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Behaviour of Concrete Subjectecd to Defferrents Elevated Temperatures

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ABSTRACT
In this research, the influence of aggregates sizes, cover to reinforcement, Concrete age, and exposure period on the mechanical properties of normal concrete (NC) subjected to different elevated temperatures will be investigated. The total number test specimens of 100 standard 150mm cubes including control specimens were used to evaluate the residual compressive strength of concrete under different elevated temperatures and exposure time. The cubes specimens was cured for one, three, seven, fourteen and twenty eight days, respectively (1, 3, 7, 14, 28 days). The cubes were subjected to the following varying temperature: 100ºc, and 300ºc. For each of the temperature above, the cubes were subjected to that temperature for the duration of 30mins.
The results generally, show that, combined aggregates concrete has better fire performance than the concrete made using single aggregates size. In the case of concrete made using single size aggregates. M_2 perform better than M_4, which show that, as the aggregate increases in size, more voids will be created and loss in weight will be increased.
Keywords: Aggregate, reinforcement, elevated temperature, concrete

I. INTRODUCTION

Concrete, a leading construction material in civil engineering is some time exposed to elevated temperature due to natural hazard (Vodk et al, 2004). Subjecting concrete to high temperature leads to transformations and reactions that cause the progressive breakdown of cement and consequent loss in load bearing capacity (khoury, 1992; Earline et al., 1992; Hanson 1990; and Handoo et al, 2002).

Several factors will be identified for the deterioration of concrete due to high temperature. These include decomposition of the calcium hydroxide with time and water, expansion of lime on re–hydration, destruction of gel structure, phase transformation in some types of aggregates and development of micro–crakes due to terminals in compatibility between cement paste matrix and aggregate phase (Mohammad et al, 2009).

During fire outbreak, concrete elements [beam and columns] are exposed to different temperatures. Heating considerably changes the strength, physical properties and stiffness of both concrete and steel. The modulus of elasticity decreases as the temperature increases (Gruz, 2009).

Husen (2006) examined the variation in compressive and flexural strength of ordinary and high performance concrete exposed to high temperature of 200, 400, 600, 800 and 1000^{0}C; and then cooled in air of water . The compressive and flexural strength of these concrete specimens were compared with each other and with unheated specimen. From the results obtained, he concluded that for ordinary and high performance concrete expose to high temperature; the flexural and compressive strength decrease with the increase in temperature, and is greater when the specimens were cooled in water.

Noumowe, et al. (2010) had reported the effect of high temperature exposure on the properties of concrete. Ahmed et al, (2012) reported the fire exposure effect on some mechanical properties of concrete at three temperature level of (400, 500 and 700) ^{0}C with four different exposure duration of 0.5, 1.0, 1.5 and 2.0 hours without any imposed load during heated. He found that the residual compressive strength ranged between (70 – 85%) at 400^{0}C, (59 – 78%) at 500^{0}C and (43 – 62) at 700^{0}C. The flexural strength was found to be more sensitive to fire flame exposure then the compressive strength

Abdellalim et al, (2009), Yuzer, et al, (2004) indicate in their finding that, aggregate types have a minor effect on the concrete resistance to fire. However, the result showed that dolomite aggregate provided the highest resistance to fire while natural aggregates gave the least resistance,

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Sallvan and Poucher. (2011) report that, the quality of concrete greatly depends on the sound inherent properties of concrete aggregates, such as chemical and physical properties.

When the real structures fail in fires it is rarely not for the reason that might be expected on the basis of standard fire resistance testing. In many cases, failure is precipitated by some localize failure or distress, such as discrete cracking in concrete, rupture of tensile steel reinforcement, failure of a connection, local buckling of structure steel work, shear, (punching) failure of a concrete slab (Felix et al, 2010).

