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An Experimental Study Of Punching Shear Strength On Reinforced And Fibre – Reinforced Geopolymer Concrete Flat Slabs.

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Abstract
This research was focused on slag based geopolymer concrete with addition of steel fibre in flat slabs systems, to improve concrete properties such as flexural toughness, shear strength, impact characteristics, deflection capacity, stiffness, and concrete ductility.
In this paper investigate the effect of steel fiber ratio on punching shear resistance and cracking behavior of reinforced concrete flat slabs and geopolymer concrete flat slabs.
A total of 24 slabs were tested in this study: twelve flat slabs from OPC concrete but other twelve flat slabs from Geopolymer concrete. Volume ratio of steel fibre in concrete Vf % (0%, 1%,1.5%, 2%). Flat slab had an area of 1000 mm x 1000mm with different thickness of the slabs is assumed to be (60mm,80mm,100mm), with square column dimensions equal (100 x 100 x 300) mmat the center of the slab. The results have shown a significant increase of the punching shear strength, ultimate load capacity, energy absorption capacity, Crack pattern, mode of failure and ductility of the slabs by addition of steel fibre in concrete were analyzed here in this study.
Keywords:Geopolymer concrete, Flat slabs, Punching shear, steel fibre, Energy absorption, ductility*

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I. Introduction

Flat slabs systems are commonly used in multi-storey buildings because of saving in storey height and construction time. However, they frequently suffer from one of the major problem of flat slab is the punching shear flexure of slab column connection. this failure must be avoided.In the design of reinforced concrete flat slabs, the regions around the column always cause a critical analysis problem. Column inclines to punch through the flat slabs and footings because of the shear stresses. Due to greater uncertainty in forecasting shear failure, which is likely to occur suddenly with no advance warning of danger; therefore, shear failure, both beam and punching type considers more dangerous than flexure failure.Design codes deal with the punching failure problem in different ways. For example, Egyptian Code Practice ECP 203-2017 and American code ACI 318-14 have similar provisions for punching shear. For these codes, the critical section for punching shear is at d/2 from the column face and these codes do not account for the effect of flexural reinforcement in calculation punching shear capacity [1], [2]. While Eurocode 2-2004 considers the shear critical section at a distance of 2d from the face of column and it takes the effect of flexural reinforcement into consideration.Several previous researches are used different techniques to improve behavior of reinforced flat slabs. The following concise summary submits the main developments of previous research on the punching of flat slabs [3]. development an approach that concentrates on the mechanical properties of slabs without punching shear reinforcement at failure criteria [4]. presentation another approach that considers shear reinforcement [5]. the punching resistance of a reinforced concrete flat slab may at least be doubled with the use of suitable shear reinforcement [6]. a new form of inclined stirrups that is easy to make and to install [7]. effect of flexural and shear reinforcement on the punching behavior of reinforced concrete flat slabs [8]. The addition of ceramic fibre to plain concrete has considerably increased its properties, dynamic strength, critical strain, and energy absorption [9]. Multiwalled Carbon Nanotubes (MWCNTs) fibres in the concrete studied in the range 0.1 to 0.5% by weight and fibres are poorly dispersed and strictly agglomerated in 1% of concrete weight. MWCNT improves Young’s modulus, flexural strength, and flexural toughness by as much as 160%, 109%, and275%, respectively. It also boosted the fracture energy and increased the electrical conductivity by 194% [10]. Addition of carbon fibres in geopolymer concrete improves its electrical conductivity and the electrical resistance of concrete analysed through AC-impedance spectroscopy [11]. Impact strength and compressive strength were determined for the concrete added with carbon fibre from0% to 1% by weight of concrete. The 0.5% of carbon fiber was the optimum dosage thatperformed well in mechanical properties compared to the other ratios [12].

II. Experimental details and methodology

Materials

All materials used in this study were obtained from local Egyptian resources which are commonly used in Egyptian construction. Materials used in casting slabs were: dolomite (coarse aggregate), sand (fine aggregate), ordinary Portland cement (OPC), solid part (The Ground Granulated Blast Furnace Slag (GGFBS), and alkaline activator as a liquid part (sodium silicate (Na2Sio3) and sodium hydroxide (NaOH)), fresh water, locally accessible mild and high-tensile steel with traditional reinforcement and steel fibers.Ground granulated blast furnace slag (GGBFS) were utilized as binder materials within current study.High calcium precursor GGBFS was locally produced (from Iron and Steel Factory- Helwan, Egypt)accompanied by 2.84 specific gravity and 425 m^2/kg specific surface area.Microstructure characteristics and the particle size distribution tests of (GGBFS) were carried out with dry-dispersion laser diffraction and image analysis through the usage of Scanning Electron Microscopy (SEM). The raw powder materials physical and chemicalcharacteristicsas presented in reference[13].

In this study, steel fiber crimped typeis utilized. Thelength of the used crimped type SFis30 mm while the diameter is 1mm accompanied by crimped type cross section and60 L\d ratios. The steel fiber (crimped type) wasused at various volume fractions such as (0, 1, 1.5and 2%) and added to the optimum geopolymer concretemixture. The aggregates utilizedwithin this papercomposed of river sand and crushed dolomite. The coarse aggregate was washed for 48 h before being utilized and left to dry in order to avoid the fine materials impact. Crushed dolomite from Ataqa mountain quarry was utilizedas coarse aggregate (CA) to produce GPC.The crushed dolomite was utilizedwithin two sizes, whereas the maximum nominal dimension was 10 mm. The coarse aggregate was tested following ASTM C127 as presented in reference[13].

Slab specimens and testing procedure

A total of 24 slabs were tested in this study:twelve flat slabs from OPC concrete but other twelve flat slabs from Geopolymer concrete. Volume ratio of steel fiber in concrete Vf % (0%, 1%,1.5%, 2%). Reinforced concrete slabs with one bay were used in this study. This bay had an area of 1000 mm x 1000mm with different thickness of the slabs is assumed to be (60mm,80mm,100mm) as shown in the following Figures, with square column dimensions equal (100 x 100x 300)mmat the center of slab. Twenty-four models of concrete slabs will be tested for punching shear in this study; Three groups layouts were tested in this study, namely group1, group 2 and group 3 as shown in Figure (3).

Table 4: Details of test specimens.

Number of groups	**Slab code**	**Model name**	**Type of concrete**	**Slab dimension (mm)**	**Volume fraction (vf%)**
Group (1)	S1	S1N1	OPC	1000X1000X60	0%
	S2	S1N2			1%
	S3	S3N3			1.5%
	S4	S1N4			2%
	S5	S1G1	Geopolymer concrete		0%
	S6	S1G2			1%
	S7	S1G3			1.5%
	S8	S1G4			2%
Group (2)	S9	S2N1	OPC	1000X1000X80	0%
	S10	S2N2			1%
	S11	S2N3			1.5%
	S12	S2N4			2%

	S13	S2G1	Geopolymer concrete		0%
	S14	S2G2			1%
	S15	S2G3			1.5%
	S16	S2G4			2%
Group (3)	S17	S3N1	OPC	1000X1000X100	0%
	S18	S3N2			1%
	S19	S3N3			1.5%
	S20	S3N4			2%
	S21	S3G1	Geopolymer concrete		0%
	S22	S3G2			1%
	S23	S3G3			1.5%
	S24	S3G4			2%

