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RESIDUAL COMPRESSIVE STRENGTH OF TERNARY BLENDED MIX CONCRETE CONTAINING FLY ASH AND SILICA FUME AT ELEVATED TEMPERATURES

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ABSTRACT

The danger of concrete being subjected to extremely high temperatures is increased by the widespread use of concrete as a building element for tall structures, tunnels, jet airways, nuclear reactors, pressure vessels, hot water and crude oil storage tanks, and coal gasification and liquefaction vessels used in petrochemical industries. Due to its extremely high specific gravity and limited thermal conductivity, concrete is best suited to withstand high temperatures. When concrete is exposed to high temperatures, it loses a great deal of its mechanical qualities, including strength and modulus of elasticity.This could lead to unfavourable structural malfunctions.As a result, the characteristics of concrete that survive a fire remain significant. To ascertain the ability to support loads and to restore structures damaged by fire. Numerous studies on different compounds and mixtures of substances that can enhance concrete's durability when exposed to high temperatures have been conducted.After undergoing regulated thermally exposes at the designated objective temperature, the purpose of the research is to examine the impact of increased temperature on the mechanical properties of OPC and ternary mixed concrete. Numerous investigations have demonstrated that adding admixtures of minerals improves the way concrete performs at higher temperatures. Ternary blends have been shown to enhance concrete's ability to perform in studies conducted globally. In this research, ternary blends were used in an effort to enhance concrete's resilience at higher temperatures.The goal of this study was to use ternary blends to try and enhance the resilience of concrete at higher temperatures. A binder ratio of 0.42 is employed. A collection of initial information was developed by testing three different samples of every variety of concrete at ambient temperature. After that, an oven was used for warming three different pieces of ternary blended concrete to a desired temperature at an average pace of 50C/min. Target temperatures were 100^{0}C, 200^{0}C, 300^{0}C, 400^{0}C, 500^{0}C, 600^{0}C, 700^{0}C and 800^{0}C. In order for the samples to develop constant state thermal

circumstances, they were kept at the designated optimum temperature. The furnace was switched off and the samples were left in the oven to cool to the ambient temperature after the three-hour warming exposition. Upon reaching ambient temperature, the samples underwent loads till they broke and the remaining mechanical characteristics were noted. The findings show that, in comparison with regulating concrete, ternary blended concrete performs better at mitigating the impact of temperature on retained strength. The results of the investigation regarding the retained compressive strength of concrete will help create new guidelines for the application of ternary blended concretes.

INTRODUCTION

Concrete is the high widely used building material and, due to its excellent compressive strength and moldability has shown to be the versatile in the field of civil engineering.Conversely, it is well recognized that elevated temperatures can seriously harm structural concrete.Over the last few decades, researchers have examined how concrete reacts to high temperatures, and their findings show that strength decreases as a temperature rises. A continuous decrease in residual compressive strength is observed in concrete that is made entirely of regular Portland cement.The development of fissures between two elements in concrete is one of the factors contributing to its temperature-related loss of strength. The primary reason of the incompatibility is the cement paste, notwithstanding the gravel aggregates thermal stability up to 200°C. Cement paste shrinks because high temperature cause C-S-H gel(calcium silica hydrate) to dehydrate and lose its cementing capacity. The Cao/Sio2 ratio is primarily responsible for the C-S-H gel bond. For the aforementioned reasons, fly-ash with a low Cao/Sio2 used in the operation in lieu of cement in certain parts.

With regard to strength loss, the heating process that turns$Ca(OH)_2$ into lime and water vapor is not crucial.However, the growth of lime during the cooling process could cause severe harm.By employing mineral admixtures such fly ash and silica fume, the harmful effects of calcium hydroxide can be removed. This mineral admixture's reactive SiO2 and cement's pozzolanic reaction causes a decrease in the system's Ca(OH)2 content. Two categories of elements can be distinguished that affect the strength of cement-based concretes and concrete at high temperatures: environmental conditions and material qualities. Concrete's resistance is significantly influenced by the characteristics of the aggregates, cement paste, and aggregate-cement paste bond, as well as by their thermal compatibility.Nonetheless, the heat resistance of cementitious materials is influenced by environmental parameters such as moisture regime, loading circumstances, heating and cooling rates, and the length of time exposed to the maximum temperature. The differences in the aggregate and cement deterioration over time, as well as fluctuations in the moisture content of the ingredients of the concrete, are the main causes of the property variations.

It is discovered that concrete's ability to withstand fire is significantly influenced by the pozzolans that are typically added to it to increase its strength and endurance. Numerous studies have shown that adding silica fume to concrete greatly densifies its pore structure, which causes explosive spalling as a result of steam building up pore pressure. Such concrete performed worse at higher temperatures than regular port land cement (OPC) concrete because the evaporation of physically absorbed water begins at 100ºC, which causes thermal cracks. Conversely, adding fly ash (FA) improves concrete's ability to withstand fire. These pozzolanic ingredients work best together when combined with cement to enhance the performance of concrete at higher temperatures.

AIM AND OBJECTIVE OF RESEARCH

The objective of this project is to study the residual strength of ternary blended concrete using Portland cement, fly ash (20%), and silica fume (5%).exposed to temperatures from 100ºC to 800ºC.

SCOPE OF WORK

The scope of this work is to generate data relate to residual strength of ternary blended concrete exposed to elevated temperatures.

LITERATURE REVIEW

SrinivasaRao et al.,(2004)[1]investigated how employing fly ash-based pozzolana Portland cement, elevated temperatures up to 950ºC affected the compressive strength of greater strength concrete of M60 grade. The mixing ratios that were used were 1: 0.94:1.35, with a 0.25 w/c. For varying times of one, two, and three hours, high strength concrete cube specimens were subjected to temperatures ranging from 50°C to 950°C at intervals of 50°C. Following their exposure to high temperatures, the specimens underwent a hot state compressive strength test. Next, it was determined how high temperatures affected HSC's compressive strength. Exposure to elevated temperatures causes the internal pore pressure within the cubes to attempt to escape, resulting in the creation of surface fissures on the cubes, ultimately leading to concrete spalling. Between 100 and 250℃, there is a progressive increase in compressive strength. Compressive strength increases nominally between 250 and 350℃.Throughout the entire exposure period, the concrete maintains its initial strength up to 400°C. Between 400°C and 700°C, there is a progressive decline in compressive strength.In the 800°C to 950°C temperature range, compressive strength decreases more quickly.

