THE EFFECT OF THERMAL CYCLES ON FLEXURAL STRENGTH OF HIGH STRENGTH CONCRETE (M90) COMPARED TO STANDARD CONCRETE (M25)

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Abstract: Concrete is one in all the foremost well-liked construction materials used since hundred years past. thanks to its flexibility and its North American nation age several structures around us build by concrete. This paper presents associate experimental investigation on flexural strength of concrete subjected to thermal cycles the tests were applied on traditional weight concrete specimens of size 100mm X 100mm X 500mm. The concrete was subjected to constant temperatures of 100ºC, 200ºC and 300º C for thermal cycles zero, 1, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50. every heating cycle corresponds to eight hrs. heating and later cooling for sixteen hrs. once the specified range of thermal cycles, the specimens were tested for flexural strength of concrete. check results were critically examined and also the effects of varied parameters within the gift work are mentioned. combine style of high strength concrete is influenced by properties of cement, sand, coarse combination and water-cement magnitude relation. to realize high strength, it's necessary to use lowest doable water-cement magnitude relation.

1. INTRODUCTION

General:

Concrete is that the most generally used artefact. it's versatile, has fascinating engineering properties, will be molded into any form and a lot of significantly is created with cost-efficient materials. though recent developments in plastics and different lighter materials have resulted within the replacement of concrete in some applications, the employment of concrete worldwide has exaggerated phenomenally, particularly in infrastructures comes. In fact, these developments have an advanced and improved the performance and use of concrete in structures. Concrete is Associate in Nursing extensively used material these days. In ancient days, structures were designed victimization burnt clay bricks, stone or steel. The Pyramids of metropolis, Egypt (West 1985), were designed around 2540 BC, i.e., nearly forty-five centuries past. the nice Wall of China (Calder 1983), completed in concerning 230 BC, is twenty centuries previous. However, the Romans created variety of structures with concrete. The Pantheon in Rome, Italy (Gunnar 1997), was created nearly nineteen centuries past. it's a vi m thick mass concrete lined by forty-three.3 m diameter concrete dome roof. the autumn of empire semiconductor diode to the loss of knowledge concerning concrete technology. The Egyptians, Romans, Chinese, Mayans and Indians (National Geographic Society 1986) were victimization numerous sorts of natural cements at the start of 1700AD. These cements contained in them some sort of lime-sand mortar.

Concrete:

Concrete features a extremely heterogeneous and sophisticated microstructure. Therefore, it's terribly troublesome to represent realistic models of its microstructure from that the behavior of the fabric will be dependably foretold. However, data of the microstructure and properties of the individual elements of concrete and their relationship to every different is helpful for physical exercise management on the properties. The options of the concrete microstructure will be summarized as follows: 1st, there's the surface transition zone, that represents a little region next to the particles of coarse combination. Existing as a skinny shell, typically10 to fifty fifty thick around giant combination and therefore the surface transition zone is mostly weaker than either of the 2 main elements of concrete, namely, the mixture and therefore the bulk hydrous cement paste. Therefore, it exercises a so much larger influence on the mechanical behavior of concrete than is mirrored by its size. Second, every of the 3 phases is itself a point in character. for example, every combination particle might contain many minerals additionally to small cracks and voids. Similarly, each the majority hydrous cement paste and therefore the surface transition zone typically contain a heterogeneous distribution of various sorts and amounts of solid phases, pores and small cracks. Third, not like different engineering materials, the microstructure of concrete isn't Associate in Nursing intrinsic characteristic of the fabric as a result of the 2 elements of the microstructure, namely, the hydrous cement paste and therefore the surface transition zone square measure subject to alter with time, environmental humidness, and temperature. The extremely heterogeneous and dynamic nature of the microstructure of concrete square measure the first reasons why the theoretical microstructure-property relationship models, that square measure typically therefore useful for predicting the behavior of engineering materials, aren't of a lot of sensible use within the case of concrete.

Strength – body Relationship:

The presence of small cracks within the surface transition zone between the coarse combination and therefore the matrix makes concrete too advanced a cloth for prediction of strength by precise strength-porosity relations. the overall validity of strength-porosity relation is governing. With concrete containing the traditional low-porosity or high-strength aggregates, the strength of the fabric are going to be ruled each by the strength of the matrix and therefore the strength of the surface transition zone.

Water-Cement magnitude relation

The w/c-strength relationship in concrete will be explained because the natural consequence of a progressive weakening of the matrix caused by increasing consistency with increase within the water-cement magnitude relation. This rationalization, however, doesn't contemplate the influence of the water-cement magnitude relation on the strength of the surface transition zone. In low- and medium-strength concrete created with traditional mixture, each the surface transition zone consistency and also the matrix consistency confirm the strength, and a right away relation between the water-cement magnitude relation and also the concrete strength holds. This appears not to be the case in high-strength (i.e., terribly low water-cement ratio) concrete mixtures. For water-cement ratios beneath zero.3, disproportionately high will increase within the compressive strength will be achieved with terribly tiny reductions in water-cement magnitude relation.

Admixtures

The adverse influence of air-entraining admixtures on concrete strength has already been mentioned. By their ability to scale back the water content of a concrete mixture, at a given consistency, the water-reducing admixtures will enhance each the first and also the final strength of concrete. Ata given water-cement magnitude relation, the presence of water-reducing admixtures in concrete typically includes a positive influence on the rates of cement association and early strength development. Admixtures capable of fast or retarding cement association clearly would have an excellent influence on the speed of strength gain; but, the final word strengths might not be considerably affected.

Solidifying Conditions

The term solidifying of concrete involves a mix of conditions that promote the cement association, particularly time, temperature, and wetness conditions now when the position of a concrete mixture into formwork. beneath traditional temperature conditions a number of the constituent compounds of cement begin to hydrate as presently as water is further, however the association reactions weigh down significantly once the product of association coat the anhydrous cement grains

Temperature

The influence of temperature on strength depends on the time-temperature history of casting and solidifying. Concrete casting and solidifying temperatures management the degree of cement association and therefore have a profound influence on the speed of strength development still because the final strength

Concrete Exposed to Thermal Cycles:

Concrete is formed from 2 major components; hardened cement paste and hierarchal aggregates. once such a cloth is subjected to heating/cooling cycles, unequal enlargement / contraction of the parts happens because of the distinction in constant of thermal enlargement making internal stresses that might result in cracking of the stuff. For concrete material, this development is that the termed as thermal incompatibility of concrete constituents. Concrete are often exposed to elevated temperatures throughout fireplace or once it's near to furnaces and nuclear reactors. The mechanical properties of concrete like strength, modulus of elasticity and volume deformation, decrease remarkably upon heating which ends in a very decrease within the structural quality of concrete. heat is one among the foremost vital physical deterioration processes that influence the sturdiness of concrete structures and should lead to undesirable structural failures. To improve fireplace resistance in style, or to assess the condition and potentialities of repair of a structure broken by fireplace, additional has to be identified concerning the thermal and mechanical properties of steel and concrete at elevated temperatures and residual properties once slow or quench cooling. it's comparatively straightforward to work out the residual properties by normal take a look at ways and also the results do offer abundant of the knowledge required to work out what are often saved once a hearth. However, a research worker needs to focus in deciding the residual properties of concrete at sustained or rotary heat. this type of data has become progressively in demand for many reasons. First, advanced industrial applications, specially for nuclear reactors, need a larger information of the properties of assorted sorts of concrete once subject to complicated, sustained or repetitive, mechanical and thermal stress regimes at moderately high temperatures. Second, new concrete constituents and proportions still become accessible as some industrial and military applications need special concrete that's proof against specific service temperature regimes.

