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DEGRADATION OF MECHANICAL PROPERTIES AND DETERIORATION OF CONCRETE AT ELEVATED TEMPERATURE

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ABSTRACT

The composition and characteristics of concrete batch mix as well as heating rate and other environmental conditions. The behaviour of a concrete structural member exposed to fire is dependent, in part, on thermal, mechanical, and deformation properties of concrete of which the member is composed. Similar to other materials the thermo physical, mechanical, and deformation properties of concrete change substantially within the temperature range associated with building fires. These properties vary as a function of temperature and depend on the composition and characteristics of concrete. Degradations of mechanical properties were measured using 150x150x150 mm cube, heated to temperatures of up to 600°C at 5 °C/min, and compared with results of other studies and existing codes. Pore pressures were measured using 150 x 150 x 150 mm blocks, heated to 600°C at 5 °C/min and 25°C/min. Experimental evidences of the complex, temperature-dependant moisture transport process. Which significantly influenced pore pressure and temperature developments are described

Additional experimental test results are needed in tension and the other main parameters at elevated temperatures to establish well-founded models and to improve the proposed relationships. The developed models and relationships are general, rational, and have good agreement with experimental data.

Key Words- compressive strength, High Temperature, concrete mix, mechanical behaviour

INTRODUCTION

Background of high strength concrete

In fundamental terms, the fire behaviour 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 and flexural 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.

Accidental fire situation in concrete structures is one of the major concerns of the engineers as it causes huge loss of lives and property. The concrete behaves differently under different types and combinations of stress Conditions due to the progressive micro cracking at the interface between the mortar and the Aggregates (transition zone) Structural fire safety is one of the primary considerations in the design of high-rise buildings and infrastructures, where concrete is often the material of choice for structural members. Fire safety measures to structural members are measured in terms of fire resistance which is the duration during which a structural member exhibits resistance with respect to structural integrity, stability, and temperature transmission. Concrete generally provides the best fire resistance properties of any building material. This excellent fire resistance is due to concrete’s constituent materials (i.e., cement and aggregates) which, when chemically combined, form a material that is essentially inert and has low thermal conductivity, high heat capacity, and slower strength degradation with temperature. It is this slow rate of heat transfer and strength loss that enables concrete to act as an effective fire shield not only between adjacent spaces but also to protect itself from fire damage. Clearly, the generic information available on properties of concrete at room temperature is seldom applicable in fire resistance design. It is imperative, therefore, that the fire safety practitioner knows how to extend, based on a priori considerations, the utility of the scanty property data that can be gathered from the technical literature. Also, knowledge of unique characteristics, such as fire induced spalling in concrete, is critical to determine the fire performance of concrete structural members.

Significance of research

The structural safety of such structures after exposure to high temperature. The important factor that the effect on strength be well understood. the spatial and temporal variations in exposures, including the cooling phase of the fire. Progress has been made on modelling the thermo-mechanical behaviour but the treatment of detailed behaviours, including hygral effects and spalling, remains a challenge. , the provisions for concrete strength at elevated temperatures in current major codes and authoritative guides, such as the Euro code and CEB model code, are unconstructive when applied to HSC. In fact, these provisions were developed based on NSC data and didn’t make the distinction between HSC and NSC the difference between HSC and NSC in its provisions for concrete strength at elevated temperature. However it is found slightly conservative for HSC at temperatures higher than 350°C. Thus the study proposes a strength-temperature relationship for HSC. The project provides initial findings of an ongoing study on the behaviour of high strength concrete under at elevated temperature.

