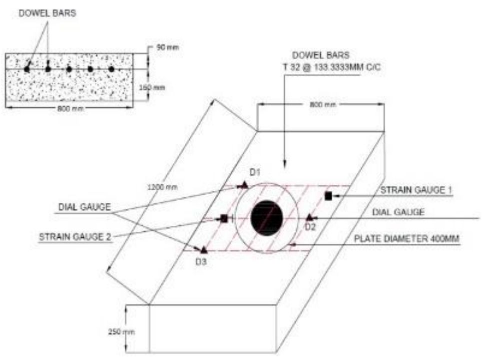

Figure 14. Details of specimen

Figure 13. Cast pavement slab specimen

Figure 15. Loading arrangements by hydraulic jack and load cell

Figure 16. Strain gauges (ST)

7. RESULTS AND DISCUSSION

Table 2. Conventionally prepared concrete slab specimen - deflection of S1, S2, and S3)

Load (kN)	Avg. at edge	Avg. at center	Avg. at edge	Avg. at center	Avg. at edge	Avg. at center
15.90	0.47	1.06	0.58	1.21	0.50	1.19
20.00	0.72	1.96	0.83	2.26	0.77	2.30
25.00	0.94	2.22	1.04	2.83	1.04	2.53
30.00	1.44	2.78	1.55	3.17	1.55	2.95
35.00	1.60	3.10	2.05	3.54	1.91	3.80
40.00	2.11	3.86	2.54	4.51	2.22	4.40
45.00	1.46	4.44	2.72	4.89	2.45	4.86
50.00	2.49	4.86	3.07	5.38	3.10	6.04
55.00	3.09	5.69	3.34	6.16	3.42	6.37
60.00	3.45	6.16	3.55	6.66	3.64	7.10
65.00	3.54	6.54	4.03	7.86	4.43	7.55
70.00	3.89	6.74	4.25	8.23	4.76	8.09
75.00	4.13	7.93	4.68	9.21	5.01	9.00
80.00	4.51	8.65	5.00	9.66	5.20	9.24
85.00	4.74	9.39	5.44	10.19	5.65	9.76
90.00	5.04	9.23	5.72	10.47	6.01	10.29
95.00	5.53	10.57	6.33	10.83	6.78	10.87
100.00	5.78	10.77	6.59	11.18	7.02	11.46
105.00	6.13	11.29	5.88	11.70	7.27	11.81
110.00	6.84	11.81	7.03	12.18	7.71	12.42
115.00	7.23	12.17	7.78	12.76	8.06	12.80
120.00	7.59	12.93	8.15	13.15	8.60	13.36
125.00	7.85	13.71	8.21	13.52	8.88	13.74
130.00	8.13	14.07	9.00	13.95	9.09	14.22
140.00	8.60	15.04	9.76	14.37	9.45	14.65
150.00	9.09	16.09	10.09	14.98	9.85	15.11
160.00	9.66	16.59	10.44	15.30	10.18	15.49
170.00	10.19	16.90	10.72	15.81	10.78	16.14
180.00	10.56	17.09	11.12	16.39	11.55	16.70
190.00	11.25	17.27	11.66	16.75	12.11	17.01
200.00	11.91	17.50	12.02	16.89	12.30	17.65
210.00	12.28	17.71	12.28	17.10	12.88	17.87

Similarly deflections of selfing and crossing specimens (S-4.S-5, S-6 and S-7, S-8, S-9) are observed using dial gauges, LVDT's and Strain gauges. The comparison between conventional specimen to selfed mass and cross mass specimen shown in figure17.

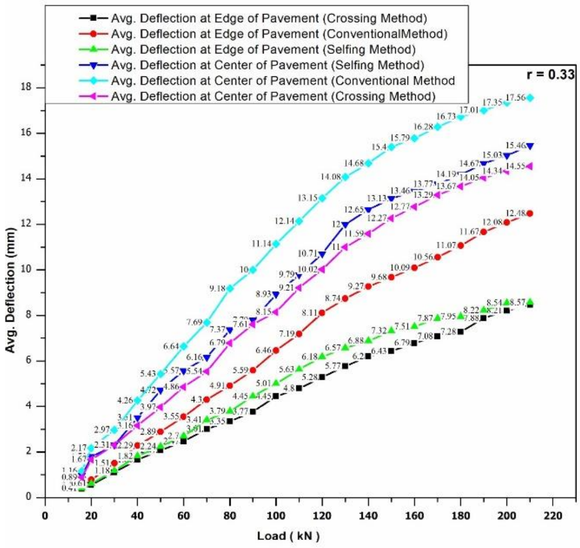

Figure 17. Average deflection vs load of pavement slab at edge and corner location

8. DISCUSSION

1. The average deflections for 40kN load applied on pavement model specimens occurred at the edge are 1.66mm in crossed mass, 1.82mm in selfed mass and 2.29mm in conventional prepared concrete mass. Similarly, the average deflection for 40kNload applied on pavement model specimens occurred at the centre is 3.16 mm in crossed mass, 3.51mm in selfed mass and 4.26 mm in conventional prepared concrete mass. From deflection and strain results, it was observed that adding a higher grade of fresh concrete to the old partially set concrete reduces deflection and improves the load-carrying capacity of joints. No cracks were observed during testing of selfed mass and crossed mass specimens up to the 70kN load, from 70kN to 150kN hair cracks were observed, and further increasing load beyond 150kN to 210kN major cracks were observed in conventionally prepared concrete Shown in figure 17.
2. Hair cracks were observed in selfing and crossing specimens during loading after 140kN load. During testing of conventionally prepared concrete specimens more deflection was observed comparatively to selfing and crossing specimens.

9. CONCLUSION

It has been discovered that when the remixing technique is used to partially set concrete at different time delay/lag, the maximum stress development increases, and the displacement value of the newly produced concrete decreases when compared to the old concrete. Strength increases when a higher grade of fresh concrete is added to the old partially set concrete (M40 old + M50 New) in a crossing method with a different blend ratio (old concrete/fresh concrete) than when the same grade of fresh concrete is added to the old partially set concrete.

The horizontal plane showed the least drop in flexure strength among the failure planes, compared to the vertical and diagonal planes. The tensile strength, stress and strain of the specimen of lower grade pavement quality concrete benefits by remixing more than those with higher grade concrete. The maximum deflection occurred at the edge of the pavement panels for all specimens prepared by conventional selfing technique and crossing technique.

The minimum deflection observed in joints prepared by crossing technique. The average deflections for 70kN load applied on pavement model specimens occurred at the edge are 3.1mm in crossed mass, 3.41mm in selfed mass and 4.30mm in conventional prepared concrete mass. Similarly, the average deflection for 70kN load applied on pavement model specimens occurred at the centre is 5.54 mm in crossed mass, 6.16 mm in selfed mass and 7.69mm in conventional prepared concrete mass.

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Vishal B Shinde
Research scholar, TEP, Department of Civil Engineering, Sardar Vallabhbhai Patel National Institute of Technology, Surat, 395007, Gujarat, India.
Shindevishal747@gmail.com
ORCID 0000-0002-4763-3855

Rakesh Kumar
Professors, TEP, Department of Civil Engineering, Sardar Vallabhbhai Patel National Institute of Technology, Surat, Gujarat, India.
krakesh1999@gmail.com
ORCID 0000-0001-7375-6376