

# **Experimental Investigation on Strength and Creep Behaviour of High Strength Concrete with Optimal Mineral Admixture Usage**

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**ABSTRACT:** This paper presents the results of experimental research work done in high strength concrete by replacing cement with mineral admixtures. The main aim of this work is to determine the creep strain values of a M60 grade concrete by replacing cement with flyash, silica fume and ground granulated blast furnace slag (GGBS) by 10%. Each mix is tested for compression, flexural, split tensile, modulus of elasticity and creep deformation values after 28 days of casting. The Creep deformation is measured using DEMEC mechanical strain gauge with 10 minutes time interval for 1<sup>st</sup> day and 30 minutes time interval for next 2 days continuously. The creep results available from this experimental work involve the specimens under sustained load. A time-dependent creep strain is provided in a graph showing its variation. From the experimental results it is observed that the creep strain is inversely proportional to the compression strength of concrete.

**KEYWORDS:** Creep, High Strength concrete, Silica Fume, Fly ash, GGBS

## **I. INTRODUCTION**

The creep is very important factor when the concrete is to be tested for long term performance. Creep is defined as the plastic deformation under sustain load. Creep strain depends primarily on the duration of sustained loading. It has been widely acknowledged that creep of concrete is greatly influenced by the surrounding ambient. Creep induces the deflection of the structural member with time. Hence the study on creep of concrete is necessary to prevent failure. The strain which is produced in the course of a creep test at the end of loading may be three or four times the initial elastic strain. Therefore creep is of considerable importance in structural mechanics. Besides that, creep may also be viewed from another standpoint, to be known as a form of relaxation of material. This occurs when the restraints are such that a stressed concrete specimen is subjected to a constant strain; creep will manifest itself as a progressive decrease in stress with time. However in most cases, the detrimental effect of creep prevails. Based on the environmental condition and time of loading the creep is classified into many categories. Basic creep is creep deformation that occurs under a constant compression at hygrometric equilibrium, without the event of moisture exchange between the ambient and the medium. Drying creep, also known as the Pickett effect is the additional creep strain in excess changes in its environment. The magnitude of creep obtained is mainly due to drying creep as water movement in concrete induced higher stress. The strain is expressed in millimetres per millimeter, resulting in a dimensionless pure number. If the moisture content increases, wetting

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creep will result. Both wetting and drying creep are considered as transitional hygral creep strains.

The term transitional thermal creep is used to describe the additional strain that occurs when the temperature of concrete changes while under load. The temperature changes can be due to the influence of the surrounding ambient or due to the heat development of cement paste hydration. Transitional chemical creep might be applied to the extra strain observed when the concrete undergoes significant chemical reactions while under load. A few examples of significant chemical reactions are such as hydration, carbonation and sulphate attack. Transitional chemical creep due to hydration may account for the relatively high creep strains observed for concrete loaded at early ages. Short term creep is known to be caused by a development of capillary stress due to redistribution of capillary water towards the largest diameter pores within the structure of hardened cement paste. It may be attributed to a change of the hygral equilibrium in the gas filled space which generates strain and stresses and eventually micro cracking which results in the short-term component of creep. The different creep stages are primary creep, secondary creep and tertiary creep.

**Primary Creep:** Primary Creep starts at a rapid rate and slows with time.

**Secondary Creep:** Secondary Creep has a relatively uniform rate.

**Tertiary Creep:** Tertiary Creep has an accelerated creep rate and terminates when the material breaks or ruptures. It is associated with both necking and formation of grain boundary voids.

## II. MATERIALS AND METHODS

In this investigation different mineral admixtures were used as replacement for cement and their short description are given below.

**Silica fume:** Silica fume<sup>[2]</sup> is a very fine non-crystalline  $\text{SiO}_2$ , is a byproduct of producing silicon metal or ferrosilicon alloys. It is made at a temperature of approximately  $2000^\circ\text{C}$ . It acts as an excellent pore-filling material. It can be used in proportions of 5-10% of cement content in a mix.

**Fly ash:** Fly ash<sup>[4]</sup>, also known as "pulverised fuel ash" in the United Kingdom, is one of the residues generated by coal combustion, and is composed of the fine particles that are driven out of the boiler with the flue gases. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide ( $\text{SiO}_2$ ), aluminium oxide ( $\text{Al}_2\text{O}_3$ ) and calcium oxide ( $\text{CaO}$ ), the main mineral compounds in coal-bearing rock strata.