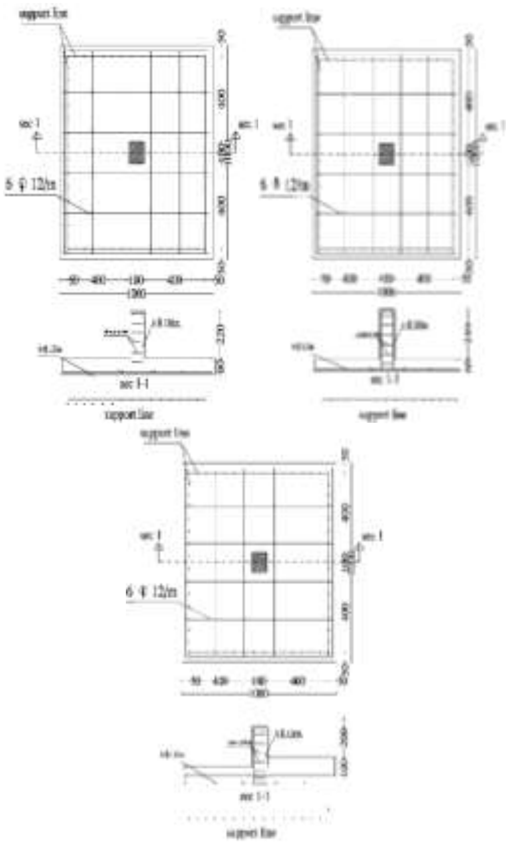


Fig3: Dimension and reinforcement of slab for group (1,2,3)

III. Test setup

Tests were carried out in the Faculty of Engineering, Fayoum University's Concrete Research and Material Properties Laboratory. A very rigid steel frame consisting of horizontal and vertical.

All slabs were tested under center point load. The load was applied monotonically in displacement control mode at a rate of 0.015 mm/sec. A vertically oriented hydraulic actuator connected to a steel reaction frame was used for application of the load to the slab specimens. All slabs tested were simply supported along four edges. Linear Variable Displacement Transducers (LVDTs) were placed under the slab in mid-span to monitor the deflection. At each load level, vertical deflection and crack patterns on the bottom surface of all slabs were recorded.

Test procedures of mechanical performance.

The hardened state experiment was conducted for analyzing the impact of steel fibre combination on the geopolymer concretes mechanical performance (flexural, splitting tensile and compressive strength). At curing of 7 and 28 days, a compressive strength experiment was conducted on 100 x 100 x 100 mm cubes dimensions according to ASTM C39 standard. However, the flexural strength (10 x10 x 50) and the splitting tensile (10 x 20 cm) tests were conducted on beam and cylindrical specimens, respectively at 28 curing days. For each mix triple specimens were tested and the results which were illustrated for indirect flexural and tensile tests are the average of three samples of each mix. Two types of mixing designs were used in this experimental study, first for Ordinary Portland Cement concrete slabs and other for geopolymer concrete slabs.All the mixes were carried out in a 320 pan mixer. The mixing time and procedure of all the mixes were constant, as far as possible, throughout the mixing period to ensure consistency. All the dry materials were first mixed together before any liquid was added. The sand was added first followed by the binder (slag) and then the coarse aggregate (dolomite). The alkaline solutions and additional water were added separately to the mix. The exact mixing procedures are given in the following sections, Mixes without fibres and Mixes with fibres.

Figure(4). shows the Casting of experimental modeled GPC and OPC Slabs and Table (5&6) shows the specified mix content weights.

Fig4:Casting of FRGPC and OPCC slabs

Table (5):shows the specified mix content weights of (OPCC).

Mixture	cement Kg	water	C.A Kg/m^3	F.A Kg/m^3	SP %	SF1
1	450	225	907	790	3	0
2	450	225	907	790	3	1
3	450	225	907	790	3	1.5
4	450	225	907	790	3	2

Table (6):shows the specified mix content weights of fibre reinforced geopolymer concrete(FRGC).

Mixture	Slag Binder Kg/m^3	Na_2SiO_3 Lit.	NaOH Lit.	C.A Kg/m^3	F.A Kg/m^3	Molarity	SP %	SF1
1	500	187.5	62.5	907	790	12	3	0
2	500	187.5	62.5	907	790	12	3	1
3	500	187.5	62.5	907	790	12	3	1.5
4	500	187.5	62.5	907	790	12	3	2

IV. Curing method of the geopolymer concrete.

Following the concretes production, the surfaces of casted specimens were coated by polyethylene film for the prevention of water evaporation and minimization of the carbonation impact. After that the specimens were hardened for 24 h at the room temperature. Afterward, the samples were demolded and stored before conducting the test in an ambient temperature curing room accompanied by a controlled temperature of 27 to 30

°C. Identical three specimens were formed for each test and the average results of the corresponding test was determined.

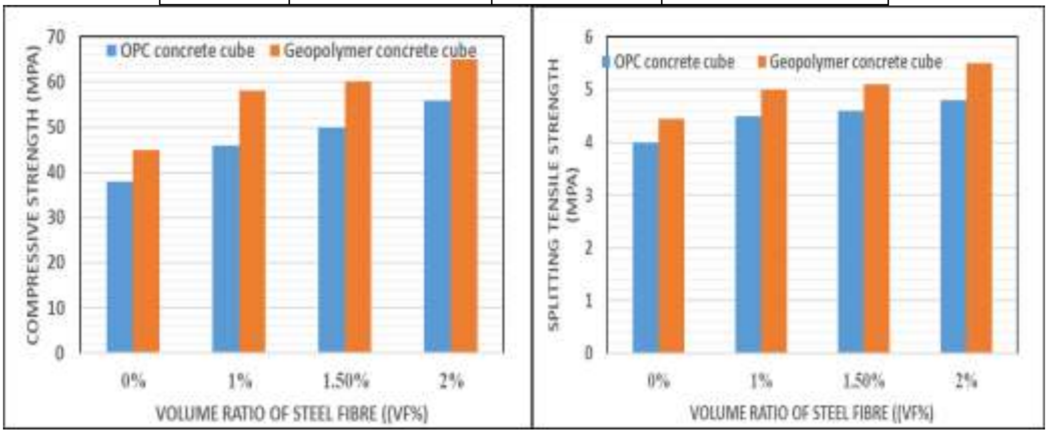
V. Results and discussions

Cubesandcylindersresultsanalysisand discussions.

The results of the mechanical properties tests of the cubes and cylinders are provided on **Table (7)** and **Figure (5)**. from which it was apparent that the compressive and tensile strength of FRGPC is relatively higher than that of OPCC, where 2% steel fibers recorded the highest compressive and tensile strength values.

Table (7): Mechanical Properties of cubes and cylinders

Type of concrete	Volume Ratios of steel fiber (Vf%)	Compressive Strength (MPa)	Splitting tensile strength (Mpa)
OPCC	0%	38	4.00
	1%	46	4.50
	1.5%	50	4.60
	2%	56	4.80
FRGPC	0%	45	4.45
	1%	58	5.00
	1.5%	60	5.10
	2%	65	5.50



a) Compressive Strength at 28 days **b) Splitting Tensile Strength at 28 days**

Fig 5: Mechanical Properties of cubes and cylinders

The results of the punching shear strength tests to the FRGPC and OPCC slabs.

Table (8): The experimental results of slabs.

