

# Stress-Strain Behaviour of Standard and High Strength Concrete



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**Abstract-** This Documentation presents the behaviour of standard and high strength concrete with stress-strain analysis. Generally, many types of research have been performed to find the stress-strain behaviour with different methods such as using UTM machines and other analytical works, this research paper includes the equipment (i.e. Compressometer) which is used to find the strain with respect to stress. To understand and predict the performance of any mix designed concrete, the parameters such as Modulus of Elasticity, ultimate strength, strain are key options. The strain is calculated by Compressometer gauge value to the gauge length and clear graphs are plotted for analysis. High strength concrete is the concrete with greater load resistance obtained by reducing water-cement ratio and adding admixtures and superplasticizers. This paper shows the different trial error methods to obtain high strength concrete. Normally Concrete gave 99% of strength in 28 days (i.e. 60.9 N/mm<sup>2</sup>), it may increase its strength beyond the target mean strength by further curing periods, so investigation beyond 28 days (i.e. 56 days and 90 days) gave us the satisfactory results with 73.06 N/mm<sup>2</sup> and 76.01 N/mm<sup>2</sup>.

**Keywords:** Compressometer, UTM machine, high strength concrete, superplasticizers.

## I. INTRODUCTION

As the technology is growing very rapidly from the past two decades, concrete is being designed with different types of new constituents, in the previous decades or in the earlier age of the concrete cement, fine aggregate, coarse aggregate are the only materials which are used in the concrete, now there are various materials which can replace those materials. High strength concrete is that whose compressive strength is more than 55MPa, according to Indian standards there are no specific codes for the high strength concrete, one has to perform different trial error methods to obtain high strength.

High strength concrete can be obtained by reducing water-cement ratio and adding the superplasticizers which are known as water reducers and other admixtures such as silica fume, flyash, GGBS.etc. the materials which are being used in the high strength concrete should be good enough to obtain the strength.

Advantages of the high strength concrete compared to normal grade concrete are mentioned below

- Greater stiffness
- High resistance to abrasion

- Greater load resistance
- High durability and long life
- Low permeability
- Safety against chemical attack

High strength concrete has to be examined properly while casting to obtain the designed strength, the below points to be kept in mind while working with HSC.

- Mix proportions should be clear and exact.
- Need for concrete mixer.
- Good property of aggregates.
- High slump value than normal grade concrete.
- High Water reducers-superplasticizers.
- Curing periods and temperature.
- Proper vibration and compaction to escape voids.
- Higher cement content.

Concrete gains its 99% strength by 28 days of curing period, the researcher has to test the samples for 3,7,14,28 days, beyond the 28 days of testing the strength may increase than the target means strength.

## Application of HSC

- High rise buildings.
- Columns on lower floors to resist higher loads.
- Long-span Bridges.
- Shear walls.
- Space-saving areas.

Working on the strain with respect to the stress and executing the stress-strain in the form of graphs is known as stress-strain analysis. A civil engineer must be familiar with the stress-strain analysis of the concrete or any other material. The stress-strain analysis gives the complete behaviour of the concrete. The ultimate stress, strain, stiffness can be analyzed.

## The need for stress-strain analysis

The stress-strain analysis guides the engineer to predict the behaviour of the concrete with different loadings, here are some benefits of the stress-strain analysis.

- It analysis the mechanical behaviour of the concrete.
- Stiffness can be easily computed by stress to strain.
- It helps to find maximum stress and strain in the concrete.

## II. MATERIALS AND TRIALS FOR HIGH STRENGTH CONCRETE

**a) Cement:** The most commonly used ordinary Portland cement is associated with the general term “concrete”. All the tests on cement were carried out as per recommendations of IS: 12269- 1989. Here are some of the test results of the OPC 43 grade cement.