**Ground Granulated blast furnace Slag (GGBS):** GGBS<sup>[5]</sup> is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. The chemical composition of a slag varies considerably depending on the composition of the raw materials in the iron production process.

## III. EXPERIMENTAL WORK

There are 4 different mixes involved in this project work which includes conventional mix (Mix 1), silica fume mix (Mix 2), fly ash mix (Mix 3) and GGBS mix (Mix 4). The cement is replaced by 10% in Mix 2, Mix 3 and Mix 4. The mix proportion is calculated such that all concrete mixes obtain equal strength so the creep strain values can be compared with each other.

Table 1: Mix Proportion

Mix	Cement	Fine Aggregate	Coarse Aggregate	Silica Fume	Flyash	GGBS	W/C Ratio
Mix 1	1	1	1.65	-	-	-	0.28
Mix 2	1	1	1.65	0.1	-	-	0.28
Mix 3	1	1	1.65		0.1	-	0.28
Mix 4	1	1	1.65	-	-	0.1	0.28

# International Journal of Innovative Research in Science, Engineering and Technology

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**Specimen details:** The compressive strength, Split tensile, Modulus of Elasticity and flexural strength of the concrete are determined by cubes of size 150mmx150mmx150mm, 150mmx300mm cylinder and 500x100x100mm prism.

Table 2: Number of specimens casted:

	Cube	Cylinder	Prism
Mix 1	6	8	3
Mix 2	6	8	3
Mix 3	6	8	3
Mix 4	6	8	3
Total Specimens	24	32	12

**Casting of specimens:** Thorough mixing of materials is essential for the production of uniform course. The mixing should ensure that the mass becomes homogeneous, uniform in color and consistency. After mixing, the moulds are filled immediately by pouring the concrete inside manually by using trowel with three layers. Compaction of concrete is process adopted for expelling the entrapped air from the concrete. Compaction is done here manually with tamping rod in the way of dispersing the homogeneous mix to avoid entrapment of air. Not strong blows as for as for strong concrete is given, blows of 20-25 numbers are given for three layer. The cube specimens are demoulded after 24 hours from the time of casting. After demoulding process, the specimens are immersed in curing tank and cured for 28 days before testing of specimens.

## IV. RESULTS AND DISCUSSION

After a curing period of 28 days the specimens were tested for Compression, Split Tensile, Flexural test, Modulus of Elasticity and Creep strain values and their results are tabulated.

Table 3: Test results:

Mix	Compression strength (N/mm <sup>2</sup> )			Split Tensile strength (N/mm <sup>2</sup> )	Flexural strength (N/mm <sup>2</sup> )	Modulus of Elasticity (kN/mm <sup>2</sup> )
	Cube		Cylinder			
	@ 7 days	@ 28 days	@ 28 days	@ 28 days	@ 28 days	@ 28 days
Mix 1	41.7	61.1	45.6	2.72	7.86	17.8
Mix 2	42.1	62.3	46.2	2.75	7.80	17.33
Mix 3	41.9	61.4	46.1	2.73	8.03	10
Mix 4	41.1	60.9	45.4	2.67	7.77	11.33

**Compression test:** The compression test is used to find the compression strength values of the cubes casted at 7 days and 28 days respectively and their result is plotted in the graph below.

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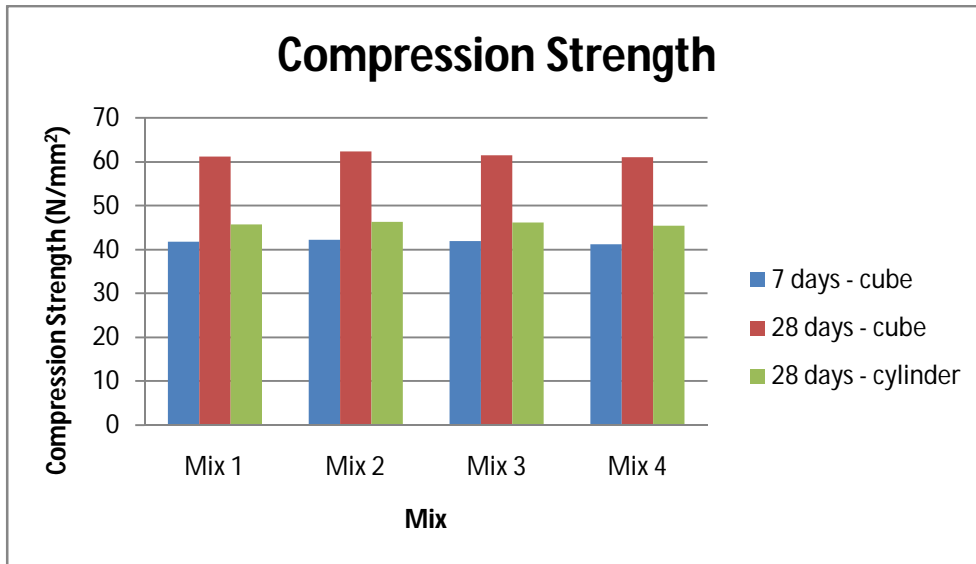


