Plane Stress Analysis on Concrete Cube with Fragmentary Restoration for Cement by Alccofine

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Abstract : Plane stress analysis is carried out by ANSYS software on concrete cube mixes with Alccofine.This experimental work deals with the effects of Alccofine, by partial replacement of cement for compressive strength. In this program 36 cube samples of size 150 mm were cast for different percentages of Alccofine with partial replacement of cement at the percentages of 0%, 5%, 10%, 15%, 20%, and 25%. From the test results it was found that strength was increased with the increase of Alccofine in the concrete after 7 days and 28 days curing. For the experimental values best fit model was developed. From the model one can easily predict the experimental values for other percentages of Alccofine. Also using ANSYS software all the concrete cubes were studied by imparting plane stress model to find out deformation, principal stresses and shear stresses.

Keywords - **Plane Stress, Principal Stress, Shear Stress, Ansys, Alccofine.**

I. INTRODUCTION

Alccofine is a mineral admixture which has unique characteristics to enhance performance of concrete in fresh and hardened stages due to its optimized Particle size distribution.It is being manufacture in India exclusively under different categories Alccofine 1200 series of 1201, 1202, and 1203 which represents fine, micro fine, ultrafine particle size respectively. In this research work Alccofine 1203 is used. Alccofine 1203 is a specially processed product based on slag of high glass content with high reactivity obtained through the process of controlled granulation. Alccofine 1203 is an ultra fine material of particle size much finer than cement, fly ash, silica etc. Hence, Alccofine provides reduced water demand for a given workability as per requirement of concrete performance. Alccofine 1203 is low calcium silicate and high calcium silicate respectively. In the workability of the concrete mix is improving and also increasing the compressive strength of the concrete mixes due to low calcium silicate.. It also helps in reduction in segregation and reduction in heat of hydration of the concrete mixes. Alccofine 1203 is producing high strength concrete and is used in partial replacement of cement, to reduce the cement content and replacing as an additive to improve concrete properties.

II.LITERATURE REVIEW

Plethora literatures are available on concrete with Alccofine powder. Several researchers conducted test results are presented for review of past experiments works. D. Sharma, S. Sharma and Ajay. G concluded that reasonably high strength concrete can be achieved by means of substituting fine aggregate with 10% to 45% of foundry slag and replacement of cement with 15% of alccofine. M. V. Sekhar Reddy, k. A. Latha and k. Surendra carried out experimental work on partical replacement of cement with fly ash and alccofine for M40 Grade concrete. The fly ash and alccofine are replaced at 5%, 10%, 15%, and 20% with cement. Alccofine showed greater results then compared with fly ash in long term Strength Properties.K. Gayathri, K. R. chandran and J. Saravanan performed research on performance of alccofine replacing the cement in concrete at 5%, 10%, 15% and 20%. It is found that 15% replacement of cement by alccofine is yielding good strength when compared to other percentages and also alccofine increases the cementing efficiency at earlier ages of concrete.M. Y. Patel, Darji and Purohit conducted experimental investigation on overall performance of compression test on concrete mix at 28 and 56 days. They concluded that concrete with combination of alccofine and glass powder gives higher compressive strength. The maximum strength was attained by replacing cement by 10% alccofine and 30% glass powder. S. M. Zubair and S.S. Jamkar conducted research which involves the use of Fly ash, Alccofine and Silicafume concluded that alccofine performs better than that of silica fume together with fly ash in fresh and harden stages of concrete.D. S. kumar, T. H. latha, N. S. Sri, T. Shobana and C. Soundarya found that the strength attained by the use of 10% alccofine showed greater to that of the nominal mix with 7 day and 28 days curing and the durability of the alccofine concrete is relatively higher than that of nominal mix. Ansari, Chaudhri, Ghuge N.P and Phatangre conducted test on M70 grade of concrete wyh fly ash and alccofine. From this investigation it was observed that partially replacement of cement by alccofine the strength of concrete was increased by 20%. It was found that alccofine is less expensive than cement and so it achieved higher strength then ordinary concrete, so it is recommended by them in Indian construction industry. Siddharth.P and Jamnu M.A observed that by adding alccofine the strength has been increased rapidly at early stages then that of fly ash. The combination of fly ashalccofine yielded better strength than that of concrete with fly ash and alccofine at all levels. The highest compressive strength is achieved by replacing cement at 10% alccofine and 30% fly ash. Saurabh, Dr. Sanjay and Dr. Devinder concluded that the use of alccofine as mineral admixture will increase the strength than traditional concrete. B. S. Sunil and B. O. Shah concluded that combination of alccofine-fly ash concrete gives more compressive strength at every age when compared to all other concrete mixes. S. Suthar, B. K. Shah and P. J. Patel investigated on cement which is replaced by weight with combinations of fly ash at 20 - 35% with alccofine at 4% to 14% and combinations of fly ash at 20 - 35% with silica fume at 4% to 14% and concluded that the combination of fly ash-alccofine increases the compressive strength at all age of the concrete then other mix. But in all the study no experimental work is conducted for M25 grade concrete and also not studied for finding principal stresses. Hence an attempt is made to use finite element analysis on M25 grade concrete with Alccofine material.

