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Analytical and Experimental study on Reinforced Concrete Beam with Partial Replacement of Cement with Fly Ash along with the Addition of Sodium Silicate

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Abstract: Concrete is a mixture of cement, aggregate and water. In order to conserve the natural resources, fly ash is used as a partial replacement for cement. The Flexural behaviour of beam was tested by performing the flexural test on beam. Cement is replaced by fly ash with different ratios along with which different percentages of Sodium Silicate is added to increase the strength of concrete. The analytical and experimental results are compared for the reinforced concrete beam. Adding Sodium Silicate to concrete reduces the calcium hydroxide in the concrete, whereas there is an increase in the calcium silicate hydrate (C–S–H gel). This C–S–H gel partially fill the micro-pores, voids and cracks in the concrete thereby improving the compactness and water permeability of the structure.
Keywords: Sodium Silicate, Fly ash, Flexure.

I. INTRODUCTION

In this project cement is replaced with fly ash partially, with addition of sodium silicate. Fly ash is a by-product obtained from burnt coal in thermal power plant. As on 2000 the production of Fly ash is 600 Million Tons. In order to conserve the natural resources, fly ash is used to replace cement, fine aggregate and course aggregate. Leaving some waste materials to the environment directly can cause environmental problem. Sodium Silicate the content of calcium hydroxide in the concrete structures decreases whereas the content of the calcium silicate hydrate (C–S–H gel) in the concrete structures increases compared with the untreated concrete structures. Sodium silicate-based concrete sealers are essentially surface hydrophilic agents because the expansive and insoluble C–S–H gels partially fill the micro-pores, micro-voids and micro cracks in the concrete structure to form smaller micro-pores, micro-voids and micro-cracks and improve the compactness and water permeability of the concrete and improves the resistance to chloride attack.

II. PRELIMINARY TEST ON MATERIALS

A. Cement

The Cement used in this study is Ordinary Portland Cement. (53 grade) conforming to IS 12269:1987. The specific gravity of 53 grade of cement used in this study is 3.09.

B. Fly ash

Fly ash is generated in thermal power plants with an imperative blow on environmental and living organism. Fly ash includes substantial amounts of silica (silicon dioxide, SiO_2) (both amorphous and crystalline) and lime (calcium oxide, (CaO). Fly ash particles are almost totally spherical shape. Where the specific gravity is 2.2%, with a bulk density of 1.1%.

C. Fine aggregate

Fine aggregate used in concrete is graded to give minimum void ratio. Grading of Fine aggregate does not increase the water demand for the concrete and should be provided with minimum voids so that the fine cementitious particles fill the space. The specific gravity of fine aggregate used in this study is 2.68.

D. Coarse aggregate

Coarse aggregate is a chemically stable material. Presence of coarse aggregate will reduce the drying shrinkage of concrete. The specific gravity of coarse aggregate used in this study is 2.86.

E. Sodium silicate

Sodium silicate is a glassy gel material that reduces the permeability in the concrete. Sodium Silicate reacts with calcium hydroxide in cement to produces C-S-H gel, which induce density and strength to fly ash concrete [6]. This C-S-H gel blocks all micro pores and cracks in concrete to improve its resistance to water permeability and chloride attack [5]. The chemical formula of Sodium Silicate is Na_2SiO_3. The Density of Sodium Silicate is 2.61g/cm^3

F. Water

Water is the main ingredient in the formation of concrete, because it helps in mixing the concrete elements like the cement, sand and coarse aggregate. The workability of concrete also depends upon the water cement ratio used in the concrete grade of mix. The chemical reactions in the concrete will not start unless water is mixed with them, as the formation of C-H-S bond formation depends mainly upon the usage of water.

III. MECHANICAL PROPERTIES

The mechanical properties were conducted on beam to analyse the flexural strength of concrete for M25 and M30 grade of concrete and with different replacement levels of ordinary Portland cement with fly ash and addition of sodium silicate.

A. Flexural strength

The Flexural strength was done in the prisms specimens 150×150×700mm size. The testing machine may be of any reliable type of sufficient capacity for the tests and capable of applying load at the specified rate. It's also measured by the compressive testing machine. For this test prisms were used and was laid sideways where the load is applied.

$$\text{Flexural strength} = \frac{Pl}{bd^2}$$

Where,

P- Load applied in kN

L- Length in mm

b- Breadth of specimen in mm

d- Depth of specimen in mm

Table 1: Flexural Strength of concrete

Mix	Grade of Concrete	
	M25	M30
Cc	4.87	5.04
20/0%	4.38	4.27
20/5%	4.56	4.45
20/10%	4.77	4.79
30/0%	3.94	4.2
30/5%	4.62	4.47
30/10%	5.18	5.39
40/0%	3.81	3.94
40/5%	4.36	4.35
40/10%	4.97	4.86

The flexural strength of M25 and M30 grade of conventional concrete and fly ash in sodium silicate concrete at the age of 28^{th} day is shown in above table. It indicates that there is an increase the flexural strength when replacing cement with Fly ash by 30% along with 10% addition of Sodium Silicate which is found optimum.