Fig 1: Compression strength results

**Split Tensile test:** The Split tensile test is considered as indirect tensile strength of concrete which involves the cylinder to be tested for tension after 28 days of casting

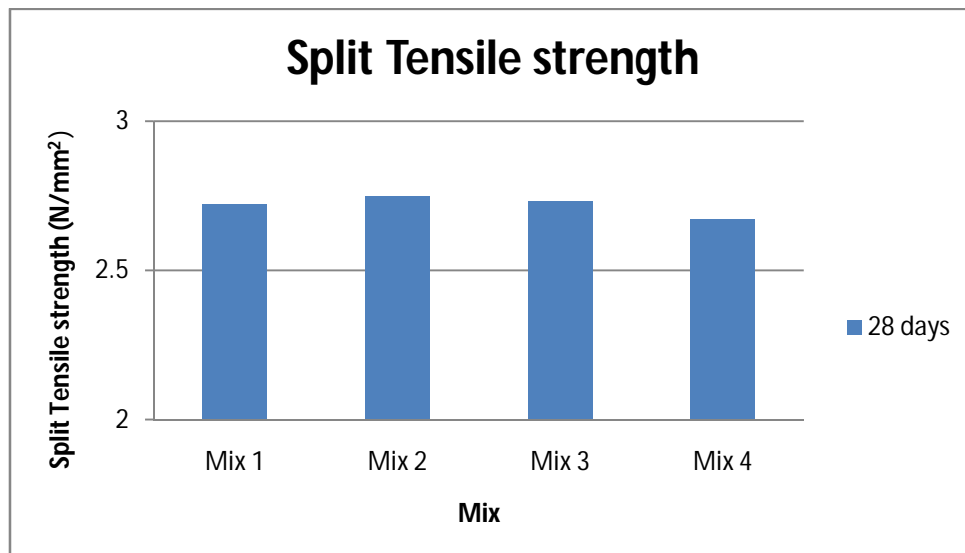


Fig 2: Split Tensile Strength results

**Flexural Strength:** Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measure by loading 100 x 100 x 500 mm concrete beams until it fails reaching its ultimate load. The flexural strength is expressed as Modulus of Rupture (MR) in  $\text{N/mm}^2$  and is determined by standard two-point loading method.

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

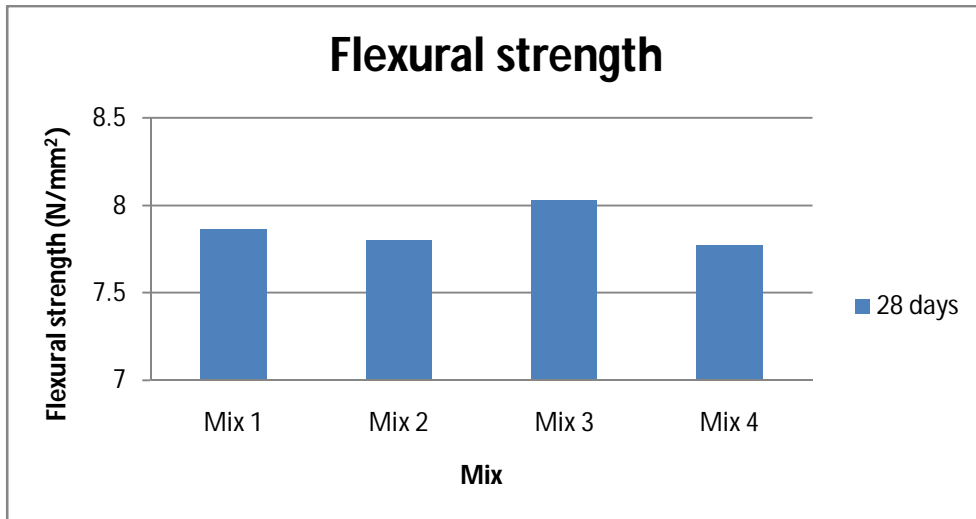


Fig 3: Flexural Strength results

**Modulus of Elasticity:** It is defined as the ratio of the stress (force per unit area) along an axis to the strain (ratio of deformation over initial length) along that axis in the range of stress in which Hooke's law holds.