III.EXPERIMENTAL WORKS

In Table 1, physical and chemical properties of Alccofine material is presented. Preliminary test was conducted concrete materials and its test results are presented in Table 2.

Table 1. Physical and Chemical Properties of Alccofine Used

Physical and Chemical properties	**Alccofine**
Colour	White
Specific gravity	2.86+_0.02
Appearance	Powder
Bulk Density (kg/m3)	600-700
Glass content	>90%
Silica dioxide (SiO2)	33-35 %
Calcium oxide (CaO)	31-33 %
Aluminum oxide (Al2O3)	23-25 %

Table 2. Preliminary Test Results

Name of the material	**Properties of material**	**Values**
OPC 53 grade	Specific gravity	3.12
	Initial setting time	30min
	Final setting time	600min
Fine aggregate	Specific gravity	2.51
	Water absorption	1.5%
	Sieve analysis	4.60%
Coarse aggregate	Specific gravity	2.60
	Water absorption	0.51%
	Sieve analysis	4.05%
Alccofine	Specific gravity	2.84

IV.EXPERIMENTAL RESULTS AND DISCUSSION

After conducting preliminary test for concrete ingredients, as per Indian standard IS: 10262-2009, concrete mix was designed for M25 grade mix.Mix ratio is 1: 1.22: 2.24: 0.4. In this program 36 cube samples of size 150 mm were cast for different percentages of Alccofine with partial replacement of cement at the percentages of 0%, 5%, 10%, 15%, 20%, and 25%. Workability testresults are presented in table3. From the table 3 it is found that workability of concrete goes on reducing while increasing Alccofine. From the test results slump value for the reference mix is 60 mm it is value goes on reducing up to 21 mm on increasing alccofines. Compressive strength after 7 days and 28 days test results are presented in table 4. But on the contrary to slump values, compressive strength goes on increasing with increased percentage of Alccofine. The compressive strength for reference mix 38.9 N/mm2,while adding Alccofine the compressive strength was found be increase up to 43.4 N/mm2 under 7 days curing.The compressive strength for reference mix 44 N/mm2, while adding Alccofine the compressive strength was found be increase up to 50.3 N/mm2 under 28 days curing.From figure 1 and 3,Max percentage improvement over reference concrete was found as 11.57 and 14.32. It can be easily predicted compressive strength of Alccofine concrete after 7 and 28 days curing by using best fit models shown in figure 2 and 4. All the values are closely matched with experimental values by referring R^2 values as 0.959 and 0.989 from figures 2 and 4.

Table 3.Workability Test on Concrete Cube

Mix	Slump Value
AF_0	60
AF_1	55
AF_2	53
AF_3	38
AF_4	30
AF_5	21

Table 4. Compressive Strength Test on Concrete Cube

Mix	Compressive Strength N/mm^2 after	
	7 Days curing	28 Days curing
AF_0	38.9	44
AF_1	38.96	45
AF_2	39	47.1
AF_3	39.7	48.4
AF_4	40.46	49.2
AF_5	43.4	50.3

