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ABSTRACT

Flat slab is widely constructed in modern buildings to achieve maximum space utilization. The design of flat slab system for punching shear in various Codes is based on empirical equations as the actual behavior of punching shear is still not well understood. At the same time, the practical applications of the sustainable concrete mixes in structural concrete production is also growing. Pulverized Fly Ashes (PFA) and other supplementary cementitious material are widely used in concrete to offset the cost of concrete and its environmental impacts. Limited research data is available about the punching shear capacity of the flat RC slabs, incorporating PFA. In this research four flat slab were tested such that one flat slab was cast from normal concrete with no PFA and the remaining 3 slabs were cast with 10%, 20% and 30% replacement of cement by PFA. Experimental punching shear results were compared with the nominal capacities proposed by BS 8110, BS EN1992-1-1/ EC2 and ACI 318. It was found that the estimates of ACI318 and BS 8110 for nominal punching shear capacities are close to the experimental results and the estimates of BS EN 1992-1-1 are conservative.

Keywords: flat slab, punching shear, Fly Ash, Codes

1. INTRODUCTION

Flat slab construction is commonly used in commercial buildings with medium heights and parking garages to obtain maximum headroom, reduce the material costs and ensure better spatial planning Khaled.S.R [1]. According to Desai [2], punching shear strength is the critical parameter of flat slabs and often governs the design requirement for flat slabs. Punching shear failure is the breaking of the portion surrounding a column from the rest of the slab. The high stressed zone around the column under flat slabs allows very little redistribution of stresses and as a result the load carrying capacity of the slab decreases. This can sometime leads to abrupt failure of the slab. Variety of techniques are used to avoid this failure due to punching shear, which include increasing the area of the column capital at the contact point with slab which increases area under punching, strengthening of flexural reinforcement or providing shear reinforcement .Miguel *et al* [3]. Dimitrios D. Theodorakopoulos [4}, investigated the punching shear of fiber reinforced lightweight concrete in punching shear. He worked on twenty full scale Column slab connections and observed that the addition of fibers has increased the punching shear resistance of the concrete. The ACI-ASCE joint committee 445 on Torsion and Shear has compiled extensive research on punching shear of high performance concrete slabs (subcommittee 445C), which forms of current body of knowledge on the punching shear[5]. Marko Bartolac, Domagoj Damjanović , and Ivan Duvnjak worked on the punching shear of flat slabs both with and without shear reinforcement and observed that most of the building codes, overestimates, the punching shear strength of RC flat slabs without shear reinforcement [6]. Liana L. J. Borges, Guilherme S. Melo, and Ronaldo B. Gomes [7], worked on the punching shear of flat slabs with openings and recommended to provide additional shear reinforcement in the area by extending the bars.

The design for punching is based on empirical equation adopted by various Codes. The variety of design equations and types of shear reinforcement used in flat slabs increases the uncertainty and risk about the behavior of punching shear. Mauricio P.F *et al* [8]. The thickness of flat slab is governed by the serviceability conditions and ultimate limit state. Aurelio Muttoni [9]. According to ACI-318-11 [10], the resisting shear to punching given by flat is determined as:

$$V_R = \frac{1}{3} b_0 d \sqrt{f_c'} \quad \text{(SI units: MPa, mm)}$$

$$V_R = 4 b_0 d \sqrt{f_c'} \quad \text{(U.S. customary units: psi, in.)} \qquad (1)$$

Where *d* is the average flexural depth of the slab, *b* is the perimeter of the critical section located *d*/2 from the face of the column, and *fc*' is the specified concrete compressive strength.

The research on punching shear of flat has started about five decades back. In early 1960's, Kinnunen and Nylander [11] tested a series of slabs in punching, varying amongst other parameters the amount of flexural reinforcement in the slab. However the punching shear is still an active research area in the world.

There is a general global consensus that the extensive emissions of CO_2 has led to Global Warming and resulting Climate Change. The environmental concerns about the adverse impacts of economic development and industrialization have forced the nations to explore alternate ways and means to reduce emission level of CO_2 and other poisonous gases. Concrete industry in the world is using huge amount of cement every year. The world cement production has reached at the level of 4.3 billion tones during 2014. The extensive production of cement also leads to enormous emissions of CO_2, as with every tone of cement production an equivalent amount of CO_2 is produced. The world cement industry is responsible for about 8% of the total CO_2, production [12]. The concrete producing experts are thus using many Supplementary Cementitious Material (SCM) such as Fly Ash, Silica Fumes, Rice Husk Ash, Ground Granulated Blast furnace Slag (GGBF) etc. to reduce the consumption of cement in concrete. The partial replacement of cement by SCM has reduced the cement consumption to some extent, yet there are some inherent problems associated with their uses. The researchers have, however have developed new techniques to overcome such shortcomings in the use of SCM [13]