M.Potharaju et al.,(2007)[2]examined how high temperatures, between 50 and 250 degrees Celsius, affected the compressive strength of M60 grade HSC manufactured with regularPPC.Compressive strength of 60 MPa was attained in the mix by using the American Concrete Institute's (ACI) mix design procedure. Ultimately, a 1:0.94:1.35 mix was used, with a 0.25 w/c. Tests were performed on 100mm cubes, and the specimens were heated to one, two, and three hours at each of the following temperatures: 50, 100, 150, 200, and 250ºC. The specimens' compressive strengths were evaluated following the heat treatment.The specimens underwent compressive strength testing following the heat treatment.When comparing OPC with PPC concrete, PPC concrete shows a greater proportion of residual compressive strength (between 1 and 10%); However, the percentage residual compressive strength falls between 100 and 250ºC more gradually at moderate temperatures but more swiftly at lower ones.Following an hour of exposure, the compressive strengths of the OPC and PPC concretes showed maximum losses of 36% and 17%, respectively.As can be seen from the data, PPC and OPC concrete were subjected to different temperatures and their effects. Out of the two types of concrete, PPC concrete performed better.

Ali Behnood et al., (2007) [3]investigated how exposure to high temperatures affected the residual compressive strength of high strength concrete in relation to varying ratios of water to cement (w/c) and silica fume (SF). A three-component concrete mixture was created to assess how SF affected the heated and unheated concrete specimens' compressive strength. The w/c ratio, which was 0.30, was used to create all three mixes. The percentages of cement replaced with SF were 10%, 6%, and 0%. In order to assess the impact of water/cement ratio on the compressive strength of concrete mixtures that have been exposed to elevated temperatures, four distinct combinations were created. Two combinations with w/c of 0.30 and 0.40 and no SF were made, whereas additional concretes with w/c of 0.30 and 0.35 and 6% SF were made. To test the impact of raising SF from 0% to 10% while concurrently lowering w/c from 0.4 to 0.3, three distinct concrete mixes were mixed beforehand.The concrete specimens with 6% and 10% SF at 600ºC showed results of strength loss rates that were 6.7% and 14.1% lower than those of regular concrete. At 100 and 200 degrees Celsius, the relative residual compressive strength was not significantly affected by the SF dose; however, the amount of SF had a substantial impact on the residual compressive strength at 300 degrees Celsius, which was comparable to the response at 600 degrees Celsius. The best doses of w/c and SF were discovered to be 0.35 and 6%, respectively.

M.S.Morsy et al.,(2008)[4]examined the behaviour of mixed cement mortars at high temperatures. In this study, OPC, MK, and SF blended cement was utilized. Sand: binder ratios in the mortars were 1:5.23. To find out how mixed cement mortar with MK and SF held up after being subjected to high temperatures, an experimental program was created.For this reason, 18 mortar mixtures containing varying percentages of MK and SF by mass of cement were made: 0%, 5%, 10%, 20%, and 30%. Every mixture contained five groups. Prior to curing, the compressive strength of the first group was measured under ambient conditions. After being exposed to 200°C, 400°C, 600°C, and 800°C for two hours, the second, third, fourth, and fifth groups underwent testing. They came to the conclusion that MK and SF increase compressive strength both before and after being exposed to high temperatures. The highest increase in compressive strength is achieved with a ternary blend consisting of 10% MK, 10% SF, and 80% OPC. In contrast, utilizing 20% SF produced the best compressive strength gain in the binary replacement.

Bishr.H.A.M et al(2008) [5]explored how high temperatures affected the residual compressive strength of concrete constructed with readily accessible regular PPC, crushed basalt aggregate, sand, and silica fume added as a dry power as a proportion of the cementitious material.Temperatures ranging from 20ºC to 900ºC and varying silica fume concentrations from 0% to 15% are research variables. A 28-day curing period in water tanks preceded the heating of the samples. For four hours, the specimens were placed in the oven to ensure that their temperatures were consistent throughout. Following that, the specimens were left in the oven to cool for a total of twenty hours, or twenty hours of heating. The samples are evaluated under compression after being heated in the oven to the appropriate temperatures and then allowed to cool to room temperature. The mean of the three measurements Obtained serves as a representation of the experimental test's state. The research findings indicate that silica fume concrete exhibits a lower compressive strength than conventional concrete at high temperatures, with the former being more susceptible to such temperatures than the latter.

M.S.Morsy et al., (2010) [6] investigated how high temperatures affected the silica flour concrete's mechanical characteristics, phase composition, and microstructure. The blended cement utilized in this study is made up of silica flour and regular OPC. A portion of the OPC were swapped out with 0, 5, 10, 15, and 20% of silica flour. 0.5 weight percent of blended cement was used as the water-binder ratio to make the blended concrete paste. Prior to being cured in water for 28 days, the newly mixed concrete pastes were initially cured for 24 hours at 100% relative humidity. The hardened concrete underwent two hours of heat treatment at temperatures of 100, 200, 400, 600, and 800ºC. The pure conventional Portland concrete was compared with silica flour concrete in terms of its microstructure, phase composition, compressive strength, and indirect tensile strength. The findings demonstrated that when silica flour is added to OPC, blended concrete that is created performs better when subjected to temperatures as high as 400°C. The mechanical and physical characteristics of silica flour concrete were examined, and it was found that 20% of the material performed better than5,10, and 15%. As a result, structural parts exposed to temperatures as high as 400ºC can employ this material.

S.Sarath et al.,(2012) [7] examined, over a two-hour retention period, the residual strength properties of normal strength concrete (M40) exposed to a range of high temperatures, including 150ºC, 300ºC, 450ºC, 600ºC, and 750ºC, to the resulting alterations in the microstructure of concrete, which are quantified as porosity through the use of Mercury Intrusion Porosimeter (MIP). Additionally, efforts are undertaken to connect the compressive strength of thermally degraded concrete with its split tensile strength. Six sets of specimens were examined in order to determine the split tensile strength (three) and residual compressive strength (three) for both the control and temperature-exposed specimens. To avoid additional hydration for MIP analysis, tiny fragments of the specimen were preserved in 100% alcohol following destructive testing. A test known as the Mercury Intrusion Porosimeter was run on the preserved specimens. The concrete specimen's initial strength (before exposure) was compared to its compressive and split tensile strengths. Additionally, porosity discovered from MIP tests was used to compare the residual strengths.The concrete cube's compressive strength significantly increases as it reaches 150°C. Observations reveal that, in comparison to a control specimen, the specimen exposed to 750°C experiences a total loss in compressive strength of approximately 73%, meaning it can only withstand roughly 27% of the load. Remaining compressive strength can be obtained by using porosity as an index. Consequently, it is possible to determine the strength characteristics of concrete by employing a non-destructive testing method.