IV. ANALYTICAL INVESTIGATION

The strength of the beam designed can be checked by Analysis method. In this research study the beam is first analysed and the compared with the experimental work in order to check and difference in the deformation obtained. The analysis is done for M25 and M30 grade of concrete, the difference in the deformation is discussed below.

A. Analytical Result For M25 Grade Concrete

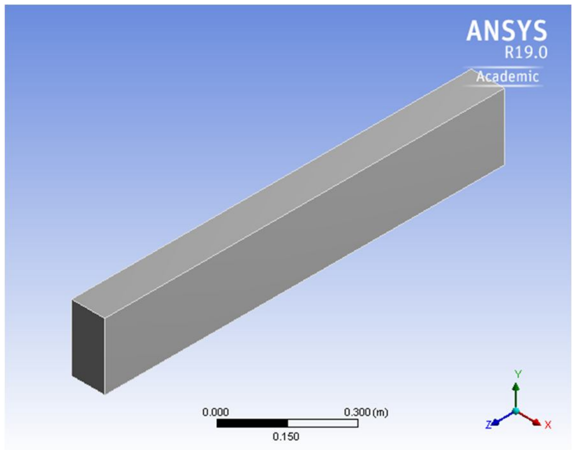

Fig 1: Beam Model

The Fig 1 indicates the size of the beam analysed in ANSYS Software. The size of the beam used here is 100mm x 200mm x1200mm. For the following dimension the beam is considered to be fixed while applying the load on the upper surface of the beam, where the deformation and normal strains are analysed.

The below Figure indicates the comparison of Analytical investigation in directional deformation of M25 grade conventional concrete and optimum replacement of cement with Fly ash by 30%, along with the addition of Sodium Silicate by10% respectively.

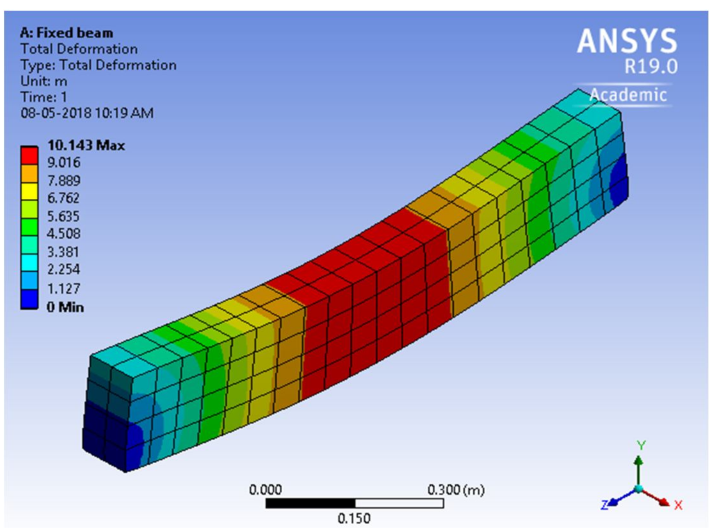

Fig 2: Deformation in M25 grade of conventional concrete

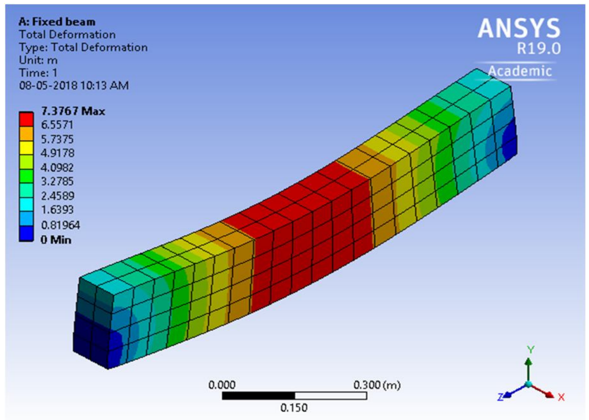

Fig 3: Deformation in M25 grade of Fly ash concrete

The above figure indicates the deformation of M25 grade of conventional concrete is 10.143m and Fly ash in sodium silicate concrete is 7.376m. The analytical model shows that the deformation of conventional concrete more compared than Fly ash and sodium silicate concrete.