Various mineral and chemical admixtures are used to improve the strength of concrete and punching shear strength of concrete and RC flat slabs, which include Pulverized Fly Ash (PFA), Ground Granulated Blast Furnace Slag (GGBS), Silica fumes, steel fibers , Alexander and Simmonds[8]., Naaman et al.[14], Cheng and Montesinos[15]. The addition of steel fibers to high strength concrete has raised the punching shear capacity of flat slabs, without loss of ductility. The high strength concrete in the absence of steel fibers is less ductile and the failure in such cases due to punching shear can be expected more abrupt than the normal strength concrete Zambrana Vargas [16], Azevedo [17], and Holanda [18]. Hanai and Holanda [19], studied similarities between punching and shear strength of steel fiber reinforced concrete slabs and beams. They reported that the punching behavior of flat slabs is analogous to the shear performance of the beams made from Steel Fiber Reinforced Concrete (SFRC). Fly ash has been extensively used a partial replacement to cement in concrete, firstly to reduce the cement consumption in concrete and thereby making it relatively sustainable material and secondly increasing the mechanical properties of concrete in fresh and hardened forms Malhotra and Mehta[20]. The environmental considerations of High volume Fly Ash (HVFA) and its contribution to develop green & sustainable concrete have been researched extensively. E.H. Yang, Yingzi Yang, and Victor C. Li [21]. Michael D. Lepech *et al*[22]. The understand behavior of RC concrete produced with blended cement, its application in various structural elements like beams, columns, flat slabs etc. is currently under active research. However investigation into the punching shear resistance of RC flat slabs incorporating Fly ash has been carried out in limited amount. This fact has been the major motivation behind this research.

The punching shear capacity is determined by various Codes by using the empirical equations as discussed below:

2. *Punching shear capacity according to BS EN 1992-1: 2004. Eurocode 2(EC2)*[18]

The design punching shear capacity of a flat slab is given by the expression below in EC2 [18].

VRD1 = C_{RDC} k (100ρl f_{ck}) 1/3ud/1000 kN

Where Recommended value of C_{RDC} is 0.18 and is taken according UK National Annex.

K = 1+ (200/d) 0.5 ≤ 2 d in mm (shape factor), u is the first perimeter of punching shear at a distance of 2 d from the face of the column. ρl = (ρly. ρlz)0.5 (For equal steel in both direction, this should be the same as ρst = 0.0082). ρly and ρlz relate to the bonded tension reinforcement in each direction. These should be calculated as a mean value, if the steel is not uniformly provided over a slab width of "3d" from each face of the column plus the column dimension (b), i.e. (b + 6d) for a square column.

3. Punching Shear Capacity according to BS8110 [19]

The ultimate punching shear capacity of slab without shear reinforcement and removing partial safety factor γ =1.25 is given in the equation below.

$$V_{cu}=0.27(100\rho_{st}f_{cu})\ 0.33\ (400/d)\ 0.25\ (ud/1000)\ \text{kN}$$

Where (400/d) ≥ 1 (shape factor), u = 4 x 3d + uo

In the calculation of punching shear capacity of slabs the limit of 40N/mm^2 for f_{cu} is ignored.

4. ***Punching Shear Capacity according to ACI318-11*** **[6]**

According to ACI 318-11 [5] the ultimate shear strength of slabs without pre stress is given by the following equation. V_{uo} = ud (V_n), kN

Where, u is the length of the critical perimeter taken at a distance of d/2 from the face of the loaded area. d is the effective depth in mm, V_n is the nominal punching shear strength in MPa and shall be the smallest of following values;

$V_n = \phi\ (1+2/\beta_c)\ \sqrt{f_c}/6$ or $V_n = \phi\ (\alpha_s\ d/u+2)\ \sqrt{f_c}/12$

$V_n = \phi\ \sqrt{f_c}/3$

ϕ is the partial safety or capacity reduction factor and its value is 0.75 but is ignored for the calculation of Punching shear resistance in this exercise.

Where α_s, is 40 for interior column, 30 for edge and 20 for corner column. β_c is the ratio of longest column dimension to the shorter column and should be equal to or greater than 2. $Fc^{'}$ is the concrete cylinder crushing strength at 28 days.

All the three codes have used different parameters and partial safety factors for the calculation of punching shear resistance, which affects the final results. The partial safety factors of 1.5, 1/1.25 and

0.75 are used by BS-EN 1992-1-1/EC2 [18], BS8110 [19] and ACI318 [6] respectively for the calculation of punching shear strength.

In this research, four full scale flat slabs, one cast from control mix with no fly ash and three specimen of flat slab cast from concrete with 10%, 20% and 30% replacement of cement by fly ash were tested. The result of punching shear capacity were compared with the values determined by equations proposed by EC2 [18] BS8110 [19] and ACI318 [6].

5. RESEARCH SIGNIFICANCE

The punching shear resistance of flat slabs is determined with the help of empirical equations proposed by various Codes for normal Reinforced Concrete. Limited date is available about the behavior of flyash added concrete in punching shear. In this research the fly ash concrete is used to determine the punching shear capacity of slabs and compared with the provisions of the Codes. Average mid span deflections and cracking patterns of the slabs, strains in the steel reinforcement and strain in concrete in compression are also recorded.