Modes of failure:

Spalling- The fire performance of a concrete structural member is spalling. This property is unique to concrete and can be a governing factor in determining the fire resistance of an RC structural member. Spalling is defined as the breaking up of layers (pieces) of concrete from the surface of a concrete member when it is exposed to high and rapidly rising temperatures such as those encountered. in fires. These actions lead to the development of fractures and expulsion of chunks of material from the surface layers. More specifically, the main prerequisites for spalling have been established as: moisture content of at least 2%, and steep temperature gradients within the material. It is sometimes argued that high-strength concrete is more prone to spalling, due to its lower porosity and hence the increased likelihood of high pressure developing within the concrete structure. This process is often assumed to occur only at high temperatures, yet it has also been observed in the early stages of a fire and at temperatures as low as 200°C. The mechanism leading to spalling is generally thought to involve high thermal stresses resulting from rapid heating and/or large build-ups of pressure within the porous concrete, which the structure of the concrete is not able to dissipate, due to moisture evaporation.

Cracking-Thermal expansion and dehydration of the concrete due to heating may lead to the formation of fissures in the concrete rather than, or in addition to, explosive spalling. Transient strain occurs during the first time heating of concrete, but it does not occur upon repeated heating. Exposure of concrete to high temperature induces complex changes in the moisture content and chemical composition of the cement paste. Moreover, there exists a mismatch in the thermal expansion between the cement Paste and the aggregate. Therefore, factors such as changes in chemical composition of concrete and mismatches in thermal expansion lead to internal stresses and micro cracking in The concrete constituents (aggregate and cement paste) and results in transient strain in the concrete. . It was found that the penetration depth is related to the temperature of the fire, and that generally the cracks extended quite deep into the concrete member. Major damage was confined to the surface near to the fire origin, but the nature of cracking and discoloration of the concrete pointed to the concrete around the reinforcement reaching 700°C. Cracks which extended more than 30 mm into the depth of the structure were attributed to a short heating/cooling cycle due to the fire being extinguished.

EXPERIMENTAL PROGRAM

Testing report on various trial mixes

Testing report for cube Compressive strength of different trial mixes.
Trial Mix Batch Six cubes (15 cm x 15 cm x 15 cm) were casted and tested for Compressive strength.

TABLE 1.MIX PROPORTION Batch

Material	Proportions
Cement	553 kg/m^3
Coarse aggregate	1141 kg/m^3
Fine aggregate	740 kg/m^3
w/c ratio	0.31
HRWR	450 ml per 50 kg of cement
Silica fume	7%

TABLE 2 Cube Compression Testing Report of Batch-I

S.NO	Date of Testing	No. of Days	Cube-I	Cube-I
B-I	22-06-2014	28	37	36
B-I	22-06-2014	36	41	43
B-I	22-06-2014	45	41	43
B-I	25-06-2014	60	44	46
B-I	25-06-2014	28	37	36

Trial Mix Batch II

TABLE 3 MIX PROPORTION Batch-II

Material	Proportions
Cement	475 kg/m^3
Coarse aggregate	1042.5kg/m^3
Fine aggregate	719 kg/m^3
w/c ratio	0.31
HRWR	500 ml per 50 kg
Silica fume	10%

TABLE 4.Cube Compression Testing Report of Batch-II

S.NO	Date of Testing	No. of Days	Cube-I	Cube-I
B-I	22-06-2014	30	38	36
B-I	25-06-2014	45	40	38
B-I	25-06-2014	60	44	46

Trial Mix Batch III

In batch B-III six beams (15 cm x 15 cm x 15 cm) were casted

TABLE 5.MIX PROPORTION Batch-II I

Material	Proportions
Cement	500 kg/m^3
Coarse aggregate	1060 kg/m^3
Fine aggregate	680 kg/m^3
w/c ratio	0.32
HRWR	450 ml per 50 kg of cement
Silica fume	500 kg/m^3

TABLE 6 Cube Compression Testing Report of Batch-III

S.NO	Date of Testing	No. of Days	Cube-I	Cube-I
B-I	04-07-2014	36	38	36
B-I	11-07-2014	45	43	40
B-I	26-07-2014	60	44	45