Table 2: Deformation Results for M25 grade

Mix	Deformation Result (m)
Conventional	10.143
M25+30%Fly ash+10%Sodium Silicate	7.3767

The above Table 2 indicates the deformation of M25 grade of conventional concrete and Fly ash in sodium silicate concrete. It's found that the deformation of conventional concrete more compared than Fly ash and sodium silicate concrete.

The below Figure indicates the comparison of Analytical investigation in Strain for M25 grade of conventional concrete and optimum replacement of cement with Fly ash by 30%, along with the addition of Sodium Silicate by 10% respectively.

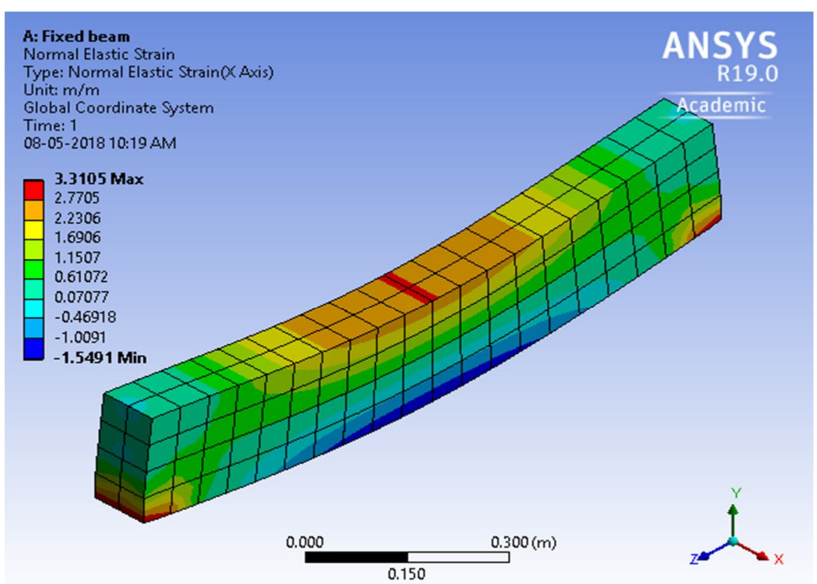

Fig 4: Strain in M25 grade of conventional concrete and fly ash concrete

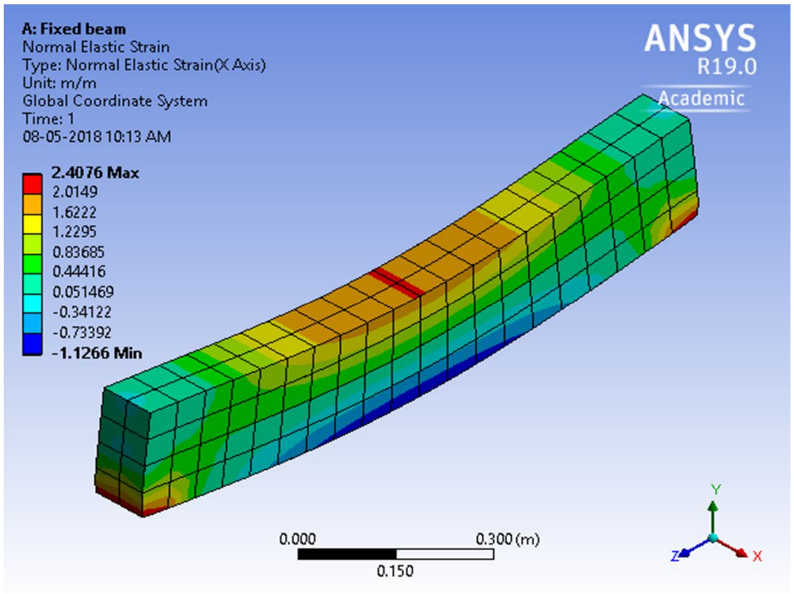

Fig 5: Strain in M25 grade of fly ash concrete

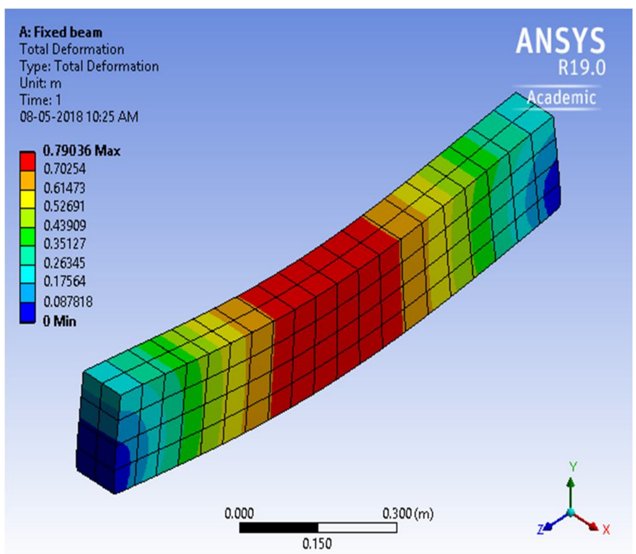

Fig 6: Deformation in M30 grade for conventional concrete

The above figures indicate the strain of M25 grade of conventional concrete is 3.3105 and Fly ash in sodium silicate concrete is 2.1076. The analytical model shows that the strain of conventional concrete more compared than Fly ash and sodium silicate concrete.

Table 3 Strain Results for M25 grade

Mix	Strain Results
Conventional	3.3105
M25+30%Fly ash+10%Sodium Silicate	2.1076

