Influence On Static And Cyclic Thermal Loading Patterns On Physical Properties And Structural Behaviour Of Concrete

Adekunle P. Adewuyi *, Leungo Carol Lentswe
Department of Civil Engineering, University of Botswana, Gaborone, Botswana

*Corresponding Author: adewuyia@ub.ac.bw

***Abstract*—Fire is one of the most serious potential risks for buildings and structures. The failure of fire structural concrete varies depending on the nature of the fire, the mechanism of loading and the form of construction. The service life of concrete elements in building depends on the effectiveness of safety and maintenance practices as well as the promptness of response of fire service agency to emergency calls. The objective of the experimental study was to determine the physical properties and structural behavior of concrete at normal and elevated temperatures up to 400°C under static and cyclic thermal loadings. The results revealed that the mass, the compressive strength, and split tensile strength of concrete specimens decreased with temperature and exposure duration. The deterioration due to mass loss and compressive strength was 33% and 39% higher for cyclic thermal loading than the static thermal loading. However, there was 12% recovery in the tensile strength of concrete in the cyclic thermal than the static thermal loading. Mass loss in concrete cubes was slightly greater than the cylinders due to the escape of vapours and gases equally from all faces, which is not the case with cylinders. The split tensile strength of the heated specimens decreased with rise in temperature as well as the number of thermal cycles with the loss in the split tensile strength of concrete after 3 cycles of exposure varying from 10.7% to 42.9%. It can therefore be concluded that all non-destructive testing of concrete structure is essential after fire hazard to suggest the ideal rehabilitation and strengthening process that will not compromise the serviceability and functionality of the concrete building.**

***Keywords*—Mass loss, compressive strength, split tensile strength, structural deterioration, concrete, elevated temperature, thermal loading, residual strength, service life**

I. Introduction

Concrete is arguably the most important building material, playing a part in all building structures. Its virtue is its versatility, i.e. its ability to be moulded to take up the shapes required for the various structural forms. It is also very durable and fire resistant when specification and construction procedures are correct [1,2]. It is one of the most enduring, economical, and fit-for-purpose building materials. Concrete is the single largest manufactured material in the world and accounts for more than 6 billion metric tons of materials annually [2, 3].

Concrete, however, has a very low tensile strength, which makes stress unstable and appears to be brittle. Tension stresses and shrinkage during the curing stage contribute to the creation of cracks that allow moisture to enter and concrete loss of strength, resulting in cracks when subjected to tensile stresses. Therefore, in the stress zones, reinforcements are provided to hold tensile forces and to restrict crack widths [4]. The most common component of structural engineering is reinforced concrete structures because it has proven to be a very good construction material with desirable characteristics such as toughness, strength, rigidity, fire-resistant properties, low cost, excellent environmental insulation and the ability to form into any given shape [5].

Fire is considered one of the most serious potential risks for buildings and structures. Fire in buildings is caused by many factors including lightning strikes, electrical faults or sparks, electronic malfunction, power surge, loss of control of fire in residential and industrial settings, negligence in storage or use of fuel, failure of an aged insulating layer, a secondary accident after a natural or accidental disaster [6-8]. The failure of fire structural concrete varies depending on the nature of the fire, the mechanism of loading and the form of construction. Loss of bending or tensile strength, loss of bond strength, loss of shear or torsional strength, loss of compressive strength, and concrete spalling may lead to failure [9,10].

Temperature is typically responsible for three forms of transition. The first one is cracking in the surface zone and microcracking. Cracks usually form along the aggregate surface, possibly representing the variations between cement paste and aggregate in the linear expansion coefficient. In particular, larger cracks will occur where the rise in temperature has affected reinforcement [6,10]. The phases in aggregate and paste are modified and oxidation and dehydration are related to the key changes occurring in aggregate and paste. Moisture loss can be rapid and probably affect the development of cracks. In general, the paste changes color and different color zones can grow. At about 300°C and from pink to whitish grey at about 600°C, a change from buff or cream to pink appears to occur. Finally, the dehydration of the hydrated cement steps in where cementitious paste becomes friable, very brittle and quickly broken down at a temperature greater than 600°C with significant shrinkage cracking, honeycombing and usually concrete [7].

