Effect of Fire Flame (High Temperature) on the Self Compacted Concrete (SCC) One Way Slabs

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Abstract:
Experimental work was carried out to investigate the effect of fire flame (high temperature) on specimens of one way slabs using Self Compacted Concrete (SCC).
By using furnace manufactured for this purpose, twenty one reinforced concrete slab specimens were exposed to direct fire flame. All of specimens have the same dimensions. The slab specimens were cooled in two types, gradually by left them in the air and suddenly by using water. After that the specimens were tested under two point loads, to study, the effect of different: temperature levels (300ºC, 500ºC and 700ºC), and cooling rate (gradually and sudden cooling conditions) on the concrete compressive strength, modulus of rupture, flexural strength and the behavior of reinforced concrete slab specimens and comparing the results with specimens without burning (reference specimens). The results showed that, the concrete compressive strength, concrete modulus of rupture and the flexural strength decreases while the maximum (central) deflection increases with increasing the fire flame temperature. For suddenly cooled specimens the residual flexural strength is less than that of gradually cooled specimens while the deflection is greater. For slabs with 20 MPa concrete strength and gradually cooled, the residual bending strength percent is 81.5%, 75% and 62.3% ,while the increase in central deflection is 5%, 33%, and 105% at burning temperature 300ºC, 500ºC and 700ºC respectively. For suddenly cooled specimens of the same strength and exposed to the same temperatures above the residual flexural strength is 77.9%, 68.3% and 58.3% while the increase in central deflection is 25%, 52%, and 118% respectively. When the strength of concrete specimens increase, the residual flexural strength experiences small increase and the increase is of lower rate in the central deflection for 300 ºC and 500 ºC burn temperatures while the decrease is significant for 700 ºC burning temperature.
Key words: SCC, elevated temperature, fire flame

الخلاصة:
تم اجراء بحث عملي لبحث تأثير درجات الحرارة العالية (الحريق) على نماذج من البلاطات المسلحة باتجاه واحد والمصنعة من الخرسانة ذاتية الرص. باستخدام فرن تم تصنيعه لهذا الغرض،تم تعريض واحد وعشرون نموذج بلاطة خرسانية الى حرارة اللهب المباشر ، وجميع النماذج لها نفس الابعاد . ثم تبرد النماذج بطريقتين، تبريد بطئ بتركها في الهواء، وتبريد فجائي باستخدام الماء وتحميلها بنقطتي تحميل لدراسة تاثيرمختلف: درجات الحرارة المختلفة (300ºC, 500ºC و 700ºC) ، و معدل التبريد (تدريجي ، فجائي) على مقاومة الخرسانة، معامل الكسر، مقاومة الانحناء وتصرف البلاطات الخرسانية ومقارنة النتائج مع النماذج غير المحروقة (نماذج السيطرة). أظهرت النتائج أن مقاومة الخرسانة، معامل الكسر، ومقاومة الانحناء تقل بينما يزيد الانحراف الأقصى بزيادة درجة حرارة الحريق . كما أظهرت النتائج أنه لحالة التبريد الفجائي فان مقاومة الانحناء المتبقية تقل بينما يزيد الانحراف الأقصى مقارنة مع حالة التبريد التدريجي حيث تبين أن نسبة مقاومة الانحناء المتبقية للبلاطات ذات مقاومة (20MPa) والمبردة تدريجيا هي 81.5% ، 75% و 62.3% بينما كانت نسبة الزيادة في الانحراف الأقصى 5% ، 33% و 105% للنماذج المعرضة الى 300ºC, 500ºC و700ºC على التوالي . أما لحالة التبريد الفجائي ولنفس المقاومة ودرجات الحريق أعلاه فان مقاومة الانحناء المتبقية هي 77.9% ، 68.3% و 58.3% بينما كانت الزيادة في الانحراف الأقصى 25%، 52% و118% على التوالي. كما أظهرت النتائج أن الزيادة في مقاومة الانضغاط تؤدي الى زيادة في نسبة مقاومة الانحناء المتبقية بمقدار قليل بينما تزيد نسبة الانحراف الأقصى بمقدار ضئيل عند الحرق بدرجات حرارة (300 ºC و 500 ºC) وتقل بمقدار مهم عند الحرق بدرجة حرارة 700 ºC .

Introduction:

High temperature due to fire have a significant effect on the strength and deformation characteristic of various structural components such as columns, beams, slabs, ets. But the slab member is the most affected member, because of its wide exposed surface area with respect to its thickness. Also, the fire may at one side of the slab; this causes a gradation in temperature across the slab depth.

At the beginning researchers were focusing on the chemical and physical changes within the concrete, such as the decomposition of calcium hydroxide ($Ca(OH)_2$), the incompatibility at the aggregate–cement paste boundary and the crystal transformation of quartz (SiO_2) **[Lau A. and Anson M., 2006]**. **[Peter J. Moss et al., 2008]** studied the fire behaviour of two-way reinforced concrete slabs. He found that the concrete and the reinforcing steel near the bottom of the slab heat up well before the top reinforcing steel and the top of the concrete, and once the bottom steel temperature exceeds 300°C, the yield strength of the steel decreases with increasing temperature, so that the negative (sagging) bending strength of the concrete section diminishes, as does its membrane strength. **[Mehrafarid Ghoreishi et al., 2010]** studied the response of flat plate concrete slab systems to fire exposure, they concluded that the combined fire and imposed loading can severely change structural behavior.**[Jeremy Changi et al., 2006]** studied the analyses of hollow-core concrete floor slabs exposed to fire to reduce the effect of temperature. Most of the researchers deal with heat without flame or gasses which accomplished to the fire, little researchers deal with the effect of exposing reinforced concrete slabs to direct fire flame and the time of concrete in direct contact with fire flames.

