THE EFFECT OF HEAT ON THE CONCRETE STRENGTH

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ABSTRACT
This research studies the effect of fire on the compressive strength of concrete. In this study Concrete mix was designed to give a compressive strength of 40 MPa. after that the concrete mixture was spilt into cubes 150 mm^3 cubic. The concrete cubes were then exposed to fire at 240c° temperatures for different times for 1,2,3 and 4 hours . Cubes also heated in electrical furnace at temperatures of 240c°and 300c. The change in the characteristic of the concrete after exposed to fire was then checked by Schmidt hammer, Ultra-Sonic tests and crashing test respectively to measure the compressive strength. The results showed that the concrete compressive strength decreases with the increase in exposure time. The total reduction in compressive strength after four hours of burning at 240c° was 45 % for 28days age cubes ;this reduction was38 % when using electrical furnace at 240c° whereas the reduction at 300c° was 46%.separation in outer shell of specimens occurred much higher under the influence of direct flame compared to furnace heating.
KEYWORDS : Concrete , compression, fire, UPV, temperature, flame

1. Introduction:

Historically, the fire performance of concrete has often been taken for granted considering its non-combustible nature and ability to function as a thermal barrier, preventing heat and fire spread.

Design criteria have been based on the results of testing to “standard” fire exposures . typically expressed in terms of required concrete cover. However, the general applicability and usefulness of this approach may be debated since the heating regimes in real-world fires may be quite different.

In particular, initial heating rates can be more rapid and all real fires have a distinct “cooling phase”; both of these conditions are recognized as imposing additional stresses on in situ structures which may be highly restrained. Thus there are still obvious gaps in knowledge of the true behavior of concrete structures in fire. In fundamental terms, the fire behavior of concrete is linked to the temperature-dependent material properties, Since the thermal diffusivity is rather low, compared to steel, strong temperature gradients are usually generated within fire-exposed concrete members. Together with the high thermal inertia, this means that the core region may take a long time to heat up. Thus, whilst the compressive strength of concrete is rapidly lost beyond a critical temperature, which is not too dissimilar to the equivalent temperature for loss of steel strength, structural effectiveness is not affected until the bulk of the material reaches the same temperature. This requires an analysis of the thermal response of the entire structural element.

Another problem which occurs when concrete is exposed to fire is spalling, This is the phenomenon involving explosive ejection of chunks of concrete from the surface of the material, due to the breakdown in surface tensile strength. It is caused by the mechanical forces generated within the element due to strong heating or cooling, i.e. thermal stresses, and/or, by the rapid expansion of moisture within the concrete increasing the pore water pressure within the structure. Spalling may occur under a variety of circumstances where strong temperature gradients are present, both in the heating and cooling phases.

The performance of concrete in fire depends both on the details of its composition and its type, i.e. normal-strength, high-performance (HPC) or ultra-high-performance[1-8].

There are a number of physical and chemical changes which occur in concrete subjected to heat[4] Some of these are reversible upon cooling, but others are non-reversible and may significantly weaken the concrete structure after a fire. Most porous concretes contain a certain amount of liquid water. This begins to vaporize if the temperature exceeds 100°C, usually causing a build-up of pressure within the concrete. In practice, the boiling temperature range tends to extend from 100 to about 140°C due to the pressure effects. Beyond the moisture plateau, when the temperature reaches about 400°C, the calcium hydroxide in the cement will begin to dehydrate، generating more water vapor and also bringing about a significant reduction in the physical strength of the material. Other changes may occur in the aggregate at higher temperatures. In isolation, the thermal response of the aggregate itself may be straightforward but the overall response of the concrete due to changes in the aggregate can be much different. For example, differential expansion between the aggregate and the cement matrix may cause cracking and spalling In combination, these physical and chemical changes in concrete will have the effect of reducing the compressive strength of the material[1-8].