Assessment of fire-exposed concrete helps to understand the severity of the damage and its effect on the design life and serviceability of the structure and post fire sustainability. If the degree of concrete damage is known, it is possible to make a proper decision as to whether the structural feature requires replacement or repair. In our previous study, It also helps to take precautionary steps for the known cause of the damage to avoid the damage in future. The selection of aggregate is a major concern in concrete design to increase the durability of concrete when exposed to fire. There are two types of aggregate widely used in construction: carbonate aggregate and aggregate silica. Compared to carbonate aggregate, silica aggregate offers higher thermal conductivity and expansion, higher fire resistance, and increased spalling resistance in concrete [11].

In our previous study, Adewuyi & Lentswe [12] presented an experimental investigation to verify and validate the accuracy of most commonly used prediction models for concrete strengths under exposure to elevated temperature or heat. All structural members lose strength and stiffness when exposed to high temperatures or heat as encountered in fire. The physical properties of a fire-damaged concrete starts at the visual observation such as the change in color, cracking and spalling that may appear at the surface when the concrete is exposed to high temperatures [13].

Li & Purkiss [14] found that color or external appearance changes are reliable insights on deterioration of concrete when exposed to different degrees of heat or fire. Concrete changes colour to pink or red when exposed to temperatures of 300°C to 600°C, while temperature from 600°C to 900°C changes the color of concrete to whitish gray and buffers between 900°C and 1000°C. As exposure temperature rises, concrete loses moisture thereby causing decrease in the density or mass of concrete. The form of aggregate is strongly affected by the preservation of concrete mass at elevated temperatures [6,15,16]. Li et al. [17] investigated the effect of 200°C to 1,000°C temperature exposure on the compressive, splitting tensile and flexural strength of normal and high-strength concrete with respect to water content, specimen size, strength and temperature profiles. It concluded that the strength loss was lower in larger specimens.

The strengths of cube specimens subjected to elevated temperatures ranging from 100°C to 800°C were calculated by Yaragal et al. [18] in steps of 100°C with a 2-hour retention time. Weight loss and the residual compressive strength retention characteristics were analyzed after exposure. The results of the test showed that weight and strength decreased significantly with an increase in temperature. The weight loss of the specimen increased above 200°C as the exposed temperature increased. With an increase in the grade of concrete, there was a decrease in specimen weight loss after elevated temperatures were observed. Overall, there was a significant loss (74 percent) in the strength of concrete grades M20, M25 and M30 when exposed to higher temperatures. However, for grades M35, M40 and M45, the loss of strength was around 80 percent. The minimum residual strength observed was found at 800°C to be 18 percent for M45. For NSC, equations to estimate the residual compressive strength for two temperature ranges were derived.

Janotka & Nurnbergerova [19] investigated the performance of concrete at elevated temperature in nuclear power plants. The study revealed loss of concrete strength for temperatures ranging from 100^{o}C to 200^{o}C because of the loss of chemically bound water leading to the formation of air voids. Furthermore, the overheating of concrete may lead to the malfunctioning of the cooling system of the nuclear power plants that might be hazardous. One of the pioneer studies on the subject showed that mechanical properties of concrete are directly affected when concrete is exposed to high temperature [20]. This is primarily due to the cracking concrete at the interface of aggregate and cement paste due to the difference in thermal behaviour of the two materials [21,22].

Depending on the effectiveness of maintenance culture and fire services, building may experience multiple fire hazards during its service life and the duration and temperature exposure depend on the promptness of fire service agency to respond to emergency calls. Hence, the purpose of this experimental study was to evaluate the physical properties and residual strength of concrete in compression and tension by testing the heated specimens after cooling under constant and cyclic thermal loadings.

II. Experimental Programme

The experimental methodology consists of mix proportioning, casting of specimens, exposing the specimens to elevated temperature and testing to determine deterioration pattern in terms of physical properties and strength. The methodology is summarized in the following section.