Structures Subjected to Thermal Cycles:

Heating cycle causes progressive deterioration of the mechanical properties of concrete. The compressive, tensile and bond strength and modulus of snap area unit reduced whereas Poisson’s quantitative relation is raised. Porosity, wetness content, its thermal properties, density etc., determines the fireplace electric resistance of the concrete. At high temperatures, hydraulic cement concretes bear vital changes in their properties, because of the degradation of its internal structure. The concrete structures can be exposed to high temperatures because of totally different reasons. in the main throughout exposure to fire; another one can be once the structure or its components area unit a section of business installations. Special applications like apparatus vessels, missile launching pads, turbo jet runways, and engine take a look at cells need enduring higher temperatures. At elevated temperatures, standard concrete losses strength because of formation of cracks between cement paste and combination and associated thermal incompatibility between the 2 gradients.

2.OBJECTIVE:

TO STUDY THE EFFECT OF THERMAL CYCLES ON FLEXURAL STRENGTH OF HIGH STRENGTH CONCRETE (M90) COMPARED TO STANDARD CONCRETE (M25)

3.LITERATURE:

Campbell Allen and Low investigated the effect of elevated temperatures on concrete for reactor vessels. Cycles of temperature up to 300°C were applied to the concrete made with Ordinary Portland cement and dolerite aggregate. The initial heating rate was indicated by the thermocouples at the centre of the test cylinders was 50°C per hour and equilibrium at 200°C and 300°C was reached after 6 hours and 8 hours respectively. The cylinders were kept in equilibrium temperature for 9 hours and cooled initially at 100°C per hour, ambient temperature being reached after 6 hours. Progressive loss of compressive and tensile strength was observed, combined with large reduction of elastic modulus. Up to 250°C the loss of compressive strength of concrete cylinder after one thermal cycle is small, in fact at 200°C a slight increase in strength is apparent and is linked with the accelerated hydration of the cement during heating cycle. A strength loss of approximately 15% occurs when concrete is exposed for one cycle to 300°C. For exposure at 300°C a reduction of 36% in compressive strength was noted after 5 cycles and further 4% reduction occurred after 10 cycles. The tensile strengths of the heat- treated specimens are always lower than those of the reference cylinders. At 200°C and 250°C changes are slight, i.e. 7% and 4%. However, after exposure at 300°C for one cycle, the reduction in the tensile strength is 16% in case of concrete cured for 28 days and 14% for the 90-day cured concrete. A large reduction in tensile strength about 50 % was observed after 10 cycles. Repeated cycles of exposure do not significantly affect the weight changes. Modulus of elasticity was adversely affected by heating. After one cycle at 200°C a decrease of 25% is observed. One cycle at 300°C causes a decrement of 28%. Further cycles of heating and cooling cause the downward trend to continue and after 10 cycles at 300°C, the modulus is only 67% of the original value.

Campbell Allen and Desai studied the influence of aggregate on the behaviour of concrete at elevated temperatures. Three aggregates, lightweight expanded shale, fireclay brick and a pure limestone, have been used in high strength concrete subjected to cycles of temperature up to 300°C. The temperature cycles were carried out in a laboratory oven with mechanical ventilation. Up to 20 cycles were applied with a maximum temperature selected as 300°C, 200°C and 65°C. The temperature of the air in the oven and the temperature at the centre of two cylinders in each test batch were continuously recorded by an automatic 6- channel recorder from copper constant couples. One cylinder containing a thermocouple was suspended in the oven from a balance located outside so that weight changes can be recorded during the cycle. The fastest rate of heating did not exceed 60°C/h. The maximum temperature was maintained for 10 hours after the cylinder had reached equilibrium temperature. All concretes showed marked deterioration of mechanical properties but the extent of deterioration was governed by the breakdown of bond between the aggregate and the mortar.

Bairagi and Dubal investigated the effect of thermal cycles on compressive strength, modulus of rupture, dynamic modulus of elasticity of concrete. Tests were carried out on M20 concrete mix (1:2.4:3.6) with a water-cement ratio 0.55. The concrete specimens were heated to maximum temperatures of 60°C and 90°C from a room temperature of about 27°C, for a number of thermal cycles varying from 0 to 365 cycles (0, 30, 60, 120, 240, 365) Each cycle consists of a heating period of 8 hours and a subsequent cooling period of 16 hours. After a requisite number of thermal cycles, the specimens were tested for the dynamic modulus of elasticity, flexural and compressive strength. The dynamic modulus of elasticity was determined by the resonant frequency method. The value of E_d was 22.52 x 10^3 N/mm^2 before heating (zero thermal cycles) reduced to 18.67 x 10^3 N/mm^2 after 30 thermal cycles and thereafter reduced gradually to 16.58 x 10^3 N/mm^2 after 365 thermal cycles. It is reduced by 26% after 365 thermal cycles when the samples are heated to 60°C. But when samples heated to 90°C, it is reduced by 27% after 30 thermal cycles and 41% after 365 thermal cycles. In the case of samples heated at 60°C, the reduction in the compressive strength was 26% after 365 thermal cycles and 35% of reduction was observed after 365 thermal cycles when the samples were heated to 90°C. For the specimens heated at 60°C, the percentage reduction in the modulus of rupture with respect to the samples not subjected to heat cycles varies from 3.9% to 19.1% for various heat cycles, while that for the specimens heated at 90°C, the variation is from 17% to 23.6%. For higher number of thermal cycles, the rate of reduction was found to be decreasing.

Carette et al investigated the changes in mechanical properties of a stone mixture concrete once exposure to temperatures of 75°C and 300°C for periods up to eight months and 600°C for one month. once 8-month's exposure to 75°C, compressive and splitting-tensile strengths were ninety-eight and ninety-four severally, of their reference values. However, once exposure to 600°C for simply one month, compressive and splitting-tensile strengths were solely twenty-three and thirty eighth, severally, of their reference values. In companion mixes wherever either ash or furnace dross was used, improvement in retention of mechanical properties occurred once exposure to sustained high temperatures as a result of partial replacement of the cement. Mears investigated the impact of long-run exposure (up to thirteen years) at moderate elevated temperature (65°C) on the mechanical properties of a stone mixture concrete. Tests conducted throughout this study were somewhat uncommon as a result of the specimens were initial subjected to a simulated temperature-vs.-time cement association cycle. Also, as a result of the concrete combine was being evaluated for associate application that older exposure to salt bearing groundwater at elevated temperatures (~65°C), each normal and sulfate-resistant Portland cements were investigated. Specimens, once being subjected to the simulated cement association cycle, were hold on either in water at 19°C (control specimens) or in a very sodium sulphate resolution (2000 ppm) at 65°C. oftentimes throughout the take a look at program, the sodium sulphate resolution was modified, that needed cooling to space temperature; the specimens were therefore additionally subjected to thermal sport. Results of the study indicated that there was no proof of long-run degradation in compressive strength for any of the concrete mixes and warmth treatments utilized, which for a given compressive strength the dynamic modulus of snap was lower for the concrete that had been heated. Cooling down and reheating the stone and flint mixture mixes for a complete of eighty-seven cycles didn't seem to cause degradation in strength.