Due to the war in Sirte city many buildings were subjected to fires the study conducted to identify the impact of these fires on the strength of concrete and examine ways of repair. The study rely in laboratory tests and in situ, using compressive strength machine and indirect tests such as Schmidt Hammer and UPV

Fig. 1 A building affected by fire in Sirte

2. Mix Design and Proportions:

For this study the target design strength was 40MPa. The proportions of the concrete mix are summarized in Table 1. The normal strength concrete was made under controlled laboratory conditions. All cubes used for testing were taken from mixture with the same proportions.

Table (1): Mix Proportions

Mix proportion			W/C Ratio	Slump (mm)
Cement	Sand	Gravel		
1	2	3	0.55	90

3. Concrete specimens under direct flame fire:

Experiments have been conducted on samples of 150 mm^3 cubes aged 28 days in their sound to know their characteristics and resistance primary and then was exposed directly to the fire at a constant temperature of 240 ^oC as shown in figure 2 and at different times of fire exposure of 1 ,2,3and 4 hours to measure the change in the properties of concrete especially the compressive strength after each time of combustion.

Fig. 2 Sample exposed to direct flame

The equipments used on the specimens were Schmidt hammer, UPV and compression strength to check the compressive strength, the results of the tests at 28 days are shown in figures 3, 4 and 5.

3.1 Schmidt Hammer test for specimens aged 28 days

Figure 3 shows the relationship between time of burning and rebound number for 28days age, the graph shows that the rebound number decreased steadily with the increase in burning time the total reduction in rebound number after four hours of burning was about 40%.

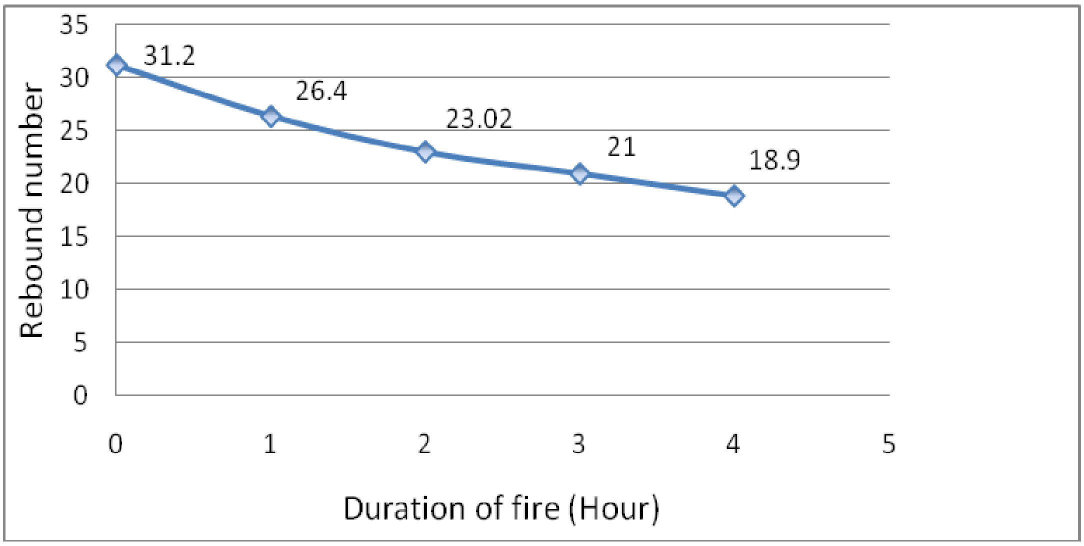

Fig. 3 The relationship between time of fire and rebound number

3.2 Ultrasonic pulses velocity (UPV) test for specimens aged 28 days

Figure 4 shows that the UPV decreased steadily at the first three hours of burning after that the velocity of waves stay approximately constant at the last hour of burning, the total reduction in velocity after four hours of fire at 240c was 83%.