Number of groups	Slab code	symbol	Type of concrete	Slab dimensions(mm)	Volume fraction (vf %)	cracking stage		Failurestage		Ductility index (Id)	Apsorbed energy (N. mm)	% Improving ratio in using geopolymer concrete P Cr	% Improving ratio in using geopolymer concrete P ult	% Improving ratio in Absorbed energy	% Improving Effect of adding steel fibre P Cr	% Improving Effect of adding steel fibrePult	% Improving Effect of adding steel fibre in Absorbed energy	StiffnessP/D (KN/mm)
						Pcr (KN)	Dcr (mm)	Pult (KN)	Dult (mm)									
Group (1)	S1	S1N1	OPC	1000X1000X60	0%	29.26	0.72	96.05	17.73	24.52	7694.46	………	………	………	………	………	………	5.42
	S2	S1N2			1%	43.11	0.97	108.41	16.55	17.15	8397.21	………	………	………	47.35	12.88	9.14	6.55
	S3	S1N3			1.5%	45.13	1.19	110.95	15.05	12.65	8451.97	………	………	………	54.25	15.52	9.85	7.37
	S4	S1N4			2%	49.44	1.26	112.36	12.85	10.17	8736.90	………	………	………	69.00	16.99	13.55	8.74
	S5	S1G1	Geopolymer concrete		0%	41.08	1.27	118.80	16.66	13.16	9184.85	40.42	23.70	19.37	………	………	………	7.13
	S6	S1G2			1%	52.81	1.81	127.53	15.32	8.45	9681.65	22.51	17.64	15.30	28.56	7.35	5.41	8.32
	S7	S1G3			1.5%	54.05	1.96	129.13	14.53	7.41	9723.73	19.78	16.39	15.05	31.58	8.70	5.87	8.89
	S8	S1G4			2%	59.07	2.03	130.10	12.35	6.10	9889.85	19.48	15.80	13.20	43.80	9.52	7.68	10.53
Group (2)	S9	S2N1	OPC	1000X1000X80	0%	61.91	1.19	133.48	11.23	9.47	10550.59	………	………	………	………	………	………	11.89
	S10	S2N2			1%	74.03	1.27	158.24	12.16	9.61	13833.77	………	………	………	19.57	18.55	31.12	13.01
	S11	S2N3			1.5%	87.52	1.19	185.61	13.56	11.39	15447.09	………	………	………	41.37	39.06	46.41	13.69
	S12	S2N4			2%	104.56	1.17	188.26	13.66	11.68	15806.89	………	………	………	68.88	41.04	49.82	13.78
	S13	S2G1	Geopolymer concrete		0%	70.03	1.31	179.11	11.77	8.98	14234.51	13.12	34.19	34.92	………	………	………	15.22
	S14	S2G2			1.0%	83.73	1.34	189.70	12.35	9.19	14804.21	13.11	19.89	7.02	19.57	5.92	4.01	15.36
	S15	S2G3			1.5%	86.24	1.32	210.32	13.15	9.97	15107.88	-1.47	13.32	-2.20	23.15	17.43	6.14	15.99
	S16	S2G4			2.0%	95.63	1.35	220.45	13.52	10.01	15324.75	-8.54	17.10	-3.06	36.56	23.09	7.66	16.31
Group (3)	S17	S3N1	OPC	1000X1000X100	0.0%	104.15	0.89	185.66	5.89	6.60	15172.08	………	………	………	………	………	………	31.52
	S18	S3N2			1.0%	121.30	0.97	244.25	7.30	7.53	18846.73	………	………	………	16.47	31.56	24.22	33.46
	S19	S3N3			1.5%	127.92	1.06	292.35	8.69	8.20	19728.58	………	………	………	22.83	57.47	30.04	33.64
	S20	S3N4			2.0%	145.65	1.08	312.45	9.13	8.45	20838.64	………	………	………	39.85	68.30	37.35	34.22
	S21	S3G1	Geopolymer concrete		0.0%	116.83	0.70	273.40	8.30	11.91	18955.64	12.18	47.27	24.94	………	………	………	32.93
	S22	S3G2			1.0%	134.07	0.75	332.42	9.68	12.91	20770.48	10.53	36.10	10.21	14.76	21.59	9.58	34.34
	S23	S3G3			1.5%	141.12	0.76	356.24	9.92	13.05	21050.36	10.32	21.86	6.70	20.79	30.30	11.06	35.91
	S24	S3G4			2.0%	158.39	0.79	380.12	10.50	13.29	21580.98	8.75	21.66	3.57	35.57	39.04	13.85	36.20

Cracks and failure mode.

For all specimens in the three groups of slabs,punching shear failure was occurred in all the tested slabs as shown in Figure (6), Figure (7) and Figure (8). For all test slabs group (1,2 and 3), the first crack is observed over the surface of column area at almost constant load which is about ranging from(30-145.6) KN for OPC concrete and (41.1 -158.39)KN for GRFC .this behavior is referred to reach the concrete tension strength at the tension fibers side of the specimen .nevertheless, the behavior changes after the appearance of the first flexural crack, as the load increase the cracks widened and extended towards the slab support but with different speed. In general, the failure occurred at different loads and different shapes, but the loud sound at the failure is common in all groups of specimens. Slabs without steel fibre failed in brittle manner on the other hand, slabs with steel fibre failed in more ductile manner. it noted that increasing steel fibre ratio (vf%) decrease cracks and also increase thickness of the slab decrease cracks in test slabs.

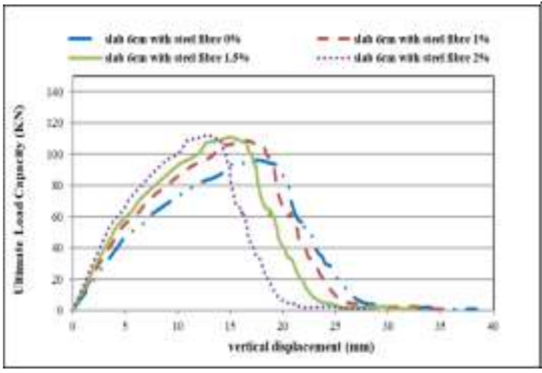
Fig 6: crack pattern of the tested slabs for group (1).

Fig 7: crack pattern of the tested slabs for group (2).

Fig 8: crack pattern of the tested slabs for group (3).

Load - deflection response of group (1) slabs.

The results in Table :8 andFig (10, 11 ,12 and 13) for fibre reinforced OPC concrete slabs show that the tested specimen S4 has higher value of peak load with other specimens in two stage crack and failure. The peak load increased by adding VF% from 1% ,1.5% and 2% of steel fibre to OPC concrete slabs increased the peak load value in cracking stage (Pcr)as shown 29.26 KN,43.11 KN,45.13 and 49.44 KN for slabs S1,S2,S3 and S4 but the peak load value in failure stage (Pult)as 96.05 KN ,108.41 KN,110.95KN and 112.36 KN for the same slabs (S1,S2,S3 and S4). In the same time The deflection increasing at the cracking stage (D cr) as shown 0.72mm ,0.97mm, 1.19mm and 1.26 mm for slabs S1, S2, S3 and S4 but the deflection value decrease in failure stage (D ult) as 17.73 mm ,16.55 mm ,15.05 mm and 12.85 mm for the same slabs (S1, S2, S3 and S4).for reinforced geopolymer concrete slabs (FRGC) show that the tested specimen S8 has higher value of peak load with other specimens in two stage crack and failure. The peak load increased by adding VF% from 1% ,1.5% and 2% of steel fibre to reinforced geopolymer concrete slabs(FRGC) increased the peak load value in cracking stage (Pcr)as shown 41.08 KN,52.81 KN , 54.05 KN and 59.07 for slabs S5,S6,S7 and S8 and also the peak load value increased in failure stage (Pult)as 118.80 KN ,127.53 KN,129.13 KN and 130.10 KN for the same slabs (S5,S6,S7and S8). The deflection increasing at the cracking stage (Dcr)as shown 1.27mm ,1.81mm, 1.96 mm and 2.03 mm for slabs S5, S6, S7 and S8 and the deflection value decrease in failure stage (Dult) as 16.66 mm, 15.32 mm, 14.53 mm and 12.35 mm for the same slabs (S5, S6, S7 and S8).