Curette and Malhotra had conducted experiments to gauge the relative performance of stone and dolostone mixture normal cement concretes beneath sustained exposure to extreme temperature. once 28-d wet cure followed by twenty-six weeks of temperature solidifying, the take a look at specimens were exposed for up to four months to temperatures starting from 76°C to 450°C, and one month for a 600°C exposure. The loss of compressive strength of specimens exposed to elevated temperature was proportional to the exposure temperature. At temperatures of 150°C and better, a rise long of exposure from forty-eight h to four months resulted in additional decreases in strength. all told cases, any major loss in strength was found to occur among the primary month of exposure. generally, the throw concretes (water-cement quantitative relation = zero.6) were slightly less affected than the richer concretes in terms of relative strength loss once exposure. Suzuki et al investigated the impact of elevated-temperature exposure at 65°C, 90°C, or 110°C for periods up to three.5 years in Japan in support of nuclear energy plant facilities. Either volcanic rock or arenaceous rock coarse aggregates were utilized within the concrete mixtures. Cementitious materials studied enclosed category B ash, moderate heat cement and fly ash, and traditional cement. Heating conditions adopted were: (1) long-run heating tests [allowable temperature aside from native areas (long-term) (65°C), allowable native temperature (long-term) (90°C), temperature at that water is taken into account to evaporate apace (110°C)]; (2) short heating tests [allowable temperature(short-term) (175°C)]; and (3) thermal sport tests for up to a hundred and twenty cycles [cycled heating temperatures (20°C to110°C to 20°C) to simulate temperature variations throughout operational periods]. 3 cylindrical specimens were ready for every take a look at condition and dose either sealed conditions, wherever evaporation of water was prevented or unsealed conditions, wherever evaporation was allowed. throughout the thermal-cycle heating take a look at, compressive strength once heating was larger than before heating beneath each sealed and unsealed conditions. However, the quantitative relation of increase was smaller than beneath constant heating, suggesting the influence of thermal sport. For a similar variety of thermal cycles, the compressive strength was systematically higher for the sealed specimens relative to it obtained from unsealed specimens. beneath unsealed conditions specimens exhibited very little influence of variety of cycles on compressive strength for thermal cycle numbers larger than 5 (i.e., very little amendment in compressive strength worth for cycles larger than five). beneath unsealed conditions the modulus of snap exhibited an identical trend to it obtained for constant heating therein it had been reduced by concerning five hundredth. a significant a part of the reduction occurred within the early stages of the thermal sport. beneath sealed conditions throughout thermal sport the coefficient of elasticity showed an inclination similar to that of the compressive strength, however the modulus of snap didn't increase the maximum amount because the compressive strength of the sealed specimens. Billing noted that, once specially ready heat resistance cement concrete, continual cycles of heating and cooling didn't manufacture additional reduction in strength and modulus of snap once the primary cycle

4.PRIMARY INVESTIGATION

Introduction

To achieve the required strength of standard concrete of M25 grade and high strength concrete of M90 grade, preliminary investigations has been carried out. This chapter deals with the properties of ingredients of concrete, mix design, various parameters and their effect on concrete.

Justification of parameters of present study

Temperature range: Ambient to 300°C at an interval of 100°C. In general, for structural applications involving service temperatures in the range of ambient to 300°C, provided many temperature cycles of large magnitude are not present. The critical temperature for Portland cement concrete is 400°C above which the concrete would disintegrate on subsequent cooling.

Duration of exposure:

Grade of the concrete: Previously many structures are built with standard concrete (M25 grade) and the same is gradually replaced by high strength concrete in due to its advantages like high strength, greater load bearing capacity, thin cross sections etc. So the properties and performance of high strength concrete subjected to thermal cycles is mandatory. Hence the grades of concrete for present investigation are M25 and M90.

Age: Any structure will be in service after the age of 28 days. So in this study, the specimens are subjected to thermal cycles after curing for 28 days. At later ages rate of gain in strength is very slow. Hence, the study is restricted to the age of 28 days.

Method of cooling:

Drying of concrete is defined as providing the proper conditions to allow the concrete to achieve a moisture condition appropriate for its intended use.

Unstressed residual strength test: This method is chosen because it helps to assess post fire of concrete.

The mechanical properties that are chosen for the present study at elevated temperatures are compressive strength since the concrete is strong in compression. Along with the compression the tensile strength of the concrete and modulus of rupture is to be determined using split tensile strength test and flexure test. In addition to the above parameters weight loss is also studied to predict the durability of fire affected concrete. Study of these parameters (flexural strength) show the complete behaviour of concrete exposed to elevated temperatures.

Type of cement:

Material properties

The materials for the present experimental work are as follows:

Cement

Ordinary Portland cement with 28 days compressive strength of 63.6MPa is used. Locally available cement which conforms to IS: 12269-1987 is used for present study. The specific gravity of cement is 3.105. The physical properties of cement are given in Table.

Mechanical properties:

	CHEMICAL REQUIREMENTS		
1.	Insoluble material(% by mass)	0.68	28.96 Max
2.	Magnesia(% by mass)	1.16	6.00 Max
3.	Sulphuric anhydride(% by mass)	1.73	3.00 Max
4.	Loss on ignition(% by mass)	1.15	5.00 Max
5.	Total chlorides(% by mass)	0.006	0.10 Max
	PHYSICAL REQUIREMENTS		
1.	Fineness	5.5%	10% max
2.	Standard consistency(%)	30	
3.	Setting time a) Initial b) Final	 155 225	 30 min 600 min
4.	Soundness a) Le-chatelier method b) Autoclave method	 1.0 0.026	 10.0 Max 0.8 Max
5.	Compressive strength 3 days 7 days 28 days	 39.61 50.05 63.60	 Min. 27 MPa Min. 37 MPa Min. 53 MPa

Physical Properties of cement

Fine Aggregate

Locally available river sand with specific gravity 2.65 is used as fine aggregate. The fine aggregate used is conforming to Zone II according to the Table 4 of IS: 383-1970 with the fineness modulus 2.92. The fine aggregate can be medium sand but not fine sand. Fine sand will not give much strength as in the observations of Aykut Ceiten and Ramon Carrasquillo. Fine aggregate should be free from deleterious materials and organic and inorganic compounds. To avoid bulking the sand is sufficiently air dried.

IS Sieve Size	Weight retained(kg)	Cumulative weight retained (kg)	Cumulative percentage weight retained	Cumulative percentage passing
80mm	0	0	0	100
40mm	0	0	0	100
2.36mm	0.000	2.000	100.000	0.000
1.18mm	0.000	2.000	100.000	0.000
600µ	0.000	2.000	100.000	0.000
300µ	0.000	2.000	100.000	0.000
150µ	0.000	2.000	100.000	0.000
Total	2.000			
Fineness Modulus = 738.5 /100 = 7.38				

Sieve analysis of fine aggregate

Coarse Aggregate

IS Sieve Size	Weight retained(kg)	% weight retained (kg)	Cumulative percentage weight retained	Cumulative percentage passing
80mm	0	0	0	100
40mm	0	0	0	100
20mm	0	0	0	100
10mm	0	0	0	100
4.75mm	.010	1	1	99
150µ	.0715	7.15	99.3	0.7
Total	1.0		292.1	
Fineness Modulus = 292.1/100 = 2.92				

Granite, dark blue in colour, which is angular in shape with specific gravity 2.78, is used as coarse aggregate for the present investigation. The fineness modulus is 7.38. The sample sieve analysis is given in the Table 3.2.3.1. Coarse aggregate should be strong and durable. It need not be hard and it may not have high strength and stiffness with the cement paste. Before using coarse aggregate in concrete mix, it is wetted and dried alternatively in order to remove the deleterious material and to ensure saturated surface dry condition[5]

Mix Design for M90 Grade Concrete

Optimization of the composition of high strength concrete M90 was done based on the factorial design model of Rougeron and Aitcin. This technique is based on the statistical analysis obtained from a set of experiments and Iso curves were developed relating to the dosage of cement, silica fume, superplastizer, water- binder ratio with a constant aggregate content. The lowest cement dosage adopted in this technique is 353 kg/m^3 and the highest one is 682kg/m^3. The selection of the ingredients for high strength concrete are less empirical but Aitcin developed the curves by least laboratory work. These curves are used for initial trail mixes and optimized further.