SSSV GopalaRaju et al.,[8]examined how concrete performed while exposed to high temperatures under various cooling circumstances, for varying lengths of time, and during a given number of exposure cycles. After 28 days of curing, M20 concrete is used to make concrete cubes, which are then subjected to specified temperatures. Concrete cubes are subjected to high temperatures (from 100ºC to 1000ºC, with a 100ºC increment)1000ºC capacity bogie furnace. The work employs two cooling techniques; Water-cooled samples are immersed in water once they have reached the necessary temperature, while air-cooled samples are chilled to room temperature. Concrete cubes are subjected to exposure times of 0.5, 1, 2, and 3 hours. The cubes are exposed 1, 2, 3, and 4 times after being cooled using the appropriate chilling techniques in order to account for the cyclic heating impact. It has been noted that when temperature rises, residual compressive strength decreases. In comparison to air-cooled cubes, a greater strength reduction is seen in water-cooled cubes. Within the first 30 minutes of exposure, the majority of strength loss is seen. The impact of heating repetitions did not result in a loss of strength at low temperatures. The first heating cycle experiences the greatest strength drop at high temperatures, whereas the remaining cycles experience very little.

Tarun et al., studied (2012) [9] the impact of temperature on sulphate attack resistance, air and water permeability, compressive strength, and resistance to chloride ion penetration.Two distinct HPC formulations were mixed to achieve an 85 MPa 28-day compressive strength. By weight of cementitious materials, mix 15E had 25% Class C fly ash, 17% Class F fly ash, and 6% silica fume, while Mix 15P contained 9% Class C fly ash and 14% silica fume. Variable Temperature Curing Environment (VTCE) and conventional moist-curing were the two types of curing techniques employed. To replicate the effects of hot weather curing, the temperature was adjusted for the VTCE from 29 ± 3ºC for 12 hours per day to 41 ± 3ºC for the last 12 hours. When the mixtures were 28 days old, the moist-cured and VTCE-cured specimens had compressive strengths of 99 MPa and 100 MPa for Mix 15P and 84 MPa and 88 MPa for Mix 15E, respectively. Regarding compressive strength, resistance to ion penetration by chlorides, sulphate attack, and alkali-silica interaction, both HPC combinations exhibit superior performance.In comparison to specimens that were moistly cured, VTCE-cured specimens exhibited a greater rate of strength development across all combinations. As the percentage of silica fume in cementitious materials grew from 6% to 14%, the resistance to chloride-ion penetration increased as well. With increasing age, or strength, concrete's resistance to chloride-ion penetration improved.

Monal. D et al., (2012) [10]evaluated the compressive strength of fly ash and silica fume-containing cement-based concretes at high temperatures and after being abruptly quenched in water. For an hour, four distinct compositions of concrete containing different proportions of fly ash and silica fume were exposed to high temperatures (150ºC, 300ºC, 450ºC, 600ºC, and 750ºC).One mixture has 100% OPC, another contains 70% OPC and 30% fly ash, a third mixture contains 70% OPC and 25% fly ash and 5% silica fume, and a fourth mixture contains 70% OPC, 20% fly ash, and 10% silica fume. After being cooled by abrupt quenching in water, the specimens' remaining strengths were ascertained by axial compressive strength tests. The original values and the weight and strength decreases were compared. In the current scenario of abrupt cooling by water quenching, the specimen's overall percentage weight loss increases as the exposure temperature rises. Except for series C at high temperatures of about 450ºC, the residual compressive strength often declines with temperature.In comparison to the other series, specimens from Series B (OPC 70/FA30) exhibit superior fire resistance. Between the two SF replacement series, series D (OPC70/FA20/SF10) is seen to have greater fire endurance than the other, with a 14% improvement in strength retention as compared to OPC at 750ºC. Nonetheless, for this series, a 64% drop is observed at 750ºC.

PRELIMINARY EXPERIMENTAL PROGRAMS

CEMENT

Normal Portland cement (OPC53grade), which complies with IS: 8112-1989 [77], was utilized for the duration of the testing programme. It came from only one place, MAHA Gold LTD. in Hyderabad. The cement's physical and chemical characteristics were examined in accordance with IS: 4031-1988 & IS: 4032-1985 [78], accordingly, and it meets the requirements of IS 8112-1989, which is the "specification for Portland cement of 53 grade." This cement was delivered in closed plastic bags, each one weighing about 50 kg, and was stored in an area that was dry till it was needed for the mixing process.

Fly ash:

LCFA falls into the category of typical pozzolans, which are made of silica glass that have been altered with iron, aluminium, and alkaline solutions. The particles have a normal diameter of 20 µ and range in size from a maximum of one µ to one hundred µ. They take the shape of solid spheres (Mehta, 1993 [18]). Because LCFA needs Ca(OH)2 to generate compounds that increase strength (pozzolanic reactive), it is used in conjunction with Portland cement, a substance that hydrates to generate Ca(OH)2It can be substituted for cement in concrete and reduces hydration of heat while increasing endurance. Moreover, because of the filling action and pozzolanic reactivity, it aids in the rise of strength. In Visakhapatnam, India, National Thermal Power Corporation produces the lignite coal used to make the fly ash for this study. Arequirement of IS 3812 (Part I) 2003 are met by this fly ash [19].

Silica Fume:

Very tiny quantities of the extremely reactive substance silica fume are added to concrete to improve its qualities. It results from the manufacturing of ferrosilicon alloy and silicon metal.Compared to fly ash or Portland cement, the SF's spherical particles are approximately a hundred times smaller in size. It is an extremely thin powder. I.e. Almost 95 percent of the particles have a diameter of less than 1µm, making them incredibly small with a range ranging from 0.03 to 0.3µm.The size of the particles has a significant impact on the chemical and physical contributions of silica fume to concrete (ASTM 1240 [21Compared with other pozzolans, SF has a 13–20 times larger particular area of surfaces.The extremely reactive nature of its amorphous silicon dioxide concentration makes it an ideal pozzolanic ingredient for concrete.When calcium hydroxide and silica fume combine, new a binder material known as calcium silica hydrate is created.The GRR Associations Block Auto Nagar in Visakhapatnam, India provided the silica fume utilized in this investigation.

