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Behavior of reinforced geopolymer concrete flat slab exposed to high temperature

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ABSTRACT

In this study, fifteen 700x500 mm concrete flat slabs made of geopolymer concrete were examined under concentrated to identify the maximum punching shear resistance under the influence of various factors such as steel fiber content, slab thickness, flexural reinforcement ratio, in addition to replacing 10% of metakaolin by silica fume under the influence of temperature increasing up to 300 ºC in addition to testing ninty control specimens to investigate the mechanical properties. It was observed there was a beginning to change in the structural behavior when the temperature reached 100 ºC due to an increasing in the pressure by the liquid vapor, then a important drop in the capacity and behavior when reaching the temperature 300 ºC. The presence of iron fibers led to a decreasing in the distance between the edge of the column and the critical section, which reduced the punching shear values. Decreasing of the maximum and cracking of the punching shear were recorded at 37% and 42%, respectively, when the temperature increased to 300 ° C.

Keywords: Punching shear, mechanical properties, failure angle, temperature,critical section

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1 Introduction

One of the common and dangerous construction problems is the exposure of concrete slabs to punching shear forces if the concrete thresholds are not available between the columns. Therefore, the international codes defined the design process in such types and reached a set of solutions, including increasing the thickness of the slab and making the drop panel at critical area around the column-slab joint column or using column capital, see Fig.1.

Figure 1. Punching shear failure

In the upper and final floors, the sections of the columns may be small, especially in the large spans of the slabs, which cause the stresses of the punching to be unsafe. Also, when using the post tension system in slabs that are not supported on the beams, this leads to a decrease in the thickness of the slabs, this leads to the punch stress being unsafe. Likewise, in towers and tall buildings, composite sections are used in columns of steel and concrete, which causes a reduction in the concrete section of the column, which leads to the stresses of the punching being unsafe. Therefore, there are a numbers of treatments for such cases, as shown in Fig.2.

Figure 2. Punching shear preventers

It is estimated that the production of cement used to make cement increased from about 1.5 billion tons in 1995 to 2.2 billion tons in 2010.The problem is that the cement industry is responsible for some CO2 emissions as producing one ton of Portland cement releases about one ton of CO2 into the atmosphere.In addition, CO2 emissions are involved in global warming and climate change. Efforts have been directed to find alternatives to ordinary Portland cement.This includes the use of additional cement materials such as fly ash, silica fumes, granulated blast furnace slag and rice husk ash. In terms of global warming, polymer-floor concrete has a much lower environmental footprint and can significantly reduce CO2 emissions to the atmosphere generated by the cement industry.

In 1988 Davidovits suggested that an alkaline liquid could be used to react with (Si) and (Al) in a source material of geological origin or in secondary materials such as fly ash and rice husk ash to produce cement materials. The term "geopolymer" was used to represent these components because the chemical reaction that takes place in this case is a polymerization process.

Geopolymers depend on alumina silicates to be rich in (Si) and (Al). These may be natural minerals such as kaolinite or clay. Also use secondary materials like fly ash, silica fume, slag or rice husks as source material. Alkaline liquids is a soluble alkaline mineral, usually sodium or potassium. The most common alkaline liquid is a mixture of sodium hydroxide or potassium hydroxide (KOH) and sodium silicate or potassium silicate.

The main difference between polymer concrete and Portland cement is the ingredients. The oxides of silicon and aluminum in low-calcium fly ash react with an alkaline liquid to form a geopolymer paste that binds loose coarse aggregates, fine aggregates and other unreacted materials together to form geopolymer concrete.

As in the case of Portland cement, coarse and fine aggregate occupies about 60 to 70% of the mass of polymeric concrete.

Mutaz [1] studied the effect of factors such as steel fiber content and limestone content on the mechanical properties and punching shear strength of concrete slabs made of self-compacting concrete. A number of specimens were examined with dimensions of 1000 x 1000 mm and thicknesses of 50 and 70 mm under concentrated load. The most important finding was the sudden failure of the slabs without any prior warning, and an increase in the maximum load capacity amounted to 97% when using the 2% fiber content.

Abdul-Muttalib and Samir [2] studied the effect of slab thickness on the punching shear resistance of concrete slabs made of reactive powder concrete reinforced with polymeric carbon bars. The research focused on studying the moment when the first crack appeared. Four specimens with dimensions of 1150x1150 mm and thicknesses of 80, 100, 120 and 150 mm were tested under concentrated load. The main result of the research was that the appearance of the first crack was at a load ratio ranging between (33-56) percent of the maximum load. It was also found that the maximum load of the roof increased by 70% when the thickness increased by 55% for the slabs made of this concrete and reinforced in this way.