[Harada et al 1972] found that the residual bond strength between the concrete and the reinforcement was 44% of the control specimen at a temperature 300°C, while the residual strength of compression strength was 60% at the similar temperature.

Material Properties:

Cement:-

Ordinary Portland Cement (OPC) produced at Al-Sharkiya factory from the Kingdom of Saudia Arabia was used in this work. It was stored in a semi-dry place (Laboratory conditions) to avoid exposure to atmospheric condition. The physical properties and chemical composition of cement are shown in **Tables 1 and 2** respectively. Test results indicate that the adopted cement conform to the **[Iraqi specification No.5/1984]**.

Fine aggregate:-

The used sand was from Al-Khirbeet factory. It was of (4.75mm) maximum size. **Table 3** shows the chemical and physical properties for sand. The sieve analysis of sand used throughout this work lies within the range defined by **[ASTM C33-03]**.

Coarse aggregate:-

Crushed aggregate with (10mm) maximum size from Al-Suleiman factory for land concrete blocks was used as coarse aggregate in all mixes. The grading obtained from the results of sieve analysis of the aggregate lies within the range defined by **[ASTM C33-03]**. **Table 4** shows the chemical and physical properties for gravel.

Superplasticizer (SP) :-

For the production of self-compacting concrete, super plasticizer (high water reducing agent HWRA) based on poly carboxylic ether is used. One of a new generation of polymer-based super plasticizer designed for the production of SCC (Glenium 51) is used. (Glenium 51) has been primarily developed for the applications in the ready mixed concrete industries where the highest durability and performance are required. It is specific gravity is 1.1, at 20°C, PH=6.5 as issued by the producer. In this study, the dosage of (G51) was (3%) of cement weight mixes.

Silica fume:

Silica fume mineral admixture or micro silica: composed of ultrafine, amorphous glassy spheres of silicone dioxide (SiO_2), produced by Crosfield Chemicals, Warrington, England.

Concrete mix proportions:

There were three types of compressive strength of self-compacted concrete in this study, thus three mix types are required. The ratios of mixes were resulted by casting trial mix cubes and testing in (7 days) age. Every trial mix had three cubes of (100*100*100 mm). The details of mixes for SCC concrete samples are shown in **Table 5** below. Plain bars of 3mm diameter are used in each direction at the bottom of slab. The properties of the bars are shown in **Table 6**. The three types of concrete were mixed by horizontal drum laboratory mixer with a capacity of 0.05 m^3. In all the mixes, the aggregates and cement were first mixed dry for about 1 minute. The water, silica fume and the superplasticizer together were mixed externally in a pan then added to the mixer, after that mixing continued for a further 1 minute.

Experimental program:

Twenty one reinforced concrete slabs were tested. All of specimens have the same dimensions, length is 500mm, width is 250mm and the thickness is 40mm. The reinforcement is the same for all specimens which is $(6-\phi 3mm)$ in long direction and $(8-\phi 3mm)$ in short direction. The dimensions and reinforcement details of the slabs are shown in **Figs. 1 and 2**. Specimens were tested in the structural laboratory of the College of Engineering at Baghdad University.

The specimens are divided into three groups A, B and C. Group A contains three specimens which are not exposed to temperature representing the reference specimens; each specimen has a different strength (20, 30 or 40 MPa). Each of the groups B and C have nine specimens; the difference between them is in the method of cooling after exposing to high temperature. Group B is gradually cooled while group C is suddenly cooled by water. Each of the group B or C is divided into three subgroups; each of them has a different strength (20, 30 or 40 MPa). The three specimens of each subgroup are exposed to a different temperature (300, 500 or 700 C). The detailed classification of groups is shown in **Table 7.** The control samples were two types. First type was cubes (100x100x100)mm to test the compressive concrete strength and second type was prisms (100x100x500)mm to test modulus of rapture of concrete.

The furnace was manufactured by using 3mm thick steel plate to burn one specimen in each time, as shown in **Fig. 3**. The specimens were cast, then moist cured for seven days, after that dried by air in the laboratory. Eighteen specimens were burned by exposing to fire flame at age 45 days at three temperatures levels 300, 500 and 700 C and for similar exposure period of 1 hour after reaching the target temperature.. After this period, the fire flame was turned off, the slab specimens were removed and the specimens was cooled either gradually by left in air or suddenly by using splash of water till reaching the normal temperature. The temperature was monitored by using digital thermometer inside the furnace and a thermocouple wire (Type K) made of Nickel-Chromium covered with cement to resist the temperature, with a digital temperature reader.