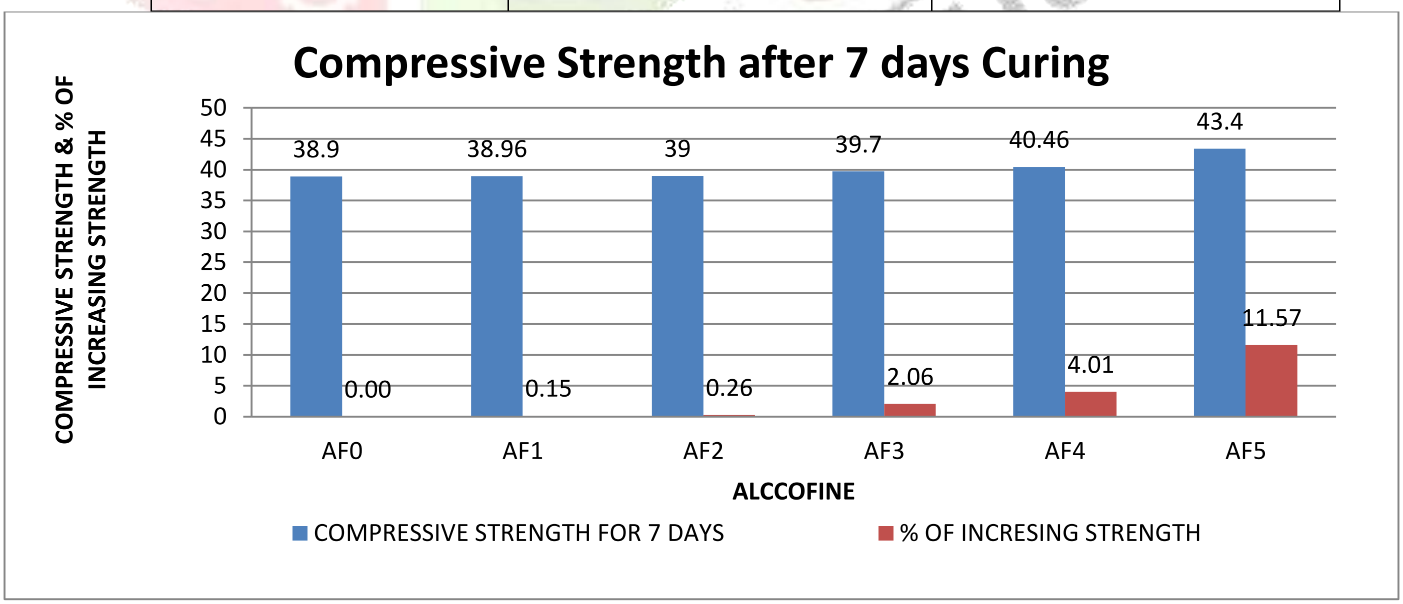


Figure 1. Compressive Strength after 7 Days Curing

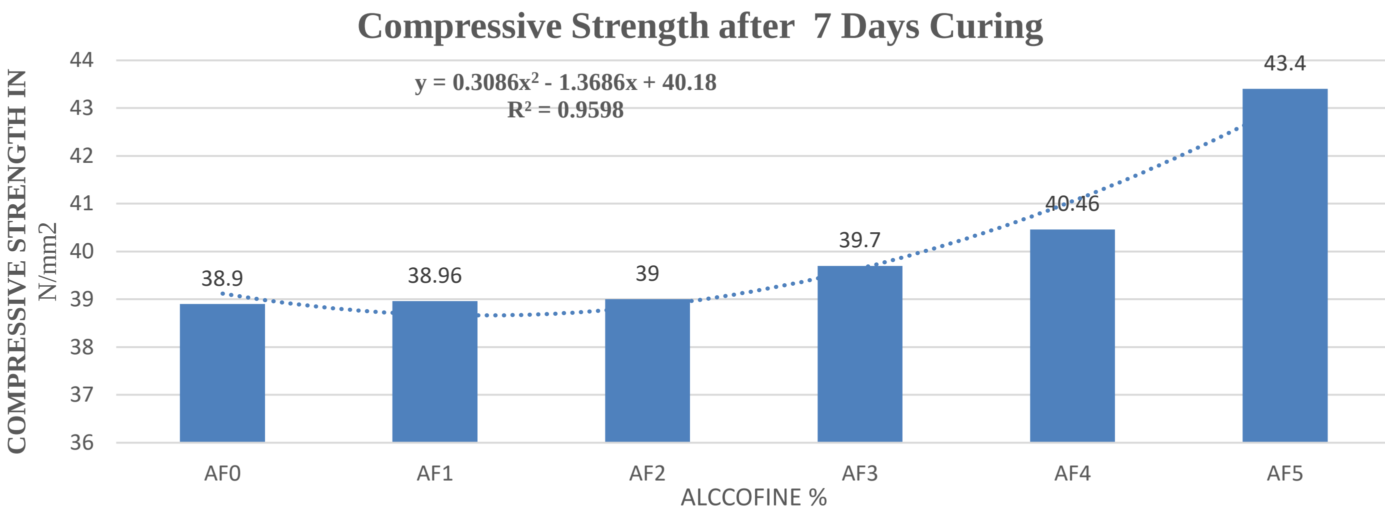


Figure 2. Best Fit Model for Compressive Strength after 7 Days Curing

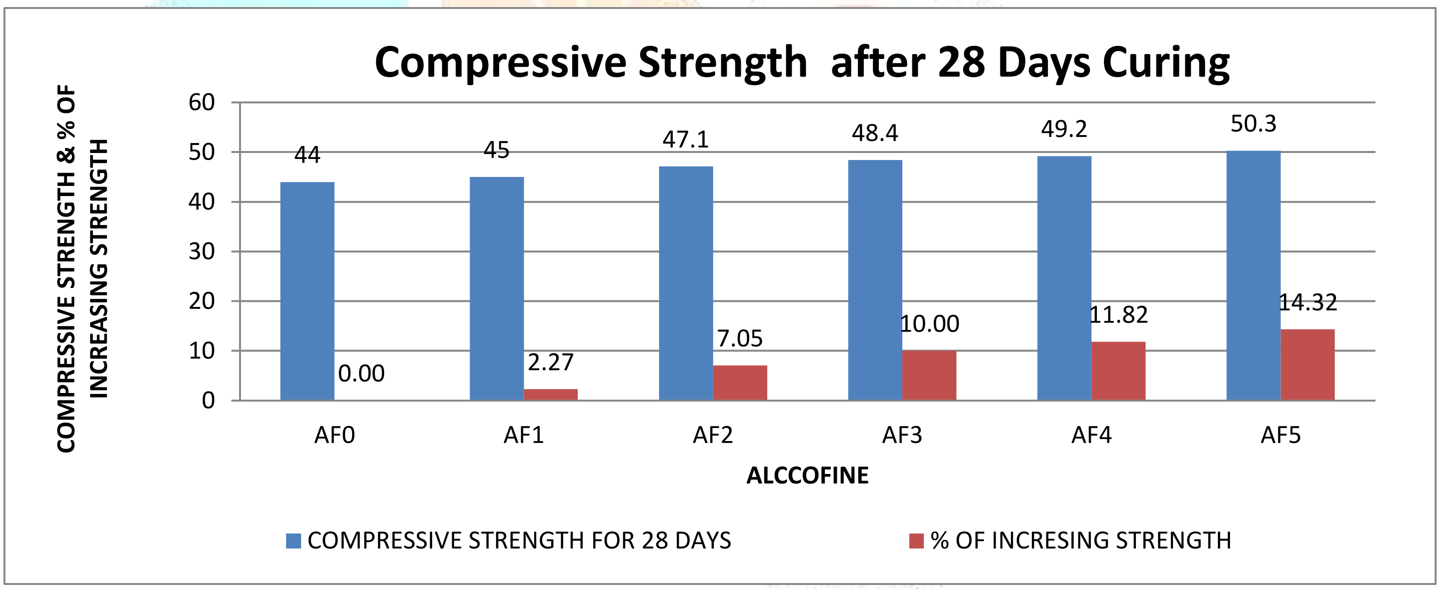


Figure 3. Compressive Strength after 28 Days Curing

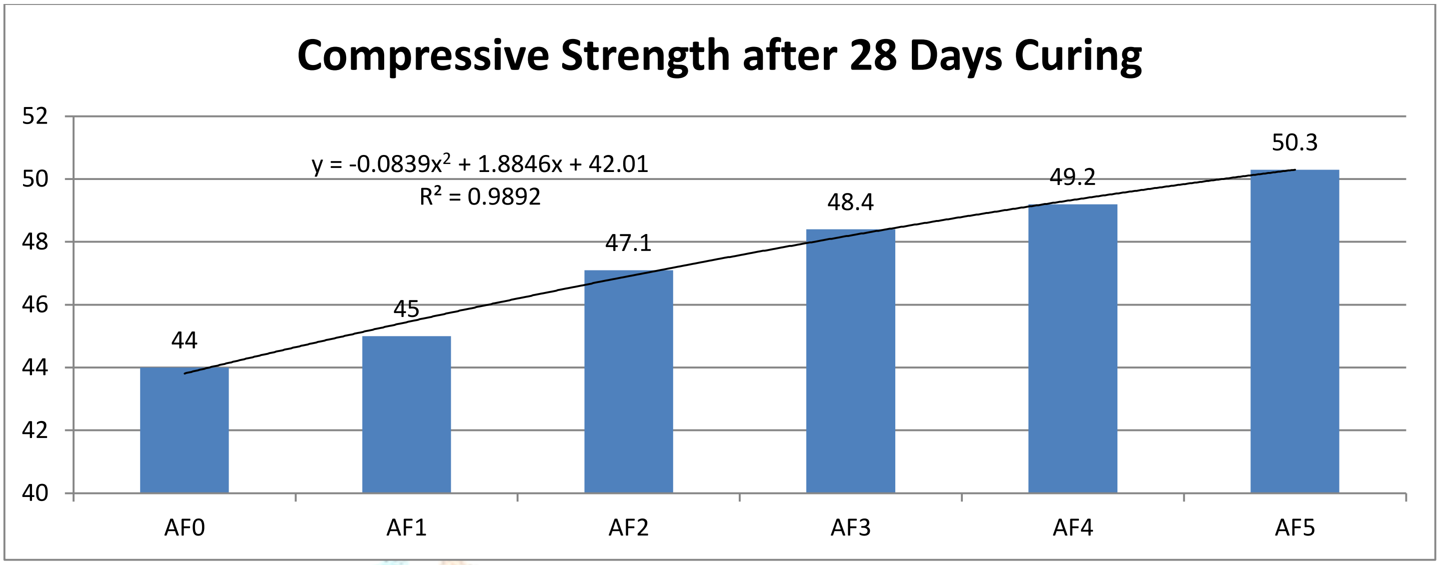


Figure 4. Best Fit Model for Compressive Strength after 28 Days Curing

Easily predicted compressive strength of Alccofine concrete after 7 and 28 days curing by using best fit models shown in figure 2 and 4. All the values are closely matched with experimental values by referring R^2 values as 0.959 and 0.989 from figures 2 and 4.

V. PLANE STRESS ANALYSIS

Though concrete cube is a three dimensional solid element, it is appropriate to analyze as a plane stress model by considering 1mm thick. By using symmetry shape of cube, one fourth of it was considered. Consequently size of the model becomes 75mmx75mmx1mm thick continuum.By using discretization technique, continuum