The above Table 3 indicates the strain of M25 grade of conventional concrete and Fly ash in sodium silicate concrete. It's found that the strain of conventional concrete more compared than Fly ash and sodium silicate concrete.

B. Analytical Result For M30 Grade Concrete

The below Figure indicates the comparison of Analytical investigation in directional deformation M30 grade of conventional concrete and optimum replacement of cement with Fly ash by 30%, along with the addition of Sodium Silicate by 10% respectively.

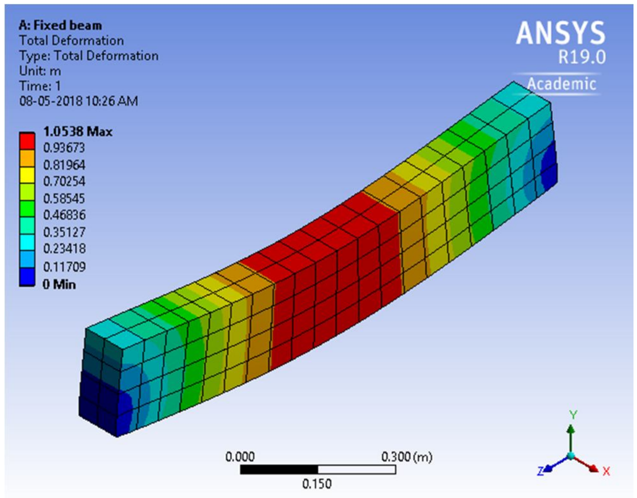

Fig 7: Deformation in M30 grade for fly ash concrete

The above figures indicate the deformation of M25 grade of conventional concrete is 0.7903m and Fly ash in sodium silicate concrete is 0.2573m. The analytical model shows that the deformation of conventional concrete more compared than Fly ash and sodium silicate concrete.

Table 4: Deformation Results for M30 grade

Mix	Strain Results
Conventional	0.79036
M30+30%Fly ash +10% Sodium Silicate	0.257396

The above Table 4 indicates the deformation of M25 grade of conventional concrete and Fly ash in sodium silicate concrete. It's found that the deformation of conventional concrete more compared than Fly ash and sodium silicate concrete.

The below Figure indicates the comparison of Analytical investigation in Strain for M30 grade of conventional concrete and optimum replacement of cement with Fly ash by 30%, along with the addition of Sodium Silicate by10% respectively.