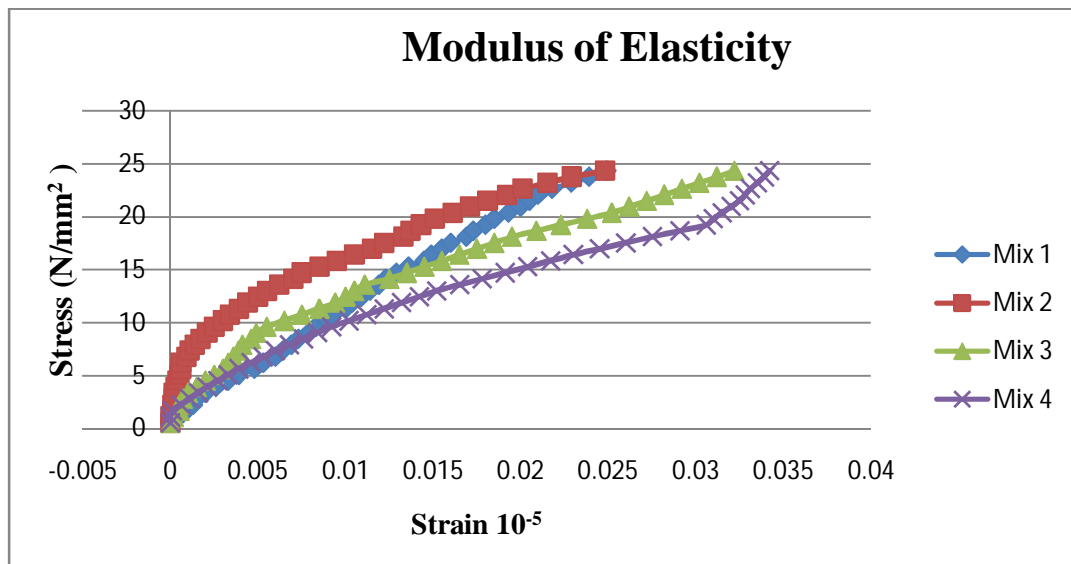


Fig 4: Modulus of Elasticity

**Creep Strain:** Creep is defined as the long term deformation of concrete under sustained loading. Immediately before loading the creep specimens, determine the compressive strength of the specimens. At the time unsealed creep specimens are placed in the loading frame, cover the ends of the control cylinders to prevent loss of moisture. Load the specimens at an intensity of not more than 60 % of the compressive strength at the age of loading. Take strain readings immediately before and after loading with 10 minutes time interval for the first day and 30 minutes time interval for the next two days.

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016



Fig 5: Experimental setup

The Creep Strain values of all mixes are calculated for 3 days of loading and their average is found out which is used for comparison of results.

Table 4: Average Creep Strain values

Mix	Strain
Mix 1	190.74
Mix 2	184.18
Mix 3	189.59
Mix 4	192.70

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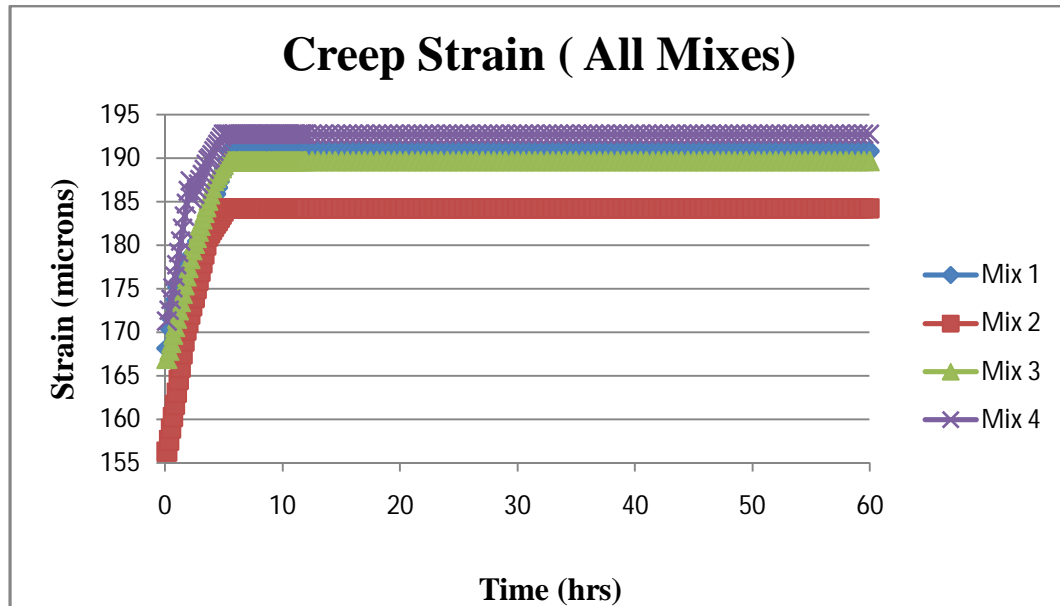