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**Table No.1.properties of cement**

SN	Description	Results
1.	The specific gravity of cement	3.3
2.	Fitness of cement	2.27
3.	Initial setting time	28 minutes
4.	Final setting time	232minutes
5.	Compressive strength	42.78

**b) Aggregates:** One of the major contributing factors to the quality of concrete is the quality of the aggregates. In this study only, the vital parameters of aggregates have been studied as per the procedures laid down in IS 2386 (Part 1-8) for the testing of aggregates for concrete. The properties of fine and coarse aggregates are mentioned in the below tabular forms.

**Table No.2.properties of coarse aggregates**

SN.	Description	Results
1.	Fineness modulus	8.09
2.	Specific gravity	2.64

**Table No.3.properties of Fine aggregates**

SN.	Description	Results
1.	Fineness modulus	3.22
2.	Specific gravity	2.61
3.	Grade zone	2

**c) Water:** Water is used for the mixing of all the materials, for this activity we need to have clean water which is free from any bacterium and wish matter confirming according to IS 3025-1964 and IS 456-2009 is used.

**d) Silica fume:** Silica fume is the by-product resulting from the reduction of high purity coal, or in the production of silica and ferrous silica alloys. The silica fume has a high content of amorphous silicon dioxide and consists of very fine spherical particles with average particle size about 100 times smaller than a grain of ordinary Portland cement.

**Table No.4.properties of silica fume**

SN.	Description	Results
1.	Diameter	0.1 – 0.2 microns
2.	Specific gravity	2.3
3.	Density	150-700 kg/m <sup>3</sup>
4.	Surface area	30000 m <sup>2</sup> /kg

**e) Superplasticizer:** Superplasticizer is the main chemical used for attaining high strength concrete. The Superplasticizer is used as the water reducers and does not require any significant change in the mix proportioning. It can significantly improve the dispersibility of cement particles and thus permit a decreasing water-cement ratio. Tamcem 60R superplasticizer has been used for the high strength concrete trial methods.

The properties of the Tamcem 60R are mentioned in the below table.

**Table No.5.properties of superplasticizer**

SN.	Description	Result
1.	Form	Liquid
2.	Colour	Thick brown

3.	Density(g/cm <sup>3</sup> )	1.07+-0.02
4.	Solid ontent(%)	27.00+-1.30
5.	Ph	5.0+_1.0
6.	Chloride ontent	< 0.1

To obtain high strength, different trial error methods to be done. The table no 10 shows the different proportions of cement, FA, CA, silica fume, superplasticizer.

**Table No.6 Trial No1@M60**

Age in days		7	14	28
Number of cubes		3	3	3
Cube strength in MPa	Cube1	35.4	55.21	57.84
	Cube2	34.34	51.26	55.39
	Cube3	33.03	5.8	57.29
Average compressive strength In N/mm <sup>2</sup>		34.26	53.09	56.84

**Table No.7 Trail No2@M60**

Age in days		7	14	28
Number of cubes		3	3	3
Cube strength in MPa	Cube1	32.21	51.8	57.35
	Cube2	30.03	45.2	51.38
	Cube3	31.29	47	53.25
Average compressive strength In N/mm <sup>2</sup>		31.17	48	53.99

**Table No.8 Trial 3@M60**

Age in days		7	14	28
Number of cubes		3	3	3
Cube strength in MPa	Cube1	44.82	60.12	67.7
	Cube2	41.97	61.97	68.95
	Cube3	43.98	62.95	70.9
Average compressive strength In N/mm <sup>2</sup>		43.59	61.68	69.1

**Table No.9 Trial4@M60**

Age in days		7	14	28
Number of cubes		3	3	3
Cube strength in MPa	Cube1	39.87	55.3	61.61
	Cube2	35.81	52.6	57.07
	Cube3	38.05	51.9	58.42
Average compressive strength In N/mm <sup>2</sup>		37.91	53.28	59.03