Trial Mix Batch-IV

Six cubes (15 cm x 15 cm x 15 cm) were casted

Table 7.Mix proportions Batch B-IV

Material	Proportions
Cement	450 kg/m^3
Coarse aggregate	1030 kg/m^3
Fine aggregate	750 kg/m^3
w/c ratio	0.33
HRWR	450 ml per 50 kg of cement
Silica fume	10 %

TABLE 8 Cube Compression test Report of Batch-IV

S.NO	Date of Testing	No. of Days	Cube-I	Cube-I
B-I	04-07-2014	7	42 MPa	39MPa
B-I	11-07-2014	21	39 MPa	34 MPa
B-I	26-07-2014	28	42 MPa	43 MPa

STANDARDIZED MIX

Different mixes are tried and variation of cube Tensile strength is measured with mix proportions and finally mix with maximum cube compressive strength is taken as standard mix. After standardization of mix beams and cylinders were casted.

In all 90 cylinders & 30 beams were cast in the form of different batches. To derive inference they were subjected to various temperature ranges and conditions of gradual cooling and sudden quenching. All the batches cast in this semester were having the same mix proportions (mentioned in the table below). This mix was derived on the basis of various trial mixes done in the previous semester. But problem of variation in atmospheric temperature was critical as temperature changes drastically in summer (in this situation water readily evaporated from the mix resulting in improper hydration of cement), and alternatively there comes the variation in the cube Tensile strength as calculated at different environment concreting conditions.

Testing report for modulus of rupture of standardized mix beam specimens subjected to elevated temperatures

Observation

TABLE 9.Beam tested at room temperature

S.No.	Date of testing	No. of days	beam-I	beam-II	beam-III
B-01	28-08-14	36	13.33Mpa	13.45Mpa	13.36Mpa

TABLE10. Beams tested after exposing them to 300 ̊C for the duration of 2 hours.

S.No.	Date of testing	No. of days	beam-I	beam-II	beam-III
B02	28-08-14	36	15.55Mpa	14.3 Mpa	16.67Mpa

TABLE11.Beams tested after exposing them to 300 ̊C for the duration of 3 hours.

S.No.	Date of testing	No. of days	beam-I	beam-II	beam-III
B03	29-08-14	42	14.53MPa	14.01Mpa	13.44Mpa

Specimens subjected to heating for 2, 4, 8 hours duration and tested for flexural strength

TABLE 12. Beam tested at room temperature

S.No.	Date of testing	No. of days	beam-I	beam-II	beam-III
B(1)	06-09-14	42	13.38MPa	12.34Mpa	13.39Mpa

TABLE 13. Beams tested after exposing them to 600 ̊C for the duration of 2 hour

S.No.	Date of testing	No. of days	beam-I	beam-II	beam-III
B(2)	06-09-14	42	13.45MPa	14.01MPa	14.45Mpa

TABLE 14.Beams tested after exposing them to 800 ̊C for the duration of 3Hours.

S.No.	Date of testing	No. of days	beam-I	beam-II	beam-III
B(3)	07-09-14	42	12.32MPa	13.33MPa	13.01Mpa

CONCLUSION

The high strength concrete with dense structure less resistance to high temperature than ordinary strength concrete. the relative decrease of compressive strength of ordinary concrete is not related to its strength at room temperature . The behaviour of concrete in fire is not well defined at present, and further research is required. The response of concrete materials to heating is fundamentally complex; for example, degradation in the physical properties of concrete varies strongly depending on the details of the concrete mix, including the moisture content, and relevant environmental parameters, such as the maximum fire temperature and fire duration. Systematic studies are required on the effects of different heating conditions on concrete. A more significant challenge arises in relating these detailed small-scale behaviours to the performance of whole structures in realistic fires. Though good progress has been made on modelling the mechanical behaviour of concrete structures, the use of detailed models to predict spalling behaviour remains a significant challenge. Moreover, capability to predict structural interactions, which may have a role in failures, is poorly developed. The additional decrease of the strength of the concrete heated to temperature caused by its sudden cooling will be the most significant for temperature which are not very high and range for instance between600°C -800°C.

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