A. *Materials*

In this investigation, ordinary Portland cement of grade 52.5 with specific gravity of 3.15 conforming to ACI Standard was employed in the study. The sieve analysis for coarse aggregate and fine aggregate was carried out. Coarse aggregate was crushed granite of maximum nominal size of 19 mm with water absorption of 0.26%. Fine aggregate was well-graded crusher sand of maximum nominal size of 4.75 mm and water absorption of 1.55% and fineness modulus of 3.13. The particle size distribution curves of the aggregates are plotted in Fig. 1. The properties of cement such as consistency, setting times, soundness and compressive strength are summarized in Table 1.

TABLE 1: PHYSICAL PROPERTIES OF CEMENT

Standard Consistency (%)	30
Specific gravity	3.15
Initial setting time (min)	290
Final setting time (min)	450
Soundness (mm)	1.0
Compressive strength (N/mm^2)	
3 days	24.5
7 days	30.8

Crushed granite as coarse aggregate

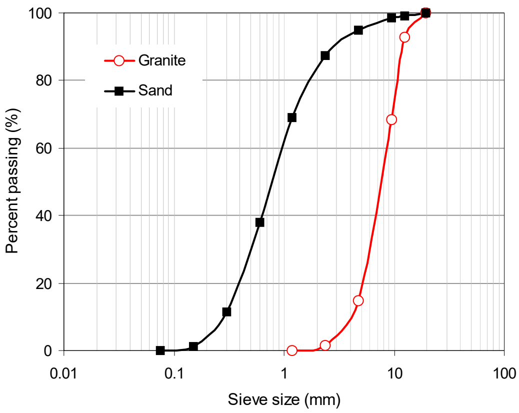

Fig. 1: Samples of particle size distribution of fine and coarse aggregates

The aggregates were free from deleterious materials and the physical properties were carried out in accordance with BS 812 [23]. The properties of fine and coarse aggregates are presented in Table 2. It is obvious that the fine and coarse aggregates employed as constituents of the concrete in the study are well-graded. Potable water of pH of 7.1 which conformed to the requirements of BS 3148 [24] was used in mixing the aggregates and cement. The mix was designed for a target compressive strength of 41.9 MPa according to ACI Standard. The concrete mix produced fresh concrete properties of workability (slump value) of 70 mm. The final mix proportions of concrete constituents are summarized in Table 3.

TABLE 2: PROPERTIES OF AGGREGATES

Properties	Crusher sand	Crushed granite
Specific Gravity	2.34	2.64
Bulk Density (kg/m^3)	1240	1464
Moisture content (%)	4.24	1.61
Fineness modulus	3.13	2.59
Aggregate Crushing Value (%)		12.9
Impact Value (%)		7.13

TABLE 3: MIX PROPORTION OF CONSTITUENTS FOR A CUBIC METRE OF CONCRETE

Property	Content (kg/m^3)
Cement content	418
Fine aggregate	735
Coarse aggregate	1010
Water	216

B. *Mix proportioning and casting of concrete specimens*

A fixed concrete mix proportions with a fixed water-cement ratio of 0.52 considered for the study. Cement, fine and coarse aggregates were 418 kg/m^3, 735 kg/m^3 and 1010 kg/m^3 respectively which produced a bulk density of 2379 kg/m^3. This represented a concrete mix ratio of 1:1.76:2.42 in proportion of cement, fine and coarse aggregates. No plasticizer was added into the mix in this study. Each concrete mix proportion was prepared in a rotating drum mixer. The aggregates and cement were placed in the drum and mixed in parts with water to ensure a better bond between the cement paste and the aggregates. All mixing and sampling of concrete were carried out in accordance with the procedures given in BS 1881[25].

The workability of fresh concrete was determined via slump test in accordance with ASTM C143 [26]. The apparatus used included tamping rod, cone and a measuring rule. Test specimens were prepared and cast into moulds of different sizes. Ninety-three (93) cubes of size 100 mm were cast, cured and tested for compressive strengths according to BS 1881 [25] at curing age 28 days. Fifteen specimens were tested for constant thermal loading at room temperature of 20°C, while seventy-eight specimens were reserved for cyclic thermal loading at temperatures 200°C to 400°C for testing at ages 1 day, 3 days and 7 days. Compression testing machine, employed for crushing of cubes and splitting of cylinders as per the requirements of EN 12390 [27] as shown in Fig. 2. Compression load was applied without shock and continuously increased at a uniform rate of between 0.3 ± 0.1 MPa/s until the specimen failed. The maximum crushing or spliting load, the appearance of the specimen and any unusual feature in the type of failure was recorded for analysis. The compressive strength was determined by calculating the ratio of the crushing load to the cross-sectional area of the cube specimens.