EXPERIMENTAL PROGRAM

5.1. Slab Specimen:

Four reinforced concrete slab specimens were tested for punching shear strength. Dimensions were the same for all slab specimens i.e. 1150 mm x 1150 mm in plan and depth of 120 mm. The specimens had a square central stub column, 200 mm x 200 mm. The results of punching shear can be better observed with large size of slab however due to limitation of the testing set up, relatively smaller flat slabs is selected. The clear span to depth ratio (a/d) comes out to 4, which resembles relatively common examples of flat slab system, where the a/d is in the range of 4-8. Each slab specimen had holes drilled for rods and the rods were connected on to the steel sections placed over the slab to hold it down. This was meant to offer reactions on the sides of a square 990 mm x

990 mm, corresponding to the nominal lines of contra flexure at 495 mm from the center of the column (0.2 L of the span) as shown in Figure 1.

5.2. Steel reinforcement:

In all four slab specimens, twelve high yield 10 mm ribbed bars were used as tension reinforcement in both directions at 100 mm centers, which gave the reinforcement ratio ρ_{st} as 0.82. With 15 mm as the clear cover, the mean effective depth "d" for the two-way reinforcement is given as 95 mm. Seven 6 mm bars were provided in each direction at 180 mm centers, as nominal reinforcement near the other face of the slab. The stub column was provided with four 12 mm high yield bars and three 8 mm links at equal centers. The reinforcement details are given in Fig.2.

5.3. Material and Mix proportioning of concrete

The details of material and mix proportioning are given in Table1.

Concrete was designed for 28 days compressive strength of 30 MPa with a margin of 5 MPa for all slab specimens, except the trial specimen which was designed for 40 MPa with a margin of 5 MPa. The design compressive strength for all the slab specimens was kept the same to check the effect of partial replacement of cement with PFA in concrete on punching shear strength performed after 28 days. The mix proportions of the slab mixes are given in Table 1. The concrete mixes used for different RCC slab specimens are summarized below.

100PC- Trial	represents the 100% PC concrete trial mix.
100PC-Control	represents the 100% PC concrete control mix.
90PC/10PFA	represents the concrete mix with 90% PC &10% PFA by weight.
80PC/20PFA	represents the concrete mix with 80% PC & 20 % PFA by weight.
70PC/30PFA	represents the concrete mix with 70% PC & 30 % PFA by weight.

Table 1 Concrete mix proportions for slab specimens

Mix	Constituent Materials kg/m³						Material Properties			
	Free Water	PC	PFA	Aggregate		W/C ratio	Density (Kg/m³)	Cube Comp Strength (MPa)	Tensile Strength (MPa)	Modulus of Elasticity (GPa)
				Coarse	Fine					
100PC-Trial	195	375	-	1220	575	0.52	2400	38.0	5.0	42.0
100PC-Control	195	325	-	1245	600	0.60	2400	35.0	5.0	41.70
90PC/10PFA	185	298	33	1204	580	0.56	2415	37.0	6.0	42.80
80PC/20PFA	180	279	70	1260	520	0.52	2415	39.0	6.0	42.20
70PC/30PFA	170	258	111	1276	560	0.47	2415	42.0	6.5	39.80

The maximum size of aggregate used in slabs was 14mm.

5.4. Testing procedure

Test arrangement is shown in Figure 1 . The load was applied upwards by means of a hydraulic jack, in equal increments of 10 kN. At each load level, deflection and the cracking pattern was recorded. Four linear variable differential transducer (LVDTs) were used to determine deflections near the column and the two supports in one direction for the calculation of average mid-span deflection.

6. RESULTS & ANALYSIS

6.1. Failure loads and estimates of punching shear capacity

Punching shear strength test was carried out after twenty eight days of casting, for all the slab specimens. Table 2 shows the experimental results of the punching shear failure loads and the nominal punching shear capacities calculated according to BSEN1992-1-1/EC2[18], BS 8100[19] and ACI 318[6]. All the slab specimens failed in the range between 240 kN and 255 kN. The difference between the punching shear resistances of slabs is about 6 %, which is negligible and It can be observed, that that the punching shear failure load for the 100PC-Control concrete mix is higher than the punching shear failure load of other slab specimens.

The punching shear failure load of 90PC/10PFA, 80PC/20PFA and 70PC/30PFA concrete slab specimens is 2 %, 6 % and 4 % lower than the 100PC-Control concrete mix.

It can be concluded from these results that partial replacement of PC PFA up to 30 % has negligible effect on the punching shear strength and can be used in flat slabs without any special design requirements unless the required compressive strength is achieved. The punching shear strength of the reinforced concrete slab is independent of the cementitious material used in the concrete and depends on the concrete compressive strength, reinforcement ratio and the shape factor as described by Park *et al* [20], Desai [2] and in different codes of practices. The use of PFA in concrete as a partial replacement of PC saves embodied CO_2 emissions and the embodied energy of concrete, thereby making it relatively green material than conventional PC.

It can be seen in Table 2 that the ratios (V_F/V) between the experimental punching shear failure load (V_F) and the failure load estimated according to BS 8110[19] (V) are between 1.04 and 1.11 with coefficient of variation (CoV) as 3.10%.

The ratios (V_F/V_{Rdc}) between the experimental failure loads and the failure loads estimates (V_{Rdc}) of EC2 (BS EN 1992-1)[18], are between 1.18 to 1.26 with coefficient of variation (CoV) as 3.20%. The ratio indicates that the Eurocode 2 [18] estimates are lower than the actual experimental results and hence the equations are conservative.