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II. LITERATURE REVIEW

The several mechanisms will be identified for the deterioration of concrete due to high temperature. These include decomposing of the calcium hydroxide with time and water, expansion of lime on re–hydration, destruction of gel structure, phase transformation in some types of aggregate, and development of micro–cracks due to thermal in compatibity between cement paste matrix and aggregate phase (Mohammad et al, 2008).

High temperature causes chemical and micro structure changes such as water migration, (diffusion, drying), increased dehydration, interracial thermal incompatibility, and chemical decomposition of hardened cement paste and aggregate. Zhang et al (2000) decreased the strength and stiffness of concrete and increase irrecoverable. Furthermore, the effect of elevated temperatures at varied heating scenarios on the strength of plain concrete has been investigated by many researchers (Mohamed bai, et al., 2010; Khalaf and Devenny, 2004; Chan, et al,1999; Min et al, 2004; Xiao and Falkner, 2006; Mahdy et al, 2002; Abramowics and Kowalski, 2005. However, there is need to investigate the effect of aggregates size, concrete aging, exposure time and concrete cover to reinforcement on the concrete mechanical and physical properties of concrete exposed to different elevated temperature.

Allen and Desai (2010) used three different aggregates; a light weight shale, a fireclay brick and a pure lime stone in the strength of concrete subjected to high temperature. The concrete consisting fire clay brick showed the best mechanical properties while lime stone deteriorated most considerably with maximum reduction in compressive strength.

III. METERIALS AND METHODOLOGY

3.1 Materials

3.1.1 Cement

The cement to be used for the whole work is Sokoto Ordinary Portland Cement (OPC), which will be procured in a single consignment and properly stored.

3.1.2 Fine Aggregate

a) Sand: River sand will be used as fine aggregate, which will be collected from Mafara river in Talata Mafara.

3.1.3 Coarse Aggregate

a) Conventional Coarse Aggregate: Machine crushed granite will be obtained from a local Quarry at Sado, Gusau road.

3.1.4 Water

The water used throughout casting operation of the specimens was municipal water that is drinking and portable and has no definite test or odour.the water used in carrying out the preliminary test was sourced from main laboratory of the department of civil engineering, Abdu Gusau Polytechnic, Talata Mafara.

3.2 Method

3.2.1 Preparation / production of cement Test Specimens

The specimen for the tests will be produced, the total number test specimens of 100 standard 150mm cubes. Including control specimens and they will be used to evaluate the residual compressive strength of concrete under different elevations temperatures and exposure time

3.2.2 Curing specimens

The specimens will be demoulded, immersed and kept in to curing tank at room temperature until testing age after twenty four hours of casting. In this work, cubes specimens will be cured for one, three, seven, fourteen and twenty eight days, respectively (1, 3, 7, 14, 28 days).

3.2.3 Heating (Cubes Specimens)

Heating of specimens will be carried out in accordance with Australia/New Zealand Standard (2005) and BS1881-116 (1983). As earlier stated, 100 cubes specimen sample will be produced; 66 of which are the control specimens as earlier said and will be subjected to different temperatures in electrical furnace. The remaining 34 is extra will be subjected to different temperatures in electrical furnaces. This test was done in Abdu Gusau Material laboratory Talata Mafara. The cubes were subjected to the following varying temperature: 100ºc, and 300ºc. For each of the temperature above, the cubes were subjected to that temperature for the different duration: 30mins.

After the heating for the targeted duration, the cubes specimens are removed and allowed to cool for twenty fur hours (24 hrs.) and the cubes strength are determine in accordance to BS8110, 1997.

3.2.4 Specimens Weighing

After all the specimens were demolded, cured and attained the required ages testing. Their respective weight were taken both before heating and after except the control specimens which were weighed once.