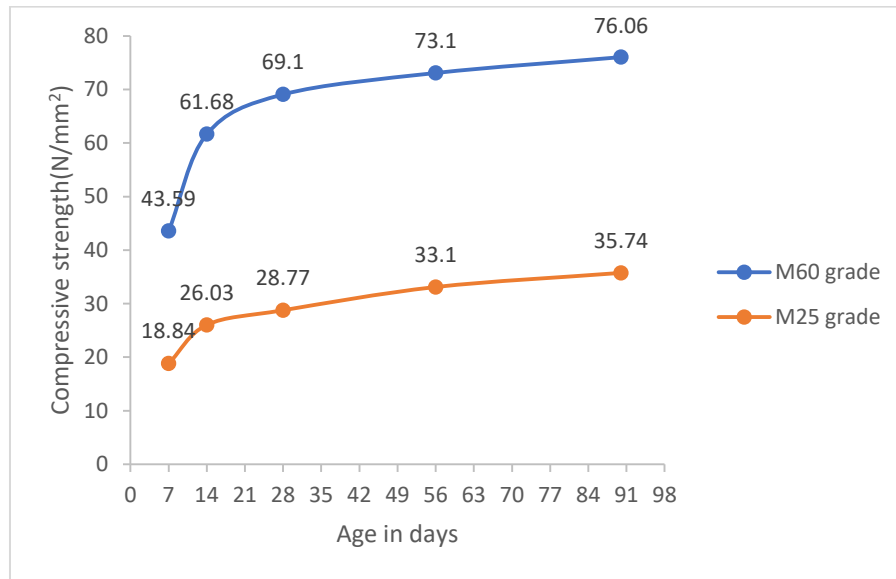
**Table NO.10 Trial mixes**

Trial mix number	Water to binder ratio	Cement: Fine aggregate: coarse aggregate	Superplasticizer	Admixture replacement	The strength obtained at 28days
1	0.23	1: 1.22: 2.02	1.5% of cement	7% of cement	56.84 N/mm <sup>2</sup>
2	0.27	1: 1.59: 2.65	1.5% of cement	10% of cement	53.99 N/mm <sup>2</sup>
3	0.25	1: 1.37: 2.34	1.7% of cement	10% of cement	59.03 N/mm <sup>2</sup>
4	0.23	1: 1.26: 2.09	1.8% of cement	10% of cement	69.1 N/mm <sup>2</sup>

The results of each mix design samples are tested for 7,14,28days. Trial Number4 has been obtained the High strength on an average of 69.1 N/mm<sup>2</sup> The compressive strength of M60 and M25 has been tabulated below for 7,14,28,56,90 days.

**Table No.11 Compressive strengths at different curing days.**

Mix design		M60 grade					M25 grade				
Age in days		7days	14days	28days	56days	90days	7days	14days	28days	56days	90days
Number of cubes		3cubes	3cubes	3cubes	3cubes	3cubes	3cubes	3cubes	3cubes	3cubes	3cubes
Cube strength in MPa	Cube1	44.82	60.12	67.7	72.89	76.28	20.02	26.98	30.8	35.1	37.18
	Cube2	41.97	61.97	68.95	71.83	74.8	17.89	25.01	26.92	30.86	34.43
	Cube3	43.98	62.95	70.9	74.6	77.1	18.63	26.12	28.61	33.41	35.61
Average cstrength in N/mm <sup>2</sup>		43.59	61.68	69.1	73.10	76.06	18.84	26.03	28.77	33.1	35.74



**Fig 1. Compressive strengths with different curing periods**

**III. METHODOLOGY FOR STRESS STRAIN ANALYSIS**

- a) The strain is analyzed by Compressometer by the ratio of gauge value to the gauge length of the cylinders.  
Strain = Gauge value/Gauge length.  
i.e. Gauge value is the reading on the dial gauge.  
Gauge length is equal to 150mm which is the diameter of the cylinder.
- b) Stress is calculated by the formula load to the area  
Stress = Load/area  
Area =17662.5 mm<sup>2</sup> .
- c) The modulus of elasticity is obtained by the ratio of stress to the strain

Modulus of elasticity E = Stress/strain.  
The higher the modulus of elasticity, the greater the stiffness of the specimen.  
18 cylinders were cast for both standard and high strength concrete and Figure 2 represents the 18 different curves with different loading and strains.  
The below graph shows the strain with respect to the stress for both standard and high strength concrete at 28,56,90 days of curing.