Results and discussions:

Compressive strength:

The test results of compressive strength as shown in **Table 8** of the cubes (100*100*100mm) after burning by fire flame furnace showed that, increasing the temperature resulted in reducing the compressive strength with approximately the same percentage in all strengths of concrete (f 'c=20, 30 and 40MPa) grade with respect to each group of cooling type until (500°C). Also, the cooling method had a clear effect on compressive strength of the cubes, where the cubes cooled suddenly by spraying them with water were less strength than the others which cooled gradually by leaving them in air (laboratory condition), as shown in **Figs. 4-A, 4-B & 4-C** . The average percentage of residual the compressive strength for all strength groups was (89%) for the cubes cooled gradually in air and (84.4%) for the cubes cooled suddenly by water. The results of gradual cooling agreed with **[Anagnostopoulos N. et al., 2009]** dealing with normal concrete. The values of the decreases in compressive strength depend on the nature of the aggregate and the initial moisture content of the concrete. The changes in strength have been attributed to a combination of decomposition of the hydrated pastes, deterioration of the aggregates and the thermal incompatibilities between paste and aggregate leading to stress concentrations and microcracking **[Mindess S et al., 2003]**. Concrete is a brittle composite material that consists of binder (cement) paste and aggregates (fine and coarse aggregates). These materials have different mechanical and physical properties, including different coefficients of thermal expansion. At a lower elevated temperature, the thermal expansion of the cement paste is slightly greater than that of the aggregate. Consequently, in the concrete matrix, the cement paste is under hydrostatic compression, and the aggregates are under biaxial compression and tension. As the temperature further increases, the thermal strain of the cement paste changes to negative (shrinking) due to chemical changes, whereas the aggregate continues to expand. The corresponding stresses in concrete are that, the aggregates are under hydrostatic compression and the cement paste is under biaxial compression and tension. Also, the development of micro-cracks increases beyond (300°C) and firstly occurs around calcium hydroxide $Ca(OH)_2$ crystals, and partial volatilization of calcium silicate hydrate gel commenced at about (500°C). The pore size and porosity of the hydrate matrix will increase, and the mechanical properties (compressive strength and modulus of rupture) of the hydrates will be weakened **[Piasta J., 1984]**. For the cubes of 20 MPa nominal compressive strength, the percent of residual strength after exposing to 300, 500 and 700^o C was 92%, 77% and 47% respectively for the specimens cooled gradually. The results agreed with that obtained by other researchers deals with normal concrete, **[Nevile and Brooks 1987]** and **[Al-khafaji 2010]** and for the specimens which cooled suddenly (high rate of cooling), the residual compressive strength was slightly lesser than that for gradual cooled specimens, it was 86%, 70% and 40% respectively for the same burning temperature. This may be due to the grading progression of decreasing temperature (cooling), which will never be uniformly through the concrete cross section, because losing temperature will delay for the inner concrete than that of the outer concrete, this process will create internal damaged stresses, and it will be worse with increasing the cross section of the concrete member. **[Mohamedbhai 1986]** conclusions agreed with these results till 500^o C (for the normal concrete) but in contrast with that at 700^{o}C, his conclusion was, cooling rate affects on the residual concrete strength till 600 C temperature, but it had no affect at more than this temperature, this may be because of using electrical furnace which can not allow to control the real cooling rate because of the delay time between the end of the exposure temperature and the cooling process.

When the strength of concrete cubes increased, the residual compressive strength percent is decreased, generally, this decrease is little. The maximum decrease in the percent of residual strength when the concrete strength increased from 20 MPa to 30 MPa is 6% for gradual cooling and 3% for sudden cooling, while the maximum decrease in this percent when the concrete strength increase from 20 MPa to 40 MPa is 9% for gradual cooling and 7% for sudden cooling.

Modulus of Rupture:

The effect of the elevated temperature and method of cooling on the modulus of rupture is similar to the effect of these factors on the compressive strength, these effects are shown in **Figs. 5-A, 5-B and 5-C**. For the prisms of 20 MPa nominal compressive strength, the percent of residual modulus of rupture after exposing to 300 ,500 and 700 ^{o}C was 93%, 80% and 40% respectively, for the slab specimens cooled gradually. While for the specimens which cooled suddenly (high rate of cooling), the residual modulus of rupture was slightly lesser than that for gradual cooled specimens, it was, 90%, 74% and 35% respectively at the same above elevated temperatures. This because of the formation of cracks due to increase in temperature, and a net of surface cracks appeared in all faces of prisms due to increase the difference in thermal expansion between the aggregate and cement paste. This difference in thermal expansion increased during the cooling process and had a big effect in sudden cooling method.

When the strength of concrete increased, the residual modulus of rupture percent is decreased, generally, the decrease in modulus of rupture percent is little. The maximum decrease in the percent of residual modulus of rupture when the concrete strength increased from 20 MPa to 30 MPa is 6% for gradual cooling and 7% for sudden cooling, while the maximum decrease in this percent when the concrete strength increase from 20 MPa to 40 MPa is 9% for gradual cooling and 13% for sudden cooling.

Deflection:

All slab specimens were tested under two point loads as shown in **Fig. 6**. The exposing temperature and method of cooling affected the value of central deflection greatly. **Fig.7** shows the effect of temperature and cooling method on the central (maximum) deflection for specimens of 20, 30 and 40 MPa strength. The test results showed that the increasing of temperature resulted in increasing the deflection as shown in **Fig.7**. Also, the cooling method (rate of cooling) of specimens has a clear effect on the deflection values of burned specimens. Where the specimens cooled suddenly by spraying them with water have more deflection than the others cooled gradually by leaving them in air (for the specimens of the same concrete compressive strength and the elevated temperature). Slab specimens with 20 MPa concrete strength and gradually cooled, the increase in central deflection compared with the reference specimen is 5%, 33%, and 105% at burning temperature 300ºC, 500ºC and 700ºC respectively. But for suddenly cooled specimens the deflection was greater than that of gradually cooled specimens, the increase in deflection compared with that of the reference was 25%, 52% and 118% at burning temperature of 300ºC, 500ºC and 700ºC respectively**.** This because of the formation and propagating of the cracks due to the burning process, which had a great effects on the rigidity of the slab specimens, causing a high mid span deflection. Also, the rate of cooling effects on this propagation and growing of cracks, where it increased as the rate of cooling increased, result in decrease the rigidity and increase in deflection. When the concrete strength of specimens increased, the central deflection decreased (for the same burning temperature and cooling method), as shown in **Fig. 8**, meaning that enhancing in rigidity by decreasing the deflection.