Fig. 2: Test setup of concrete cubes for compressive strengths.

Ninety-three cylinders of 150 mm diameter and 300 mm length were cast, cured and tested at 28 days for the split tensile strength of concrete. Fifteen cylinders were tested for constant thermal loading condition at room temperature of 20°C, while seventy-eight cylinders were reserved for cyclic thermal loading condition at temperatures 200°C to 400°C for testing at ages 1 day, 3 days and 7 days. The split tensile strength was carried out as per BS EN 12390 [28]. After curing, water was wiped out from the surface of specimen and diametrical lines were drawn on the two ends of the specimen using a marker to verify that they are on the same axial place. Plywood strips were placed on the lower plate followed by the concrete cylinder specimens and the upper plate was brought down to touch the plywood strip. The load was applied continuously without shock at an approximate rate of 14-21 $kg/cm^2/min$ and the breaking load was recorded for each test specimens.

C. *Post-thermal exposure testing of concrete specimens*

All the specimens were cured for 28 days, and air dried in the laboratory for 24 hrs. Finally, the specimens were subjected to a temperature range from 100^{o}C to 400^{o}C in an electric oven of 415 volts with a maximum of 400 ^{o}C. The concrete specimens viz cubes, cylinders and beams were presented for testing the compressive strength, split tensile strength and flexural of concrete after exposure to elevated temperature. The specimens were then air cooled and tested.

For the instantaneous and constant thermal loading, the oven was set such that the internal environment attained the target temperatures 100^{o}C, 200^{o}C, 300^{o}C, and 400^{o}C within the first 60 minutes and then kept constant for additional 135 minutes. Forty-five minutes duration was considered as the most likely response time by the fire service after fire incident (residential and industrial) with obstructions and disruptions on the way is 45 minutes according to the Gaborone City Council Fire Department (2016-2020). As a result, the concrete specimens were subjected to elevated temperatures for 45 minutes. After heating, the specimens were allowed to cool down for 24 hours under the room temperature and subsequently tested for mass loss, compressive and split tensile strength in accordance with BS 1881 [25].

For the cyclic loading procedure, the specimens followed the previously highlighted process except that the heating process was repeated after 3 days and 7 days. The specimens were placed in an open environment to allow cooling and absorption of atmospheric moisture. Cyclic thermal loading was done to simulate cases where there is a fire hazard, the fire was put out and after some time the building was rehabilitated by painting but what happens after some instant the structure suffers another cycle of fire.

III. RESULTS AND DISCUSSION

A. *Instantaneous thermal loading of conccere specimens at elevated temperature*

The results of the study are presented and discussed with reference to the aim of the study, which was to evaluate the structural performance and deterioration trend of concrete beam when exposed to increasing temperature from 20°C to 400°C at varying time durations. The compressive and tensile strength test results at varying exposure temperature are shown in Fig. 3.

The instantaneous thermal loading effect on compressive strength of cubes is shown of Fig. 3 (a). It is observed that the compressive strength decreases with an increase in temperature in a non-linear relationship. It was observed that the strength of unheated cubes was greater than the strength of heated cubes at all temperature levels. Based on the experimental data, concrete lost about 6% of its original compressive strength when heated to 100°C and 15% at 400°C. Moreover, the results yielded a coefficient of regression of 0.94. The reductions in compressive strength of concrete when exposed to elevated temperatures can be attributed to the dehydration of concrete by driving out of free water and fraction water of hydration of concrete due to high temperatures [18]. The strength loss experienced agrees with the findings of Long & Nicholas [30] that concrete loses about 10–20 % of its compressive strength at elevated temperature, although Omer [6] reported a loss of 10% at 600°C. The slight difference could be as a result of the nature of the aggregate used, the grade of concrete as well as the sizes of the specimen. The experimental data was obtained using the 100 mm cube specimens which had a smaller surface area compared to the 150 mm cube specimens used by Omer [6] and Long & Nicholas [29].