The ratios V_F/V_{uo} between the experimental failure loads and the failure loads calculated according to ACI 318 [6] are between 1.12 and 1.2 with CoV as 3.3% . From these observations it can be concluded that BS 8110 estimates for punching shear strength, are close to the real experimental punching shear strength values and the estimates of the Eurocode 2 [18] and ACI318 [6] for punching shear strength are conservative, which is in accordance with the literature reviewed.

Table 2 Experimental & Code predictions of punching shear strength of flat slabs

MIX	Strength	Punching shear strength				ACI	EC2	BS
		Experimental V_n	BSEN1992-1/EC2 V_{Rdc}	BS8110 V	ACI318 V_{uo}	V_F/V_{uo}	V_F/V_{Rdc}	V_F/V_{cpde}
	MPa	kN	kN	kN	kN			
100PC-Control	40	255	203	229	212	1.26	1.11	1.20
90PC/10PFA	40	250	203	229	212	1.23	1.09	1.18
80PC/20PFA	41	240	204	231	214	1.18	1.04	1.12
70PC/30PFA	42	245	207	233	217	1.18	1.05	1.13
Mean	40.75	247.50	204.25	230.50	213.75	1.21	1.07	1.16
CoV (%)	3.2%	2.6%	1%	0.83%	1.1%	3.20%	3.1%	3.3%

7.2 Crack Pattern:

The test arrangement is shown in Figure 3.23 with the slab specimen loaded for punching shear strength. Load was applied upwards by means of a hydraulic jack, in equal increments of 10 kN. At each load level, deflection and the cracking pattern was recorded. Before assembling the testing rig, the slab was lifted with the fork lift and its central stub column was put centrally on a wheelie trolley, which can move in every direction and then the final position of the slab was adjusted over the holes in the floor made for the rig. The steel rods were screwed in the insets of the holes in the floor after passing through the slab holes. After this, the slab was lifted on four jacks on the sides to position the main jack under the column.

The pattern of cracking in all the specimens of flat was observed and it was found similar. Initially radial cracks originate in the middle of the slab, which gradually extended to the edges. Some circumferential cracks also developed before punching shear failure. The pattern of crack development was in close agreement with the work of Chana 21]. The average crack width at the point of failure was nearly similar for all slab specimens and was in the range of 0.25 mm to 0.35 mm which is similar to the maximum crack width of 0.31 mm, recorded by Chana [21] in his research on punching shear resistance of RCC flat slabs.

The final pattern of the cracks after failure is shown for different slab specimens are shown In Figure 3 (a). The critical perimeter at which the slab failed in punching shear is shown In Figure 3 (b). It can be seen from Figure 3b, that the critical perimeter is located at a distance of about 250 mm from the center of the loaded column and it was in a similar range for the other slab specimens, which are approximately equal to 2.0d (190 mm) from the face of the column as calculated in EC2 [18].

6.2. *Mid span deflection*:

Data collected from the data logger for LVDT's was analyzed in the Excel spread sheet to calculate the average mid-span deflection. Deflections recorded by the central LVDT's were adjusted to take into account the deflection of the supports. Average mid-span deflections for different slab specimens are given in Table 3. The average mid-span deflection for all the slab specimens was between 3.6 mm and 4.7 mm. It can be seen in Table 3 that 90PC/10PFA and 80PC. The average mid- span deflection of the 100PC/30PFA concrete slab specimen is about 0.7 mm higher than the 100PC-Control slab specimen but is not considered significant with regard to design requirements. The typical punching of column in flat slab is shown in Fig. 4 and mid span deflection has been given in Fig. 5

Table 3 Average mid span deflections for various specimens of slabs.

Mixes	Average mid span deflection mm
100PC-Control	4.0
90PC/10PFA	4.2
80PC/20PFA	3.8
70PC/30PFA	4.7

6.3. Strain in steel reinforcement:

For determining the strains in the main reinforcement bars, micro measurements CEA series linear steel strain gauges were used. Strains in reinforcement were measured at the point of maximum moment near the central stub column. Data obtained from the data logger attached to the strain gauges was analyzed to get the values of strain at different levels of load applied on the slab. A relationship between the applied load and the strain in reinforcement bar at each load level is presented in Figure 6. At the initial load stages, the strain in the reinforcement bar increased with the increase of applied load. As the load approached the punching shear capacity there were irregularities in the strain distribution due to cracking.