Superplasticizer (SP)

Superplasticizers are high range water lowering admixtures that are used to increase the workability or flow at lower water-to-cement ratios without sacrificing compressive strength.When these admixtures disperse in cement agglomerates, they form a thin film surrounding the cement particles, which greatly reduces the paste's viscosity. In this investigation, the superplasticizer utilized in the concrete mixes was CEMWET SP-3000 (PCE-2), a high range water reducing without chlorides that is based on Poly Carboxylic Ether (PCE) and comes in a water-based form. With standard requirements of IS: 9103-1999 [93] and ASTM C 494 Type G [92], this super-plasticizer is offered as an average brown coloured solution in water.For the super plasticizer, the values are 1.1 for specific gravity and 7 for pH.The source of the material was Asians Chemicals in New Delhi. 0.5–1.32% of the mass of the binder's component is the adding rate of SP in this study.

Fine aggregate

This experiment used clear river sand as the fine aggregate, which was verified to IS: 383-1970 and gathered from an adjacent crusher in Visakhapatnam.According to applicable [IS 2386 (I, III), 1963], the fine aggregate was evaluated for its physical requirements, including fineness modulus, specific gravity, bulk density, and sieve analysis. The outcomes were displayed in Table 3.1, and its sieve analysis—which corresponds to the classification zone III graph—was displayed.

Coarse aggregate

The form and surface roughness of these aggregates, as well as the largest size as well as their distribution of sizes, are the main characteristics that affect the qualities of the two new and newly cured concretes. While proportioning the concrete, other factors to take into account are its density, porosity, water absorption capacity, and moisture content.

According to IS: 383-1970, the coarse aggregate employed in this study was crushed quartzite rock free of flaky and elongated particles.64:36 grading aggregates, or 64% of 10 mm to 20 mm and 36% of 6 mm to 10 mm, were chosen based on the coarse aggregate size. I.e. Specific gravity, bulk density, flakiness index, elongation index, water absorption, and slake durability are among the physical characteristics of the coarse aggregate.

Water

The drinking water utilized for the process of mixing and curing processes came from the GITAM in Visakhapatnam. It was devoid of any oils, acids, alkalis, sugar, salts, organic compounds, or other chemicals that could harm steel or concrete, as per various sections of IS: 3025 – 1964[101].There shouldn't be any pH values lower than six. According to clause 5.4 of IS: 456 – 2000[102], the substances contained are below the allowed limitations.

MIX DESIGN PROCEDURE

The primary goal of designing a mixture for concrete is to determine the ideal ratios between the different components to produce both new concrete with desired characteristics like workability and hardened concrete with unique compressive strength and durability.

In addition to those specifications, it is crucial to get ready the mix for concrete as inexpensively as you can while taking the necessary considerations for durability and strength into account. This means utilizing a small quantity of cement that is needed per unit of volume of concrete. Many factors must be taken into consideration when choosing the design mix for concrete because it is made by combining many distinct elements. I.e. The main factors governing the ratios of the components in the mixture have been identified, nevertheless, thanks to ongoing investigations in this area by a number of researchers.

When designing a mixture for concrete, the next fundamental information must be provided.

- After twenty-eight days fck (grade designation), the concrete's fundamental compressive strength (i.e. is, the value beyond that only a certain percentage of the test findings are permitted to fall)
- Cement type
- The greatest aggregate nominal size
- The least amount of cement
- Regulations on cement quantity and the proportion of water to cement in accordance with IS456 to guarantee appropriate durability.
- The concrete's compressive strength standard deviation
- Workability
- The extent of quality assurance

- Conditions of exposure according to IS: 456
- Cement specific gravity and fine and coarse aggregate types
- Fine aggregate's modulus of fineness.

MIX PROPORTIONS OF BINARY AND TERNARY MIXES

Ternary Mixes (CFS series):

This investigation looked at a single ternary mix concrete mixture. The CFS725 variety of ternary concrete mix is made by partially replacing fly ash (20%) and silica fume (5%), respectively, by the weight of cement. In CFS725 for instance, the composition is 75% cement, 20% fly ash, and 5% fumes of silica.Table 3.7 displays the mix of ratios that were chosen for the ternary mix.

OPC and ternary mixes' cumulative strength and final mix proportions

S.No	Mix	Mix proportion	Water/binder Ratio	Cement (kg)	Fly Ash (kg)	Silica fume (kg)	San d (kg)	Gravel (kg)	SP (kg)
1	OPC	1:1.93:3.3 9	0.42	365 (100 %)	0	0	704	1237	1.82
7	CFS725	1:1.93:3.3 9	0.42	273.75 (75 %)	73 (20 %)	18.25 (5 %)	691	1214	2.92

Total cubes moulded for every combination at seven days of age

Mix ID	Room Temp (27^{0}C)	100^{0}C	200^{0}C	300^{0}C	400^{0}C	500^{0}C	600^{0}C	700^{0}C	800^{0}C
Time (hr)	27^{0}C	3hr	3hr	3hr	3hr	3hr	3hr	3hr	3hr
OPC	3	3	3	3	3	3	3	3	3
CFS725	3	3	3	3	3	3	3	3	3

Mix ID	Room Temp (23^{0}C)	100^{0}C	200^{0}C	300^{0}C	400^{0}C	500^{0}C	600^{0}C	700^{0}C	800^{0}C
Time (hr)	23^{0}C	3hr	3hr	3hr	3hr	3hr	3hr	3hr	3hr
OPC	3	3	3	3	3	3	3	3	3

CFS725	3	3	3	3	3	3	3	3	3

Total Number of cubes casted for each mix at 28 days age

Compressive Strength during Elevated Temperature Exposure of Ternary Blended Mix Concrete

Remaining compressive strengths after seven days compressive strength, MPa

Mix ID	Room Temp (23^0C)	100^0C	200^0C	300^0C	400^0C	500^0C	600^0C	700^0C	800^0C
Time (hr)	23^0C	3hr	3hr	3hr	3hr	3hr	3hr	3hr	3hr
OPC	27.33	31.28	33.62	26.91	24.53	21.62	16.76	12.51	8.46
CFS725	29.24	36.84	37.05	30.35	26.64	23.82	19.31	15.12	11.82

Residual compressive strengths at twenty-eight days compressive strength, MPa

Mix ID	Room Temp (23^0C)	100^0C	200^0C	300^0C	400^0C	500^0C	600^0C	700^0C	800^0C
Time (hr)	23^0C	3hr	3hr	3hr	3hr	3hr	3hr	3hr	3hr
OPC	35.61	37.25	38.4	34.72	32.8	28.16	22.1	18.64	12.34
CFS725	38.2	38.72	39.84	36.48	34.4	31.3	26.7	21.36	14.2