Flexural strength:

The results of testing the specimens after burning by fire flame furnace showed that the increasing of burning temperature resulted in reducing the flexural strength. Also, the cooling method of specimens gives an important effect on flexural strength values of burned specimens. This may be because of the debonding between the reinforcement and the damaged concrete due to the difference in the thermal expansion them; also, the concrete may loss its compressive strength at the compression zone. The specimens cooled suddenly by spraying them with water they have less strength than the others which cooled gradually by leaving them in air, these effects are shown in **Table 9**. For the specimens of 20 MPa nominal compressive strength, the percent of residual strength after exposing to 300 , 500 and 700^o C was 81.5%, 75% and 62.3% respectively, for the specimens cooled gradually. While it is for the specimens which cooled suddenly (high rate of cooling), the residual bending strength was slightly lesser than that of gradual cooled specimens, it was 77.9%, 68.3% and 58.3% respectively. When the strength of concrete specimens increased, the residual flexural strength percent is increased. Generally, the increase in flexural strength is little. The maximum increase in the percent of residual strength when the concrete strength increased from 20 MPa to 30 MPa is 6% for gradual cooling and 3% for sudden cooling, while the maximum increase in this percent when the concrete strength increase from 20 MPa to 40 MPa is 9% for gradual cooling and 7% for sudden cooling. The nominal bending strength is calculated from the equation:

$$\therefore M_n = \rho b d^2 f_y (1- 0.59\rho\, f_y/f'_c)$$

Where:
Mn= nominal bending strength.
ρ= percent of steel with respect to effective sectional area (b*d)
b= slab width
d=effective slab depth.

From the results above, there is a good agreement between theoretical and actual bending strength for the control specimens, the maximum difference between them is 6 % .

Conclusions

Based on the results obtained in this investigation, the following can be concluded**:**

- The strength of concrete, degree of burning temperature, method of cooling affect the residual compressive strength of concrete, modulus of rupture of concrete, deflection and flexural strength of slab specimens.
- The increase in the degree of burning temperature decreased the residual compressive strength of concrete , modulus of rupture of concrete and flexural strength of slab specimens, while it increased deflection. For (20 MPa) nominal compressive strength, the percent of residual compressive strength after exposing to 300C, 500C and 700 C and cooling gradually was 82%, 77% and 47% respectively. While for the same exposing temperature and the same method of cooling ,the percent of residual modulus of rupture was 93%, 80% and 40% respectively, the percent of residual flexural strength of slab specimens was 81.5%, 75% and 62.3% respectively, the increase in

- Central deflection of slab specimens was 5%, 33%, and 105% respectively.
- When the strength of concrete cubes increased, the residual compressive strength after burning is decreased , while there is a little increase in flexural strength of slab specimens .For central deflection percent there is a slight increase for burning temperature 300C and 500C and a significant decrease for 700C burning temperature.
- When the specimens were cooled suddenly, there is an decrease in the residual compressive strength percent, residual modulus of rupture percent and residual flexural strength percent, while there is an increase in the central deflection percent compared with the gradual cooling. Generally the decrease in residual strengths and increase in central deflection percent was little.
- The results showed that there is a good agreement between theoretical and actual flexural strength of reference specimens, the maximum difference between them is 6%.

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Table 1: Physical properties of cement*

Physical Properties	*Test results*	*Limits of (I.O.S.) No.5/1984*
Specific surface area (Blaine method), m^2/kg	483	≥230
Setting time (Vicate apparatus), Initial setting, h:min Final setting, h:min	 2:50 4:30	 ≥00:45 ≤10:00
Compressive strength, MPa 3 days 7 days	 35.60 40.70	 ≥15.00 ≥23.00
Soundness (Autoclave) method, %	0.25	≤0.8

*** Physical analysis was conducted by National Center for Construction Laboratories and Research.**

Table 2: Chemical composition and main compounds of Cement*

Oxides composition	*Content %*	*Limits of (I.O.S.) No.5/1984*
CaO	62.21	-
SiO_2	20.18	-
Al_2O_3	5.00	-
Fe_2O_3	3.60	-
MgO	2.31	<5.00
SO_3	1.44	<2.80
L.O.I.	3.29	<4.00
Insoluble residue	1.11	<1.5
Lime Saturation Factor,L.S.F.	0.94	0.66-1.02
Main compounds (Bogue's equations)		
C_3S	57.04	-
C_2S	14.83	-
C_3A	8.60	-
C_4AF	10.95	-

- **Chemical analysis was conducted by National Center for Construction Laboratories and Research.**

Table 3: Chemical and physical sand test results. *

Properties	*Test results %*
Absorption%	0.82
Specific gravity	2.49
Sulfate content (SO_3)%	0.32