1. **Target Strength**

Determine the mean target strength f_t from the specified characteristic compressive strength at 28-day f_{ck} and the level of quality control.

$f_t = f_{ck} + KS$

Assuming 5% fall of the results K = 1.65

Where S is the standard deviation assumed for M90 grade.

Target strength = 90 + 1.65*5 = 98.25 N/mm^2

2. Choice of Slump

The value of slump is assumed to be less than 1inch (25mm) therefore slump is adjusted to the desired value by addition of superplasticizer.

3. Choice of Maximum Size of Aggregate

Maximum size of coarse aggregate for the strengths greater than 9000 psi (60MPa) = 10 mm (3/8 inch) as per Table 6.2 ACI 211.4R-08.

Suggested maximum-size coarse aggregate

Required concrete strength, psi	Suggested maximum-size coarse aggregate, in.
<9000	**3/4** to 1
>9000	**3/8 to 1/2**

4. Estimation of Mixing Water and Water Binder Ratio

For compressive strength > 100 MPa, w/b = 0.22 from Iso curves

If saturation point of SP is not known initially, it is suggested starting with a water content of 145 l/m^3

5. Calculation of Cement Content

Cementitious material = 145/0.22

= 660 kg/m^3

6. Estimation of Coarse Aggregate

Volume of coarse aggregate per unit of volume of concrete = 0.65

Bulk density of coarse aggregate of size 10 mm = 1700 kg/m^3

Quantity of coarse aggregate = 1700*0.65 = 1105 kg/m^3

7. Estimation of Fine Aggregate

Volume of water = 145/1000 = 0.145 m^3

Volume of cement = 660/(3.105*1000) = 0.2126 m^3

Volume of coarse aggregate (Max. 10 mm size) = 1105/(2.78*1000) = 0.3975 m^3

Volume of fine aggregate = 1- (0.145+0.2126+0.3975) = 0.245

Quantity of fine aggregate = 0.245*2.65*1000 = 650 kg/m^3

8. Mix Proportions

Achieved mix proportions for M90 grade of concrete

Cementitious material	:	Fine aggregate	:	Coarse aggregate	:	water/ binder ratio
660	:	650	:	1105	:	145
1	:	0.985	:	1.674	:	0.22

Actual Mix Proportions

The above mix proportions for both M25 and M90 concrete are optimized after few trails since cement content is too high and also to achieve required strength economically. The final proportions are tabulated in table

S.No	Ingredient	Standard Concrete M25	High strength concrete M90
1	Cement (OPC 53 grade)	370 kg/m^3	594 kg/m^3
2	Micro silica (10 % of cementitious material)	NIL	66 kg/m^3
3	Fine aggregate	740 kg/m^3	650 kg/m^3
4	Coarse aggregate	1214 kg/m^3	1105 kg/m^3
5	Water	165 l/m^3	145 l/m^3
6	superplastcizer	NIL	Master Glenium ACE 30 (10 ml per kg of cement)

5.EXPERIMENTAL PROGRAM:

Introduction Based on the combo proportions given in annexure, prisms of concrete are forged and tested so as to research flexural strength for prime strength concrete(M90) similarly as commonplace concrete(M25) subjected to thermal cycles when cured to twenty-eight days. every thermal cycle consists of heating of the specimens for eight hours and succeeding cooling for remaining amount in an exceedingly day. when the required range of thermal cycles, the specimens were tested for flexural strength of concrete. take a look at results were critically examined and also the effects of assorted parameters within the gift work are discussed. it's indicated that heating/cooling of concrete affects its sturdiness performance because it loses up to twenty-seven and thirty second of its compressive and flexural strength, severally. For all tested specimens, the best loss of strength is discovered when thirty cycles. The specimens when heated for eight unit of time and exposed to air for rest sixteen hrs. this method of cooling of concrete steady to temperature is named air cooling. Cracks could develop within the concrete specimen by sharp cooling thus air cooling is preferred because it surface at a relentless rate. Process of casting and solidification of concrete specimens Introduction Based on the combo proportions given in annexure, prisms of concrete are forged and tested so as to research flexural strength for prime strength concrete(M90) similarly as commonplace concrete(M25) subjected to thermal cycles when cured to twenty-eight days. every thermal cycle consists of heating of the specimens for eight hours and succeeding cooling for remaining amount in an exceedingly day. when the required range of thermal cycles, the specimens were tested for flexural strength of concrete. take a look at results were critically examined and also the effects of assorted parameters within the gift work are discussed. it's indicated that heating/cooling of concrete affects its sturdiness performance because it loses up to twenty-seven and thirty second of its compressive and flexural strength, severally. For all tested specimens, the best loss of strength is discovered when thirty cycles. The specimens when heated for eight unit of time and exposed to air for rest sixteen hrs. this method of cooling of concrete steady to temperature is named air cooling. Cracks could develop within the concrete specimen by sharp cooling thus air cooling is preferred because it surface at a relentless rate. Process of casting and solidification of concrete specimens the sequence of feeding ingredients within the combiner depends on the properties of mix and people of mixer. during this work, a little quantity of water is fed 1st, followed by coarse combination in SSD condition and fine combination. These materials are mixed uniformly and cement with small silicon oxide is fed into the mixer. sometimes admixture is finished in 2 totally different stages: dry admixture is finished before the addition of water and wet admixture is finished when addition of water. when dry admixture of the ingredients for one minute, hr. of water is further to the ingredients and mixed uniformly. The remaining four-hundredth of water is mixed with super softener, Master Glenium ACE thirty and is introduced into {the combine the combination the combo}and ingredients are mixed for three minutes till the mix is uniform. the whole admixture time is five minutes. when admixture, the concrete is poured on the pre wetted platform then stuffed into molds. The moulds are created with forged iron that meets the wants of IS: 10086-1982. The angle between the interior faces of the cube and beam moulds is 90°± zero.5°. Prisms of size one-hundred-millimeter x one-hundred-millimeter x five hundred millimeter are employed in flexural take a look at to work out flexural strength. every and each layer within the concrete within the mould is compacted by means that of vibratory table having specification in keeping with IS: 7246-1974 for forty-five seconds. All moulds are maintained for the amount of twenty-four hours in damp air. Then the specimens are remolded, marked and are cured in an exceedingly solidification tank with H2O. The temperature within the tank is maintained at 27°±1°. they're cured for an amount of twenty-eight days. All high strength concrete specimens should be water cured as presently as potential before association starts. If the external water isn't provided to the concrete by that point, shrinkage can develop terribly quickly and can be to blame for cracks. thus, they're cured for an amount of twenty-eight days when demolding. Flexure tests are usually want to verify the flexural modulus or flexural strength of a fabric. A flexure takes a look at is more cost-effective than a tensile take a look at and take a look at results are slightly totally different. The Universal testing machine of forty Ton capability is employed to check flexural strength as shown in Plate half dozen. The bed of the testing machine is supplied with 2 rollers, twenty-five millimeter in diameter, on that the specimen of size one-hundred-millimeter x one-hundred-millimeter x five hundred millimeter is supported. These rollers are mounted so distance from centre to centre of supported is forty cm. The load is applied through 2 similar rollers mounted at the third points of the supporting span, which is, spaced at thirteen.3 cm center to center. The load is split equally