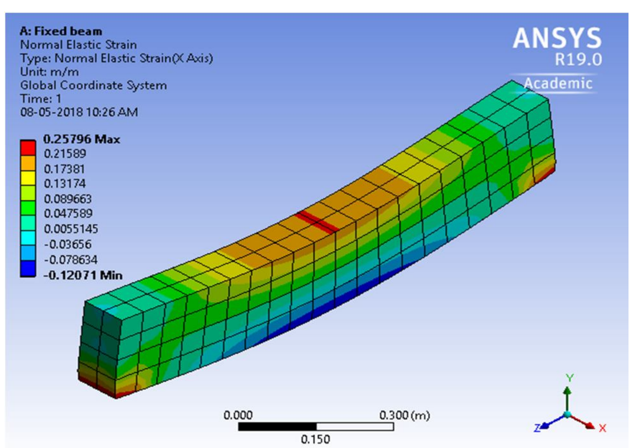

Fig 8: Strain in conventional concrete

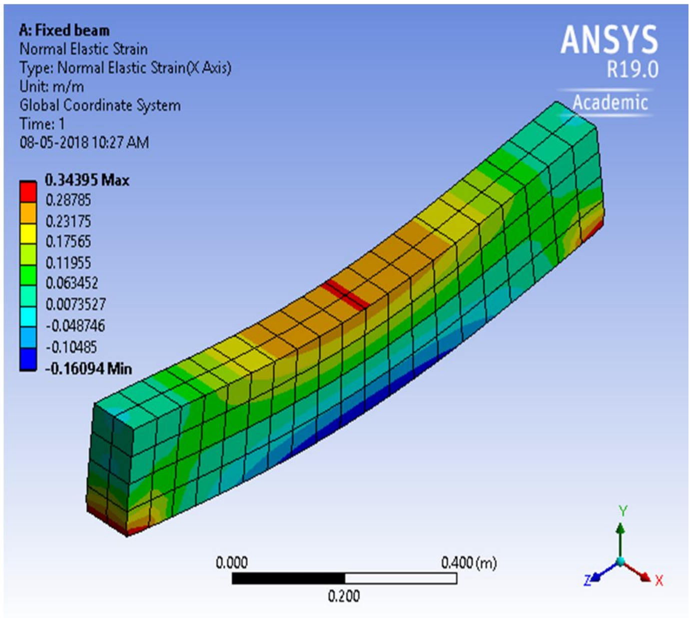

Fig 9: Strain in Fly ash concrete

The above figures indicate the strain of M25 grade of conventional concrete is 0.2479 and Fly ash in sodium silicate concrete is 0.01273. The analytical model shows that the strain of conventional concrete more compared than Fly ash and sodium silicate concrete.

Table 5: Strain Results for M30 grade

Mix	Strain Results
Conventional	0.24796
M30+30%Fly ash +10% Sodium Silicate	0.012731

The above Table 5 indicates the strain of M25 grade of conventional concrete and Fly ash in sodium silicate concrete. It's found that the strain of conventional concrete more compared than Fly ash and sodium silicate concrete.

C. Experimental Investigation

The reinforced concrete beam is casted and is cured for 28 days. The cured beam is then placed in the tested machine where a two-point loading is subjected to the top surface of the beam. The deformation in the beam is measured by using a dial gauge at the mid bottom span of the beam.

D. Test Set -Up For Beam Under Loading

The test program consists of casting and testing of four beams, all having size 200×100×1200 mm and designed as simply supported beam with 2nos of 12mm diameter bars as longitudinal main reinforcement. The beams were cast using M25 and M30 grade of concrete and Fe 415 grade of steel. Ordinary Portland cement, Fine aggregate and the coarse aggregate were used. After 28 days curing specimens were used tested in UTM to determine the flexural strength.

Fig 10: Test setup for beam specimen

The M25 grade of concrete beam tested by using UTM to determine the deflection and ultimate load capacity of the beam. The above figure shows that the setting of beam on UTM and to applied under a loading.

E. Results For M25 Grade Beam Under Loading

R.C.C beam containing the longitudinal reinforcement of two members of 12mm dia bars. The beam is subjected to two-point load. A graph in which increasing the compression load on the beam are plotted along the vertical axis, and the deflections resulting from these loads are plotted along the horizontal axis. Ultimate load for M25 grade of Fly ash and Sodium Silicate concrete beam was 80kN and conventional beam was 110kN. The ultimate load for the concrete beam is more compared to the conventional concrete beam.

The below Figure indicates the arrangement of beam on the UTM. It found that comparison of Load Vs Deflection of conventional concrete in M25 and optimum percentage of 30% replacement of cement with Fly ash, with the addition of Sodium Silicate by 10% of concrete respectively.

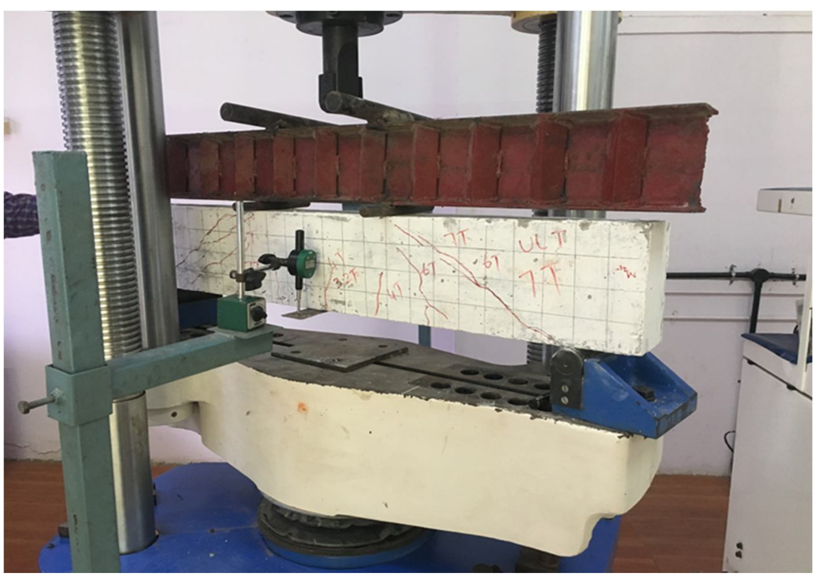

Fig 11: Beam specimen for M25 grade

The M25 grade of concrete beam tested by using UTM to determine the deflection of the beam. The above figure shows that the cracks formed on the beam under the loading and the beam failure at maximum ultimate loading.