For high yield steel used in the experiment the yield strain is equal to yield stress/ modulus of elasticity i.e. 500/200000=2500 μmm/mm. The modulus elasticity of steel is taken as 200000 MPa and the yield stress for grade 500 steel is 500 MPa. From the strain results of steel in the slab specimens it can be seen that the strain in the steel was in the range of 2500 to 3500 μmm/mm at the point of failure. It means that the reinforcement in the slab has exceeded its yield strength, and has yielded in the punching shear test. This is in accordance with the earlier research Regan [22]. At the time of failure, severe cracking and deterioration in the compression block concrete appears to have caused excessive strains in the tension reinforcement and corresponds to the excess of its yield strength. The strain value of reinforcement confirms the quality of the reinforcement bars in accordance with the characteristic strain at maximum force for class A reinforcement bars (ε_{uk}%) ≥ 2.5 given by BS-EN1992-1-1(2004). [18]

6.4. Strain in Concrete:

Strains on the compression face of the slab specimens were recorded by using the electric concrete strain gauges. Strain values were recorded at the point of maximum moment just near the central stub column where the load was applied. Strains on the concrete surface of different slab specimens at different levels of applied load are presented in Figure 7. As for the strains in the main tension reinforcement, strain on the compression face of concrete slab increased with the increase in load applied and as this reached the punching shear failure load; there were irregularities in the strain values of concrete. The strains on the compression face of the slab specimens almost all had same pattern.

It can be seen that the strain on the compression face of concrete increased with PFA level at a given applied load. Overall there is a negligible difference in the strain values of concrete for all slab specimens at the failure load and suggest no specific consideration needs to be given for their use in structural applications. The ultimate yield strain of normal weight concrete is 3500 µmm/mm according BS-EN 1992-1-(2004).[18]. It can be seen from the strain results that the compression block of concrete for the slab specimen has not reached its crushing point at failure load and confirms the failure mechanism as punching shear failure, rather than compression failure of concrete.

7. CONCLUSIONS

1. The results has shown that partial replacement of PC by PFA upto 30% by weight has no adverse effect on punching shear capacity and the mid-span deflections in flat slabs. Based on the tests carried out and the materials used, concrete containing PFA can be used in flat slab structures without any special requirements for design and the design methods and equation recommended by various Codes, for RC concrete can be used without any modification.
2. The relationship between average mid-span deflections at different levels of load applied has a similar pattern for PFA and PC concrete mixes. The average mid span deflection at the failure load for the different slab specimens was in the range of 3.6 mm for 100PC-Control specimen and 4.7 mm for 70PC/30PFA concrete slab specimen. The average mid span deflection for the slab specimen containing PFA is slightly more than the 100PC-Control slab specimen but is negligible to be considered for design considerations and also confirms the failure of the slab specimens as punching shear.
3. The pattern of cracking on all specimens was similar. Radial cracks formed in the middle of the slab, extending gradually to the edges. Some circumferential cracks developed

before punching shear failure. The average crack width at the point of failure was similar for all slab specimens and was in the range of 0.25 mm to 0.35 mm. The first crack appeared in the load range of 80 kN to 90 kN for all slab specimens. In all the slab specimens, the critical perimeter of the crack was at a distance of about 2.0 d from the face of the loaded column, which confirms the authenticity of the critical perimeter distance of 2.0 d from the face of the column, given by Eurocode 2[18].

4. There is no significant difference in the concrete strain on the compression face of the slab specimen and steel strain in the main reinforcement for different RCC slab specimens containing PFA, which is important for their use in structural applications.
5. The comparisons of punching shear capacity with the values given by various Codes, show that EC-02, has predicted the punching shear of flat slabs more accurately as compared to ACI318-09 and BS8110.

FUTURE RECOMMENDATIONS

The region of flat slab around the column represent, disturbed region (D-region) in RC concrete, where ordinary beam theory cannot be applied, hence special design and steel detailing is required in such region. This can be further investigated with the help of using Strut and Tie Modeling (STM) or any other suitable method for D-region.

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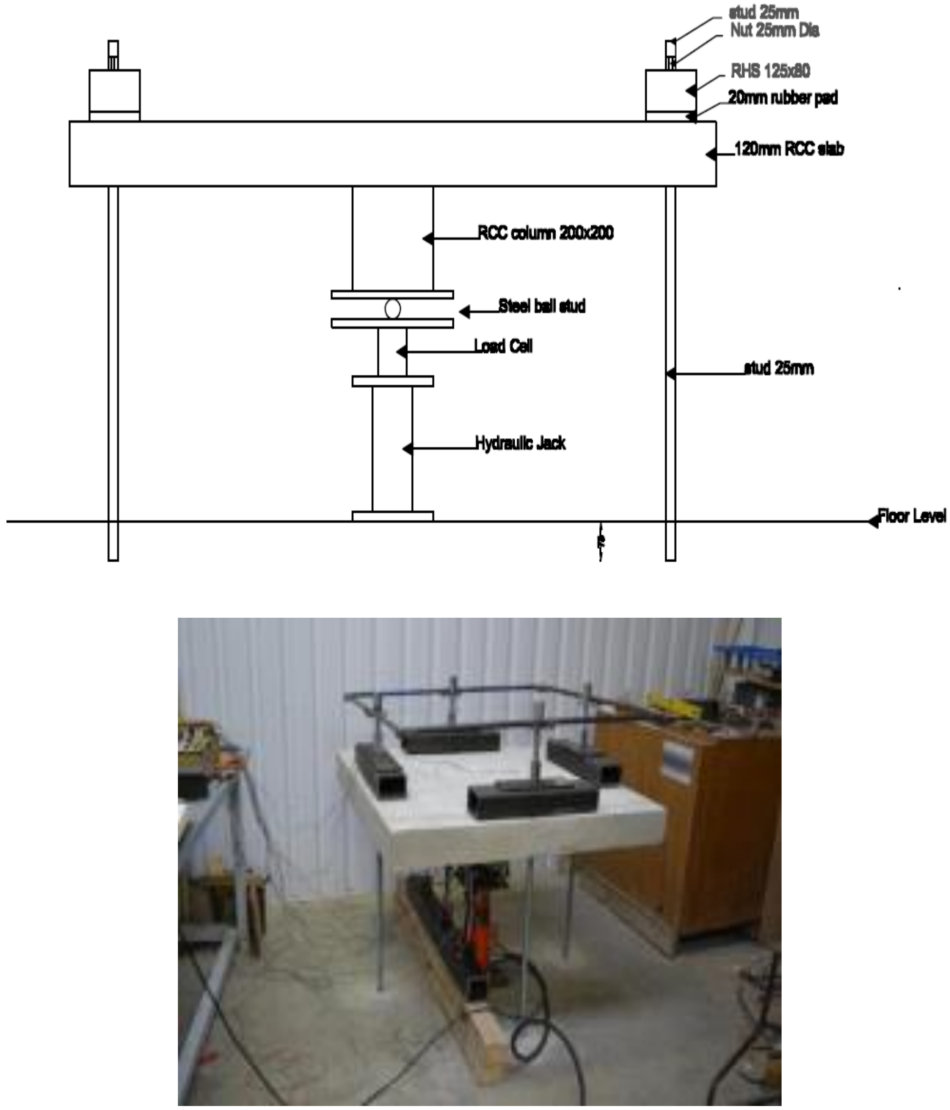