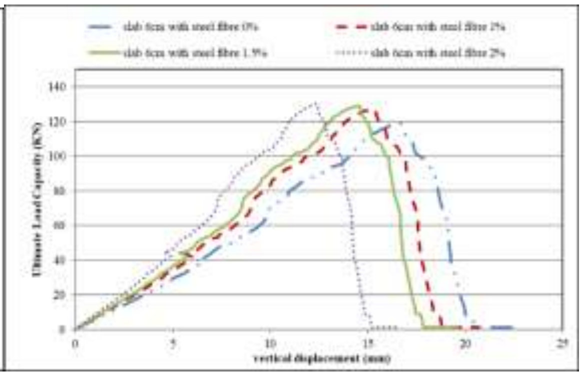
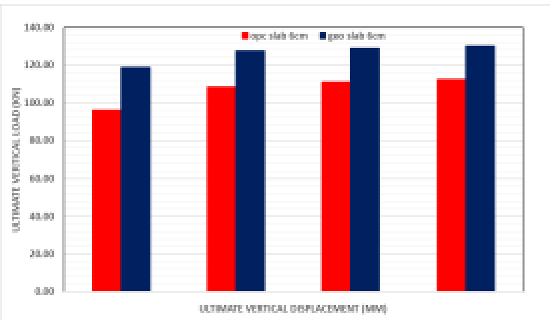


Fig10:Load – deflection curve for OPCC group(1) **Fig11: Load – deflection curve for GFRC group(1)**



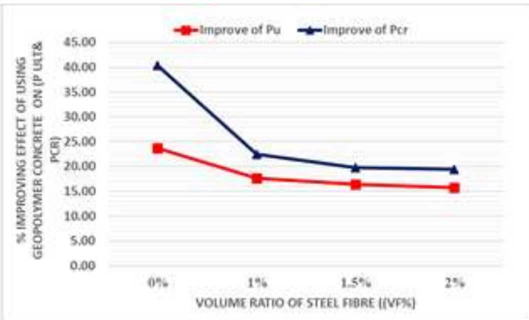
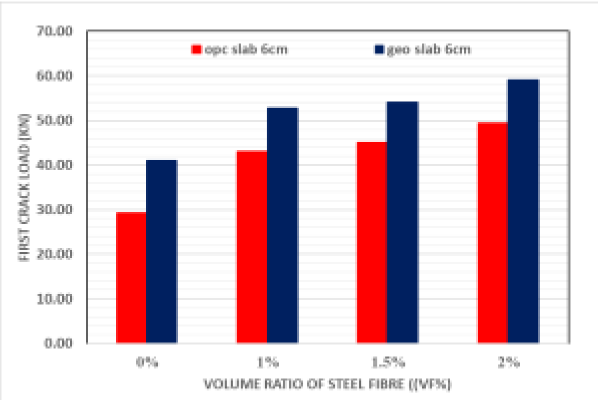


Fig12: Load – ultimate vertical displacement curve Fig 13 : % improving effect of using (GRFC)on Pult &Pcr .

Effect of geopolymer concrete on behaviour of punching capacity of slabs for group (1).

Table (8)and Figures (14&15). illustrated that Adding Steel fibres increased the first crack load for OPC concrete slabs (Pcr) by 47.35%,54.25% and 69% respectively relative to ultimate load for OPC concrete slabs and the first crack load for geopolymer concrete slabs (Pcr) by 28.56% ,31.58% and 43.8% respectively relative to ultimate load for geopolymer concrete slabs.

Table (8)and Figures (16&17). illustrated that Adding Steel fibres increased the ultimate load for OPC concrete slabs (Pult) by 12.88%,15.52% and 16.99% respectively relative to ultimate load for OPC concrete slabs and the ultimate load for geopolymer concrete slabs (P ult) by 7.35% ,8.70% and 9.52% respectively relative to ultimate load for geopolymer concrete slabs.



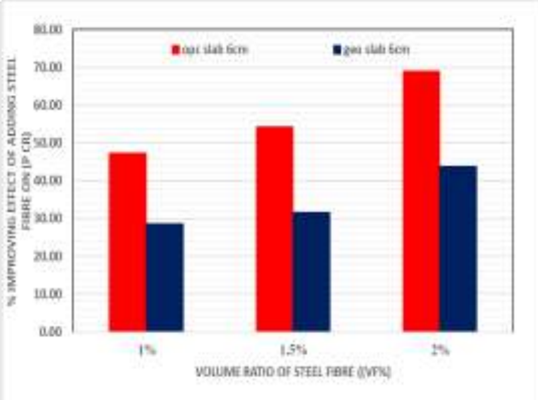
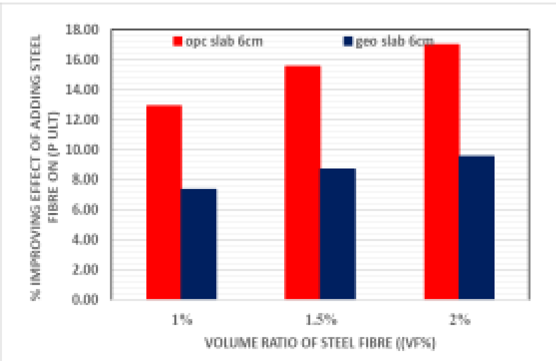


Fig 14: Effect of using (GRFC)on Pcr for slabs. Fig 15 : %Improving effect of adding steel fibre(%vf) on Pcr .



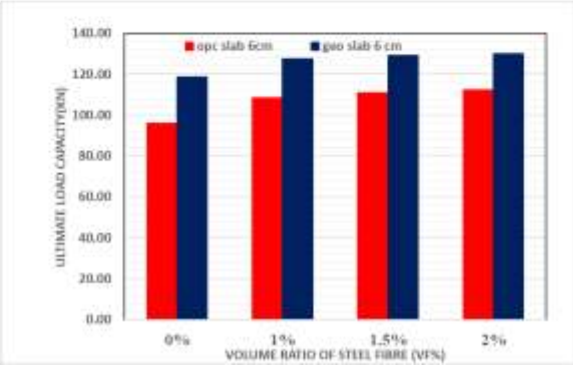
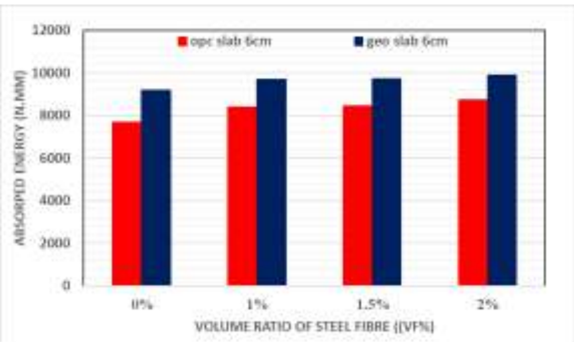


Fig 17: %Improving effect of adding steel fibre(%vf) on Pult.Fig 16: Effect of using (GRFC)on Pult.

Energy absorbed and ductility for group (1).

Table (8) and Figures (18&19). illustratedthatthe absorbed energy for all specimens improved by using geopolymer concrete by 19.37%, 15.3%,15.05 % and 13.20% respectively. Additionally, increasing the volume ratio of steel fibre improved the strain energy for all specimens slabs by 9.14%,9.85% and 13.55% (OPCC) and 5.41%,5.87% and 7.68% (geopolymer concrete slabs) respectively. From all results it is concluded that increasing the aspect ratio of steel fibre increasing the strain energy.