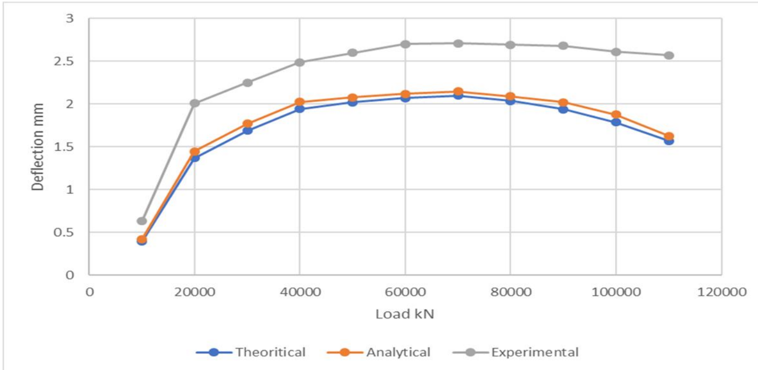

Fig 12: Load vs Deflection for conventional concrete

The above Figure 12 indicates the comparison of Load Vs Deflection for conventional concrete with M25 grade of concrete and optimum percentage of 30% replacement of cement with Fly ash.

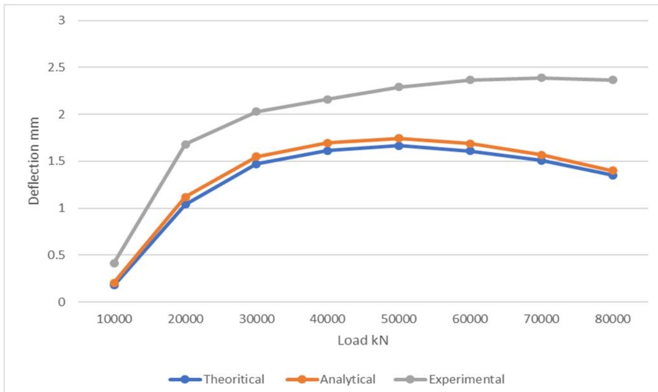

Fig 13: Load vs Deflection for Fly ash and Sodium Silicate concrete

The above Figure13 indicates the comparison of Load Vs Deflection of Fly ash and sodium silicate for M25 grade and with 30% replacement of cement with Fly ash, with the addition of Sodium Silicate by 10%.

Table 6: The deflection of conventional and Fly ash with Sodium Silicate concrete beam for M25 grade

S.no	Type of concrete	Ultimate Load (kN)	Deflection (mm)
1	Conventional beam	110	2.57
2	Fly ash and Sodium Silicate beam	80	2.36

From the above Table 6 shows that the Fly ash and Sodium Silicate concrete beam gives less deflection than the conventional concrete beam for M25 grade.

F. Results For M30 Grade Beam Under Loading

R.C.C beam containing the longitudinal reinforcement of two members of 12mm dia bars. The beam is subjected to two-point load. A graph in which increasing the compression load on the beam are plotted along the vertical axis, and the deflections resulting from these loads are plotted along the horizontal axis. Ultimate load for M30 grade of Fly ash and Sodium Silicate concrete beam was 90kN and conventional beam was 120kN. The ultimate load for the concrete beam is more when compared with the conventional concrete beam.

The below Figure indicates the comparison of Load Vs Deflection of conventional concrete in M30 and optimum percentage of 30% replacement of cement with Fly ash, with the addition of Sodium Silicate by 10% of concrete respectively.