1.1 Experimental program

This research includes studying the mechanical properties, the compressive strength , fracture modulus, indirect tensile and elastic modulus as well as finding workability and density of concrete, of geopolymer concrete based on metakaolin and using alkali solution and ordinary aggregate as a fine and coarse aggregate after its exposure to temperatures of 100 and 300 degrees Celsius, then studying the behavior of geopolymeric concrete flat slab under the influence of temperature, where load deflection curve, crack load, maximum load, failure angle, critical area, crack pattern and type of failure.

The most parameters will be adopted, which are the amount of flexural reinforcement, the content of the steel fiber, the partial replacement of metakaolin with silica fume, as well as the thickness of the slabs

2 Material and methods

2.1 Metakaolin

Kaolin (or kaolin) is a type of fine, soft, white rocks, which are mostly composed of the mineral kaolinite (Al2 (OH) 4Si2O5); The product from feldspar rocks. It is also known as Chinese clay or clay. Kaolin is mainly used to make porcelain and earthenware, and in the manufacture of porcelain. Kaolin is also used in the manufacture of paper. It can be used to treat water.Kaolin powder was obtained locally. The sample was thermally treated with an electric oven at 600-700 ° C for 2 h, in which a metakaolin was obtained.The chemical structure of methacholine includes many compounds, Table 1. The chemicals represented in some types of minerals and their oxides, such as the oxides of silicon, aluminum, iron and some other types The proportions of these compounds differ according to their presence in the kaolin, some of which are present in high proportions and some are present in proportions a little bit, see Fig.3.

Table 1. Content of main oxides in used metakaolin

Component	Calcium oxide	Silicon oxide	Aluminum oxide	Iron oxide	Magnesium Oxide	Potassium oxide	Sodium oxide	Chlorine
Symbol	CaO	SiO2	Al2O3	Fe_2O_3	Mgo	K2O	Na2O	CL
%	18.80	52.01	29.56	2.28	0.90	0.75	0.20	0.22

2.2 Alkaline Solution

The alkaline solution was prepared by mixing sodium oxide, which is a flakes with distilled water, then the mixture was added with sodium silicate and left for 24 hours, the recommended ratio has been adopted by Wissam et.aL [3] to obtain a 14 molarity.

2.3 Sand and Crushed Gravel

Local sand graded within zone 3 was used as fine aggregate with a fineness modulus of 2.67, a sulfate content of 0.41%, a clay content of 3.7%, and a specific gravity of 2.65. Whereas crushed gravel was used as coarse aggregate whose grades are in the range of 5-12 mm with a sulfate content of 0.088%, a clay content of 2.1% and a specific gravity of 2.61. All the physical and chemical properties of aggregates conform to the specifications of Iraqi Standard 45/1984[4].

2.4 Steel Fiber

Hook steel fibers were used, with a length of 130 mm, a diameter of 0.13 mm, and a aspect ratio of 100, which is a good value that reflects the efficiency of these fibers. The density of fibers was 7820 kg/m3 and Poisson's ratio 0.26, see Fig.3.

2.5 Steel Reinforcement

Uses deform reinforcing bars with a diameter of 6 mm and 80 mm spacing between the centers of the bars in both vertically and horizontally direction. The average yield stress of these bars was 590 MPa, while the ultimate stress was 715 MPa. The distance between the bars was changed once to 100 mm for Group C. The properties of laboratory-tested bars proved its conformity with the Iraqi standard 2091/1999[5].

2.6 Superplasticizer

The super plasticizer that was used in the preparation of geopolymeric concrete is Glenium 51 manufactured in the United Arab Emirates with a value of PH 6.8, a light brown color, free of chlorine, and used at a dose of 3 liters per cubic meter.

2.7 Silica Fume

Silica is a by-product of the ferrosilicon metal production process in electric arc furnaces and it is obtained from smoke rising through furnace chimneys by the condensation process. Silicon dioxide makes up about 90% of the composition of silica, and its particles are spherical in shape and super smooth, being about 100 times softer than cement. Part of the cement materials used in the concrete mixture can be replaced by silica in proportions ranging between 7-15% of its weight. Silica is manufactured in Europe, Egypt, South Africa and India. One ratio, 10% weight of metakaolin, was used in this study to increase the compressive strength, See Fig. 3.

2.8 Water

Tap water was used in preparation of geolpolymer concrete as addition water.

2.9 Mixtures

The mixture M1, detailed in Table 2, was design and approved as the main plan, while two secondary mixtures, M2 and M3, were approved, in which steel fibers were added by 1% of the total volume of the mixture that was used in the group D mixture and denoted as M2 and 10% From metakoline was replaced with silica fume in the mixture of Group E and named M3.