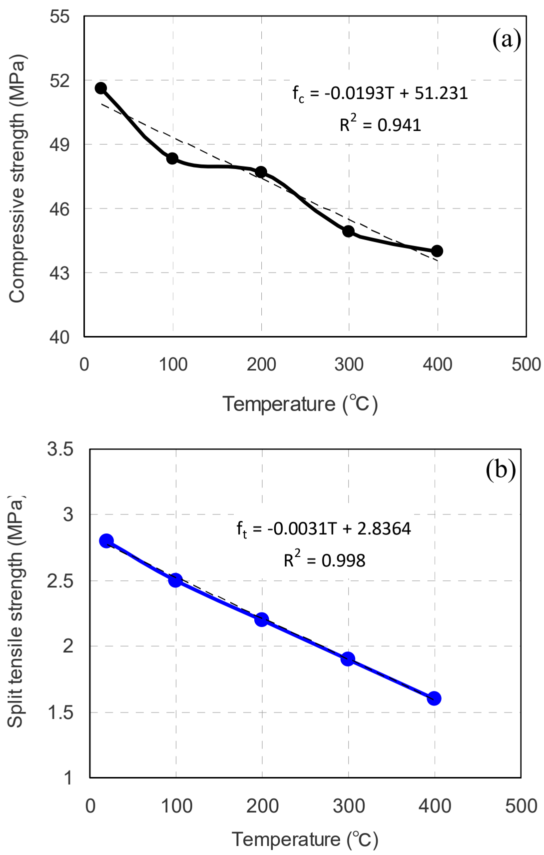

Fig. 3. Compressive and tensile strength of concrete at different temperature

The instantaneous thermal loading effect on split tensile strength of cylinders is shown of Fig. 1 (b). It is observed that the split tensile strength decreases with an increase in temperature in a linear relationship. It was observed that the strength of unheated cylinders was greater than the strength of heated cylinders at all temperature levels. Concrete cylinders lost 0–10% of their original split tensile strength when heated to 100°C, and 42–60% when heated to 400°C, according to the experimental results.

Li et al. [17] concluded that the decline in tensile strength of NSC with temperature can be attributed to weak microstructure of NSC allowing initiation of microcracks. At 300°C, concrete loses about 20% of its initial tensile strength. Above 300°C, the tensile strength of NSC decreases at a rapid rate due to a more pronounced thermal damage in the form of microcracks and reaches to about 20% of its initial strength at 600°C. HSC experiences a rapid loss of tensile strength at higher temperatures due to development of pore pressure in dense microstructures HSC [30].

Concrete being a poor conductor of heat, its exposure to high temperature causes thermal gradient between its outer and inner layers, which is responsible for the cracking of concrete at high temperature. The thermal gradient mainly depends on the heating rate, cooling rate, intensity of heat and concrete thermal properties. Further, during exposure to elevated temperature, pore pressure also develops in the concrete, which depends up on the intensity of heat, rate of heating and size of the specimen. The pore pressure developed in the concrete may be as high as 8 MPa which may be greater than its tensile strength [15,16].

B. *Constant thermal loading of concrete specimens at elevated temperature*

The mass loss, compressive and tensile strength test results at constant thermal loading conditions under varying duration of exposure are shown in Fig. 4.

Fig. 4 (a) shows concrete mass loss as a result of testing cubes at various temperatures. The mass loss of all samples expressed as a percentage of the original mass at room temperature to the mass of concrete cubes after heated. It is evident that the longer the heating period, the mass loss of the concrete had the tendency to increase. At first 45 minutes of heating, as the temperature was increased starting from 100°C at increments of 100°C up to 400°C the mass loss increased from 1.5 to 2.0 %. When concrete was heated for 90 minutes, its mass reduced about 2.3 to 2.5 %. This is due to the loss of water content in the concrete. After being heated up for 135 minutes sample loss, about 4.1 to 4.6 % of its original mass. The mass loss curves of 200, 300 and 400 °C approach to each other with the increase in time of fire exposure.