between the 2 loading rollers, and every one roller are mounted in such a fashion that the load is applied to the topmost surface as forged within the mould, on 2 lines spaced at thirteen.3 cm apart. The axis of the specimen is fastidiously aligned with axis of the loading device of the specimen and also the rollers as shown in Plate seven for each grades of concrete. The load is applied while not shock and increasing unceasingly at a rate such the acute fiber stress will increase at just about at a rate of a hundred and eighty kg/min for the ten cm specimens. and also, the load is hyperbolic till the specimen fails, and also the most load applied to the specimen throughout the take a look at is recorded.
The most common purpose of a flexure test is to measure flexural strength and flexural modulus. Flexural strength is defined as the maximum stress at the outermost fiber on either the compression or tension side of the specimen. Flexural modulus is calculated from the slope of the stress vs. strain deflection curve. These two values can be used to evaluate the sample materials ability to withstand flexure forces.

The flexural strength of the specimen is expressed as the modulus of rupture

$$f_b = \frac{P \times L}{b \times d^2}$$

when a is greater than 13.3 cm.
The flexural strength of the specimen is expressed as the modulus of rupture

$$f_b = \frac{3P \times a}{b \times d^2}$$

when a is in between 11.0 cm and 13.3 cm. If a is less than 11.0 cm the test result is discarded.
Where, a = the distance between the line of fracture and the nearest support
b = measured width in cm of the specimen
d = measured depth in cm of the specimen was supported, and
P = maximum load in kg applied on the specimen.
The real dimensions of the specimens are taken into consideration for calculation. Average of three specimens is taken as flexural strength provided variation is not more than 15% on the average. A total of 270 prisms were cast and tested for both grades of concrete that is M25 and M90 at 28 days after exposed to elevated temperatures of 100°C, 200°C, 300°C and 400°C from room temperature for number of thermal cycles varying from 0 to 50 (0, 1, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50). After a requisite number of thermal cycles, specimens were air cooled, weighed and tested.

6.RESULTS AND DISCUSSION

The details of the laboratory experimentation carried on concrete prism were presented in the previous chapter. In this chapter laboratory test results were presented.

LABORATORY TEST RESULTS

In the laboratory, flexural strength tests were conducted by using thermal cycles at different temperatures with a view to determine the variation in flexural strength with increase in temperature. The variation of flexural strength, weight loss with temperature were discussed in detail in the following sections.

Results of flexural strength

Flexural strength of M25 grade concrete at 100 °C

The table presents the values of % relative weight loss and flexural strength for thermal cycles of M25 grade concrete at 100 °C temperature

Results of M25 grade concrete at 100 °C

Grade of concrete	Temp (°C	No. of Cycles	Initial wt. of specimen (Kg)	wt. of specimen after heating (Kg)	% Loss of weight	Load (KN)	% Relative change in flexural strength	flexural strength (N/mm2)
M25	**100**	0	12.275	12.275	0	10	100	7.5
M25	**100**	1	12.325	11.893	3.5	15.5	103.33	7.75
		5	12.11	11.63	3.965	13	97.67	7.5
		10	12.21	11.72	4.013	12	95	7
		16	12.4	11.915	4	11.5	95	7
		20	12.23	11.72	4.17	11	90.33	6.5
		26	12.49	11.965	4.203	10	81.66	6
		30	11.81	11.31	4.2323	9.5	73.33	5.5
		35	11.985	11.476	4.2456	9	68.33	5
		40	12.325	11.79	4.2689	8	63.34	4.75
		45	12.359	11.827	4.298	7.5	63.34	4.75
		50	12.563	12.02	4.32	7.5	63.34	4.75

Flexural strength of M25 grade concrete at 200 °C

The table presents the values of % relative weight loss and flexural strength for thermal cycles of M25 grade concrete at 200 °C temperature.

Results of M25 grade concrete at 200 °C

Grade of concrete	Temp (°C)	No. of Cycles	Initial wt. of specimen (Kg)	wt. Of specimen after heating (Kg)	% Loss of weight	Load (KN)	% Relative change in flexural strength	flexural strength (N/mm2)
M20	200	1	12.425	11.835	4.748	12.5	90	6.25
		5	12.64	12.015	4.944	12	79.54	6
		10	12.605	11.97	5.037	11	77.72	5.55
		15	12.155	11.505	5.347	11.5	77.27	5.75
		20	12.41	11.74	5.398	11.25	72.72	5.85
		26	12.31	11.84	5.392	10.5	70.45	5.325
		30	12.355	11.67	5.382	10	68.18	5.114
		35	12.621	11.94	5.395	10	68.18	5.114
		40	12.356	11.687	5.412	9.5	65.9	4.942
		45	12.654	11.968	5.421	9	63	4.773
		50	12.5203	11.839	5.456	9	63	4.773

Flexural strength of M25 grade concrete at 300 °C

The table presents the values of % relative weight loss and flexural strength for thermal cycles of M25 grade concrete at 300 °C temperature.

Grade of concrete	Temp (°C)	No. of Cycles	Initial wt. of specimen (Kg)	wt. of specimen after heating (Kg)	% Loss of weight	Load (KN)	% Relative change in flexural strength	flexural strength (N/mm2)
M25	300	0	12.275	12.275	0	15	100	7.5
		1	12.521	11.904	4.925	13	86.67	6.5
		5	12.314	11.696	5.015	12	80	6
		10	12.583	11.937	5.128	11.5	76.66	5.75
		16	12.346	11.69	5.275	11	73.33	5.5
		35	12.159	11.447	5.855	10	66.67	5
		40	12.156	11.438	5.901	9	60	4.5
		45	12.367	11.638	5.893	8.5	56.66	4.25
		50	12.569	11.825	5.912	8.5	56.66	4.25

Flexural strength of M90 grade concrete at 100 °C

The table presents the values of % relative weight loss and flexural strength for thermal cycles of M90 grade concrete at 100 °C temperature.

Results of M90 grade concrete at 100 °C

Grade of concrete	Temp (°C)	No. of Cycles	Initial wt. of specimen (Kg)	wt. of specimen after heating (Kg)	% Loss of weight	Load (KN)	% Relative change in flexural strength	flexural strength (N/mm2)
M90	100	1	11.75	11.45	2.499	24	109.09	12
		5	11.625	11.227	3.421	19	86.72	9.5
		10	12.223	11.789	3.546	18	80	9
		16	12.013	11.577	3.625	17	76.45	8.5
		20	12.321	11.843	3.879	16	73.9	8
		26	12.152	11.672	3.945	16	73.9	8
		30	11.945	11.47	3.985	14.5	66.45	7.25
		35	11.963	11.489	3.962	14	63.19	7
		40	11.852	11.378	3.996	13	60	6.5
		45	12.357	11.861	4.012	13	60	6.5
		50	12.159	11.657	4.125	13	60	6.5

Flexural strength of M90 grade concrete at 200 °C

Table presents the values of % relative weight loss and flexural strength for thermal cycles of M90 grade concrete at 200 °C temperature.