Table 2. Mixtures details

No	Meta-kaolin Kg/m3	Sand Kg/m3	Crushed Gravel Kg/m3	Alkaline Solution L/m3	Super Plasticizer L/m3	Addition Water L/m3	Steel Fiber Kg/m3	Silica Fume Kg/m3
M1	420	640	1100	175	3	30	-	-
M2	420	640	1100	175	3	30	78.2	-
M3	378	640	1100	175	3	30	-	42

2.10 Specimens

2.11 Mechanical properties

Ninety of control specimens had been casted to check the mechanical properties of geopolymer concrete, three cylinders with dimensions of 200 × 100 mm were casted to check the compressive strength for each temperature and the same to verify indirect tensile strength, while a three prism with dimensions of 100 × 100 × 500 mm were used to find the value of the rapture modulus for each Temperature. A single cylinder value of 300 x 150 mm dimensions was used for each temperature to find the modulus of elasticity for each mixture.


Steel Fiber Silica Fume Metakaolin

Figure 3. Used materials

2.12 Punching shear of flat slab

Fifteen specimens of geo-polymeric concrete flat slabs with dimensions of 700 x 500 mm, Fig. 4, to study the effect of temperature rising from the laboratory degree (27 ºC) to 100 and 300 ºC and investigated the effect of slab thickness, flexural reinforcement ρ, steel fibers Vf and the compressive strength of concrete (silca fume content S.F%) on punching shear capacity. The specimens were divided into five groups as shown in Table 3.

Table 3. Details of tested flat slabs

Group	Slab No.	Temp. 0C	Thickness mm	ρ	Vf %	S.F%
A	S1	27	50	0.0073	0	0
	S2	100	50	0.0073	0	0
	S3	300	50	0.0073	0	0
B	S4	27	60	0.0073	0	0
	S5	100	60	0.0073	0	0
	S6	300	60	0.0073	0	0
C	S7	27	50	0.0057	0	0
	S8	100	50	0.0057	0	0
	S9	300	50	0.0057	0	0
D	S10	27	50	0.0073	1	0
	S11	100	50	0.0073	1	0
	S12	300	50	0.0073	1	0
E	S13	27	50	0.0073	0	10
	S14	100	50	0.0073	0	10
	S15	300	50	0.0073	0	10

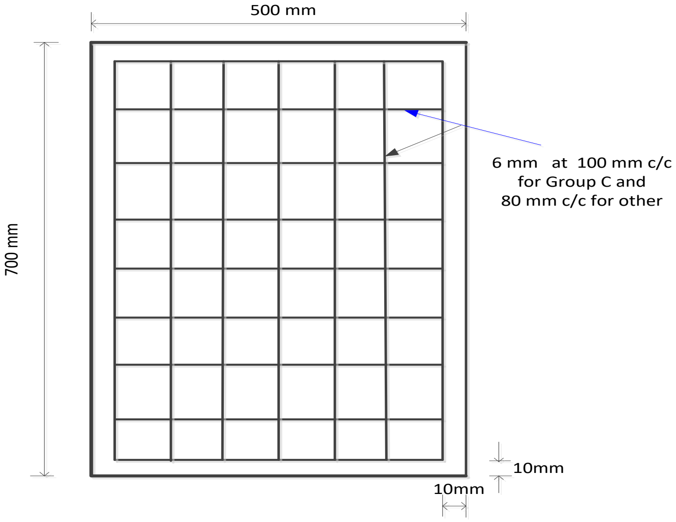


Figure 4. Flat slabs dimensions

2.13 Curing

After opening the molds made of wood for the flat slabs and from the plastic for control specimens, they were treated by leaving them in the air inside the laboratory for 28 days.

2.14 Specimens heating

Use an electric oven with dimensions 800 x800 x 1000 mm to raise several of the slabs specimens degree from 27 ºC to 100 ºC and other reached to 300 ºC. Then the samples were taken out and left to cool with air and later dyed with white color in preparation for testing.

3 Results and discussion

3.1 Mechanical properties

3.1.1 Fresh geopolymer concrete

Examination of the mechanical properties of the fresh geopolymer concrete was carried out immediately after mixing Sahar et. al. [6]. Vicat needle device was used to find the initial and final setting times, while the cone and plate were used to calculate the amount of slump according to ASTM C143-89a/1989[7], Table 4.