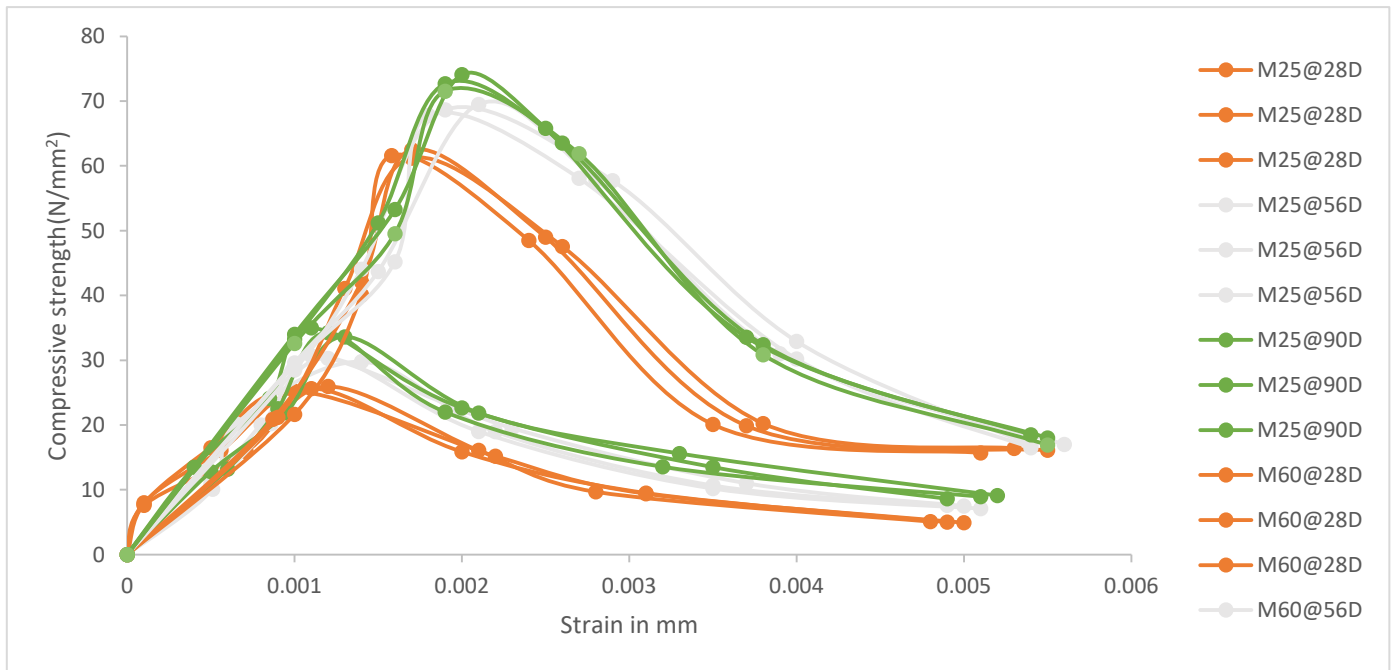


Fig 2. Stress-strain graph of M60 grade and M25 grade

IV. RESULTS AND DISCUSSION

- 1) The analysis of stress-strain variation between the standard and high strength concrete gave the ultimate stress and strain of cylinders which is mentioned in below tabular form. Greater the modulus of elasticity higher the stiffness.
- 2) The modulus of elasticity of high strength concrete is more than twice of normal grade concrete

Table No.12 Modulus of elasticity with respective to stress and strain

Age	28 days			56days			90 days		
	Max stress	Strain	E(N/mm <sup>2</sup> )	Max stress	Strain	E(N/mm <sup>2</sup> )	Max stress	Strain	E(N/mm <sup>2</sup> )
M25	25.60	0.0011	23387.22	30.26	0.00123	24808.86	34.29	0.0012	28740.83
M60	61.7	0.0016	35061.9	68.65	0.0019	35632.8	72.77	0.0020	37651.7

- 3) The compressive strengths of cubes for both standard and high strength concrete are more than the target mean strength for curing period beyond 28 days.
- 4) Figure 3 and Figure 4 show the compressive strengths for 28,56,90 days.