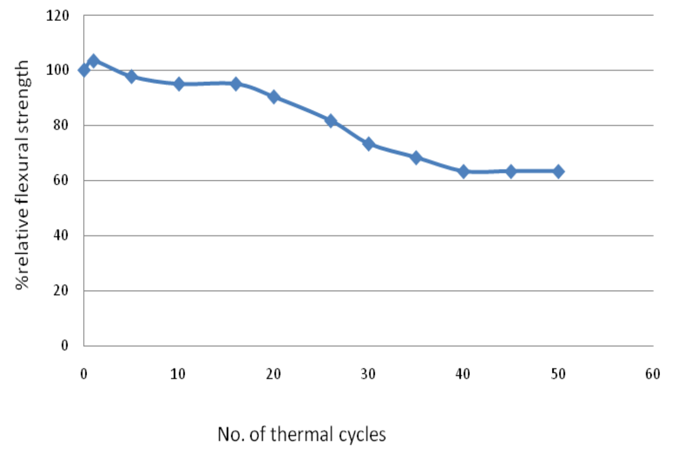
Grade of concrete	Temp (°C)	No. of Cycles	Initial wt. of specimen (Kg)	wt. of specimen after heating (Kg)	% Loss of weight	Load (KN)	% Relative change in flexural strength	flexural strength (N/mm2)
M90	200	1	11.805	11.51	2.499	18	80	8.75
		5	11.82	11.37	3.807	16.5	75	8.25
		10	12.35	11.856	4	16	74	8
		15	11.955	11.46	4.14	15	66.67	7.5
		20	12.095	11.555	4.46	14	63.34	7
		26	12.415	11.203	4.452	13	60	6.5
		30	11.945	11.415	4.487	12	53.34	6
		35	12.045	11.503	4.496	12	53.34	6
		40	11.845	11.311	4.5012	11	50	5.5
		45	12.069	11.524	4.513	11	50	5.5
		50	11.862	11.323	4.536	11	50	5.5

Flexural strength of M90 grade concrete at 300 °C

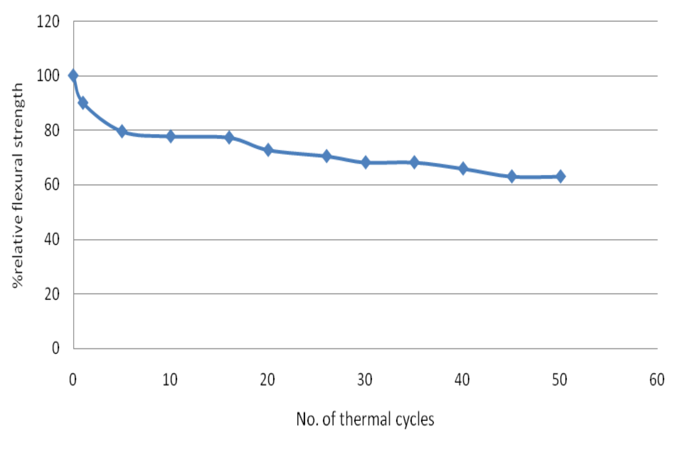
Table presents the values of % relative weight loss and flexural strength for thermal cycles of M90 grade concrete at 300 °C temperature.

Grade of concrete	Temp (°C)	No. of Cycles	Initial wt. of specimen (Kg)	wt. of specimen after heating (Kg)	% Loss of weight	Load (KN)	% Relative change in flexural strength	flexural strength (N/mm2)
M90	300	1	11.625	11.215	3.524	17.5	79.54	8.75
		5	11.852	11.407	3.752	16	72.72	8
		10	12.054	11.577	3.952	15.5	70.45	7.75
		16	11.955	11.448	4.235	15	68.18	7.5
		20	12.035	11.489	4.53	14.5	65.9	7.25
		26	12.365	11.762	4.875	13.5	61.36	6.75
		30	11.752	11.361	4.985	12	61.36	6.75
		35	12.245	11.637	4.964	11	59.1	6.5
		40	11.847	11.274	4.835	10	56.81	6.25
		45	12.441	11.825	4.9512	9.5	54.54	6
		50	12.354	11.74	4.963	9.5	54.54	6

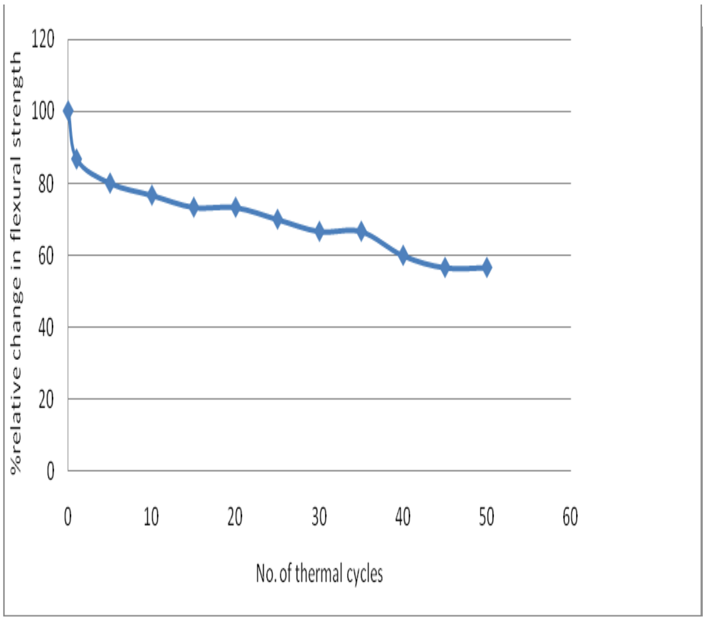
6+-Relative flexural strength of M25 grade concrete at 100 °C



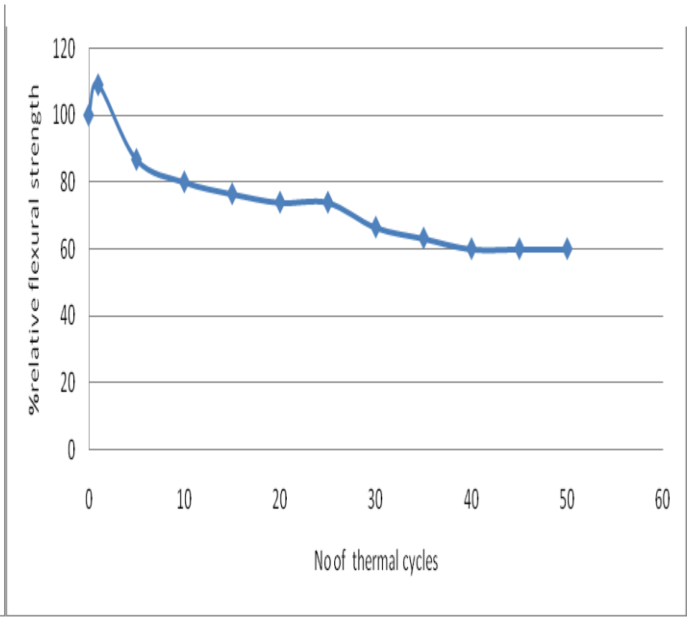
Relative flexural strength of M25 grade concrete at 200 °C