***Test was conducted in the laboratories of engineering college-al -Anbar University**

Table 4: Chemical and physical gravel test results. *

Properties	*Test results %*
Absorption%	0.64
Specific gravity	2.62
Sulfate content (SO_3)%	0.05
Dry loose-unit weight kg/m^3	1562
Material finer than 75 μm%	1.36

***Test was conducted in the laboratories of engineering college-al-Anbar University**

Table 5: Details of SCC mixes

No.	*Mix of strength(MPa)*	*Cement Kg/m^3*	*Fine agg. Kg/m^3*	*Coarse agg Kg/m^3.*	*SP (Glenium51) Lit/m^3*	*S.F Kg/m^3*	*Water Lit/m^3*
1	**19.6≈20**	**400**	**600**	**640**	**12**	**8**	**228**
2	**28.8≈30**	**400**	**600**	**640**	**12**	**8**	**200**
3	**37.8≈40**	**500**	**600**	**640**	**15**	**10**	**200**

Table 6: Properties of steel bars

Approximate diameter(mm)	*Measured diameter*	*Yield stress fy (MPa)*	*Modulus of Elasticity(GPa)*	*Ultimate stress (MPa)*
3	**2.93**	**800**	**195.924**	**950**

***Test was conducted in the laboratories of engineering college-al-Anbar University**

Table 7. Details of concrete slab specimens.

Group	**Concrete Strength**												**Type of cooling**
	20MPa				**30MPa**				**40MPa**				
	Temp. (°C)				**Temp. (°C)**				**Temp.(°C)**				
	NE	**300**	**500**	**700**	**NE**	**300**	**500**	**700**	**NE**	**300**	**500**	**700**	
A	**1**	**-**	**-**	**-**	**1**	**-**	**-**	**-**	**1**	**-**	**-**	**-**	**-**
B	**-**	**1**	**1**	**1**	**-**	**1**	**1**	**1**	**-**	**1**	**1**	**1**	**Gradual.**
C	**-**	**1**	**1**	**1**	**-**	**1**	**1**	**1**	**-**	**1**	**1**	**1**	**Sudden.**

***NE* = Note Exposed to Fire (Reference Specimen)**

Table (8): Results of compression test for burned and reference cubes

Groups of Method Compressive *f 'c*	Compressive Strength of Cubes				Method of Cooling
	*Reference Cube (MPa)	Burned Cubes (MPa)			
		Temperature of Burning			
		300°C	500°C	700°C	
Grade 20 MPa	19.6	18.03	15.09	9.21	Gradually
		16.85	13.72	7.84	Suddenly
Grade 30 MPa	28.8	25.63	20.45	12.96	Gradually
		24.48	19.29	10.94	Suddenly
Grade 30 MPa	37.8	32.51	25.70	15.87	Gradually
		30.99	23.81	12.47	Suddenly

* Control Specimens without burning.

Table 9: Maximum bending strengths of slabs

Compress. Strength f'_c	Maximum bending strengths of slabs (N.m)							
	Refer. slabs		Main slabs (burned slabs)					
	Nominal Bend. strength	Actual Bend. strength	300°C		500°C		700°C	
			Sudd.	Grad.	Sudd.	Grad.	Sudd.	Grad.
20MPa	925.98	900	701.25	733.5	615	675	525	561
30MPa	966.27	969.9	825	831.375	750	810	547.5	701.25
40MPa	986.526	1050	945	969.9	831.375	900	675	750

