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Behaviour of Steel Fiber Reinforced Polymer Cement Concrete Slab Under Four Point Concentrated Loading

S.Vinay Babu and N.Venkata Ramana

Abstract: This article provides the behavior of polymer two way slab under four point concentrated loading. The slab with dimension of 600x600x75mm has been tested under simply supported condition. The slab was prepared with M20 grade concrete and this concrete mix was supplemented by 10% Bethemcharla stone powder and 10%Bisphenol-A epoxy polymer. In addition those additives steel fibers were added to the mix in the proportion of 0, 1 and 2% by volume. One more mix was cast without any additives and it considers as reference mix and used for comparison of other slabs. The slabs with additives in the mix showed superior performance in strength and stiffness characteristics. From the results it found that, the slab with 2% steel fiber showed 41.30% higher strength than the reference slab.

Key words: Simply supported slab, polymer, Bisphenol-A, Stone powder, Failure loads, Energy absorption, Stiffness

I. INTRODUCTION

Polymer concrete is formed by the polymerization of monomer and coarse and fine aggregates, and sometimes in addition to those industrial waste materials also used as filler material, for the composite. The polymerized monomer possess good bond with aggregates and led to solid material, it may termed as polymer concrete. Due to rapid curing and high strength of this concrete, it is used as repairing materials for construction industry and not replaced the cement concrete perhaps it's cost is high. Many times the precast elements such as acid tanks, manholes, drains, high way barriers etc are fabricated with this polymer concrete (Raman Bedi (2013)). In order to utilize this polymer to cement concrete few studies Ohama Y (1995), Ohama Y et.al (1997), May YW et al (1986), Nawy EG (1978) and Jo YK (1995) were taken place with and without combination of hardener. O Richard Alonge et al (2017) was studied the properties of concrete with combination of metakaolin, nano silica and epoxy without hardener. From the past review it is observed that, many research works has attention to know the basic properties of concrete.

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***** Correspondence Author
S. Vinay Babu*, Ph.D Scholar, Department of Civil Engineering, JNTUA Ananthapuramu, Andhra Pradesh, India.
Dr. N. Venkata Ramana, Associate Professor, Department of Studies in Civil Engineering, VTU PG Centre, Kalaburagi, Karnataka, India.

Hence in this way the present study would like to focus on slab elements which are to be loaded under four point concentrated loads. Earlier Zaki I Mahmoud (2017), V.Showjendra Kumar Reddy (2012), C.Sashidhar and N.V Ramana (2012) and H.Sudarsana Rao et.al (2012) conducted tests on slab elements upper single point loading.

II. NEED OF THE PRESENT STUDY

From the above recent past literature it is known that, no work was appeared on slab elements with polymer material and many works has been carried out on cube, cylinder and beam specimens. In the view of waste material utilization for construction industry, most of the works has been carried out with industrial by products of fly ash, silica fumes, rice husk ash etc as replacement to cement. But few works has taken place on Bethamcharla stone powder, this is waste material in the stone polishing industry. Bethamcharla is a place in the Kurnool district of Andhra Pradesh state, India and it is well know place to layered stone. This stone is utilizing for flooring purpose in and around of Kurnool district, it is extracted from the mines and brought to stone polishing industry to make desirable polishing so that, it is marketable. During polishing stage the powder is generated along with water, it can be observed as sludge at initial stage; later this sludge is dried and dumped nearby by the factories. Day to day this becomes more in quantity and causing environment pollution. In order to minimize this problem here in it planned to utilize this powder for construction industry as replacement to cement. Initially the studies are made as replacement to cement by the present author and found that 10% replacement is optimum. By using this again the work further proceeded by the Bisphenol A epoxy polymer for the concrete mix (article was communicated to journal paper) as additive to the concrete mix. By experimental investigation it is known that, 10% Bisphenol A epoxy is optimum among various dosages of 0, 5, 10, 15 and 20% by weight of cement. The present study mainly emphasized to known the performance slab elements and the slab elements made with of stone powder polymer concrete by incorporating of crimpled steel fibers at 0, 1 and 2% by volume. The work mainly intended to know strength and stiffness characteristics of slab elements, which were tested under four concentrated loads. The materials used for this investigation are presented below