Table 4. Mechanical properties of fresh geopolymer concrete

mixture	Steel Fiber Content%	Silica Fume Content %	Slump (mm)	Setting Time (mins)	
				Initial	Finial
M1	0	0	71	42	117
M2	1	0	64	36	104
M3	0	10	68	31	98

3.1.2 Hardened geopolymer concrete

Investigation of the mechanical properties of the hardened concrete was carried out according to specifications ASTM C39 1989 [8] for the compressive strength, ASTM C78 / C78M-10 [9] for modulus of rapture, ASTM C496 1989 [10] for splitting tensile strength, ASTM C469 [11] for modulus of elasticity and ASTM C642-13[12] for dry density. The results are shown in Table 5 and Fig. 5.

Table 5.Mechanical properties of hardened geopolymer concrete at 27 ^{o}C

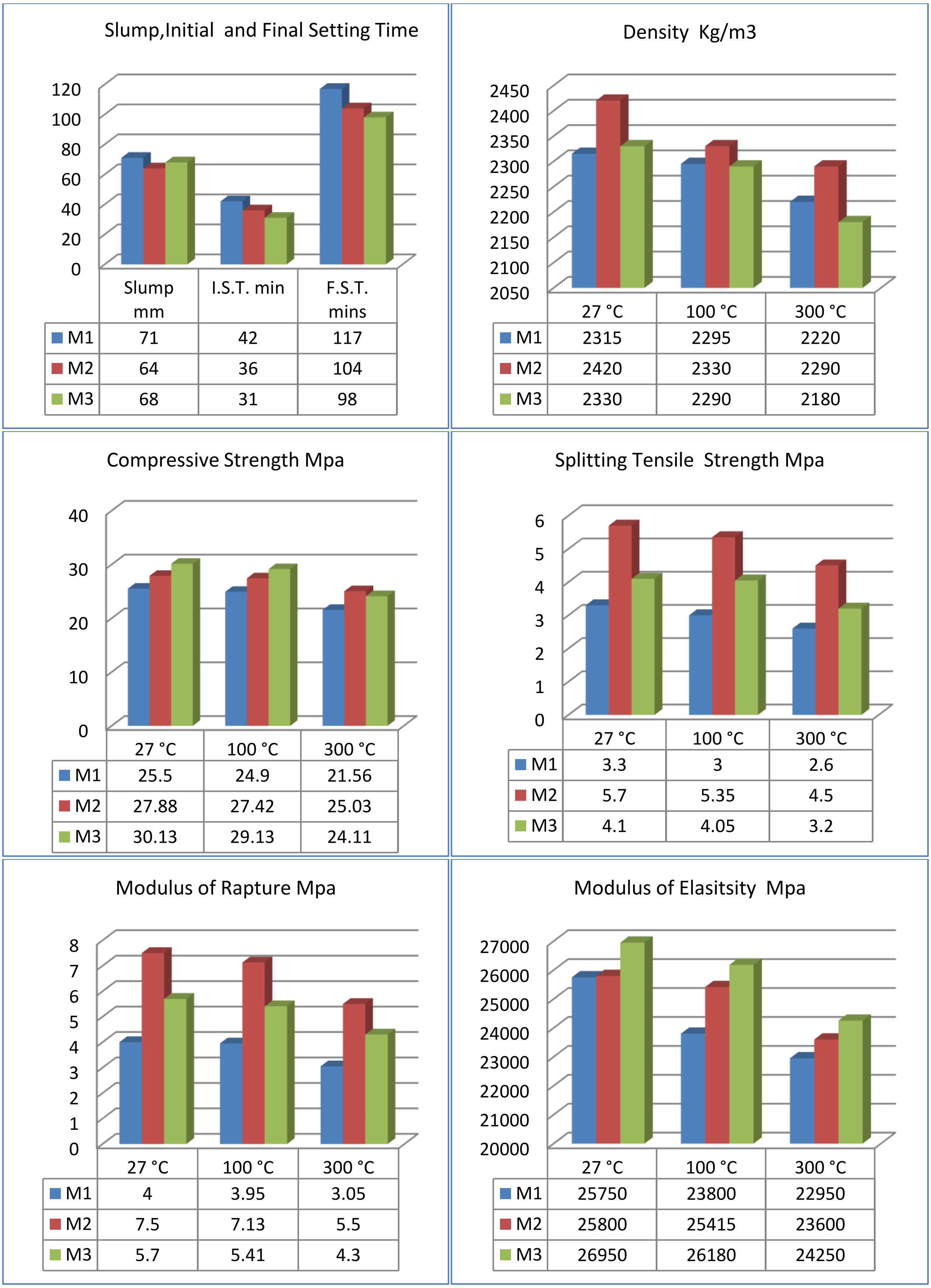
M	Compressive strength MPa	% Increasing	Splitting Strength MPa	% Increasing	Modulus of Rapture MPa	% Increasing	Modulus of Elasticity MPa	% Increasing	Density Kg/m3
M1	25.5	-	3.3	-	4.0	-	23800	-	2315
M2	27.03	6	5.7	72	7.5	88	25415	6	2420
M3	30.13	18	4.1	24	5.7	43	26180	10	2330

from the results obtained, it was noticed an increase in the amount of compressive strength and modulus of elasticity about 6% when using steel fibers by 1% of total volume of mixture, but this percentage causes an effective increase in both of the splitting tensile strength and the modulus of rapture, which reached a value of 72% and 88% respectively due to improve in shear resistance resulting from increased the ductility of geopolymer concrete.