Figure (20). illustrate that the ductility decreases by addition steel fibre ratio for OPCC slabs and GRFC slabs. Figure (21). Show that stiffness increases by increasing steel fibre ratio (vf %)



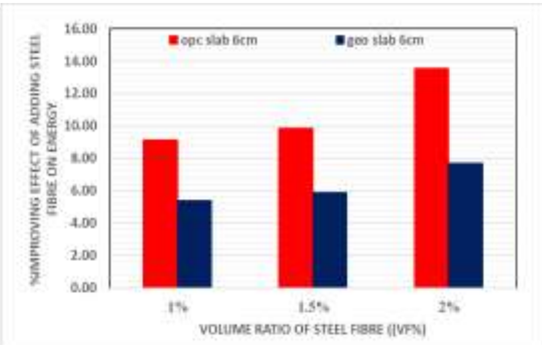
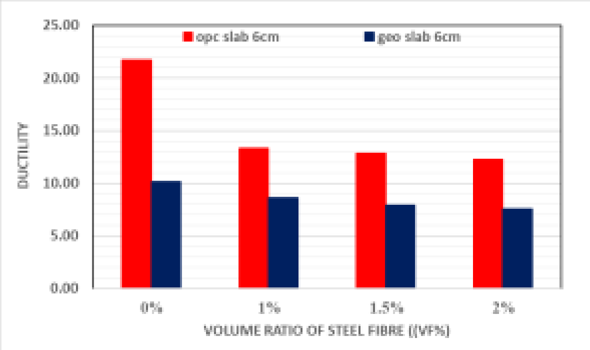


Fig 18: Absorbed energy of slabs for group (1). Fig 19 : %Improving effect of adding steel fibre(%vf) on energy for slabs.



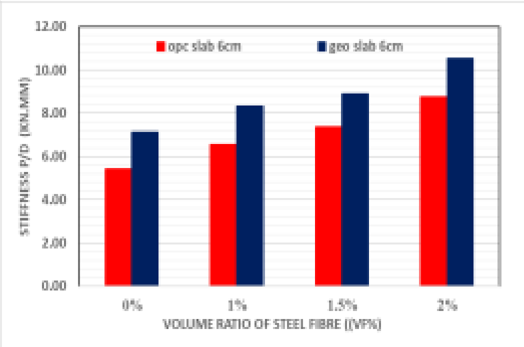


Fig 20: Measured ductility of slabs for group (1).Fig 21: Measured stiffness of slabs for group (1).

Load - deflection response of group (2) slabs.

The results inTable (8)Figures (22&23). for fibre reinforced OPC concrete slabs show that the tested specimen S12 has higher value of peak load with other specimens in two stage crack and failure. The peak load increased by adding VF% from 1% ,1.5% and 2% of steel fibre to OPC concrete slabs increased the peak load value in cracking stage (Pcr)as shown 61.91 KN,74.03 KN,87.52 KN and 104.56 KN for slabs S9,S10,S11 and S12 but the peak load value in failure stage (Pult)as 133.48 KN ,173.78 KN,185.61KN and 188.26 KN for the same slabs (S9,S10,S11 and S12).

In the same time the deflection increasing at the cracking stage (Dcr)as shown 1.19 mm ,1.27 mm, 1.19mm and 1.17 mm for slabs S9, S10, S11 and S12 and the deflection value in failure stage (D ult) as 11.23 mm ,12.16 mm ,13.56 mm and 13.66 mm for the same slabs (S9, S10, S11 and S12).

The results in Figures (24&25). for reinforced geopolymer concrete slabs (FRGC) show that the tested specimen S16 has higher value of peak load with other specimens in two stage crack and failure. The peak load increased by adding VF% from 1% ,1.5% and 2% of steel fibre to reinforced geopolymer concrete slabs(FRGC) increased the peak load value in cracking stage (Pcr)as shown 70.03 KN,83.73 KN , 86.24 KN and 95.63KN for slabs S13,S14,S15 and S16 and also the peak load value increased in failure stage (Pult)as 179.11 KN ,189.70 KN,210.32 KN and 220.45 KN for the same slabs (S13,S14,S15and S16). The deflection increasing at the cracking stage (Dcr)as shown 1.31mm ,1.34 mm, 1.32 mm and 1.35 mm for slabs S13, S14, S15 and S16 and the deflection value in failure stage (Dult) as 11.77 mm, 12.35 mm , 13.15 mm and 13.52 mm for the same slabs (S13, S14, S15 and S16).

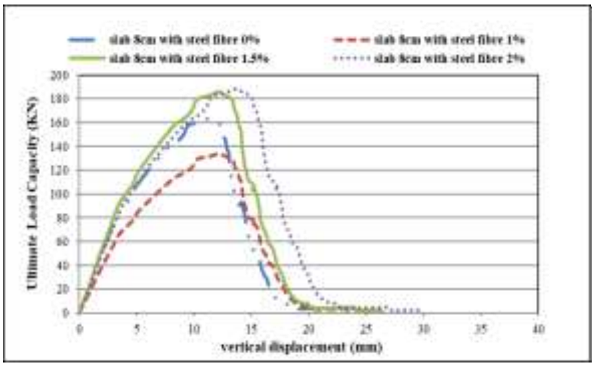
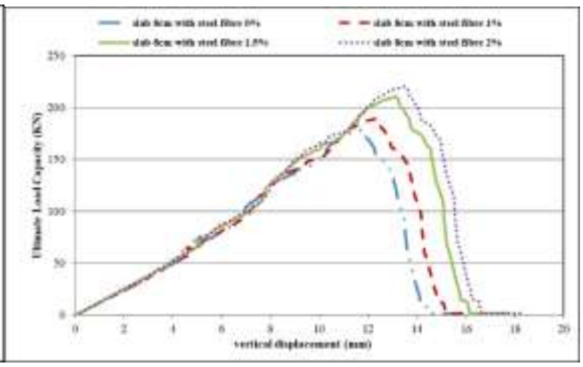
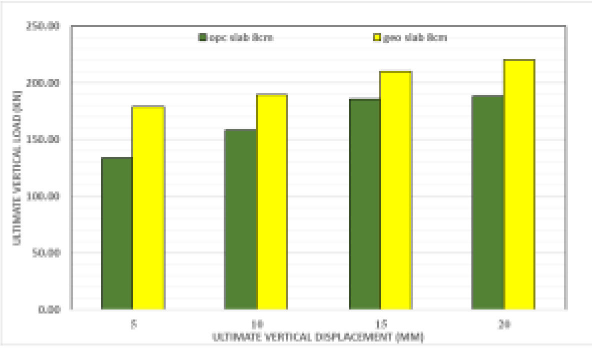



Fig 22: Load – deflection curve for OPCC for group (2). Fig 23: Load – deflection curve for GFRC group(2)



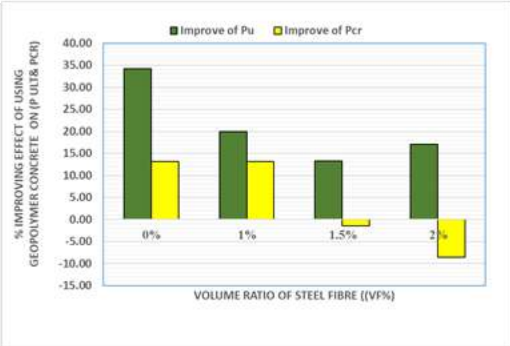
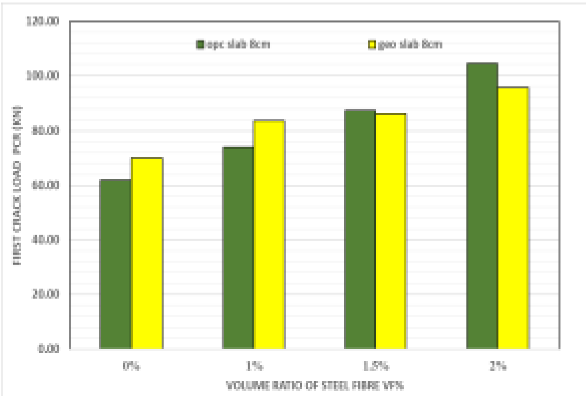


Fig 24: Load –displacement for OPCC and FRGC.Fig 25: % improving effect of using (GRFC)on Pult &Pcr.