Figure 1: Schematic diagram of testing arrangements of flat slabs

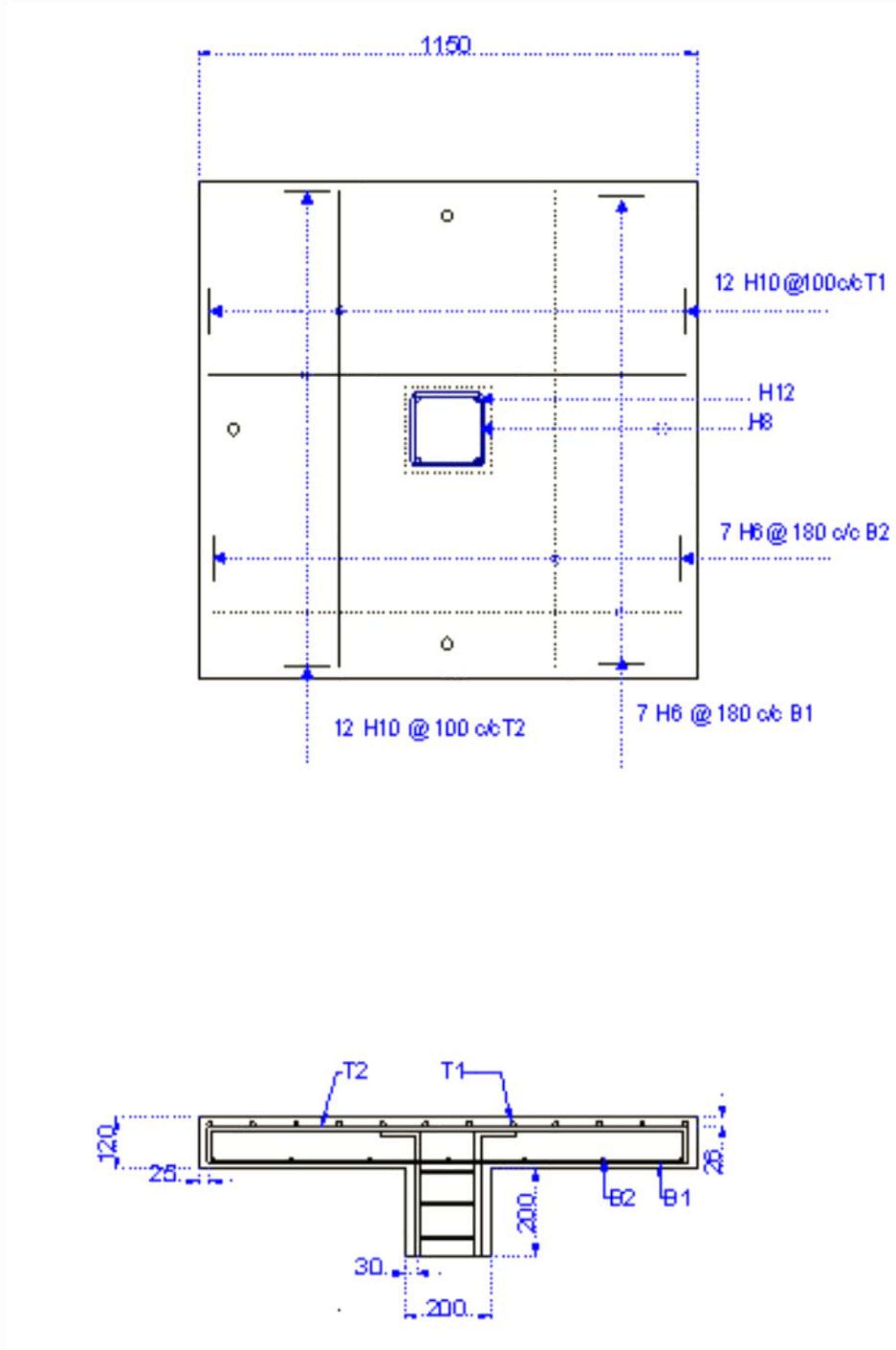


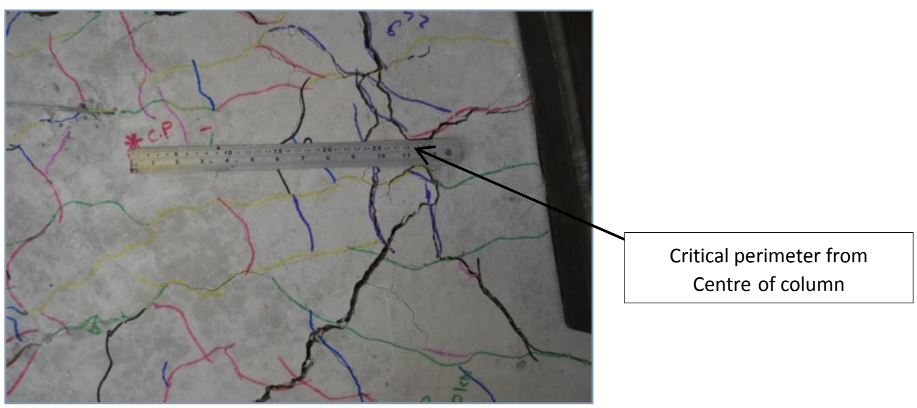
Fig 2 Reinforcement details of flat slabs.

3 a. 80PC/20PFA

3 a. 70PC/30PFA

3 c. 90PC/10PFA

3 d. 100PC



3e. Critical parameter after failure of the flat slab