III.MATERIALS AND MIX DESIGN

For the present experimental work OPC 53 grade cement, river sand (fine aggregate conforming to Zone-II) and 20mm coarse aggregate was used. M20 grade concrete was made targeted to design and for design mix IS10261-2009 code was used. As per IS code procedure the mix proportion was arrived as 1:1.59:3.01 with water cement ratio of 0.5.Total four mixes are taken in to consideration and those are designated as RS, PC0, PC1 and PC2. The RS indicate reference slab mix, PCO mix indicate the mix with an additives of 10% Bethamcharla stone powder and 10% Bisphenol –A epoxy polymer. The PC1 and PC2 mixes refers polymer slabs with 1 and 2% of steel fibers (50mm length crimpled fibers were used and these fibers having diameter of 0.75mm). For these mixes in addition to PC0 mix materials, the fibers were added by 1 and 2% by volume of specimen. Each slab was reinforcing with conventional reinforcement of 7 numbers of 10mm diameter HYSD bars in each direction.

IV.CASTING, CURING AND TESTING OF SPECIMENS

To cast the slab specimens the slabs moulds were taken with inner dimensions of 600x600x75mm. Total for four mixes, 12 slabs were cast and three samples for each mix was considered. The materials weighed with at most care and all the materials were mixed until to get uniformity. For fiber mixes again care has taken in order to avoid the balling effect. The fresh concrete has been placed in the slab mould and vibration was applied with needle vibrator. The slabs were kept for 24 hours in the mould and later they were shifted for wet and dry curing. For wet and dry curing, specimens were exposed to 7 and 21 days under water and air respectively. During wet and dry curing times the hydration and polymerization process may function effectively. After 28 days curing the slabs were tested under four concentrated loads till to failure. The load was applied with an increment of 2kN till to reach ultimate load, during loading stage central deflections are recorded using LVDT's. The testing of slab specimen can be noticed in figure 1(a) and load deflection curves also plotted for each mix which were observed in figure 2. The detailed discussion on the test results is presenting below.

V.TEST RESULTS AND DISCUSSION

Failure loads

The failure loads obtained for different slab specimens are presented in Table 1 and from this it can be observed that the 2% fiber slab specimens show higher first crack load than the 1% slab specimens. Among the specimens, the specimen PC2 recorded maximum first crack and ultimate load of 230 kN and 520kN respectively, which are the highest among all the specimens. The percentage increase of first crack load for PC0 is 27.27% when compared with reference slab. But for slabs with epoxy and fibers the increase of first crack strength is in the range of 63.63 to 109.09%. The slab with 2% volume fraction of fibers at ultimate stage is 41.30% higher than the reference slab (RS). This indicates that the strength of slab increases with increase of fiber content in the range (0 to 2% fiber volume) of tested specimens. The strength carrying capacity of slabs specimens is in the order of RS<PC0<PC1<PC2. The percentage of increase for the PC0 slab specimen at failure state is about 36.80% when compared with RS specimen. The slabs of PC0 and PC2 at ultimate stage showed the percentage of increase of strength is 36.8 and 41.30% respectively when compared with RS.

From the above results, it is observed that, the slabs with epoxy and fibers showing good performance with respect to reference slab. The load carrying capacity trend is increasing from RS to PC2 specimen; this can be evident from the obtained results