Fig 6: Creep Strain values

## V. CONCLUSION

The compressive strength, flexural strength, split tensile strength and modulus of elasticity properties of the concrete mixes are studied.

- The cube compressive strength of all the mixes are approximately equal and the cylinder compressive strength is 0.78 times of cube compression strength.
- The Split tensile and Flexural strength of all mixes are also approximately equal.
- The strain value of silica fume mix (MIX 2) is 1.035 % lower than conventional mix (MIX 1), 1.029 % lower than flyash mix (MIX 3) and 1.046 % lower than GGBS mix (MIX 4) because silica fume increases the strength of concrete which leads to lower creep strain value.
- The flyash mix (MIX 3) has the second lowest creep strain values when compared to conventional mix (MIX 1) i.e., 1.006% lower and GGBS mix (MIX 4) i.e., 1.016 % lower. The flyash is much finer than cement which increases the binder content and reducing the water cement ratio which leads to shrinkage which also affects the creep strain resulting in second lowest creep strain value.
- The conventional mix (MIX 1) strain value is higher when compared to silica fume mix (MIX 2) and flyash mix (MIX 3).
- The GGBS mix (MIX 4) has the largest creep strain values when compared to the other mixes. The GGBS mix showed less compressive strength than conventional mix which led to higher creep strain when compared to other concrete mixes.

## REFERENCES

- [1] Neville AM, "Properties of Concrete", Edinburg :Longman 1995
- [2] Mazloom M, "Estimating long term creep and shrinkage of high strength concrete", Cement and Concrete composite 30(2008) 316-326.
- [3] Neville AM, Dilger WH, Brooks JJ, "Creep of Plain and Structural Concrete", London and new York: Springer; 1983.
- [4] Woo-tai jung, "Experimental Study on the Creep Characteristics of FRC Base for composite pavement", International journal of civil engineering, Vol 7, No 10,2013
- [5] ACI Committee 209, "Prediction of Creep, shrinkage and temperature effects in concrete structures", ACI Manual of Concrete practice, Part 1,1997, 209R 1-92
- [6] Khan AA, Cook WD, Mitchell D, "Creep, Shrinkage and thermal strains in normal, medium and high-strength concrete during hydration", ACI

# International Journal of Innovative Research in Science, Engineering and Technology

*(A High Impact Factor, Monthly Peer Reviewed Journal)*

**Vol. 5, Issue 2, February 2016**

- mater J 1997;94(2):pg.156-163
- [7] Brook JJ, "How Admixtures affect Shrinkage and creep", Magazine of the American Concrete Institute – an International technical society, April 1993, Pg: 35-38.
  - [8] Collins TM, "Proportioning High- strength concrete to control creep and shrinkage", ACI mater J 1989;86(6) pg:576-580
  - [9] Ngab As, Nilson AH, Slate FO, "Shrinkage and creep of high-strength concrete", ACI J 1981;78(4):pg.255-261.
  - [10] Brooks JJ, AL-Qarra H, "Assessment of Creep and shrinkage of Concrete for the Flint shire bridge", Struct Eng 1999;77.
  - [11] Marzoukh, "Creep of High- Strength concrete and normal strength concrete", Mag Concrete Res 1991;43(155):pg.121-126.
  - [12] Tao Z, Weizu Q, "Tensile creep due to restraining stresses in high-strength concrete at early stages", J Cem Concr Res 2006;36(3):pg.584-591.
  - [13] Bissonnette B, Pigeon M, "Tensile Creep at early ages of ordinary, silica fume and fiber reinforced concretes", J Cem Concr Res 1995;25: pg:1075-1085.
  - [14] Vandewalle L, "Concrete creep and shrinkage at cyclic ambient conditions", Cem Concr Compos 2000;2293 pg:201-208.
  - [15] Gardner NJ, Lockman MJ, "Design provisions for drying shrinkage and creep of normal strength concrete", ACI Mater J 2001(March-April):pg159-167.