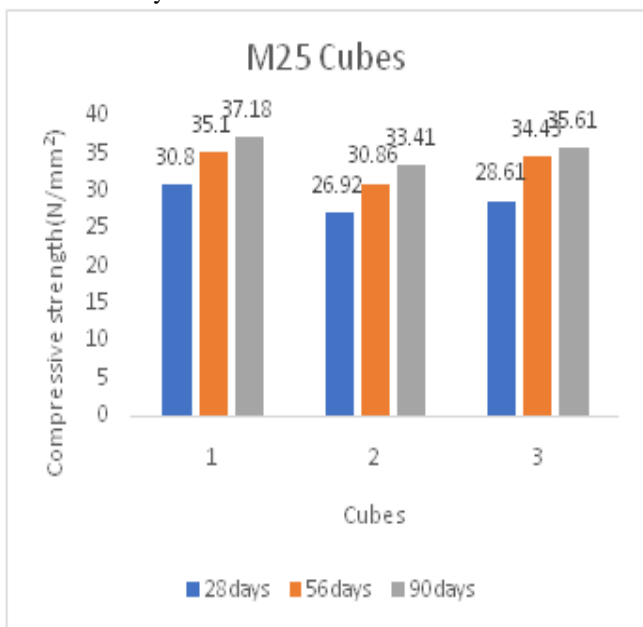


Fig 3. Compressive strengths of M25 cubes

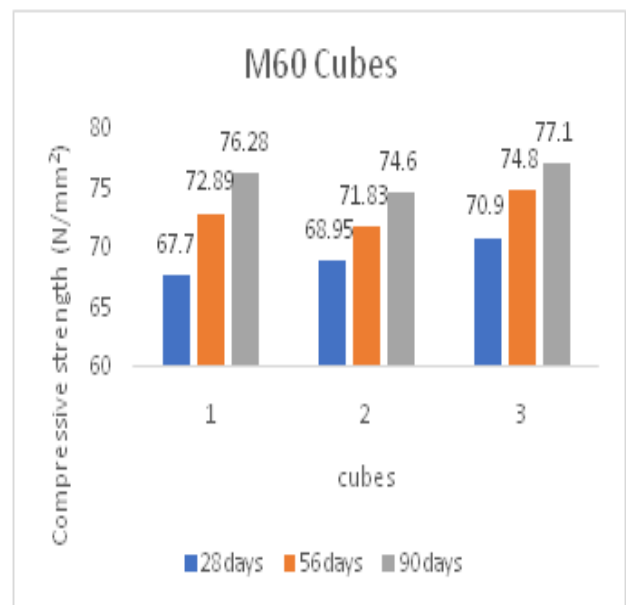


Fig 4. Compressive strengths of M60 cubes



## V. CONCLUSIONS

- The trail mix number 4 with composition of (cement : Fine aggregate : Coarse aggregate) of mix ratio (1: 1.26: 2.09) and 1.8% of superplasticizer, with replacement of cement by 10% silica fume and water to cement ratio of 0.23 gives the satisfactory results. The Average compressive strength of 69.1 N/mm<sup>2</sup> has been obtained for 28 curing days, 73.10 N/mm<sup>2</sup> for 56 curing period and 76.06 N/mm<sup>2</sup> for 90 days of curing period of M60 mix design.
- As per Recommendations of IS codes, the property of materials and mix design of high strength concrete are primary concerns, irrespective of those the trial mixes shows proper casting and compaction is also one major concern for high strength concrete.
- The Maximum elasticity obtained is 37651.7 N/mm<sup>2</sup> with a maximum stress of 72.77 N/mm<sup>2</sup> for M60 grade concrete with 90 days of curing.

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