Deflection and ductility ratio The central deflection values of various slab specimens are presented in Table 2. From this it can be observed that the central deflections of polymer slabs (with and without fibers) are more when compared with reference slab (RS). At first crack load, the specimens PC0, PC1 and PC2 show a deflection of 1.8 mm, 2.6 mm and 3.2 mm respectively. The RS shows a deflection of 1.4 mm, which is lower than all the polymer slab specimens. By observing the deflections at ultimate load of the slabs, the maximum deflection of 17.2 mm is observed for PC2 slab, which is higher than the PC0 and PC1 slabs. The PC0 and PC1 slabs specimens show a maximum deflection of 13.0 mm and 15.2 mm respectively. The Load-deflection responses obtained from the present work for all the slab specimens are plotted in Figure 2. The ductility ratio is noticed for all four slab and which were presented in the Table 1. The ductility ratio is defined as it is the ratio between the maximum deflection to deflection at first crack load. The ductility is also increasing as for the slabs in the order of RS to PC2, but the ductility ratio is decreasing. The showing of displacements is varying from slab to slab and this values is increasing from reference (11.4mm) slab to slab with 2% steel and epoxy (14mm) (it indicates the difference between ultimate deflection to first crack deflection).This indicates the mix with fiber is showing good ductility rather than the reference slab.

Stiffness

The stiffness is measured for each slab at a load of 110,140,180 and 230kN are presented in Table 2 and these loads are indicates the first crack load of RS, PC0, PC1 and PC2 slab respectively. The stiffness at 110,140 and 180kN for various slabs are decreasing, but the stiffness at 230 and ultimate load the stiffness is increased for the PC2 slab specimen. At this stage for other slabs the stiffness is in the order of decreasing, probably, the slab with 2% fiber is more effective to take the load enhancement.

Energy absorption

The energy absorption for each slab specimen is calculated by integrating the area bounded by the load-deflection curve and is presented in Figures 2. The calculated energy absorption for different slab specimens is presented in Table 3. From this it is observed that the polymer specimens exhibit higher energy absorption than reference concrete slab specimen.

If the observations made up to ultimate load, the PC2 has recorded the maximum energy absorption of 1510 Joules, which is higher than the other two slab specimens i.e. PC0 (1069 Joules) and PC1 (1458 Joules). The energy absorbing capacity increased with the increase of volume fraction of fibers to the matrix. The RS specimen has the energy capacity of 664.4 Joules which is lower than all the polymer slab specimens. If the observations made up to maximum deflection stage, similar trend was noticed. The increasing order of energy observation is 3178 to 4894 Joules and the energy absorption per unit volume is also provided for all slabs in the Table 5.6. This reflects the energy capacity of the corresponding mix; by all means it can be concluded that, the provision of polymer with and without the energy capacity increases when compared with reference mix. This increased energy absorption for epoxy slabs with fibers may be mainly due to crack-bridging, crack-deflection and fiber pull-out mechanisms that operate in the harden mix. The polymer mix without fibers also showing superior performance than the reference slab, this indicates the polymer in the mix can enact the bond between the materials of the concrete mix. Hence, it can be concluded that the polymer slab specimens showed superior performance than the reference slab specimens in four points loading

Crack pattern and bending moment coefficients

The crack pattern for all the slabs shown in the figure 1, this provides the tested slab specimens of both top and bottom surfaces. During the application of load the imitation of crack are noticed near the edges for all specimens. By increasing the load subsequently for slab specimen, the initial developed cracks were slowly widened and new cracks are formed near the already developed locations. At top surface the imprints of the loads are noticed for all specimens, the effect of imprint is more at certain location and this effect can be reflected at bottom in the form of widened crack. By taking the failure pattern for each slab with the help of yield line theory, the bending moment coefficients arrived for all slab specimens and same were presented in Table 4.In this table ‘P’ indicates the load in kN from one contact point (4P gives total load on the slab), ‘w’ indicate self weight of slab and ‘l’ indicates the effective span of the slab. By knowing these parameters it can be estimate the ultimate moment for design of slab element. In general for evaluation of moment the average moment equation can be adopted for design

Table 1: Load deflections at first crack and ultimate stages

Sl.No	Name of the slab	First Crack Load(KN)	Ultimate Load (kN)	Deflection at first crack(mm)	Deflection at ultimate load(mm)	Maximum Deflection (mm)	Ductility Ratio [col7/col5]
1	RS	110	368	1.4	3.9	12.8	9.14
2	PC0	140	460	1.8	5.1	13	7.22
3	PC1	180	500	2.6	6.4	15.2	5.84
4	PC2	230	520	3.2	6.4	17.2	5.37