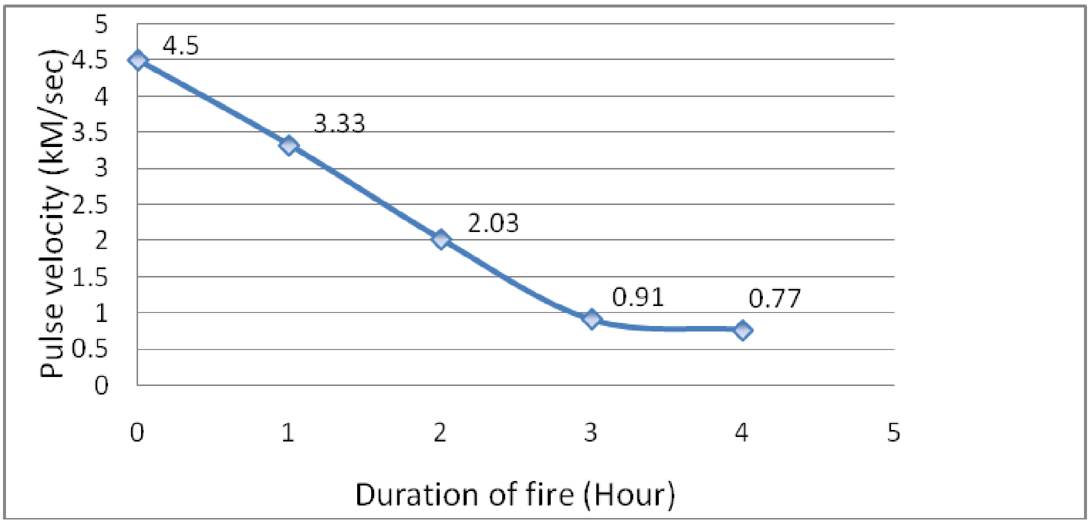

Figure 4: The relationship between time of fire and UPV

3.3 Compressive strength test results for specimens aged 28 days.

Figure 5 shows the relationship between time of burning and compressive strength, the graph shows an steady decrease in compressive strength with the increase in burning time, the total reduction in compressive strength after four hours of burning was about 45%.

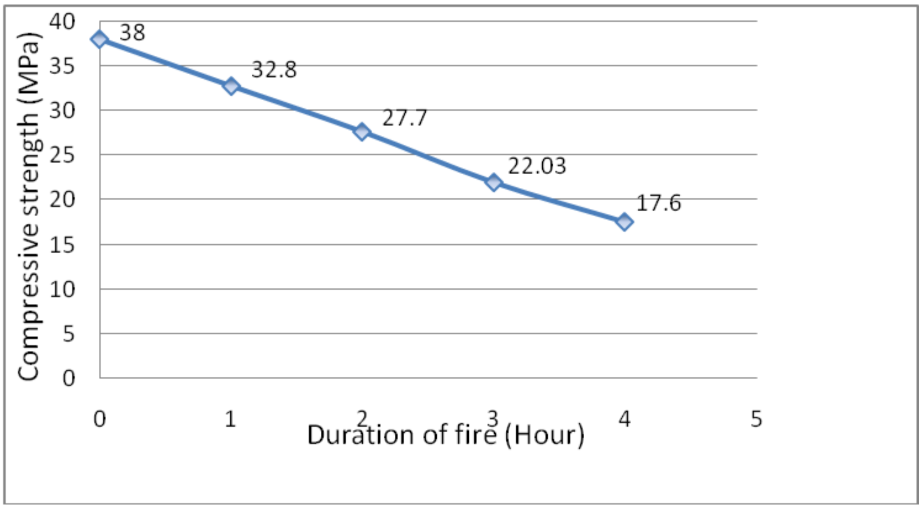

Fig. 5 The relationship between time of fire and Compressive strength

4 Concrete Specimens in the electrical oven

Concrete Samples aged 28 days were heated in electrical oven at 240 °C as shown in figure 5 for different times of heating of 1, 2, 3and 4 hours before crushing the cubes to check the effect of heat on the compressive strength, using Schmidt Hammer and UPV, figures 7, 8 and 9 shows the effects of the oven heat on the specimens.

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Fig. 6 Concrete specimens in the electrical oven

4.1 Schmidt Hammer test for specimens aged 28 days (240c°)

Figure 7 shows The relationship between the time of burning and rebound number for 28days age specimens, the graph shows that the rebound number decreased steadily with the increase in burning time the total reduction in rebound number after four hours of burning was about 28%.