Figure 3 Failure pattern of Flat slab for various mixes of Cement and Fly Ash and critical failure parameter of Flat slab

Fig 4 Punching of column in the flat slab after failure.

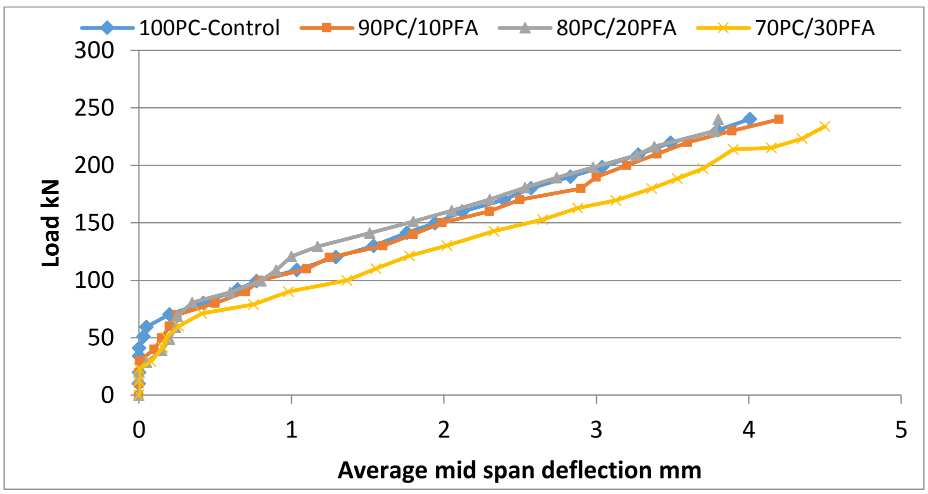


Fig 5 Mid span Deflection curves of flat slab for various mixes of concrete

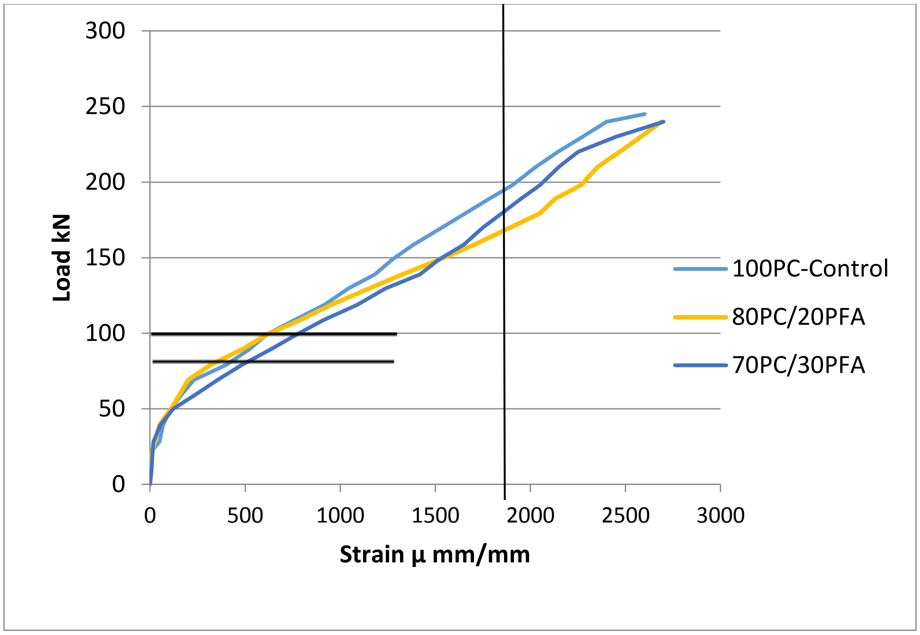


Fig 6: Strain in steel bars at different levels of applied load (µmm/mm)