COMPREESIVE STRENGTH OF OPC AND OTHER TBC MIXES AND FINAL MIX PROPOTIONS

S. No	Mix	Mix proportion	Water/binder Ratio	Cement (kg)	Fly Ash (kg)	Silica fume (kg)	Sand (kg)	Gravel (kg)	SP (kg)	slump (mm)	28Days Strength (MPa)
1	OPC CONCRETE	1:1.93: 3.39	0.42	365 (100 %)	0	0	704	1237	1.825	50	31.16
2	CFS725	1:1.93: 3.39	0.42	273.75 (75 %)	73 (20 %)	18.25 (5 %)	691	1214	2.92	50	31.64

EXPERIMENTAL PROGRAM

The GITAM University's concrete technology laboratory served as the site for the entire experimental program.The following phases are included in the laboratory experiment program:

Stage 1	first examination of each component material's characteristics.
Stage 2	Creation of OPC concrete mix in accordance with IS: 10262.
Stage 3	delivery of varying volumes of silica fume and fly ash ternary mix concretes by substituting 20% of the cement content with LCFA and 5% of the cement mass with silica fume.
Stage 4	Compressive strength test specimens are cast.
Stage 5	Examination of the quality and compressive strength of OPC and multi-blended concretes at various ages.

TEST SPECIMENS MIXING, CASTING, AND CURING

This part provides a comprehensive presentation of the intricacies involved in mixing, casting, and curing different test samples.The process of combining, pouring, and drying to achieve compressive strength.

Sample for the Compressive Strength test

Materials Preparation: To obtain the entire cementing component, cement, fly ash, and SF were first completely combined. In accordance with IS: 10262:2004[103], a homogenous mix was created by combining this cementing substance in its dry form with a combination of fine and coarse aggregate. The samples of aggregates from the grade indicated in Table 3.19 are included in each mix of concrete.

For every batch, the weight-based measurements included the amounts of cement, fly ash, silica fume, aggregates, and water. After the required quantity of test specimens were moulded, each mix of concrete had been mixed so that about ten percent surplus had been left over.

- The subsequent process involved mixing the concrete mix on a surface that was not absorbing and waterproof.
- Dry mixing was used for properly combining the cement, fly ash, and silica fume mix.
- The colour of the mix was homogeneous after the fine aggregate and all cementitious components were combined dry.
- After that, the coarse aggregate was added and combined with the fine aggregate and cementitious material mentioned above until the coarse aggregate was distributed equally throughout the batch.
- Once the dry substance was combined with the water and SP combination, the mixture was mixed until it reached a homogeneous state.

Specimens Preparation: Following mixing, the evaluation samples of the necessary size were cast as soon as possible, making sure that the concrete was fully compacted without severe separation.In layers around five centimetres thick, the concrete was poured into the mould. After achieving the appropriate compacting, each layer was compressed by vibration with a table that vibrated.

The compression strength of every single concrete mix was ascertained by casting a set of 12 cube examples, each measuring 100 mm by 100 mm by 100 mm, as illustrated in Fig. 4.1. The process followed was outlined in IS: 516 - 1959(Reaffirmed 2004) [104]. In order to conduct a compressive strength test, the samples were dried in the air for a full day and then cured for seven and a half days. Table 4.5 shows that an aggregate of 108 specimen cubes were cast for a certain mix and age.

Specimens curing: Over a 24-hour period following the moment the solution of water was added to the components, the samples were taken out of the moulds seen in Figure 4.2The samples were subsequently labelled for authentication. The necessary time for curing was then spent with the samples in fresh water storage.

OPC Mixing and Pouring of Concrete

Twenty-four hours after being taken out of the moulds

FRESH CONCRETE'S WORKABILITY

As per IS: 1199-1959 [109], the slump cone experiment was utilized to determine the workability of fresh concrete. The equipment used for the test was verified to comply with IS: 7320. Slump refers to the vertical settlements of new concrete following the removal of the mould. It is calculated as the differential that exists among the mould's height and the concrete's greatest elevation after subsidence. Despite being widely utilized on building sites worldwide, this evaluation is not a reliable indicator of workability.In addition to providing insight into the amount of water to cement proportion, the data are helpful in identifying variations in the mix's homogeneity between batches.The following protocol was employed for the slump evaluation:

After moistening the ground plate and the mould, the mould was set on top of the lateral plate.3 layers of material were added to the mould, each taking up about one-third of the mould's height when compacted. Twenty-five blows of a tamping rod were used for compacting every single layer. Following the compaction of the upper layer, a compacting rod was used to roll the concrete's surface, removing any remaining material. Gradually lifting the concrete in a vertical orientation allowed the mould to be extracted.Upon extracting the mould, the slump was quantified and noted by measuring the discrepancy among the mould's height and the test specimen's highest point, as seen in Figure 4.4.The measurement of the values in a slump.The necessary level of workability was obtained by adding a particular amount of SP to each mixing combination.

HARDENED CONCRETE TESTS.

This chapter contains a detailed description of the tests used for the numerous experiments designed to examine the functionality of multi-blended concrete mixtures. I.e. In order to evaluate and verify the superiority of both OPC and concretes with blended mixes, several tests are essential. The test protocols used to determine compressive strength were those specified in IS regulations.

Procedure for Compressive Strength Tests

When a material collapses entirely, its compressive strength is determined by calculating the amount of unilateral compressive stresses. The cube-shaped samples of each multi-blended mix concrete in this inquiry, measuring 100 by100 by 100mm, are evaluated in compliance with IS: 516-1969. An automated compression test apparatus with a 200 KN capacity was used for the test. The equipment is set to be tested in every way, having had the necessary requirements met for calibration and the plates were clean and examined for lubricant levels. The device contains a valve with control functions that allows it to regulate the rate at which it loads. Following the intended 7–28-the day curing period of time, 3 cube examples of all mixes have been taken out of the moist curing tank. In order to apply the load systematically, the samples were moved on the apparatus's revolving head. In order to apply force to the opposing sides of the cubes, the sample's flat surfaces are positioned on the supporting areas. By pressing the power button, the top of the plate came into touch with the sample. After turning on the machine, the oil's level valve was closed.In every instance, the shape of the cube was arranged so that the load applied was perpendicular to the casting direction, with an application rate of 140 kg/cm2/min maintained. This process was repeated until the specimen failed, meaning that as the load was increased further, the specimen offered no resistance, and the greatest force applied was noted. The three specimens underwent the test again, and the average strength was determined by averaging the results.Figures 4.5–4.6 depict the test configuration.