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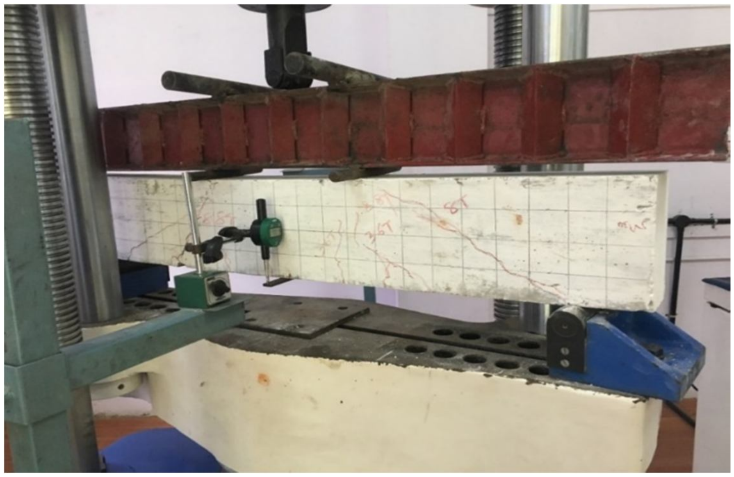

Fig 10: Beam specimen for M30 grade

The M30 grade of concrete beam tested by using UTM to determine the deflection of the beam. The above figure shows that the cracks formed on the beam under the loading and the beam failure at maximum ultimate loading.

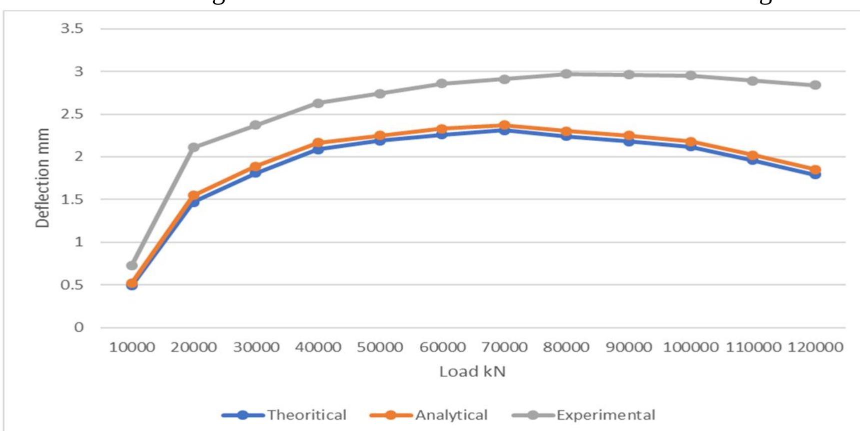

Fig 11: Load vs Deflection for conventional concrete

The above Figure 11 indicates the comparison of Load Vs Deflection for conventional concrete with M25 grade of concrete and optimum percentage of 30% replacement of cement with Fly ash.

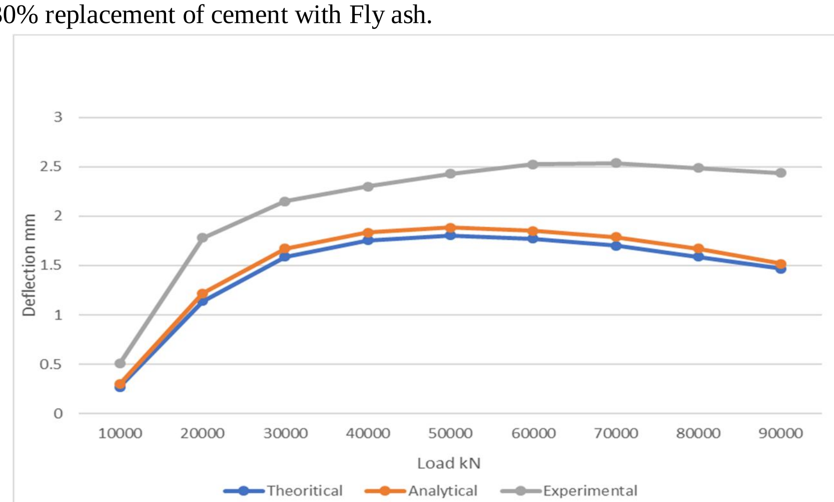

Fig 12: Load vs Deflection for Fly ash and Sodium Silicate concrete

The above Figure 12 indicates the comparison of Load Vs Deflection of Fly ash and sodium silicate for M25 grade and with 30% replacement of cement with Fly ash, with the addition of Sodium Silicate by 10%.

Table 7: The maximum load carrying capacity of conventional and Fly ash with Sodium Silicate concrete beam for M30 grade

S.no	Type of concrete	Ultimate Load (kN)	Deflection (mm)
1	Conventional beam	120	2.87
2	Fly ash and Sodium Silicate beam	90	2.44

From above Table 7 shows that the Fly ash and Sodium Silicate concrete beam gives less deflection than the conventional concrete beam for M30 grade.

V. CONCLUSIONS

A. when adding sodium silicate by 10% along with 20% of fly ash, the flexural strength decreased by 10% when compared with conventional concrete.