There was also a clear enhancing in the compression resistance and elastic modulus when replacing 10% of metakaolin with silica fume, as a result of the pozzolanic properties of this material that increase the microstructure of the concrete and improve the bonding, while this substitution led to an increase in the splitting tensile strength and the modulus of rapture of about 24% and 43% respectively.

From Figure 4, when specimens concrete is exposed to a temperature of 100 ^{o}C, there was a noticeable slighting decrease in all mechanical properties from (1-9) %, while increasing the temperature to 300 ^{o}C, causes a drop decrease (9-27) % and this may be due to an increase in heat leads to an increase in hair cracks in the microstructure and that help the onset of failure.

The density in general recorded a decrease in its values when the temperature was rised from the normal temperature due to the loss of moisture and combustible materials. This decrease ranged between (1-6) percent.



Slump,Initial and Final Setting Time

	Slump mm	I.S.T. min	F.S.T. mins
🟦 M1	71	42	117
🟥 M2	64	36	104
🟩 M3	68	31	98

Density Kg/m3

	27 °C	100 °C	300 °C
🟦 M1	2315	2295	2220
🟥 M2	2420	2330	2290
🟩 M3	2330	2290	2180

Compressive Strength Mpa

	27 °C	100 °C	300 °C
🟦 M1	25.5	24.9	21.56
🟥 M2	27.88	27.42	25.03
🟩 M3	30.13	29.13	24.11

Splitting Tensile Strength Mpa

	27 °C	100 °C	300 °C
🟦 M1	3.3	3	2.6
🟥 M2	5.7	5.35	4.5
🟩 M3	4.1	4.05	3.2

Modulus of Rapture Mpa

	27 °C	100 °C	300 °C
🟦 M1	4	3.95	3.05
🟥 M2	7.5	7.13	5.5
🟩 M3	5.7	5.41	4.3

Modulus of Elasitsity Mpa

	27 °C	100 °C	300 °C
🟦 M1	25750	23800	22950
🟥 M2	25800	25415	23600
🟩 M3	26950	26180	24250

Figure 5. Mechanical properties of three mixtures

3.2 Punching shear of flat slabs

3.2.1 Load capacity

From Table 6, It is possible to observe the discrepancy in the final punching cut between a slight increase or decrease when the temperature rises from the laboratory temperature (27) to 100 ° C, indicating the beginning of a change in behavior at this temperature predicted by a decrease in the values, while the additives were tries to compensate for this decrease and this explains the slight increase in some of the results. Corresponds to a decrease of between (9-36)% from the values obtained at the normal temperature when the temperature reaches 300 ºC. Where it can be observed the significant drop in values from those obtained when increasing the temperature to 100 ºC. As for the initial cracking load, the loads decreased in both cases, when the temperature reached 100 and 300 ºC, with percent ratio (3-22)% and (9-42)%, respectively, due to the early arrival of the concrete's resistance to tensile strength due to the heat.

Table 6. Cracking and ultimate loads capacity

Group	Slab No.	Thickness mm	ρ	V_f %	S.F %	Temperature	Cracking Load		Ultimate Load	
							KN	Increasing %	KN	Increasing %
A	S1	50	0.0073	0	0	27	10.5	-	38.3	-
	S2	50	0.0073	0	0	100	8.2	-22	39.4	3
	S3	50	0.0073	0	0	300	7.7	-27	28.0	-27
B	S4	60	0.0073	0	0	27	13.5	-	51.9	-
	S5	60	0.0073	0	0	100	14.3	6	55.0	6
	S6	60	0.0073	0	0	300	8.7	-36	43.1	-17
C	S7	50	0.0057	0	0	27	7.2	-	28.4	-
	S8	50	0.0057	0	0	100	7.0	-3	27.5	-3
	S9	50	0.0057	0	0	300	4.2	-42	18.2	-36
D	S10	50	0.0073	1	0	27	18.8	-	69.0	-
	S11	50	0.0073	1	0	100	20.1	7	73.8	7
	S12	50	0.0073	1	0	300	17.1	-9	62.8	-9
E	S13	50	0.0073	0	10	27	14.3	-	45.0	-
	S14	50	0.0073	0	10	100	13.0	-9	46.8	4
	S15	50	0.0073	0	10	300	10.1	-29	36.5	-19