This heating duration influence affect the loss of free water present and decomposition of hydration products in concrete. When concrete is exposed to high temperature, free water in the concrete will firstly be removed through evaporation. As the heating duration increases, the amount of water evaporated also increases. Later, the calcareous aggregates will be decomposed, carbon dioxide (CO_2) liberated and altered the mechanical properties of concrete. The longer the heating duration make the amount of evaporated water increases, followed by increases in void volume. The expansion in void volume of concrete will reduce its quality, thus there is reduction in their mass [18]. Conclusively, the percentage of mass loss increased as the heating duration increased.

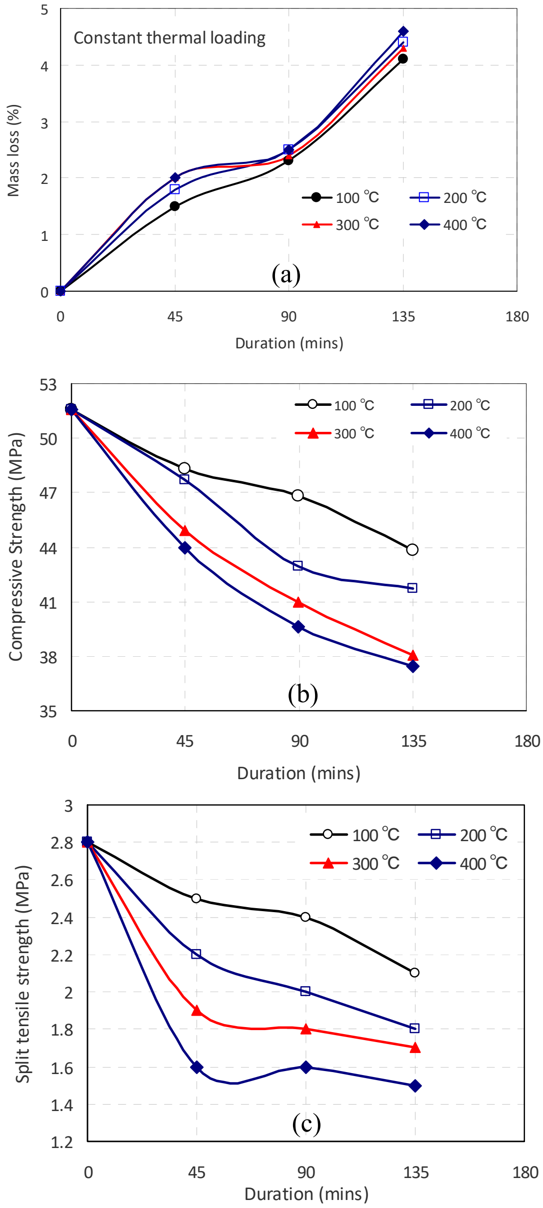

Fig. 4. Mass loss, compressive and tensile strength of concretes at constant thermal loading under varying exposure duration

After analysis of the relationship between constant thermal loading with time, it was observed as shown on Fig. 4 (b) that at 0 minutes the compressive strength was 51.6 MPa and after the first 45 minutes under the influence of 100°C the strength was had reduced to 48.32 MPa, after 135 minutes the compressive strength was found to be 43.83 MPa. The results further shows that the compressive strength of cube specimens exposed at 200, 300 and 400°C and displays that the longer the heating period, the compressive strength of the concrete had the tendency to reduce. The compressive strength of specimens subjected to varying temperatures has been shown to decrease as temperature and time increase. This heating duration influence might affect the loss of free water present and decomposition of hydration products in concrete. When concrete is exposed to high temperature, free water in the concrete will firstly be removed through evaporation. As the heating duration increases, the amount of water evaporated also increases. Later, the calcareous aggregates will be decomposed, carbon dioxide (CO_2) liberated and altered the mechanical properties of concrete [15,17]. Conclusively, the decrease in compressive strength increased as the heating duration increased.