3.2.5 Thirty Minutes (30 minutes).

table will present result of percentage weight reduction of concrete 1 - day, 3 - days, 7 - days, 14 – days, and 28 - -days old concrete at : 100ºc, and 300ºc. at 30minutes exposure time. Best of research carried out in the laboratory according to the research work the results obtained are presented below tn tabular table 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

Table 1: Percentage weight reduction of 1-day old at 100^0c/30minutes exposure

1-Day @100^0c				
Types of concrete	Weight before heating (kg)	Weight after heating (kg)	Difference (kg)	% reduction in weight
M_1	8.7	8.6	0.1	1.2
M_2	8.6	8.5	0.1	1.25
M_3	8.5	8.3	0.2	1.6
M_4	8.5	8.3	0.2	2.3

Table 2: Percentage weight reduction of 3-days old at 100^0c/30minutes exposure

3-Days @100^0c				
Types of concrete	Weight before heating (kg)	Weight after heating (kg)	Difference (kg)	% reduction in weight
M_1	8.8	8.72	0.08	0.97
M_2	8.7	8.1	0.1	1.1
M_3	8.7	8.55	0.15	1.0
M_4	8.5	8.35	0.15	1.3

Table 3: Percentage weight reduction of 7-days old at 100^0c/30minutes exposure

7-Days old @100^0c				
Types of concrete	Weight before heating (kg)	Weight after heating (kg)	Difference (kg)	% reduction in weight
M_1	8.8	8.2	0.6	5.8
M_2	8.5	8.0	0.7	8.0
M_3	8.4	7.8	0.8	9.0
M_4	8.4	7.9	0.8	11.2

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Table 4: Percentage weight reduction of 14-days old at 100^0c/30minutes exposure

14-Days old @100^0c				
Types of concrete	Weight before heating (kg)	Weight after heating (kg)	Difference (kg)	% reduction in weight
M_1	8.5	7.9	0.7	7.0
M_2	8.7	8.0	0.8	9.2
M_3	8.5	7.7	0.8	9.7
M_4	8.5	7.6	0.9	11.0

Table 5: Percentage weight reduction of 28-days old at 100^0c/30minutes exposure

28-Days old @100^0c				
Types of concrete	Weight before heating (kg)	Weight after heating (kg)	Difference (kg)	% reduction in weight
M_1	8.8	8.1	0.7	0.8
M_2	8.5	7.7	0.8	0.9
M_3	8.7	7.8	0.9	0.10
M_4	8.7	7.8	0.9	0.11

Table 6: Percentage weight reduction of 1-day old at 300^0c/30minutes exposure

1-Day @300^0c				
Types of concrete	Weight before heating (kg)	Weight after heating (kg)	Difference (kg)	% reduction in weight
M_1	8.8	8.2	0.6	1.14
M_2	8.7	8.57	0.13	1.45
M_3	8.7	7.55	0.15	1.70
M_4	8.7	7.55	0.15	1.70

Table 7: Percentage weight reduction of 3-days old at 300^0c/30minutes exposure

3-Days @300^0c				
Types of concrete	Weight before heating (kg)	Weight after heating (kg)	Difference (kg)	% reduction in weight
M_1	8.8	8.69	0.11	1.25
M_2	8.8	8.68	0.12	1.40
M_3	8.7	7.55	0.15	1.70
M_4	8.7	7.55	0.15	1.70

Table 8: Percentage weight reduction of 7-days old at 300^0c/30minutes exposure

7-Days old @300^0c				
Types of concrete	Weight before heating (kg)	Weight after heating (kg)	Difference (kg)	% reduction in weight

M_1	8.8	8.7	0.1	1.14
M_2	8.7	8.58	0.12	1.40
M_3	8.7	7.55	0.15	1.70
M_4	8.7	7.55	0.15	1.70

Table 9: Percentage weight reduction of 14-days old at 300^{0}c/30minutes exposure

14-Days old @300^{0}c				
Types of concrete	Weight before heating (kg)	Weight after heating (kg)	Difference (kg)	% reduction in weight
M_1	8.8	8.70	0.10	1.10
M_2	8.8	8.69	0.11	1.25
M_3	8.8	8.68	0.12	1.40
M_4	8.7	8.58	0.12	1.40