3.2.2 Load-deflection behavior

Through Fig. 6, it was noticed a similar behavior of the geopolymer flat slabs at the beginning of the loading, but this behavior becomes different after increasing the temperature and the appearance of cracks resulting from exceeding the stresses the tensile strength of concrete, as the components of concrete and various additives begin to reduce the bad effect of temperature, especially after 100 °C. Through groups B and D, it was clearly the effect of Slab thickness and steel fibers in compensating for the decrease in slabs stiffness as a result of cracks appearance.

3.2.3 Failure pattern and failure zone shape

The bending notches in the tension side started around the heel of the column and spread diagonally to the edges of the panels and finally the semicircular notches developed in the tension side penetrated the column. Failure can be recorded for slabs that start with the appearance of hair cracks and then develop and grow until it causes failure, accompanied by some cracks due to flexural stresses, Figure 7. The failure was also accompanied by peeling of concrete, falling gravel, and the appearance of heat effects.

The shape of the failure zone varied between circular and square with rounded corners, and this corresponds to the ACI 318-14 [13].

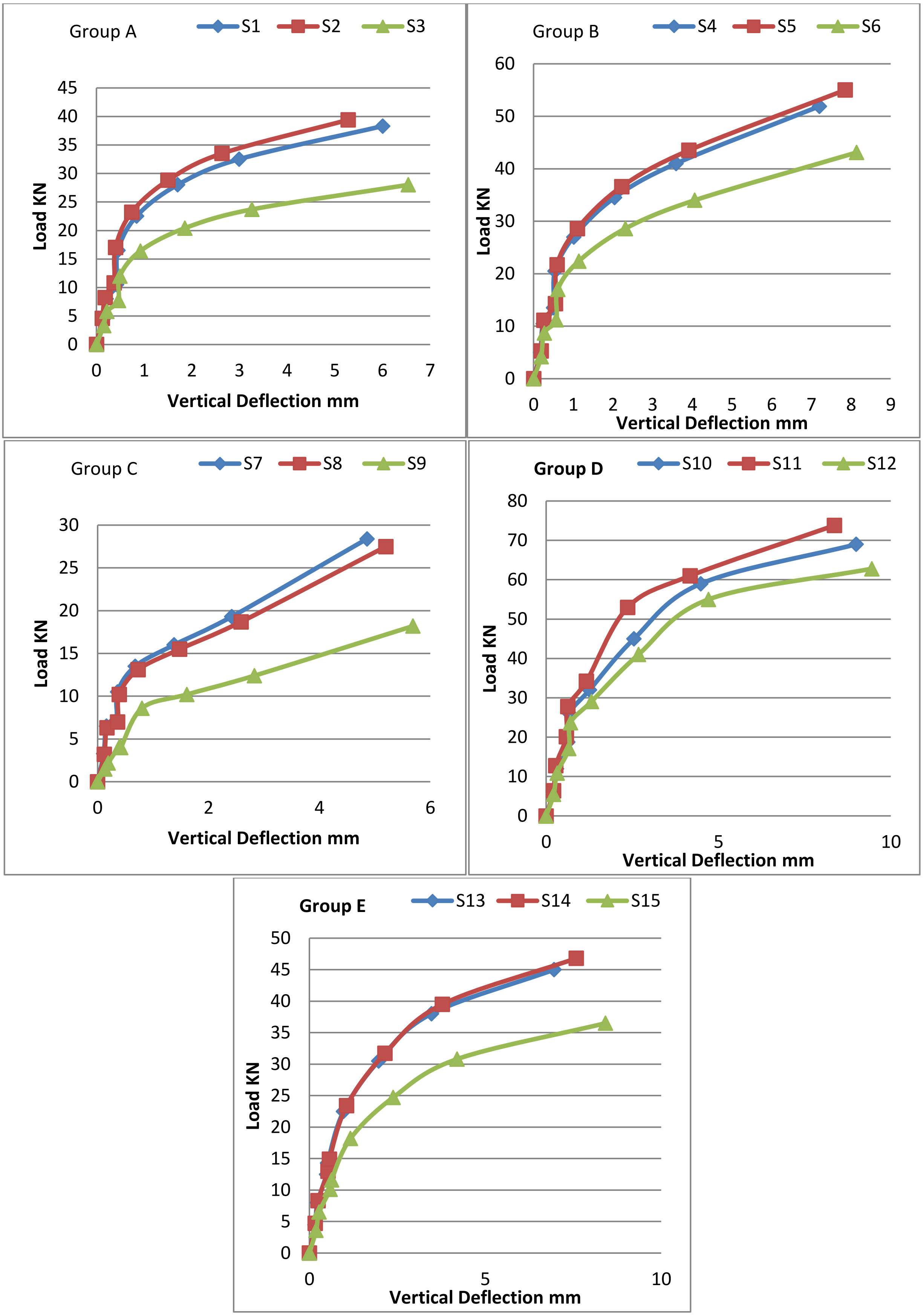


Figure 6. Load deflection curves for groups A, B, C, D and E.