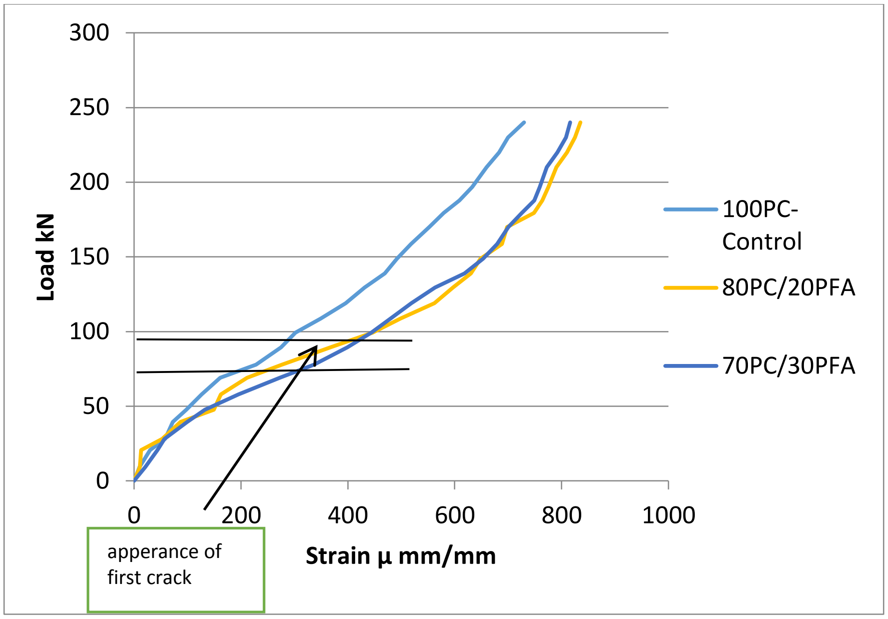


Figure 7 Strain diagram of concrete in Flat slabs.

Comments of Learned Reviewers	**Follow up**
Reviewer #1	
1- There is a relatively close research on this field entitled "Punching shear strength of steel fiber reinforcement lightweight concrete slab." The document is a PhD thesis in Sheffield University in 1980. Because the thesis is relatively close to this research, it is better to add it on the references. However, this thesis is too old.	The thesis by Dimitrios D. Theodorakopoulos at University of Sheffield (1980) studies and cited and referred in the text of revised Manuscript.
2- It was better to explain that which empirical code relations (for normal concrete) were good. Namely, the comparison between various code relations and experimental results explained.	Under conclusion SL.5, added to explain it as desired by the learned reviewers.
3- The dimensions of the slab are 1150 *1150 mm and the column dimensions are 200*200 mm. The figures of the slab at the end of failure show that the cracks extended in the entire of the slab. It seems that it was better to select bigger dimension such that the growth of cracking be stopped. Please clarify that how the dimensions have been selected.	The reason for selecting the sizes have been given in the revised draft.
4- Based of pattern of cracking around of column, is it possible to give some recommendations for reinforcement arrangement so that the cracking became minimum or crack extension be stopped. ?. Maybe this question be an idea for future investigation.	The authors agree with the learned revewer as the region around the column represent, disturbed region (D-region) in RC concrete, where ordinary beam theory cannot be applied, hence special design and steel detailing is required in such region. This can be further investigated with the help of using Strut and Tie Modeling (STM) or any other suitable method for D-region.
5- In figure 6 for comment on it, the correct word is appearance of first crack not fist crack	The word is corrected
6- Please improve the quality of figures 3 and 4 for final publish	Figure 3 and 4 improved
Reviewer 2:	
1- The literature review on flat slab column connections is limited. More recent researches should be added	More recent publications about Slab Column connections added
2- The edition of ACI 318 used, should be mentioned in text.	Added
3- The figures with higher quality should be added	Quality of Figures improved
4- The dimensions of the specimens should be presented in more detail.	Dimensions and its text improved for better visibility
5- The material properties such as concrete compressive strength and tensile yield strength of steel should be added to the paper from material tests. It helps the other researchers to use these results	Material properties added as desired
6-More discussion on the sequence of failure and yielding of reinforcements should be added to the paper.	More discussion added
As mentioned in text, the punching capacity of the connections depends on compressive strength of concrete. What is the goal of this research? The results show that concrete mix has no effect. Specially for Pulverized Fly Ash that has no improving effect on the concrete mechanical properties of concrete such as ductility and tensile strength.	Details given
Pls note that the improvements have been shown in yellow mark in the revised Manuscript	