The relationship between constant thermal loading with time on split tensile strength is shown on Fig. 4 (c). It is observed that at 0 minutes the split tensile strength was 2.8 MPa and after the first 45 minutes under the influence of 100 °C the strength was had reduced to 2.2 MPa, after 135 minutes the split tensile strength was found to be 1.6 MPa. The results show that the longer the heating period, the split tensile strength of the concrete had the tendency to reduce. The split tensile strength of specimens subjected to varying temperatures has been shown to decrease as temperature and time increase. Furthermore, the decrease in split tensile strength increases non-linearly with time at a given temperature. The reduction of the split tensile strength of concrete is due to the thermal stress that results in many microcracks and even a few macrocracks. The decompositions of $Ca(OH)_2$ and other ingredients also induce the appearance of cracks. Therefore, the effect of crack on the splitting tensile strength is more obvious than on the compressive strength. Li et al [17] agrees that the split tensile strength reduces after being exposed to elevated temperature.

C. *Cyclic thermal loading of concrete specimens at elevated temperature*

The mass loss, compressive and tensile strength test results under cyclic thermal loading conditions at different test days are shown in Fig. 5.

Fig. 5(a) depicts the variation in mass loss of concrete obtained from testing cubes at varying thermal cycles for different temperature. For the specimens, subjected at varying temperature it has been found that the loss in mass increases with a rise in the temperature. Further, at a specified temperature, the reduction in mass increases with a rise in the number of thermal cycles. The maximum mass loss has been found to be 2.1 %, 2.4 %, 2.5 % and 2.7 % after exposure to 100°C, 200°C, 300°C and 400°C temperatures respectively at 3 thermal cycles. The loss in weight at 100°C is less because it is mainly associated with the eliminate of free water or moisture from the concrete. Whereas, at 200°C, 300°C and 400°C, the chemically bound water also gets evaporated thereby increasing the loss in mass.

Fig. 5(b) shows the behaviour of concrete compressive strength when exposed to a cycle of heating and cooling: (the compressive strength of cubes heated at a temperature of 100°C with increments of 100°C up to 400°C decreases with an increase in the number of thermal cycles). An initial linear behaviour of loss in strength of concrete was evident for the first 45 minutes, which could be attributed to gradual rise in temperature.

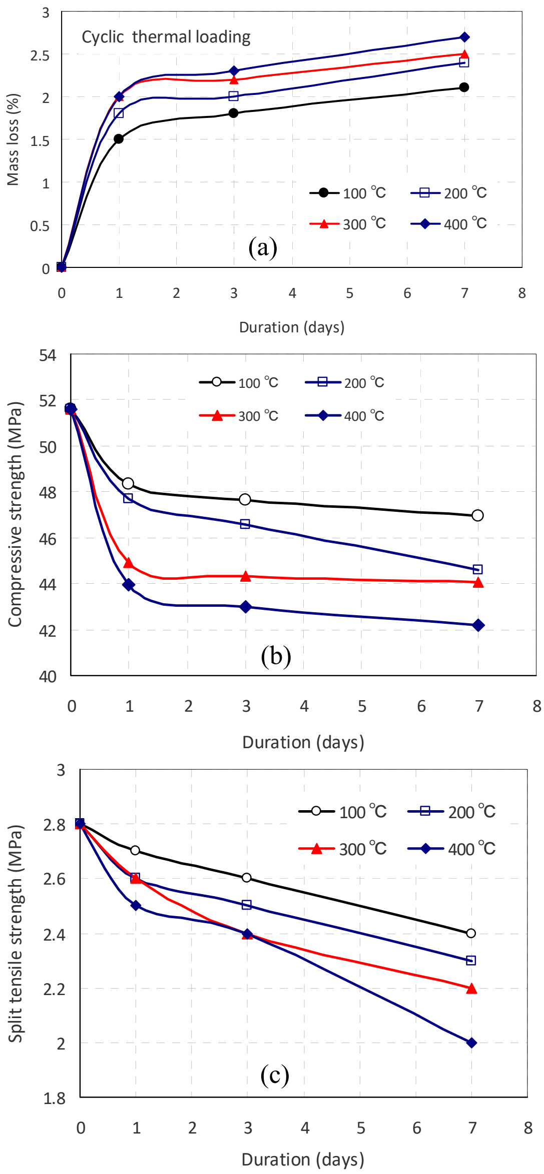

Fig. 5. Mass loss, compressive and tensile strength of concretes under cyclic thermal loading at different test days