Effect of geopolymer concrete on behaviour of punching capacity of slabs for group (2).

Table(8)and Figure (26). Presented that adding 1 %, 1.5% and 2% of steel fibers caused to the percentage of improvement in the first crack load for both OPC concrete slabs and geopolymer concrete slabs (FRGC) more than the percentage of improvement in the ultimate load capacity for OPC concrete slabs and geopolymer concrete slabs.Table(8) and Figure (27). illustrated that Adding Steel fibres increased the first crack load for OPC concrete slabs (Pcr) by 19.57%,41.37% and 68.88% respectively relative to ultimate load for OPC concrete slabs and the first crack load for geopolymer concrete slabs (Pcr) by 19.57% ,23.15% and 36.56% respectively relative to ultimate load for geopolymer concrete slabs.Table (8) and Figure (28). illustrated that adding Steel fibres increased the ultimate load for OPC concrete slabs (P ult) by 18.55 %,39.06 % and 41.04 % respectively relative to ultimate load for OPC concrete slabs and the ultimate load for geopolymer concrete slabs (P ult) by 5.92 % ,17.43 % and 23.09 % respectively relative to ultimate load for geopolymer concrete slabs.



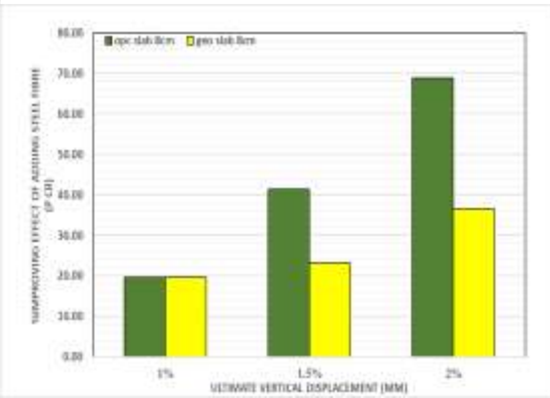
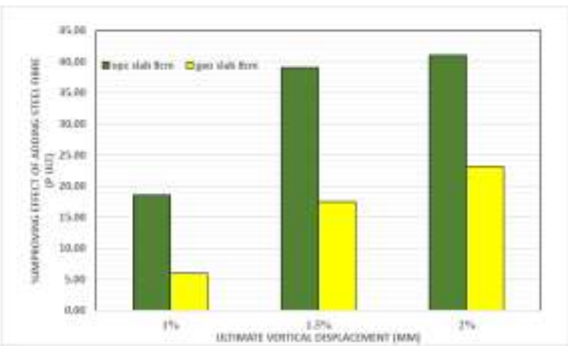


Fig 26: Effect of using (GRFC)on Pcr for slabs. Fig 27:%Improving effect of adding steel fibre(%vf) on Pcr for slabs.



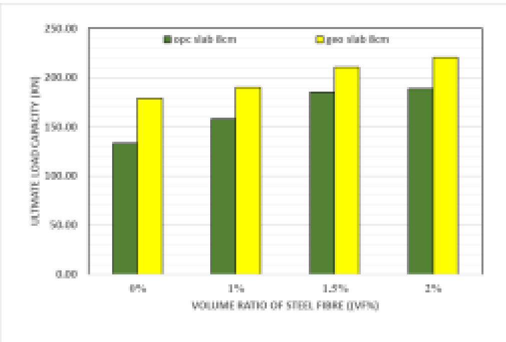
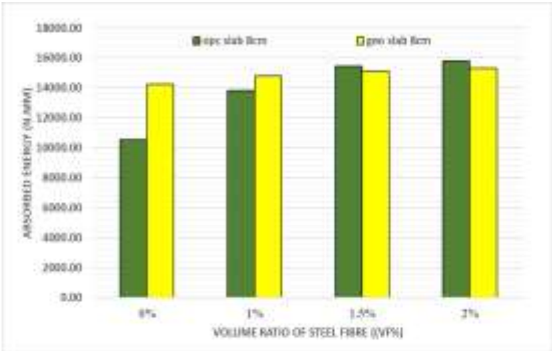


Fig 28: Effect of using (GRFC)on Pult for slabs. Fig 29: %Improving effect of adding steel fibre(%vf) on Pult for slabs.

Energy absorbed and ductility.

Table (8) and Figures (30&31). illustrated that the absorbed energy for all specimens increased by increase the percentage of steel fibre (vf %). Additionally, increasing the volume ratio of steel fibre (vf %) increases the percentage of improvement in the strain energy for all specimens' slabs by 31.12 %,46.41 % and 49.82 % for

(OPCC) and 4.01%,6.14% and 7.66% for (FRGC) respectively. From all results it is concluded that increasing the aspect ratio of steel fibre increases the strain energy but the percentage of improvement for OPCC slabs is higher than Percentage of improvement for FRGC.



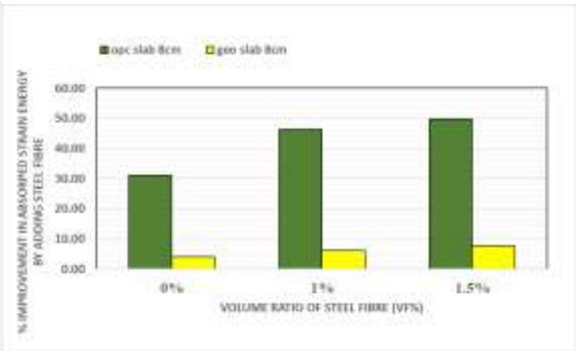
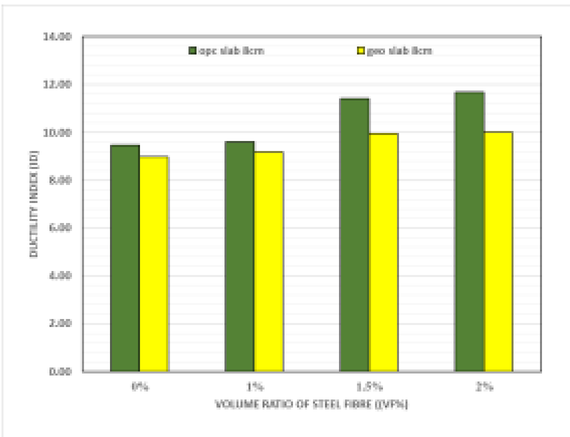


Fig 30: Absorbed energy of slabs for group (2). Fig 31:%Improving effect of adding steel fibre(%vf) on energy for slabs.

The ductility ratio of tested slab specimens is calculated as shown in Table :8It concluded from this table, that the increase in ductility is 9.47,9.61,11.39 and 11.68 for OPCC slabs and 8.98,9.19,9.97 and 10.01 for FRGC slabs.

The Initial stiffness of the test specimens was calculated from the load–deflection curves and summarized in Table (8) and Figure (33). stiffness increase by increasing steel fibre ratio (vf %) as follow, (11.89 kn/mm,13.01 kn/mm,13.69 kn/mm and 13.78 kn/mm) for OPCC slabs (S9, S10,S11 and S12) as (15.22 kn/mm,15.36kn/mm , 15.99 kn/mm and 16.31 kn/mm) for FRGC slabs (S13,S14 , S15 and S16) .