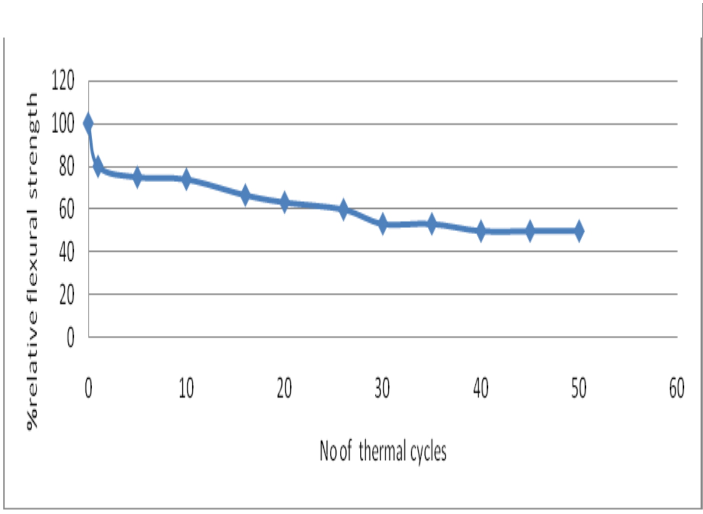
Relative flexural strength of M25 grade concrete at 300 °C



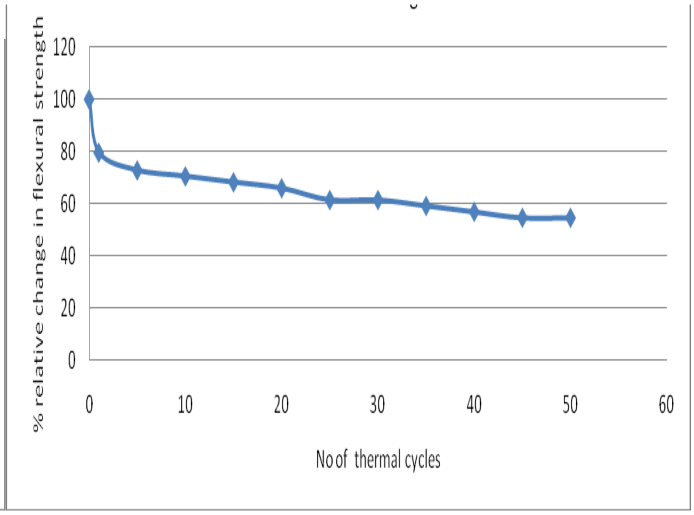
Relative flexural strength of M90 grade concrete at 100 °C



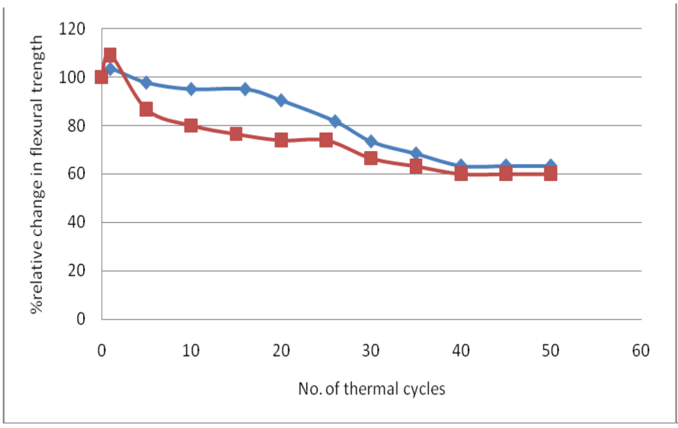
Relative flexural strength of M90 grade concrete at 200 °C



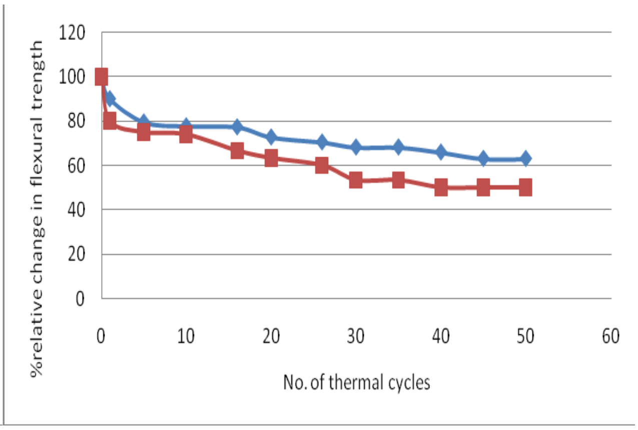
Relative flexural strength of M90 grade concrete at 300 °C



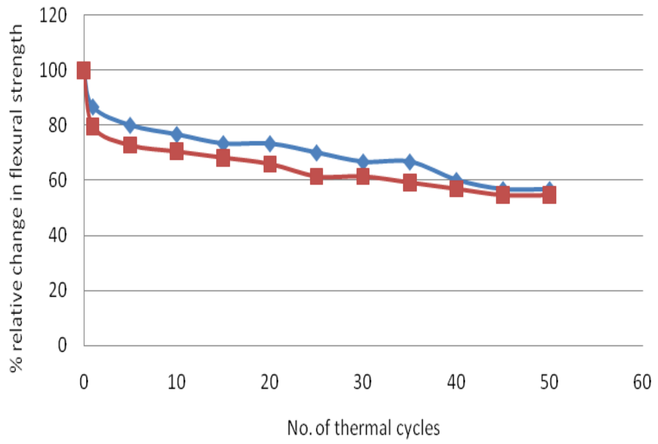
Relative flexural strength of M25&M90 grade concrete at 100°C



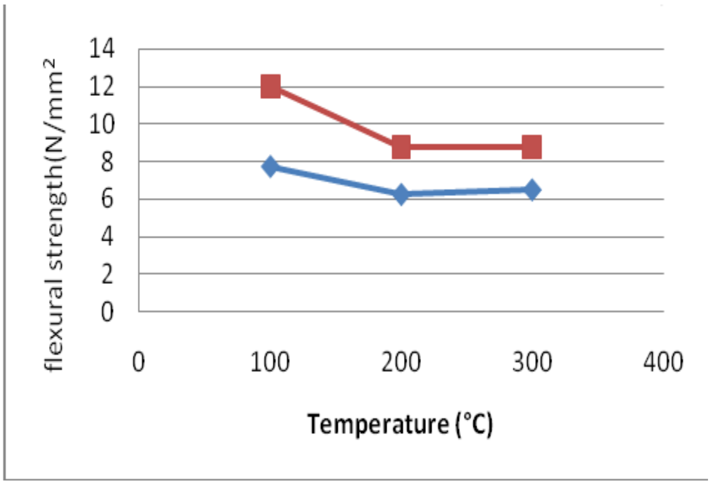
Relative flexural strength of M25&M90 grade concrete at 200°C