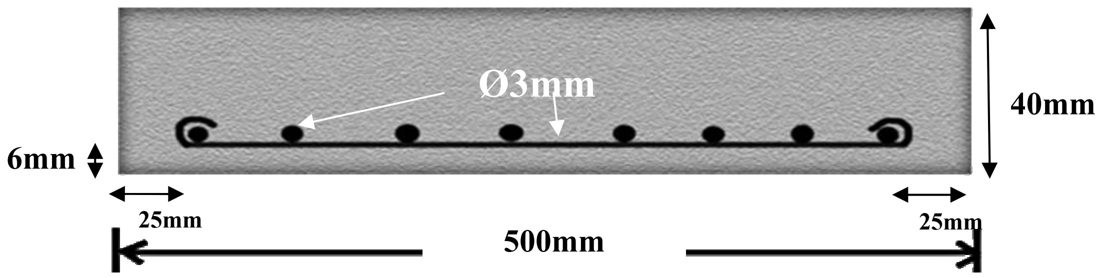


Figure 1: Side Cross Of Slab

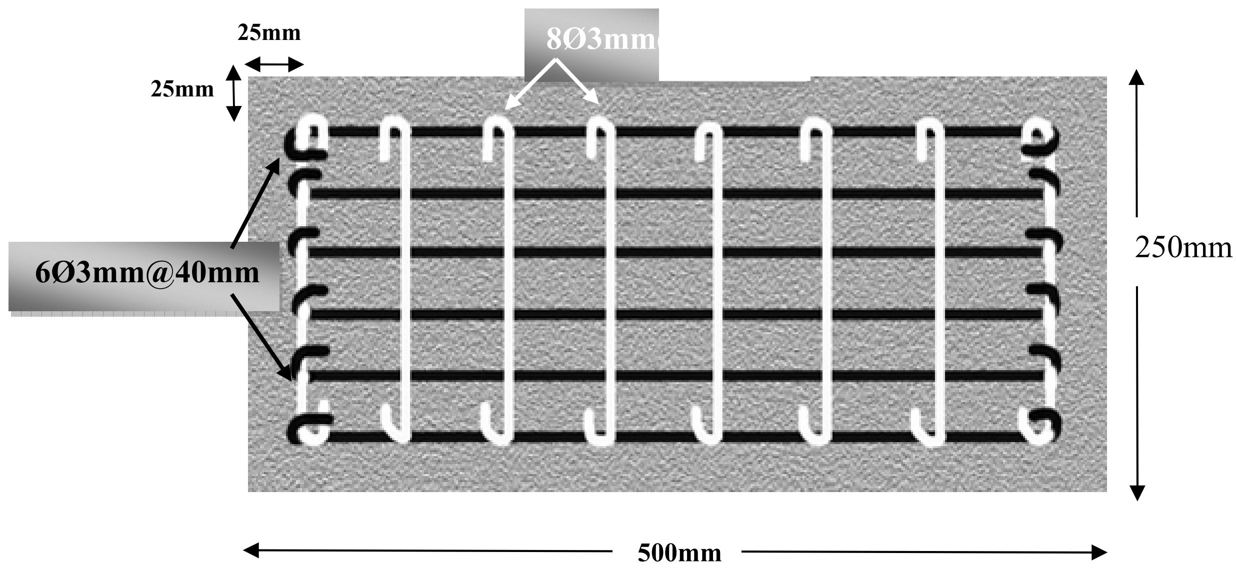


Figure 2: Top View Of Slab With Reinforcement Details

Figure 3: Flame Furnace

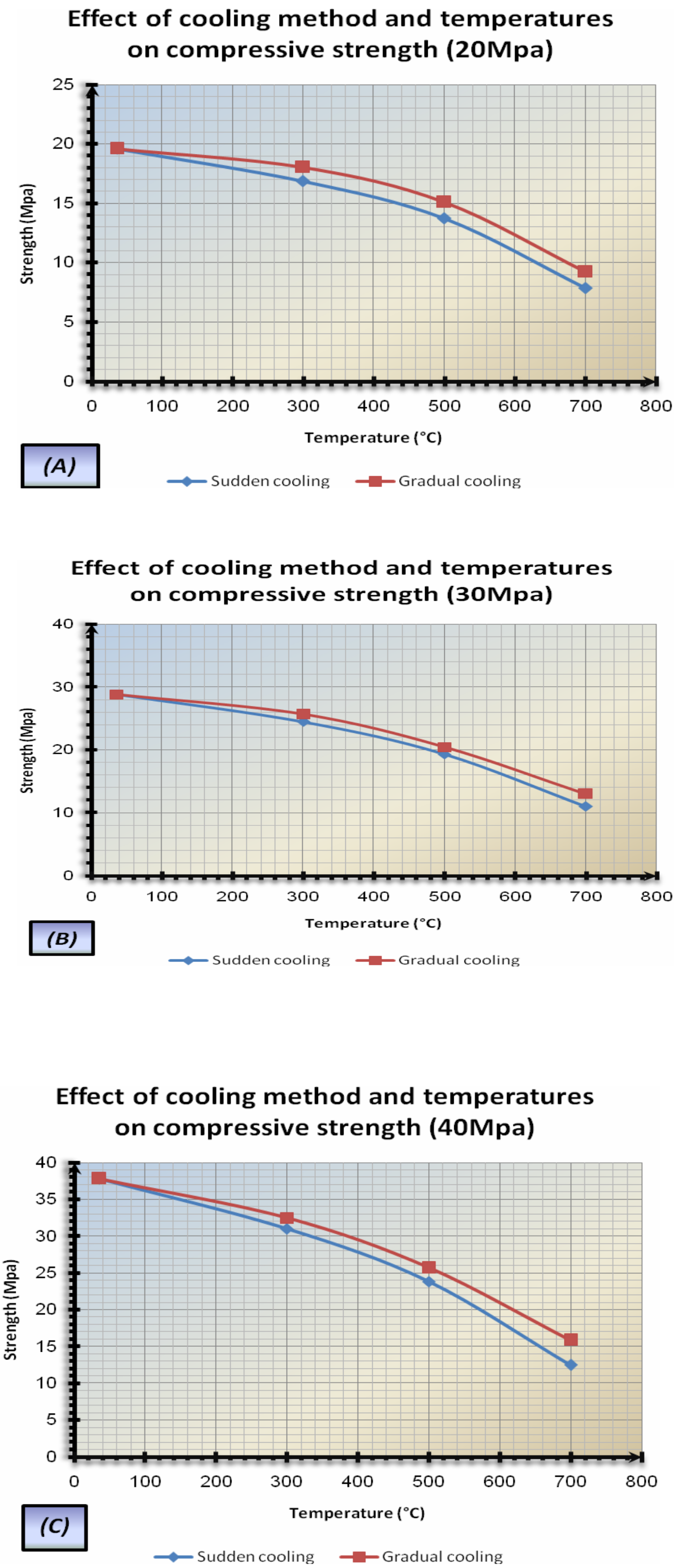