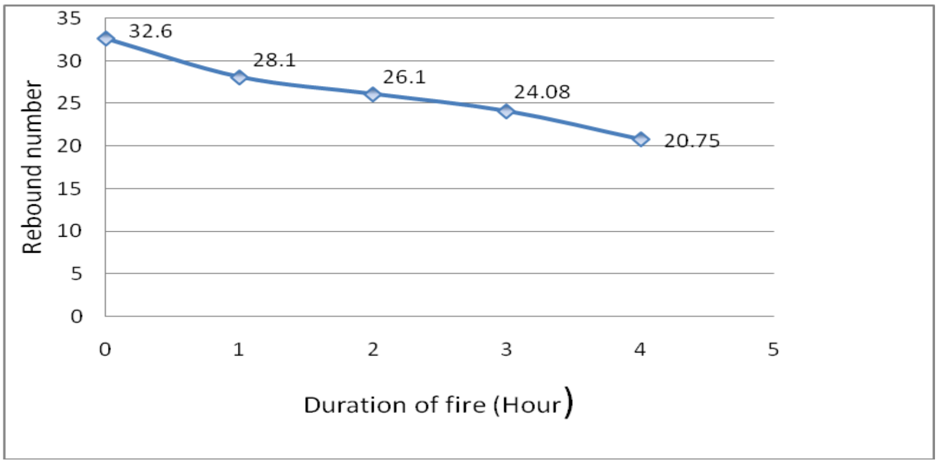

Fig. 7 The relationship between time of fire and rebound number

4.2 Speed of UPV test for specimens aged 28 days(240c°)

Figure 8 shows that as a result of concrete cubes exposure to temperature of 240 at 28 days resulted in a reduction in the speed of transmission of waves through concrete cube due to the increase of cracks through a change in the time of the fire and the percentage decline in overall speed after four hours burning about 80%.

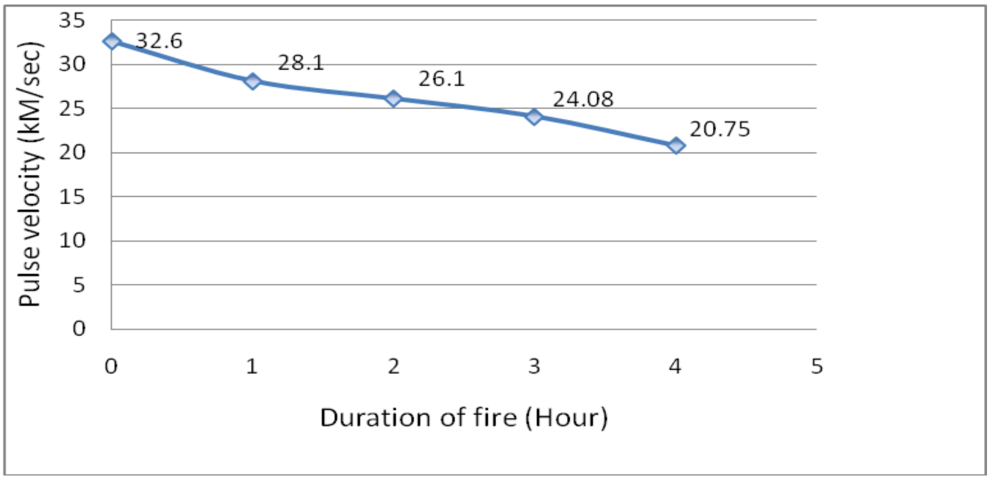

Fig. 8 The relationship between time of fire and UPV

4.3 Compressive strength test results for specimens aged 28 days at 240 °C

Figure 9 shows The relationship between time of burning and compressive strength, the graph shows a decline in the compressive strength with the increase in burning time, the total reduction in compressive strength after four hours of burning was approximately 38%.