Table 10: Percentage weight reduction of 28-days old at 300^{0}c/30minutes exposure

28-Days old @300^{0}c				
Types of concrete	Weight before heating (kg)	Weight after heating (kg)	Difference (kg)	% reduction in weight
M_1	8.9	8.81	0.09	1.00
M_2	8.8	8.70	0.10	1.10
M_3	8.7	8.59	0.11	1.25
M_4	8.8	8.68	0.12	1.25

IV. RESULTS AND DISCUSSION

The results given the percentage weight loss of various aggregates concrete mixes of M_1 M_2, M_3, and M_4, after exposure of the specimens to different elevation temperatures of : 100ºc, and 300ºc exposure time of 30minutes.

The value of weight reduction are observed to be varied from 1 – day age (1.2% and 2.3%), 3 – days age (1.2 % and 1.3%), 7 – day age 5.8% and 11.2%), 14 – days age (7.0% and 11.0%), and 28- day age (0.8% and 11.0%) at 30 minutes duration respectively. The results of percentage weight reduction of concrete cubes specimens subjected to different elevated temperatures and maintained for the period of 30 minutes, is presented in table 1 to 10 of chapter three and the graphs are as presents in figure 4.1 to 4.2 below.

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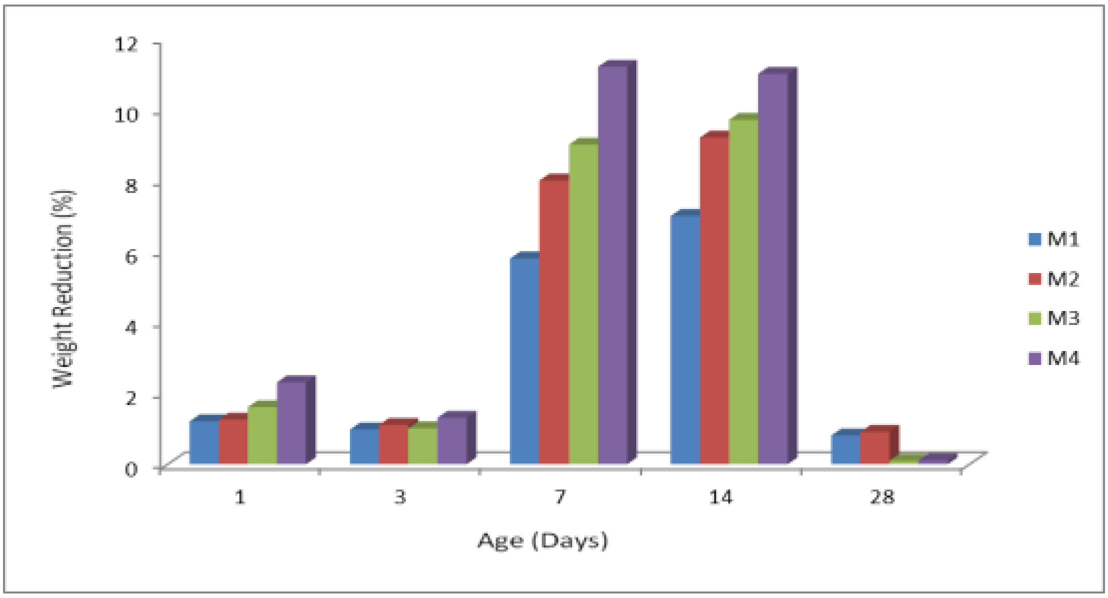