Figure 4: Effect of Cooling Method and Temperatures on Compressive Strengths

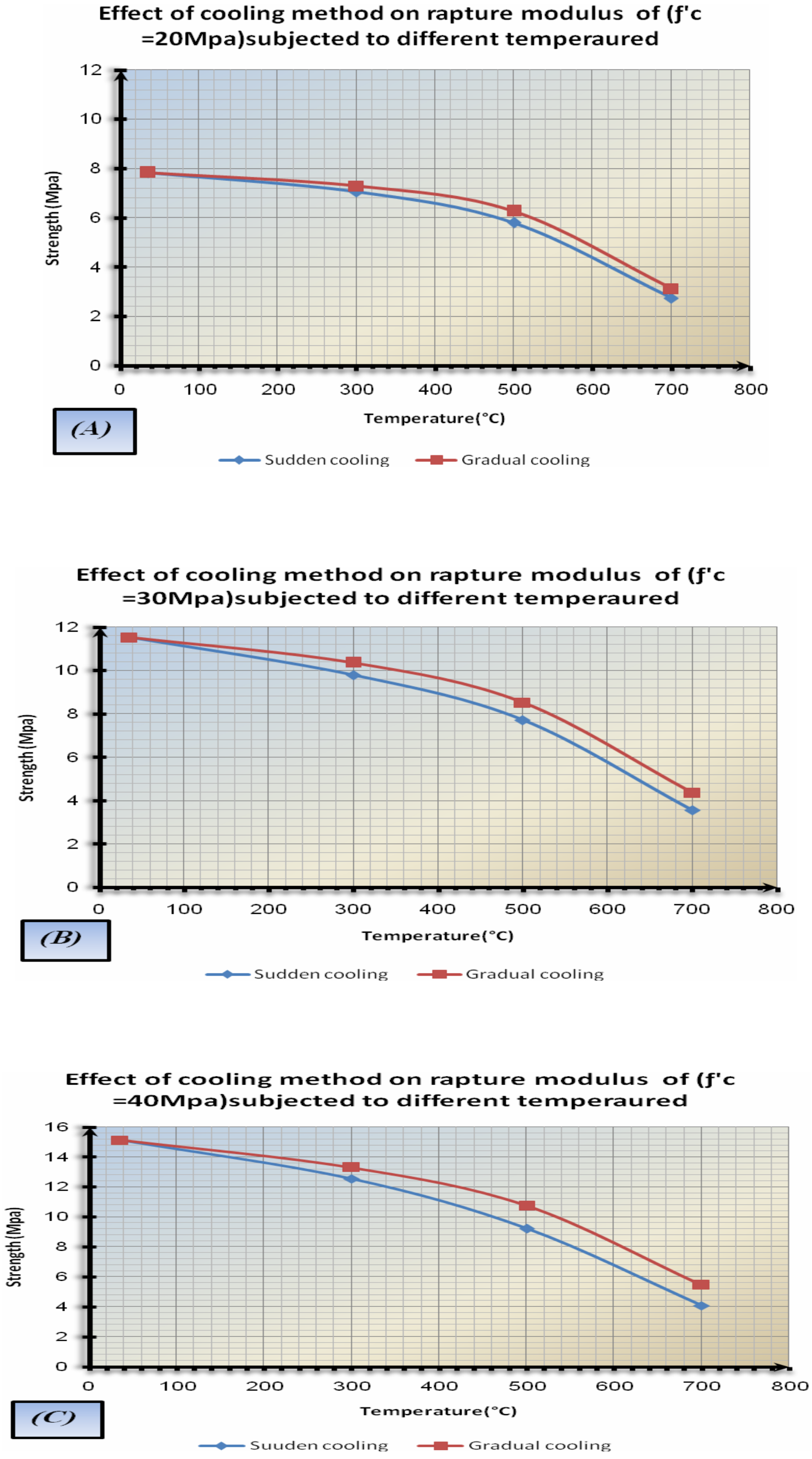


Figure 5: Effect of Cooling Method and Temperatures on Modulus of Rupture

Fig. 6: Testing Of Specimens Under Two Point Loads.