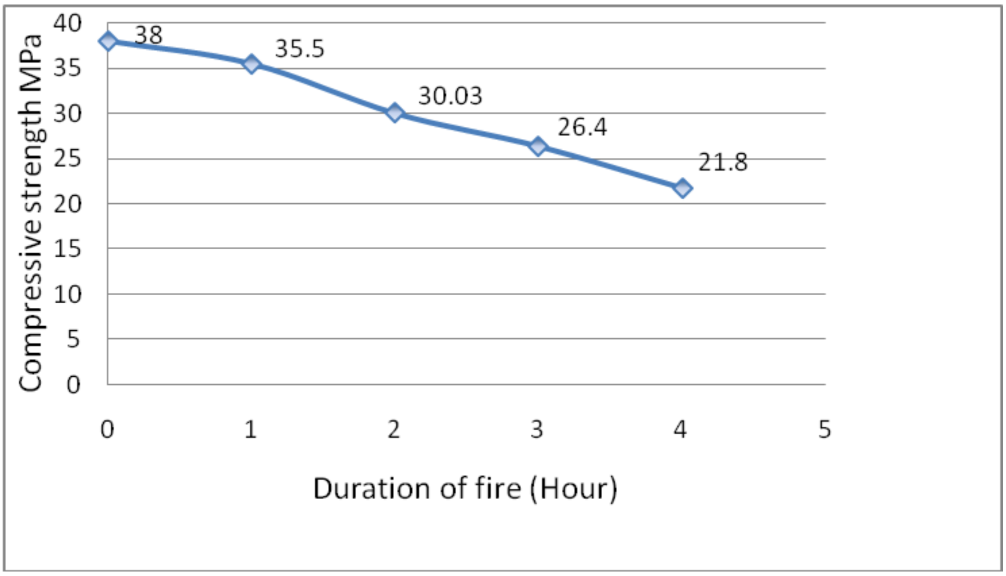

Fig. 9 The relationship between time of fire and compressive strength

5 Conclusion:

Tests were conducted on concrete cubes aged 28 days using both direct flame at temperature 240 °C and electrical oven temperatures at 240 °C at 1, 2, 3 and 4 hours and when the tested performed to assess the vulnerability of concrete from burning and heat the following is noticed:

1 - A decrease in the strength of concrete loading, and the decrease in the compressive strength of the concrete under flames and furnaces at temperatures of 240 ° C are close to each other

2 - the influence on the compressive strength of concrete at a temperature of 300 cْ was larger than 240 cْ, and the percentage decrease in the compressive strength of concrete exposed to temperature of 300 cْ for a period of four hours was about 43%.

3- From the results its noted that the rebound number readings is much highly affected by the direct flame fire than the electrical oven because of spalling.

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6 REFERENCES :

[1] Schneider, U. & Lebeda, C. (2007) Baulicher Brandschutz (Structural Fire Protection), Bauwerk Verlag, Berlin, Germany, 400 pp.

[2] Tenchev, R. & Purnell, P., An application of a damage constitutive model to concrete at high temperature and prediction of spalling, *Int. J. Solids & Structures*, 42 (2005), 26, pp. 6550-6565

[3] Terro, M.J., Numerical modelling of the behaviour of concrete structures, *ACI Struct J.*, 95 (1998), 2, pp. 183–93

[4] Bazant, Z.P. & Kaplan, M.F., Concrete at High Temperatures, Longman, London, UK1996

[5] Alarcon-Ruiz, L., Platret, G., Massieu, E. &Ehrlacher, A., The use of thermal analysis in assessing the effect of temperature on a cement paste, *Cement & Concrete Research*, 35 (2005), 3, pp. 609-613

[6] Ali, F., Nadjai, A., Silcock, G. & Abu-Tair, A., Outcomes of a major research on fire resistance of concrete columns, *Fire Safety J.*, 39 (2004), 6, pp. 433-445

[7] Carvel, R., Fire protection in Concrete Tunnels, in The Handbook of Tunnel Fire Safety (Eds. Beard, A. & Carvel, R.) Thomas Telford,
London, 2005

[8] Hertz, K.D. & Sorensen, L.S., Test method for spalling of fire exposed concrete, *Fire Safety J.*, 40 (2005), 5, pp. 466-476