Figure 4.1 percentage weight reduction at: 100ºc for 30minutes exposure

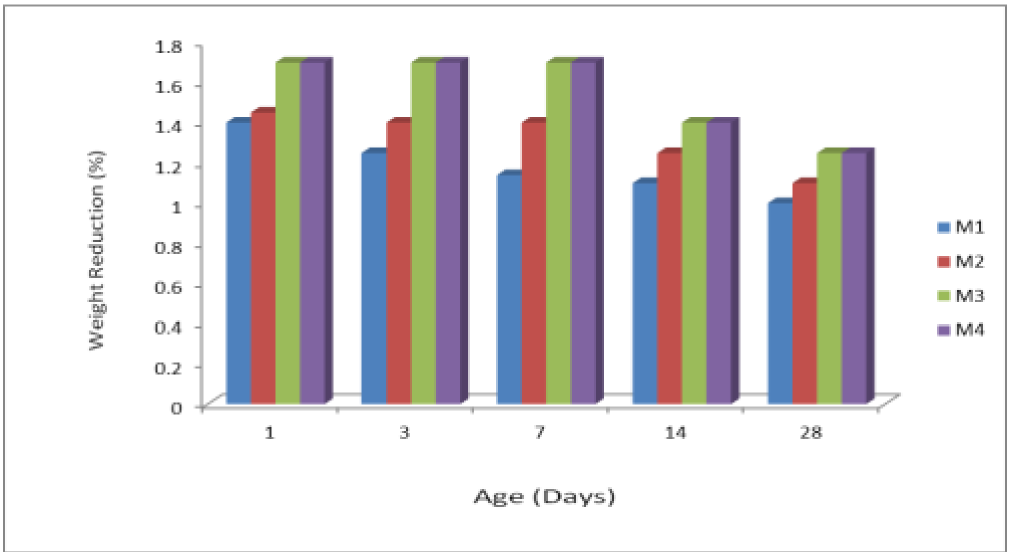

Fig.4.2 Percentage weight reduction at 300^0c for 30minutes exposure

The concrete specimens were heated in different elevated temperatures and were maintained at those temperatures for the period of 30 minutes exposure earlier state. From the results, it can be observed that, the percentage weight reduction increases with increase in temperatures and reduces as concrete ages increases. Also the result show that combined aggregate concrete appeared to have better fire performance than concrete it shows less weight in all cases. The effect of concrete age is displayed in all figures that there is more weight reduction at 1- day age concrete than at 28 – day age in all cases. The respective average weight less at 100^0c for 1- day and 28 – day age 1.3% and 0.9% at 30 minutes exposure. While at 300^0c for 1- day and 28 days age 1.5% and 1, 1% at 30minutes exposure. The results generally, show that, combined aggregates concrete has better fire performance than the concrete made using single aggregates size. In the case of concrete made using single size aggregates. M_2 perform better than $M_{4,}$ show that, as the aggregate increases in size, more void will be created and loss in weight will be increased. The same trend is displayed in all the remain figures that and M_1 displayed the least reduction in weight than the rest M in all cases due to fever voids.

V. CONCLUSION AND RECOMMENDATION

Based on the results are: -

1. The cement used is of good quantity and comply with the standard.
2. Water absorption of all aggregates are okay.
3. The average weight loss is reduced at higher age when compare to lower age, that is to say the older the age of concrete the more resistance it gives aggregate concrete.
4. Combined aggregates concrete losses less weight than single size aggregate concrete.
5. There was significant increase in weight loss as exposure period was progressively increase in 30minutes.
6. Progressive increase in weight loss was also observed when the heating temperature was progressively raised from minimum to maximum 100^0c at 300^0c respectively.
7. Rapid strength development of early age concrete above the strength of the unheated specimens was observed at 100^0c, due to higher acceleration of hydration particularly exposure time.
8. Combined aggregate concrete appeared to have high fire performance compared to single size aggregates concrete in all cases.
9. There was sharp reduction of retained strength at 300^0c after which steady decrease was experience in all cases.

5.1 RECOMMENDATION

Base on the results and discussion of the study the following recommendation was made:-

The combined aggregates concrete made using single size aggregate. M_2 perform better than $M_{4,}$ show that, as the aggregate increases in size, more void will be created and loss in weight will be increased.

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