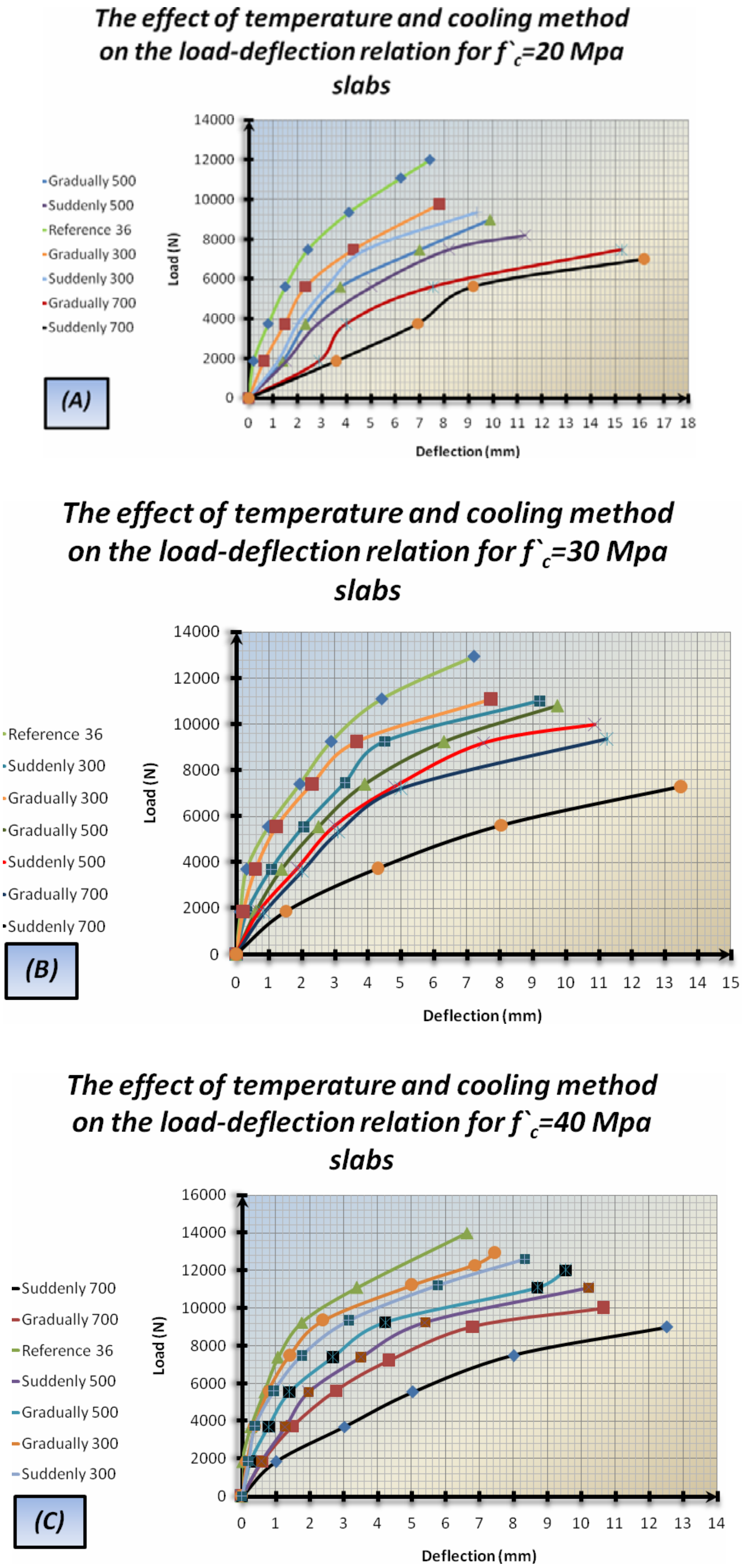
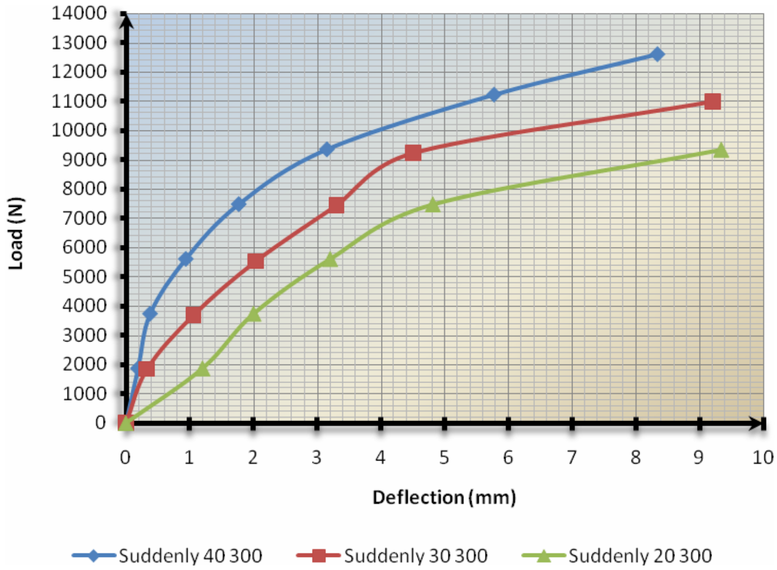


Figure 7: The Load-Deflection Relations For ($f`_C$=20, 30, & 40 Mpa) Slabs In The Temperatures (300, 500, & 700°C) With Both Cooling Method



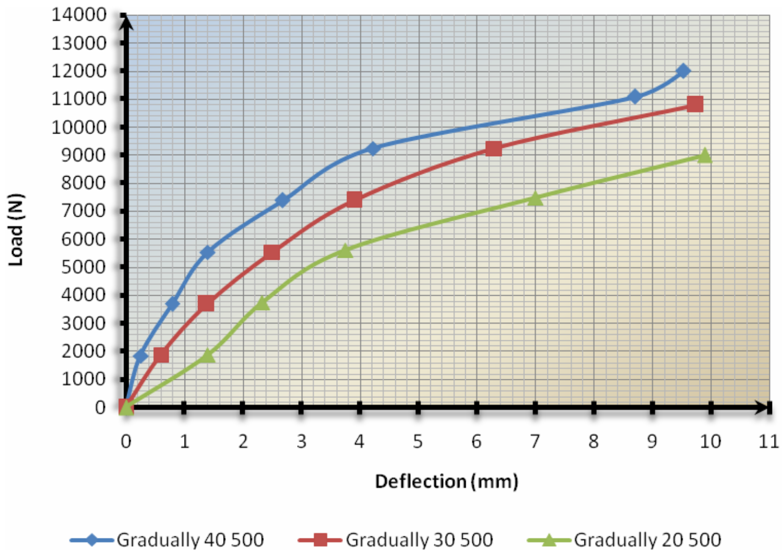


Figure8: The Load-Deflection Relation For Burned Slab Specimens Had Different Concrete Strength In Both Cooling Methods At 500^{o}c.