: COMPRESSIVE STRENGTH TESTING MACHINE

: Testing in Progress

RESULTS AND DISCUSSIONS

COMPRESSIVE STRENGTH TEST RESULTS

In order to investigate the impact of age on the development of the compressive strength, the compressive strengths of ternary mixed and OPC concrete materials were evaluated on samples that had been cure at varying ages-7 and 28 days.To determine the residual compressive strength, identical mix types were again test after being heated to 800℃ for 3 hours, with intervals of 100℃.The study examined ternary blended concretes that had 20% LCFA and 5% SF added to the cement mix in order to partially substitute it. A percentage of OPC concrete's residual compressive strength, which is a measure of the concrete's unheated compressive strength, is determined when the samples were exposed to high temperatures for 3 hours.The residual strength of ternary concrete, which is represented as the percentage of unheated compressive strength ternary concrete, is the amount of durability left over after all overheated cubes are exposed to high temperature for 3 hours.

Residual Compressive Strength.

Figures 5.1 to 5.4 display the determined remaining compressive strength values for both OPC and ternary blended mixtures at increased temperatures. Additionally, Table 1 displays the proportion of concrete's remaining compressive strength at extreme temperatures compared to the ambient temperature after seven and twenty-eight days.

Table 1: Cumulative remaining Compressive Strength of concretes in relation to the appropriate mix concrete's ability to unheated compressive strength.

7 DAYS					28 DAYS			
Temperature (^{0}C)	OPC (MPa)	Residual Comp Strength of OPC (%)	CFS725 (MPa)	Residual Comp Strength of CFS725 (%)	OPC (MPa)	Residual Comp Strength of OPC (%)	CFS725 (MPa)	Residual Comp Strength of CFS725 (%)
27	27.33	100.00	29.24	100.00	35.61	100.00	38.2	100.00
100	31.28	114.45	36.84	125.99	37.25	104.61	38.72	101.36
200	33.62	123.02	37.05	126.71	38.4	107.83	39.84	104.29
300	26.91	98.46	30.35	103.80	34.72	97.50	36.48	95.50
400	24.53	89.75	26.64	91.11	32.8	92.11	34.4	90.05
500	21.62	79.11	23.82	81.46	28.16	79.08	31.3	81.94
600	16.76	61.32	19.31	66.04	22.1	62.06	26.7	69.90
700	12.51	45.77	15.12	51.71	18.64	52.34	21.36	55.92
800	8.46	30.95	11.82	40.42	12.34	34.65	14.2	37.17

After being subjected to high temperatures of up to 800℃ for seven days, Figure 5.1 displays the remaining compressive strength of both OPC concrete and ternary blended concrete (CFS725), which contains 20% fly ash and 5% silica fume by weight of cement. Both OPC and CFS725concrete exhibit a rise in retained compressive strength up to 200℃, followed by a decline up to 800℃ in the same range of temperatures. In comparison to unheated OPC concrete at 7 days, it was shown that the retained compressive strength of OPC concrete raised by 14.45% & 23.02% at 100℃& 200℃ and then dropped by 1.54%,11.25%,20.89%,38.68%,54.22% & 69.04% at 300℃, 400℃, 500℃, 700℃, & 800℃, accordingly.Comparing unheated CFS725 concrete at 7 days to CFS725 concrete at 300℃, 400℃, 500℃, 600℃, 700℃, and 800℃, respectively, revealed that the retained compressive strength of the former raised by 25.99% & 26.71% at 100℃& 200℃ and subsequently declined by 3.79%, 8.89%,18.53%,33.96%,48.29%

&59.57%. It is obvious that for both mixtures, strength changes are negligible from 300 and 600 degrees Celsius, but after 600 degrees Celsius, there is a significant decline in the retained compressive strength.

When internally an autoclave, or rapid curing, occurs in a paste of cement, the resultant moisture action may hydrate more un-hydrated cement grains, leading to a rise in retained compressive strength at temperatures as high as 200℃[2]. The optimum temperature range to create these kinds of parameters is between 100 and 200degreesCelsius, since this is when vapor is released greatest intensely, causing the cement grains to hydrate more. Concrete with CFS725 showed a comparable improvement in remaining strength.This surge could be attributed to the hydrating of fly ash that hasn't been moistened or to SF particles that were stimulated by a rise in temperature. This behaviour is consistent with what investigators.

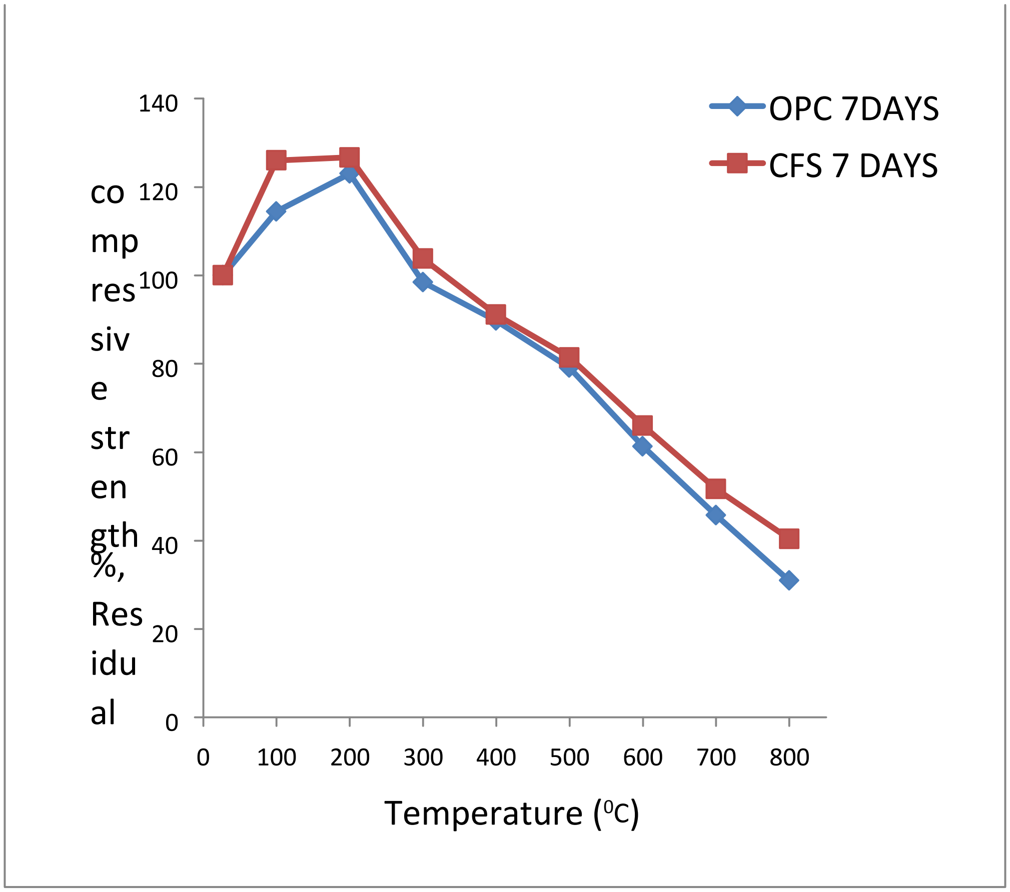

Fig.5.1 Ternary blended concrete of CFS 725 and OPC's retained compressive strength after seven days of curing. subjected to temperatures as high as 800 degrees Celsius