is divided into eight triangular elements and each element is interconnected at a discrete number of nodal points. All the triangular elements are assigned as three nodded constant strain triangle elements CST having isotropic material property. An isotropic material is a material whose stress–strain law is independent of the coordinate system, which means that regardless of the orientation of the coordinate system, the elasticity matrix is the same.CST is a linear displacement element.The strains are constant in the element. The nodes in the CST are numberedcounterclockwise direction.Each node has two degrees of freedom.At boundary nodes, x displacement and y displacements are arrested at x and y axis respectively. At interior corner node, both x and y displacements are arrested. Young's modulus and poison's ratio were taken as 38E5 and 0.3 respectively. Loading is applied at node No. 1. The procedure for plane stress analysis can be referred to any standard finite element analysis text book. For analyzing single triangular elements, size of stiffness matrix is 6X6. As there are here eight triangular elements, analysis is performed by ANSYS software by linear elastic analysis. Stress resultant like displacements, normal stress and shear stress were noted for all the concrete cubes in both x and y direction. Maximum major and minor principal stresses

$$\{\sigma\} = [D]\,\{\varepsilon\}$$

$$D = \frac{E}{1-\mu^2}\begin{bmatrix} 1 & \mu & 0 \\ \mu & 1 & 0 \\ 0 & 0 & (1-\mu)/2 \end{bmatrix} \text{..................Constitutive Matrix}$$

$$\begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix} = \frac{E}{1-\mu^2}\begin{bmatrix} 1 & \mu & 0 \\ \mu & 1 & 0 \\ 0 & 0 & (1-\mu)/2 \end{bmatrix}\begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix} \text{.................Stress Strain Relation}$$

$$\sigma_{major\,\&\,minor} = \left(\frac{\sigma_x+\sigma_y}{2}\right) \pm \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2 + \tau_{xy}{}^2} \text{.......... ....Major and Minor Principal Stresses}$$

