CHAPTER 1
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1.1 INTRODUCTION.

Since the September 11 attack on the World Trade Center, interest in the design of fire-resistance have greatly increased, and in Egypt the wide spread destruction of the Egyptian government institution and police station during January 25 revolution have given such an interest a special significance.

One advantage of concrete over the other building materials is its inherent fire-resistive properties. It is non-combustible (i.e. it does not burn) and has a slow rate of heat transfer, so in most cases, concrete does not require any additional protection.However, concrete structures must still be specially designed for fire effects. Structural components still must be able to withstand dead and live loads without collapse, even though the rise in temperature causes a decrease in the strength and modulus of elasticity for concrete and steel reinforcement. In addition, fully developed fires cause expansion of structural components.

Concrete has excellent fire-resistance properties and maintains its strength at very hightemperatures. The thermal properties of concrete depend upon the aggregate type used, due to the chemicalchanges (crystal structure) in aggregate compounds. The three commonaggregates include; siliceous aggregates (gravel, granite, flint), calcareous aggregates (limestone-dolomite) and lightweight aggregates made from sinteredfuel ash and expanded clay. Siliceous aggregate concretes have a tendency to spall dueto high thermal conductivity of such an aggregate. Calcareous aggregate concretes are relatively more stable. Lightweight concrete (LWC) has the best thermal properties of all, i.e. less than half the thermal conductivity (0.8 W/mK) of normal weight concrete (NWC) and consequently loses its strength at aconsiderably lower rate. The thermal diffusivity of LWC is only slightly lower than NWC, so the extrafire resistance in LWC comes mainly from the stability of the lightweight aggregates at high temperatures and partially from reduced temperatures. The typical density of NWC is 2350 kg/m³ and that of LWC is1850 kg/m³.

NWC initially expands with the rise in temperature but progressive loss of moisture from the cement pastecauses it to shrink and helps to offset thermal expansion of the aggregate. Heat is used up in drying, which causes further reduction in the rate of temperature rise of the concrete surface, which is low enough to start with due topoor conductivity. The loss of strength due to dehydration is quite often confined to the surface layers.

The coefficient of thermal expansion of concretes is of the same order as that of steel, but here again it isconsiderably higher for NWC, up to 14×10−6 /°C, while that of LWC is about 8×10−6 /°C. Concretethermal expansion depends considerably on the stress in concrete, so for highly compressive stressesthe thermal expansion coefficient can be considerably lower thanthat in the unstressed concrete. This is causedby the fact that creep effects become very important in concrete at around 400°C, with considerably increasingstrains for small increases in temperature beyond this point. This effect is termed as transientthermal creep and it can be so large at highly compressive stresses as to completely counter the effectof thermal expansion, even leading to contraction. Concrete stiffness (i.e. the slope of the stress/straincurve) also reduces significantly at high temperatures, which also results in additional strains. Theseeffects can cause large deflections in concrete structural members.The strength loss in concrete is slow because of the low thermal diffusivity.

The rise in temperature causes the free water in concrete to change from a liquid state to a gaseous one. This change in the state causes changes in the rate with which heat is transmitted from the surface into the interior of the concrete component.

1.2 RESEARCH OBJECTIVES.

The objectives of this thesis are to improve the fire resistance of limestone aggregate concrete and mortarby studying the effect of the fire on theirmineralogy, mechanical, physical properties and microstructure.

To achieve such objectives, many materials were used for concrete as additives or a replacement of cement content such as (silicafume, limestone powder, bentonite). Polypropylene and steel fiber were also added to concrete in order to study their effects on fire endurance. At last limestone Portland cement and some materials (brick clay powder, ceramic powder, melamine powder and bentonite) were used as a trail forthe enhancement of mortar properties that used as a plaster (external protection). Many factors such as (thickness of the cover,protection materials and depth of the concrete) were also considered.

The main goals of this study are divided into four parts:

1- Study the effect of the fire on the conventional concrete. For this aim, some investigations were performed such as:

A- The mechanical properties of the conventional concrete (compressive strength, tensile strength, flexural strength, ..…etc).

B- Thermogravimetric analysis (TGA/DTG).

C- Spalling.

D- The effect of concrete cover on the protection of the reinforcement inside the small scale slabs.

E- Themicrostructure of theconventional mix before and after the exposure to elevated temperature by scanning electron microscope (SEM).

F- The changes in the surface of the concrete specimens by visual inspection.

G- The effect of water cooling regime on the compressive strength of the concrete.

H- The utilization from TGA test to estimate the duration of fire, or the maximum temperature, that may be reached for a real concrete structure under service condition or under an accidental condition depending on the weight loss obtained from TGA curves.

I- Deceitful pull out test.

2- Study how to improve the fire endurance of the conventional concrete by adding or replacing apart of cement content by some materials (silicafume, limestone powder, bentonite), and by adding polypropylene and steel fibers directly to the mix. For this goal, the following experiments were done for all modified concrete mixtures:

A- Compressive strength.

B- Flexural strength.

C- Thermogravimetric analysis (TGA/DTG).

D- SEM.

E- Visual inspection.

F- Temperature distribution inside the small scale slabs (exposed surface, unexposedsurface and Rft temperature).

G- Spalling of the concrete mixtures as a function of weight loss.

3- To study the fire endurance of traditional mortar, limestone portlandcement mortar or that containingbentonite, brick clay powder, ceramic powder and melamine powder as a partial replacement of cement content, which can be used as an external protection. For this aim, many experiments were conducted:

A- Compressive strength.

B- (TGA/DTG).

C- SEM.

D- The effect of using these mortars as an external protection on the improvement of compressive strength of conventional concrete cubes and preventing the Rft inside the small scale slabs.

E- Spalling of the mortars as a function of weight loss.

4- A Case study on the effect of real fire on the properties of reinforced concrete roof slab of small room.

On the other hand, this study is aimed at finding the prediction temperature of the steel inside the small scale concrete slabs with different concrete cover thickness ranging from 1 in. to 3 in. and the prediction residual compressive strength of concrete cubes after exposed to 20, 200, 400 and 600°C for 2 hours through a comparative analysis by artificial neural network(ANN). All of those results are mainly compared using the coefficients of determination calculated for the models with highest R^2 values.