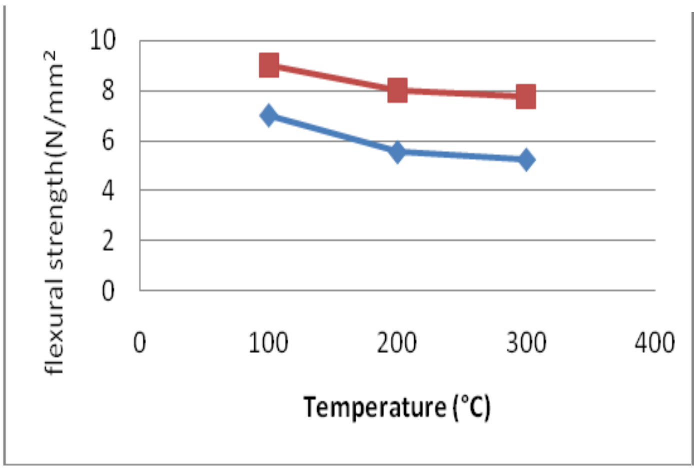
Relative flexural strength of M25&M90 grade concrete at 300°C



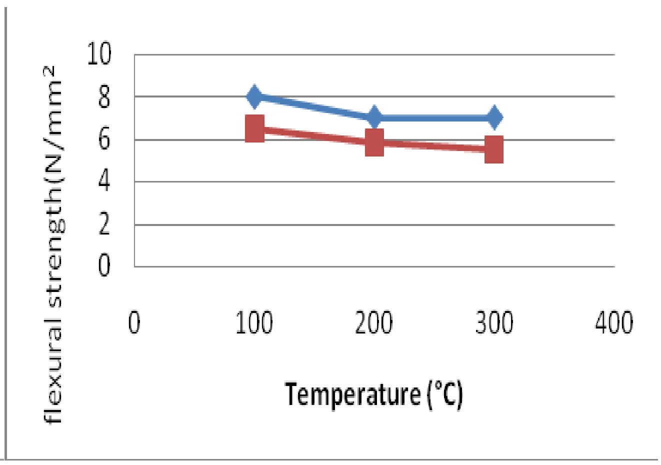
Flexural strength of M25 & M90 for 1 thermal cycle



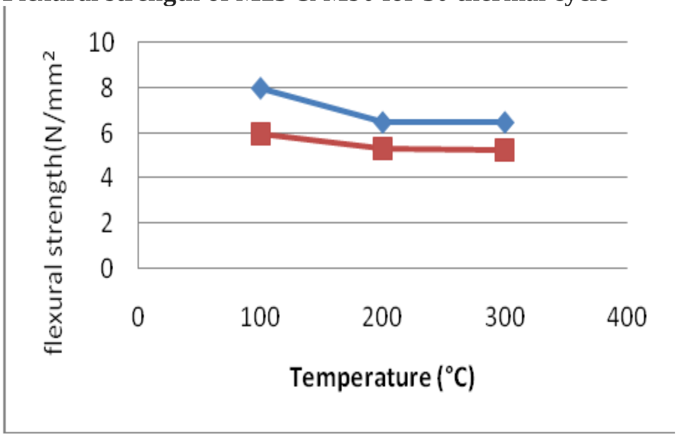
Flexural strength of M25 & M90 for 10 thermal cycle



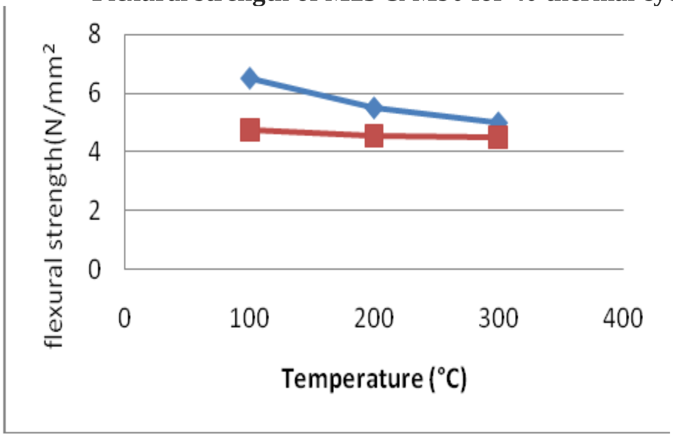
Flexural strength of M25 & M90 for 20 thermal cycle



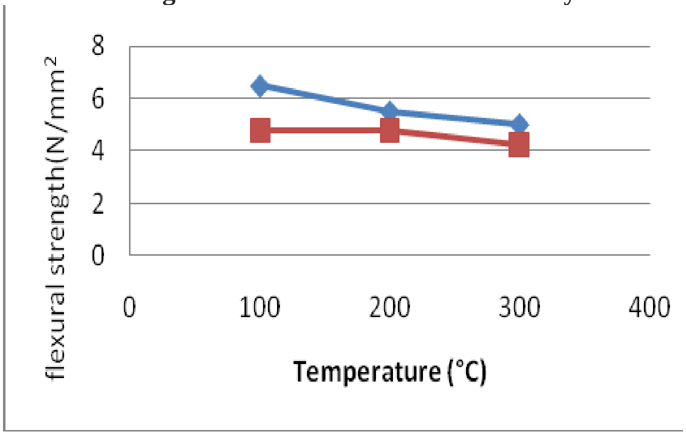
Flexural strength of M25 & M90 for 30 thermal cycle



Flexural strength of M25 & M90 for 40 thermal cycle



Flexural strength of M25 & M90 for 50 thermal cycle



7.CONCLUSION:

1) It is observed from the laboratory test results of flexural strength that, for M25 grade concrete at 100°C:
   i) There is an increase of 3.33% relative flexural strength at 1st thermal cycle.
   ii) There is a gradual decrease from 2.33% to 33.33% relative flexural strength for 5 to 35 thermal cycles and stabilize from 40 cycles.
2) For M25 grade concrete at 200°C, the relative flexural strength decreases from 10% to 34.1% for 1 to 35 thermal cycles and then stabilizes there.
3) It is observed that the relative flexural strength for M25 grade concrete at 300°C decrease from 13.33% to 40% for 1 to 40 thermal cycles and then stabilizes there.
4) It is observed from the laboratory test results of flexural strength that, for M90 grade concrete at 100°C:
   i) There is an increase of 9.09% relative flexural strength at 1st thermal cycle.
   ii) There is a gradual decrease from 13.28% to 36.81% relative flexural strength for 5 to 40 thermal cycles and stabilize there.
5) For M90 grade concrete at 200°C, the relative flexural strength decreases from 20% to 43.66% for 1 to 40 thermal cycles and then stabilizes there.
6) It is observed that the relative flexural strength for M90 grade concrete at 300°C decreases from 28.45% to 38.63% for 1 to 40 thermal cycles and then stabilizes there.
7) The relative weight loss of M25 grade concrete at 100°C, increases gradually from 3.59% to 4.17% for 1 to 35 thermal cycles and stabilizes there.
8) For M25 grade concrete at 200°C, the relative weight loss increases from 4.94% to 5.34% for 1 to 35 thermal cycles and then stabilizes there.
9) It is observed that the relative weight loss for M25 grade concrete at 300°C increase from 4.92% to 5.84% for 1 to 20 thermal cycles and then stabilizes there.
10) It is observed that the relative weight loss for M90 grade concrete at 100°C increases from2.49% to 3.24% for 1 to 35 thermal cycles and then stabilizes there.
11) The relative weight loss of M90 grade concrete at 200°C, increases from 2.49% to 3.807% for 1 to 20 thermal cycles and then stabilizes there.
12) For M90 grade concrete at 300°C, the relative weight loss increases from 3.5% to 4.89% for 1 to 30 thermal cycles and then stabilizes there.
13)The flexural strength for 100 °C will be maximum and stabilizes from 200°C for allthermal cycles both M25 and M90