During this stage the concrete was allowed to absorb as much heat, this process also shows the scenario of any fire incident, as every fire gradually rises in temperature from zero to maximum. It is observed that the strength of heated cubes is lower than the strength of unheated cubes at all temperature levels. The maximum compressive strength of concrete is 46.93, and 44.60 MPa at temperatures 100 °C and 200°C, respectively after 3-thermal cycles. However, at 300°C and 400°C temperature, the maximum compressive strength is 44.04, and 42.20 MPa after 3-thermal cycles. Thus, the maximum loss in compressive strengths of concrete is 9.0%, 13.6%, 14.7% and 18.2% for temperatures of 100°C, 200°C, 300°C and 400°C, respectively. The loss of strength is due to the destruction of the cement gel as the concrete starts to dehydrate; as the time of exposure increased, the chemically absorbed water was released.

The effects of heating and cooling of cycle on the split tensile strength of concrete as shown in Fig. 5(c) has a linear trend obtained from experimental analysis. The tensile strength results shows an initial polynomial behaviour of loss in strength of concrete for the first 45 minutes, this was as a result of the gradual rise in temperature. After 3 thermal cycles the strength drops at a slow rate. The split tensile strength of cylinders heated at a temperature decreases with an increase in the number of thermal cycles. However, for 300°C and 400°C temperature, the split tensile strength continues approach to each other with the rise in the number of thermal cycles. It is observed that the maximum loss in split tensile strengths of concrete is 10.7%, 21.4%, 32.1% and 42.9% for temperatures of 100°C, 200°C, 300°C and 400°C, respectively. The reduction of the split tensile strength of concrete is due to the thermal stress that results in many microcracks and even a few macrocracks. The decompositions of $Ca(OH)_2$ and other ingredients also induce the appearance of cracks. According to Bikhiet et al (2014), the value of tensile strength decreases as the temperature increases that due to the higher temperature and the stiffness of the adhesive decreased.

IV. Conclusion

The study was primarily intended to determine the physical properties and structural behavior of concrete at normal and elevated temperatures up to 400°C. Regression analysis was used to examine the correlation or the change between the mass loss, compressive strength loss, split tensile strength loss and flexural strength loss with time-dependent behaviour of concrete at elevated temperature

1. The mass of the concrete specimens was recorded before and after being subjected to elevated temperatures. At the constant thermal loading, mass loss was 1.5%, 1.8%, 2.0% and 2.0%, the compressive strength loss was 6.4%, 7.6%, 13.0% and 14.8%, and the split tensile strength loss was 10.7%, 21.4%, 32.1% and 42.9% for 100°C, 200°C, 300°C and 400°C respectively. For the cyclic thermal loading, the percentage mass loss was 2.1%, 2.4%, 2.5% and 2.7%, the compressive strength loss was 9.0%, 13.6%, 14.7% and 18.2%, and the split tensile strength was 14.3%, 17.9%, 21.4% and 28.6% at 100°C, 200°C, 300°C and 400°C after three cycles, respectively. The results revealed that the mass, the compressive strength, and split tensile strength decreased as the exposure temperature and duration increased.

2. It was discovered from laboratory experiment that mass loss and compressive strength loss had a comparable trend up to 2 hours of exposure, beyond which strength deterioration tripled the mass loss. The reduction in mass of concrete increases with an increase in temperature and the number of thermal cycles. The maximum loss in mass is 4.1% to 4.5% respectively at 3 thermal cycles. The loss in weight at 100°C is mainly due to the loss of free water or moisture from the concrete, whereas, at higher temperature the chemically bound water also gets evaporated. Mass loss in concrete cubes was slightly greater than the cylinders due to the escape of vapours and gases equally from all faces, which is not the case with cylinders.

3. Despite increase in the cylinder strength of concrete with exposure to the thermal cycles, the split tensile strength of the heated specimens decreases with the increase in temperature as well as the number of thermal cycles with the loss in the split tensile strength of concrete after 3 cycles of exposure varying from 10.7 % to 42.9 %.

4. Deployment of non-destructive testing of concrete structure is imperative after fire hazard to determine the residual strength in order to propose the ideal rehabilitation and strengthening process that will not compromise the serviceability and functionality of the concrete building.

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