Table 2: Stiffness at various loads

Sl.No	Name of the slab	Stiffness at 110 kN (kN/mm)	Stiffness at 140 kN (kN/mm)	Stiffness at 180 kN (kN/mm)	Stiffness at 230 kN (kN/mm)	Stiffness at Ultimate Load (kN/mm)
1	RS	78.57	87.5	78.26	82.14	94.35
2	PC0	68.75	77.77	72	76.66	90.19
3	PC1	61.11	66.66	69.23	65.71	78.12
4	PC2	50	60.86	66.66	71.87	81.25

Table 3: Energy Absorption

Sl.No	Name of the slab	Energy absorption up to peak load (kN-mm)	Energy absorption per unit volume up to peak load (kJ/m^3)	Total Energy absorption (kN-mm)	Total Energy absorption per unit volume (kJ/m^3)
1	RS	664.4	24.6	3178	117.7
2	PC0	1069	39.59	3325.5	123.16
3	PC1	1458	54	4232	156.74
4	PC2	1510	55.92	4894	179.03

Table 4: Moment equation based on yield line analysis

S. No.	Slab	Moment
1	RS	$M = 0.030\ wl^2 + 0.170\ P$
2	PC0	$M = 0.029\ wl^2 + 0.156\ P$
3	PC1	$M = 0.048\ wl^2 + 0.183\ P$
4	PC2	$M = 0.031\ wl^2 + 0.170\ P$
Average		$\mathbf{M = 0.034\ wl^2 + 0.169\ P}$

(a)Testing of slab

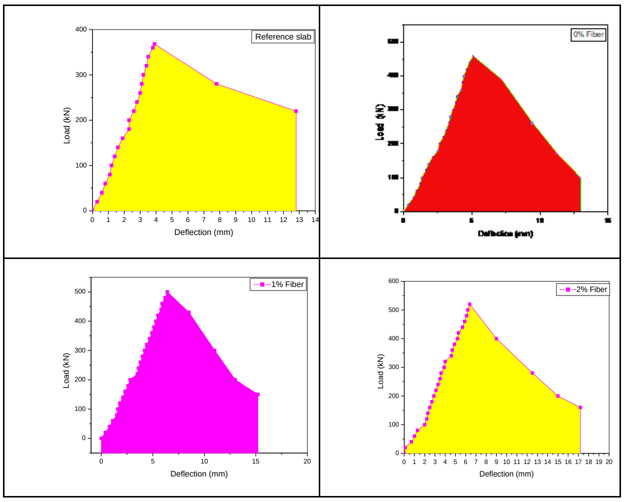
(b)Top Face of slab after failure

(c) RS slab

(d)PC0 slab

(e) PC1 slab

(f) PC2 slab



CONCLUSIONS

The following conclusions are drawn from the present study

1. The slabs with polymer cement concrete and steel fibers showed high strength than the M20 grade conventional concrete specimens (reference slab).

2. The polymer cement concrete slabs exhibit ultimate strength in the range of 460 to 520kN and maximum was noticed for 2% fiber slab specimen, which is 41.30% higher than the reference slab.

3. The slabs performance was increased in the order of PC2>PC1>PC0>RS

4. The displacement capacity of slabs was increased with increase in the fibers dosage for the polymer cement concrete slabs.

5. The energy absorption of the polymer based slabs with and without fibers was in the range of 123 to 179kJ/m^3 per unit volume and this is 4.63 to 52% higher than the reference slab (117.70kJ/m^3)

6. The crack pattern of failure samples more or less similar in view of shape .

7. The average bending moment coefficients for point load is 0.169 and 0.034 for self weight of slab.

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AUTHORS PROFILE

S. Vinay Babu,Ph.D scholar, Civil Engineering, JNTUA, Ananthapuramu, Andhra Pradesh (state), India, Email: vinaysake@gmail.com

N. Venkata Ramana, Associate Professor, Department of studies in Civil Engineering, VTU PG Centre, Kalaburagi, Karnataka (state), India, Email: rccramana@gmail.com