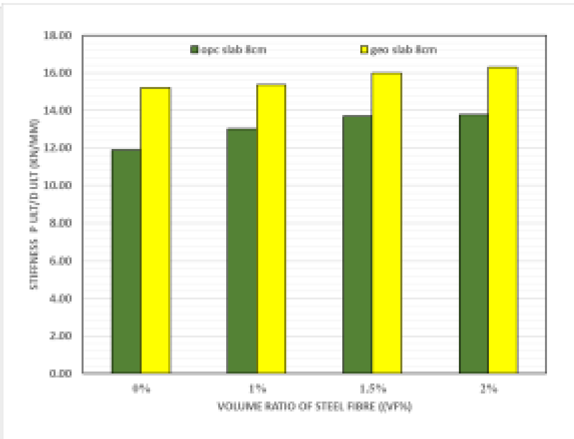


Fig 32: Measured ductility of slabs for group (2).Fig 33: Measured stiffness of slabs for group (2).

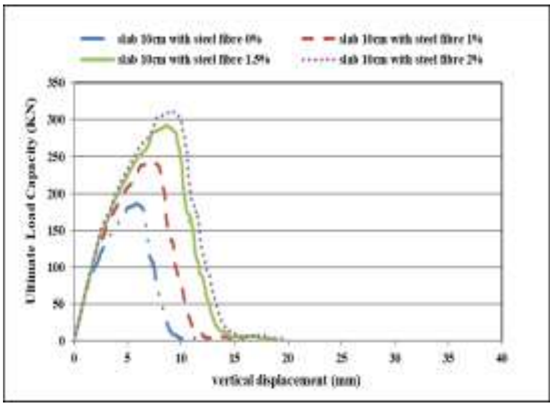
Load - deflection response of group (3) slabs.

Punching load and slab deflection were recorded during the test. Load – deflection curves for all slabs were presented in Fig (34) & (35) & (36).And compares the load-deflection responses of the eight slabs tested specimens for fibre reinforced OPC concrete and fibre reinforced geopolymer concrete (FRGC). The results in Fig (36) for fibre reinforced OPC concrete slabs show that the tested specimen S20 has higher value of peak load with other specimens in two stage crack and failure. The peak load increased by adding VF% from 1% ,1.5% and 2% of steel fibre to OPC concrete slabs increased the peak load value in cracking stage (Pcr)as shown 104.15 KN,121.30 KN,127.92 KN and 145.65 KN for slabs S17,S18,S19 and S20 but the peak load value in failure stage (Pult)as 185.66 KN ,244.25 KN,292.35 KN and 312.45 KN for the same slabs (S17,S18,S19 and S20).

In the same time The deflection at the cracking stage (Dcr)as shown 0.89 mm ,0.97 mm, 1.06 mm and 1.08 mm for slabs S17, S18, S19 and S20 and the deflection value in failure stage (D ult) as 5.89 mm ,7.30 mm ,8.69 mm and 9.13 mm for the same slabs (S17, S18, S19 and S20).

The results in Fig (36 & 37) for reinforced geopolymer concrete slabs (FRGC) show that the tested specimen S24 has higher value of peak load with other specimens in two stage crack and failure. The peak load increased by adding VF% from 1% ,1.5% and 2% of steel fibre to reinforced geopolymer concrete slabs(FRGC) increased the peak load value in cracking stage (Pcr)as shown 116.83 KN,134.07 KN , 141.12 KN and 158.39

KN for slabs S21,S22,S23 and S24 and also the peak load value increased in failure stage (Pult)as 273.40 KN ,332.42 KN,356.24 KN and 380.12 KN for the same slabs (S21,S22,S23and S24). The deflection at the cracking stage (Dcr)as shown 0.7 mm ,0.75 mm, 0.76 mm and 0.79 mm for slabs S21, S22, S23 and S24 and the deflection value in failure stage (Dult) as 8.30 mm, 9.68 mm, 9.92 mm and 10.50 mm for the same slabs (S21, S22, S23 and S24).
The results show that steel fibre increased the punching load capacity of the slab.



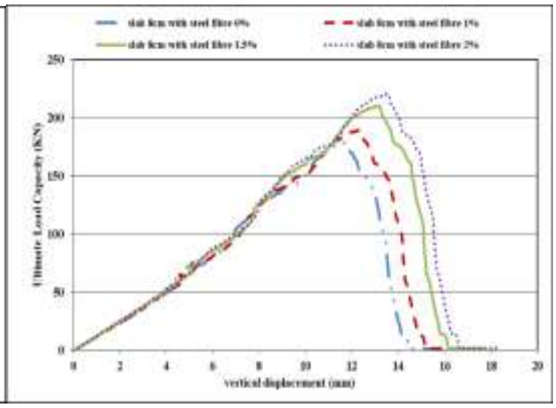
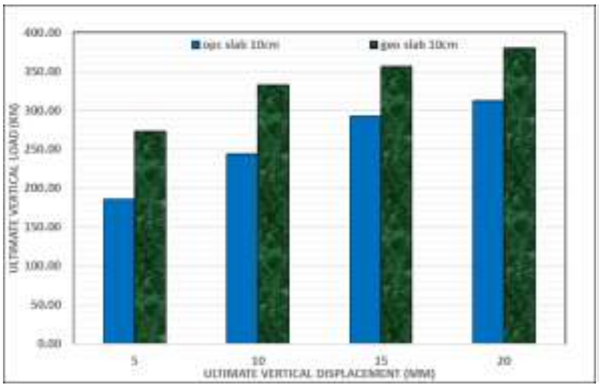


Fig 34: Load – deflection curve for OPCC for group (3) . Fig35: Load – deflection curve for GFRC group(3)



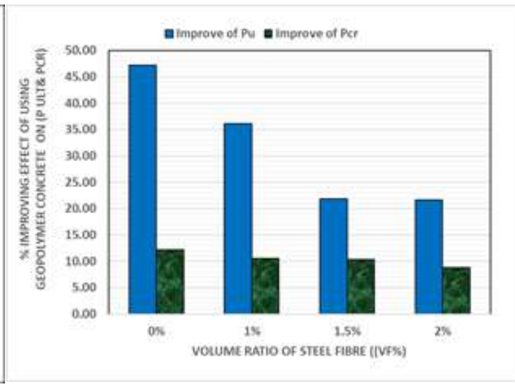


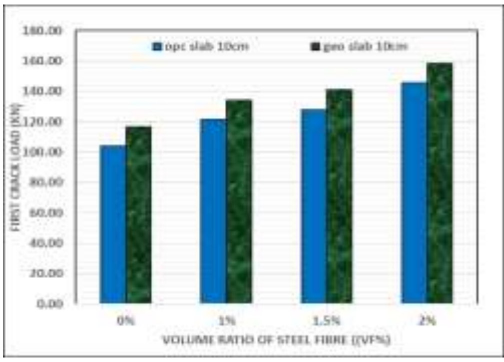
Fig 36: Load –displacement for OPCC and FRGC . Fig 37: % improving effect of using (GRFC)on Pult &Pcr.

Effect of geopolymer concrete on behaviour of punching capacity of slabs for group (3).

Table (8) and Figures (38)&(40). show that when comparing specimens in first crack zone it notes that the first crack load (Pcr) improved by using geopolymer concrete as shown (104.15 KN,121.30 KN,127.92 KN and 145.65 KN)for OPCC slabs (S17,S18,S19 and S20), but the first crack load for geopolymer slabs is (116.83 KN,134.07 KN , 141.12 KN and 158.39 KN)for slabs (S21,S22,S23 and S24). the ultimate load capacity for OPCC slabs is (185.66 KN ,244.25 KN,292.35 KN and 312.45 KN) for slabs (S17, S18, S19 and S20). On the other hand, the ultimate load capacity for geopolymer concrete slabs is (273.40 KN ,332.42 KN,356.24 KN and 380.12 KN) for slabs (S21, S22, S23 and S24).Adding 1 %, 1.5% and 2% of steel fibers caused to the percentage of improvement in the first crack load for both OPC concrete slabs and geopolymer concrete slabs (FRGC) more than the percentage of improvement in the ultimate load capacity for OPC concrete slabs and geopolymer concrete slabs.