3.2.4 Failure angle

The angle between failures, that is hierarchical, with the bottom surface of flat concrete where failure mode is often hierarchical in punching shear, see Fig.7.

A failure angle was recorded between 16.84-21.94 degrees while the reference slab recorded an angle of 19.50 degrees and this angle was increased to 21.52 degrees for the flat geopolymeric concrete slab having a steel fiber ratio of 1%. On the other hand, this angle decreased to 17.58 degrees for slab containing 10% silica fume as an alternative to methacholine in geopolymeric concrete as shown in Table 7.

Table 7. Behavior of geopolymer concrete flat slab

Slab No.	Deflection mm Crack	Yield	Ultimate	Ductility Factor	Crack Width mm	Failure Angle degree	Failure Mode
S1	0.20	0.50	6.00	12	2.4	19.50	Flexural +Punching
S2	0.18	0.53	5.28	10	2.7	19.85	Flexural +Punching
S3	0.50	0.73	6.54	9	3.1	19.68	Flexural +Punching
S4	0.43	0.51	7.20	14	2.1	20.20	Flexural +Punching
S5	0.27	0.60	7.85	13	3.0	20.94	Flexural +Punching
S6	0.34	0.74	8.14	11	3.5	20.88	Flexural +Punching
S7	0.36	0.49	4.86	10	3.3	18.75	Flexural +Punching
S8	0.19	0.58	5.20	9	3.7	18.65	Flexural +Punching
S9	0.46	0.63	5.69	9	4.0	18.57	Flexural +Punching
S10	0.49	0.56	9.00	16	1.6	21.52	Flexural +Punching
S11	0.50	0.56	8.37	15	1.7	21.81	Flexural +Punching
S12	0.49	0.63	9.45	15	1.7	21.94	Flexural +Punching
S13	0.43	0.50	6.96	14	2.1	17.58	Flexural +Punching
S14	0.53	0.63	7.59	12	2.5	16.84	Flexural +Punching
S15	0.59	0.84	8.42	10	2.7	17.68	Flexural +Punching

Figure 7. Failure pattern and failure zone shape

3.2.5 Critical section

The length of the critical area in examined geopolymeric slabs was considered equal to half the distance between the failure surface and the punching shear face, where the distance calculation is based on Fig. 8, this method is a compatible with ACI 318-14 [13] code and B.S 8110, which considered that the punching shear area is at a distance 0.5 and 1.5 of the effective depth of slab from the face of the column respectively, Ali indicating that the circumference of the critical area equals (1.16-1.5) of the total depth of the roof in the absence of steel fibers and (1.06-1.25) if it is present. Table 8 listed the distances and perimeters for each tested slab.

$$\mathrm{A} = \mathrm{r}^2 + 4\mathrm{rx} + \pi \mathrm{x}^2 \tag{1}$$

$$\mathrm{x} = \frac{-4\mathrm{r}+\sqrt{(4\pi)^2-4\pi(\mathrm{r}^2-\mathrm{A})}}{2\pi} \tag{2}$$

where, A: area of failure zone (mm^2)
R: side length of column(mm)
X: distance between the end of column and failure zone.

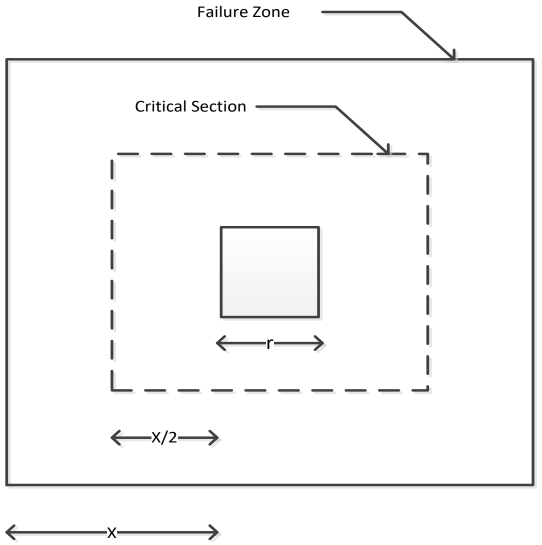


Figure 8. Method of critical section calculation

From Table 8, it can noted that the location of critical section is at (1.75-2.9) d and the presence of the steel fibers leads to be the critical section closer to the edge of the column and this reducing punching shear, while the increase in thickness of slab and flexural reinforcement get the critical section away from the column and this causes an increasing in punching shear.