After receiving exposure to extreme temperatures of up to 800^{0}C for 28 days, Figure 5.2 displays the remaining compressive strength of both OPC and ternary blended concrete (CFS725), which contains both 20% fly ash and 5% silica fume by weight of cement. Both OPC and CFS725 concrete exhibit a rise in retained compressive strength up to 200^{0}C, followed by a decline up to 800^{0}C in the same range of temperatures.When compared to unheated OPC concrete at 28 days, it was shown that the retained compressive strength of OPC concrete raised by 4.61% & 7.8% at 100 & 200degrees Celsius and then declined by 2.49%,7.89%,20.92%,37.94%,47.65% &65.34% at 300^{0}C, 400^{0}C, 500^{0}C, 600^{0}C, 700^{0}C, & 800^{0}C, accordingly. Comparing unheated CFS725 concrete at 28 days to CFS725 concrete that had been subjected to heat the remaining compressive strength of the former raised by 1.36% and 4.29% at 100 and 200degrees Celsius, accordingly. Following that, it fell by 4.5%, 9.94%,18.06%,30.10%,44.08%, and 62.82% at 300^{0}C, 400^{0}C, 500^{0}C, 600^{0}C, 700^{0}C. It is evident the two mixes show very slight strength changes from 300 and 600 degrees Celsius, but two mixes show significant remaining compressive strength degradation over 600 degrees Celsius. Around 400 and 600 degrees Celsius, there was a noticeable drop in compressive strength, which is explained by the non-evaporable water that was lost from its gel-like pores. The contraction of paste cement and the expansion of aggregates (resulting from physio-chemical reactions) are responsible for the changes in retained strength of concrete after 600℃. This results in a weakening of the bonding and transition zone between the paste and aggregates. Because of this procedure and the chemical breakdown of products of hydration, concrete that has been exposed to elevated temperatures suffers significant deteriorations and lose strength. Investigators Ali Behnood et al. (2008) [16], Hosam El et al. (2009) [17] found that this behaviour is consistent with their results. Therefore, compared to CFS725 concrete, OPC concretes showed noticeably greater amounts of loss of strength at early ages, particularly after 600℃. The reduction of the amount of water causes a rise in the forces that exist between gel particles, or Vander Walls forces, which is responsible for the compressive strength improvements at 200℃ [18].When ternary blended concrete is left to cure for seven days, its retained compressive strength is superior to that of OPC concrete.

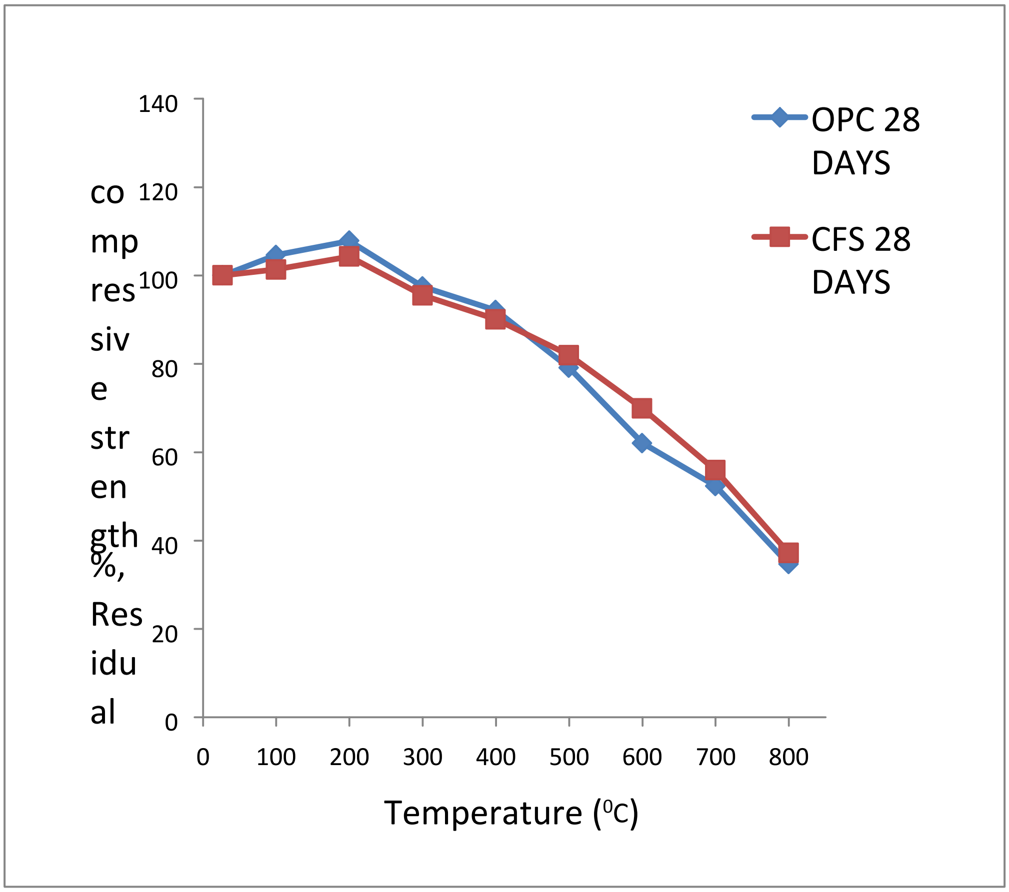

Fig.5.2 28-day-cured retained compressive strength of CFS 725's ternary blended concrete with OPC. subjected to high temperatures (800℃)