B. Thus, in this research work it was found that the strength of concrete increases with the optimum replacement of cement with Fly ash by 30% along with the addition of Sodium Silicate by 10% of concrete respectively.

C. Analysis of the beam was done by using ANSYS Software and when compared with the theoretical values, the deformation obtained was slightly similar to that of the analytical values.

D. The experimental study was done by casting beams for M25 and M30 grade of concrete along with the replacement of cement with Fly ash by 30% with the addition of Sodium Silicate by 10%.

E. The experimental result shows that the deformation of the conventional concrete beam is less when compared with the fly ash concrete beam that contains sodium silicate.

F. The ultimate load bearing capacity for conventional concrete is 110kN whereas for fly ash concrete the ultimate load bearing capacity is 80kN.

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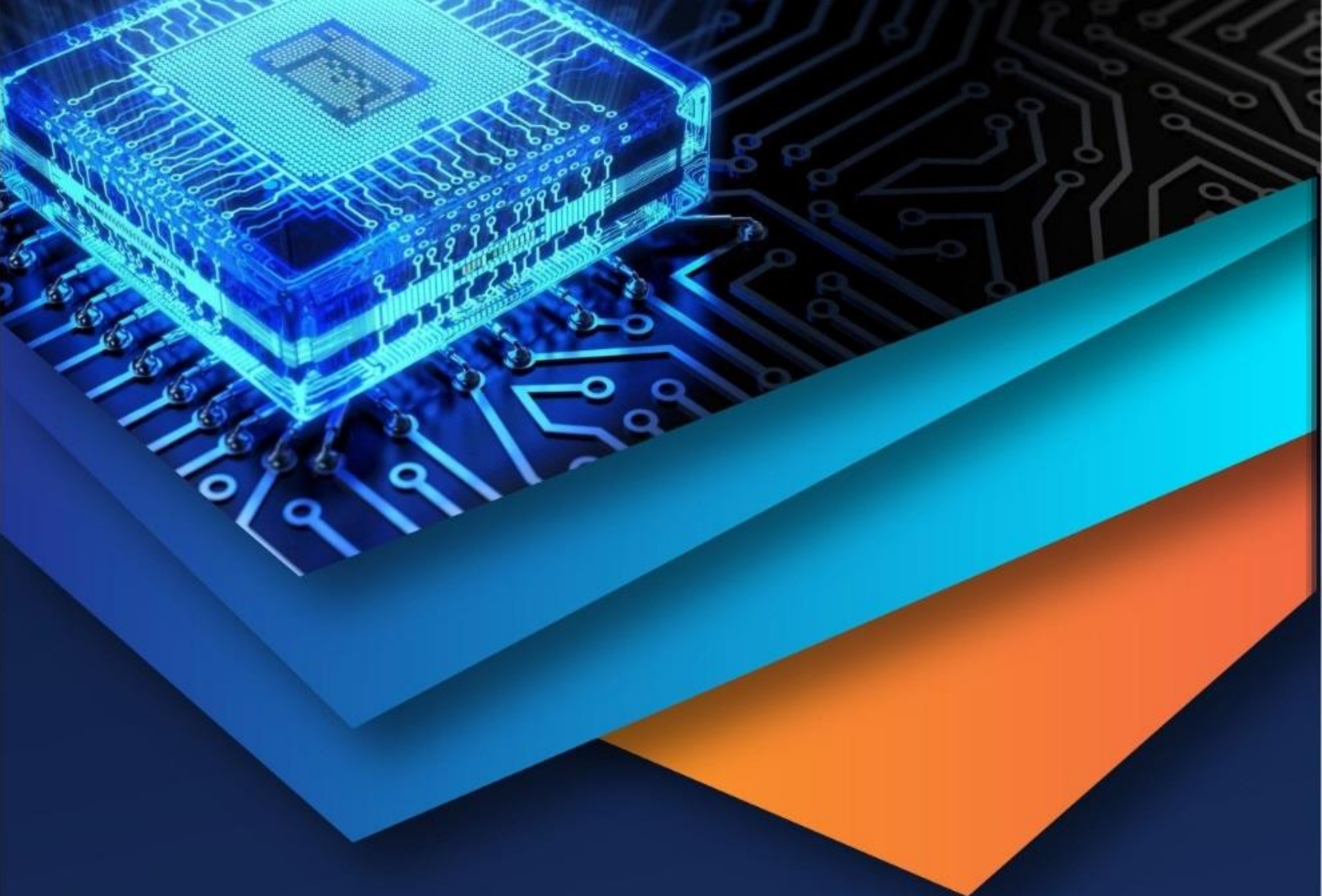

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