Table 8. Location of punching shear section

Slab	Temp. °C	H mm	D mm	Area mm^2	X mm	Location of punching shear section from face of column		
						Present study @x/2	ACI318-14@d/2	B.S.9110@1.5d
S1	27	50	40	43400	86.6	43.3	20	60
S2	100	50	40	45150	89.0	44.5	20	60
S3	300	50	40	49700	94.8	47.4	20	60
S4	27	60	48	68600	116.7	58.3	24	72
S5	100	60	48	70350	118.6	59.3	24	72
S6	300	60	48	77700	126.2	63.1	24	72
S7	27	50	40	57050	103.8	51.9	20	60
S8	100	50	40	59150	106.2	53.1	20	60
S9	300	50	40	69650	117.8	58.9	20	60
S10	27	50	40	32200	70.5	35.2	20	60
S11	100	50	40	36750	77.3	38.7	20	60
S12	300	50	40	44800	88.5	44.3	20	60
S13	27	50	40	53550	99.6	49.8	20	60
S14	100	50	40	54950	101.3	50.6	20	60
S15	300	50	40	60200	107.4	53.7	20	60

3.2.6 Ultimate punching shear stress

Table 9 shows the maximum punching shear stresses for all geopolymeric concrete slabs. It was noticed that there was a decrease in stress with the increase in temperature, ranging between (12-32)% at a temperature of 300 ° C. It was also found that in the normal temperature there was an increase in stresses when using 1% steel fiber , 10% silica fume as a replacement for metakaolin, and a 28% increase in bending reinforcement by 6%, 111% and 36%, respectively, and a decrease in stresses by 11% when increasing the thickness of the slab by 20%.

Table 9: Behavior Ultimate Punching Shear Stress

Slab	Temp. °C	D mm	Silica Fume %	Steel Fiber %	ρ	Pu KN	Perimeter of the critical punching section at x/2 mm	Ultimate Punching Shear Stress MPa
S1	27	40	0	0	0.0073	38.3	43400	2.14
S2	100	40	0	0	0.0073	39.4	45150	2.16
S3	300	40	0	0	0.0073	28.0	49700	1.46
S4	27	48	0	0	0.0073	51.9	68600	1.91
S5	100	48	0	0	0.0073	55.0	70350	2.00
S6	300	48	0	0	0.0073	43.1	77700	1.49
S7	27	40	0	0	0.0057	28.4	57050	1.38
S8	100	40	0	0	0.0057	27.5	59150	1.31
S9	300	40	0	0	0.0057	18.2	69650	0.80
S10	27	40	0	1	0.0073	69.0	32200	4.52
S11	100	40	0	1	0.0073	73.8	36750	4.51
S12	300	40	0	1	0.0073	62.8	44800	3.46
S13	27	40	10	0	0.0073	45.0	53550	2.26
S14	100	40	10	0	0.0073	46.8	54950	2.32
S15	300	40	10	0	0.0073	36.5	60200	1.72

4 Conclusions

1. An increase in both ultimate and cracking punching load of geopolymeric concrete flat slabs was recorded when increasing the thickness of the slab, flexural reinforcement, replacing 10% of metacolin with silica fume but the addition of steel fibers by 1% of the total volume caused an increase of 81% of the maximum reference load.
2. Exposure of geopolymeric concrete to heat causes a decrease in its mechanical properties and strength. This decrease is slight upon reaching a temperature of 100 ° C, however the decline then accelerates because the geopolymeric concrete contains liquid in its pores and at a temperature of 140 ° C this will increase the evaporation and generate pressure on the concrete followed by evaporating the calcium hydroxide at approximately at 300 and creating more pressure on the concrete leads to the concrete internal structure weakens and causing cracks in the concrete.
3. The presence of steel fibers causes a shortening of the distance between the critical section and the outer edge of the column, which causes a decrease in the punching shear, also the steel fiber reduces the bad effect of heat and resists the spread of cracks.
4. Predominant failure in these geopolymeric concrete flat plat was flexural plus punching.
5. A failure angle was recorded between 16.84-21.94 degrees while the reference slab recorded an angle of 19.50 degrees and this angle was increased to 21.52 degrees for the flat geopolymeric concrete slab having a steel fiber ratio of 1%.

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