Table (8) and Figure (39). illustrated that adding Steel fibres increased the first crack load for OPC concrete slabs (Pcr) by 16.47 %,22.83% and 39.85% respectively relative to ultimate load for OPC concrete slabs and the first crack load for geopolymer concrete slabs (Pcr) by 14.76% ,20.79% and 35.57% respectively relative to ultimate load for geopolymer concrete slabs.

Table (8). and Figure (41) illustrated that adding Steel fibres increased the ultimate load for OPC concrete slabs (P ult) by 31.56 %,57.47 % and 68.30 % respectively relative to ultimate load for OPC concrete slabs and the ultimate load for geopolymer concrete slabs (P ult) by 21.59 %, 30.30 % and 39.04 % respectively relative to ultimate load for geopolymer concrete slabs.



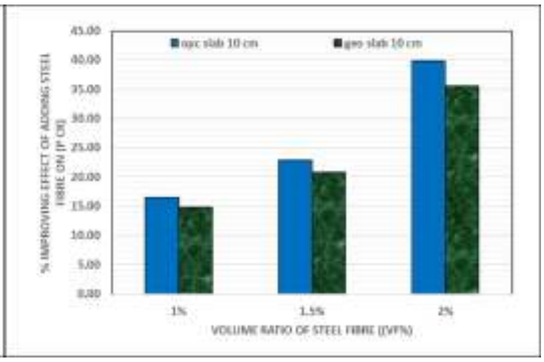
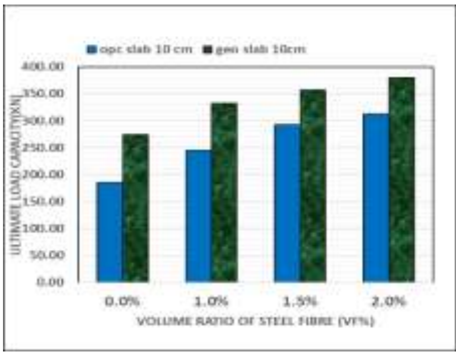


Fig 38: Effect of using (GRFC)on Pcr for slabs. Fig 39:%Improving effect of adding steel fibre(%vf) on Pcr for slabs.



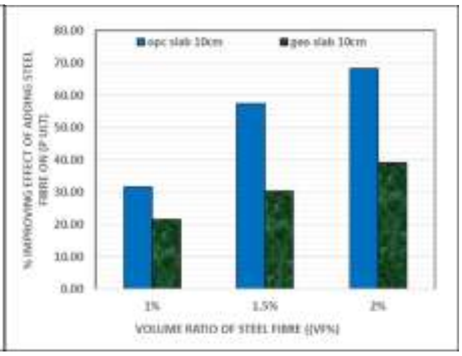
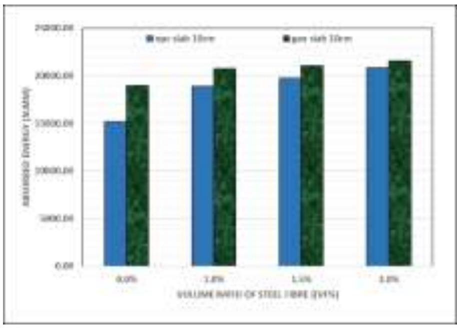


Fig 40: Effect of using (GRFC)on Pult for slabs.Fig 41:%Improving effect of adding steel fibre(%vf) on Pult for slabs.

Energy absorbed and ductility.

Table(8) and Figures (42 &43). illustrated that the absorbed energy for all specimens increased by increase the percentage of steel fibre (vf %). Additionally, increasing the volume ratio of steel fibre (vf %) increases the percentage of improvement in the strain energy for all specimens' slabs by 24.22% ,30.04 % and 37.35 % for (OPCC) and 9.58%,11.06% and 13.85% for (FRGC) respectively. From all results it is concluded that increasing the aspect ratio of steel fibre increases the strain energy but the percentage of improvement for OPCC slabs is higher than Percentage of improvement for FRGC. The ductility ratio of tested slab specimens is calculated as shown in Table(8)and Figure (44).It concluded from this table, that the increase in ductility is 6.60, 7.53 ,8.20 and 8.45 for OPCC slabs and 11.91,12.91,13.05 and 13.29 for FRGC slabs.

Table (8)and Figure (45) illustrated that the stiffness increases by increasing steel fibre ratio (vf %) as follow, (31.52 kn/mm,33.46 kn/mm,33.64 kn/mm and 34.22 kn/mm) for OPCC slabs (S17, S18, S19 and S20) and (32.931kn/mm,34.34 kn/mm, 35.91 n/mm and 36.20kn/mm) for FRGC slabs (S21,S22 , S23and S24) .



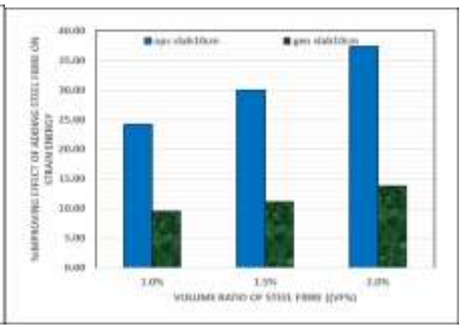
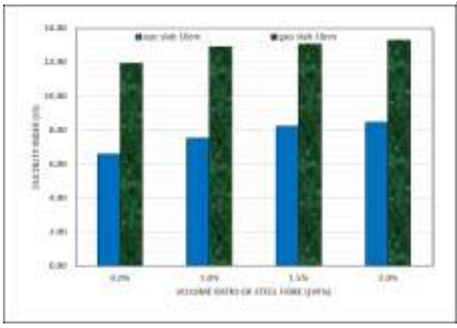


Fig 42: Absorbed energy of slabs for group (3). Fig 43:%Improving effect of adding steel fibre(%vf) on energy for slabs.



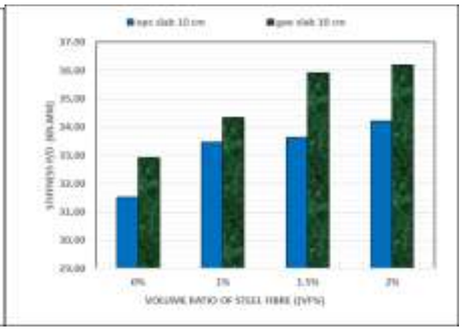


Fig 44:Measured ductility of slabs for group (3).Fig 45: Measured stiffness of slabs for group (3).

VI. Conclusion

- using geopolymer concrete for all specimens improves the punching shear capacity, strain energy, ductility, and stiffness.
- The concrete Mechanical characteristics were increased when steel fiber ratio was increased.
- The cubes so as cylinders with FRGPC have higher ultimate load capacity, deflection, and strain energy to failure rather than OPCC cubes so as cylinders. This was apparent from the compressive strength and splitting tensile strength tests.
- increasing the ratio of steel fibre enhances the ultimate load capacity for all slabs in crack and failure zone.
- increasing the ratio of steel fibre improves energy absorption for all specimens.
- slabs without steel fibre behaved in brittle way whears slabs with steel fibres have failed in more ductile manner.
- the load -deflection curves of tested slabs showed increase in ductility due to addition of steel fibre ratio for all specimens.
- the stiffness increases by increase ratio of steel fibre for all specimens.

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