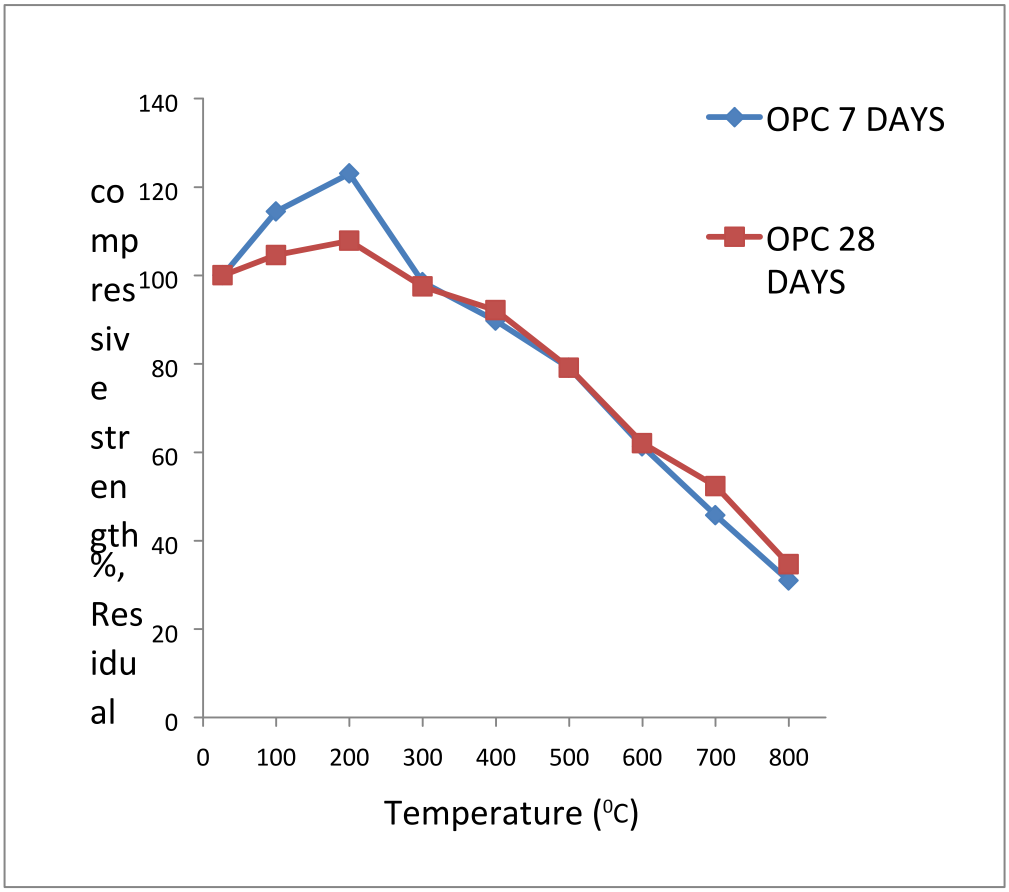

Fig.5.3 Retained Compressive OPC strength at 7 and 28 days after cure. subjected to high temperatures (800°C)

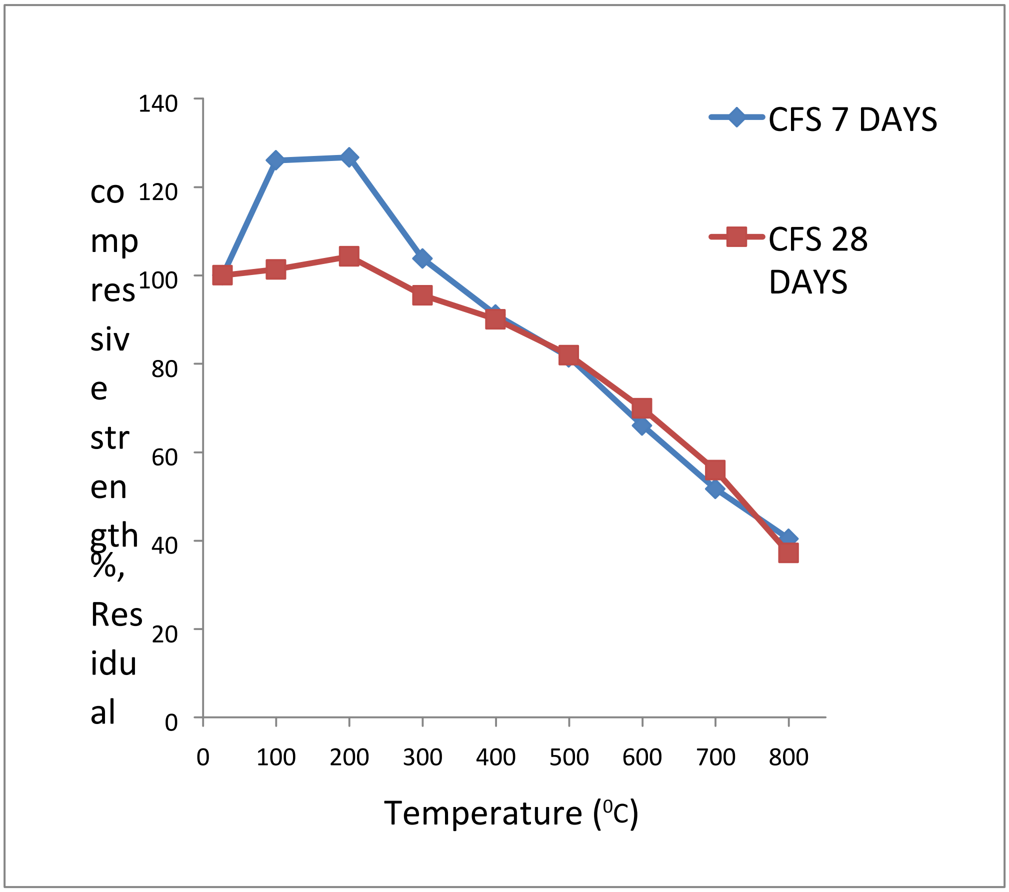

Fig.5. Retained Compressive Strength of CFS 725 after 7 and 28 days of cure subjected to temperatures as high as 800 degrees Celsius

CONCLUSIONS

1. It is discovered that the OPC concrete and ternary mixed concrete behave similarly.
2. Because of the water that was free in the concrete evaporating, the remaining strengths of both types of concrete increased to 200℃
3. When the temperature rises from 200℃ to 800℃, the remaining compressive strength of both OPC and ternary mixed concrete reduces gradually.
4. In terms of % retained strength ternary concrete performed better between 500 and 800 degrees Celsius, while OPC concrete performed better between 100 and 400 degrees Celsius.

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