Where E –young's Modulus, $\mu - poisson\ ratio$

$\sigma -$ *stress in* x, y *direction*; $\varepsilon -$ *strain in* x, y *direction*; τ_{xy} *shear stress in* xy *direction and* $\gamma_{xy} -$ *shear strain*

for all the mixes are shown in figures 5, 6, 7 and 8. Major Principal tensile stress is found invariably found in element No. 6 for all the mixes. These tensile stresses are responsible for crack propagation in the concrete. First crack may be developed as soon as tensile stress exceeds the permissible tensile strength of concrete. Maximum minor principal stresses are mostly compressive stresses and found in element No 2. Maximum shear stress is also found in element No.2. Similarly stress contours are shown and limited for AF0 and AF1 mixes having 7 and 28 days curing respectively. These are shown in figures 9, 10, 11 and 12.

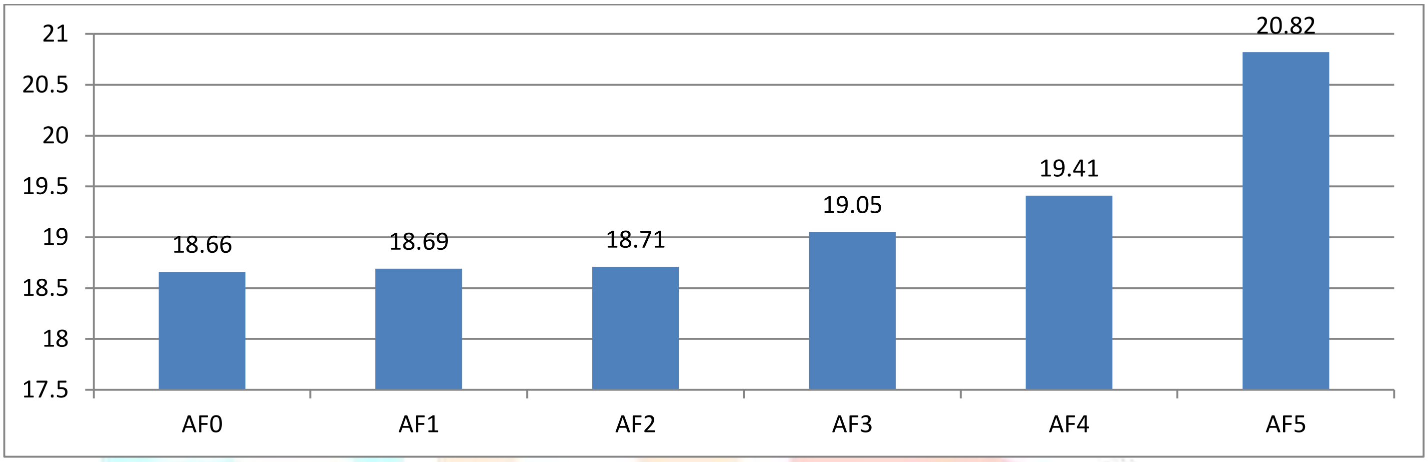


Figure 5.Major Principal Stress (Tension) after 7 Days Curing

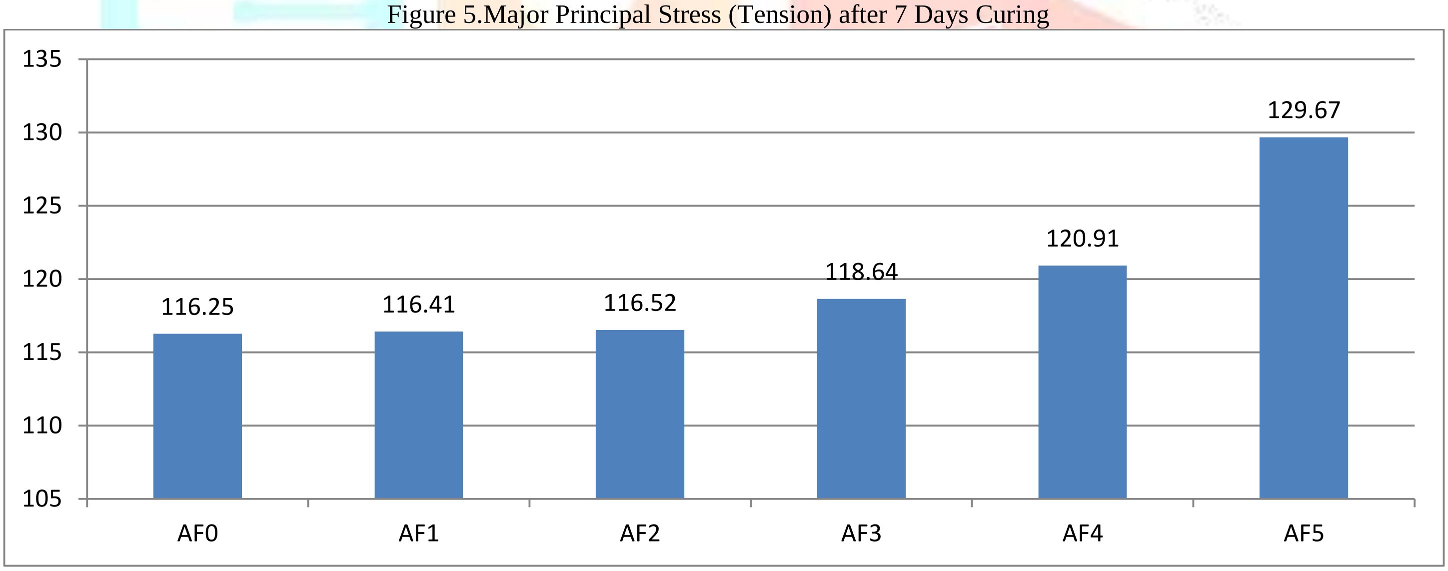


Figure 6.Minor Principal Stress (Compressive –ve) after 7 days Curing

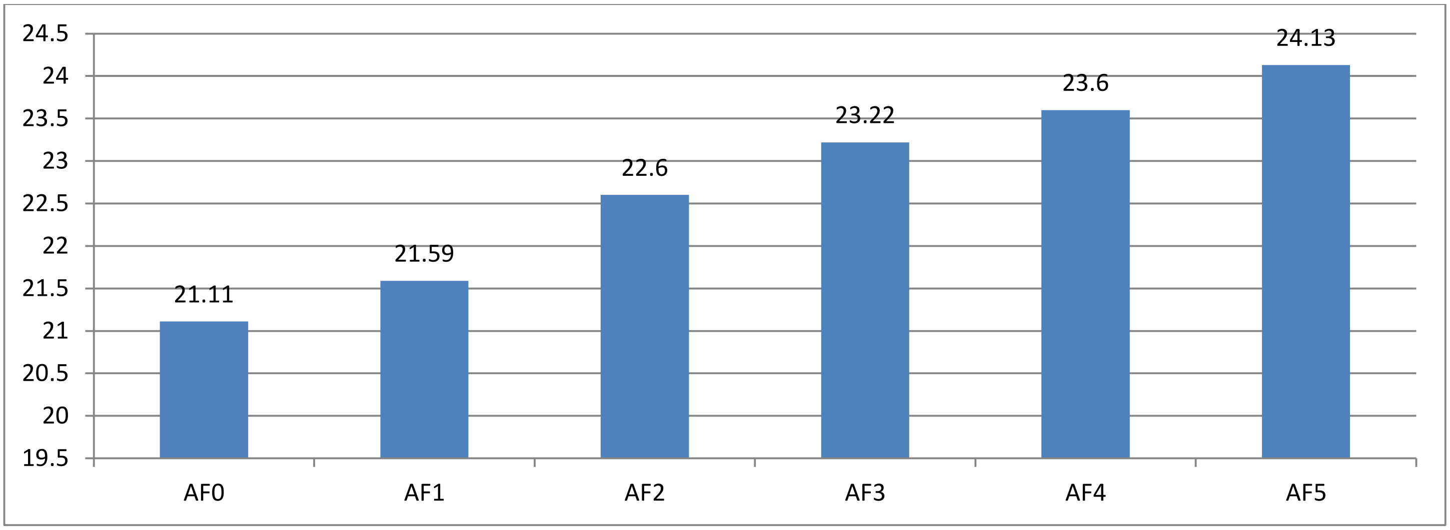


Figure 7.Major Principal Stress (Tension) after 28 Days Curing

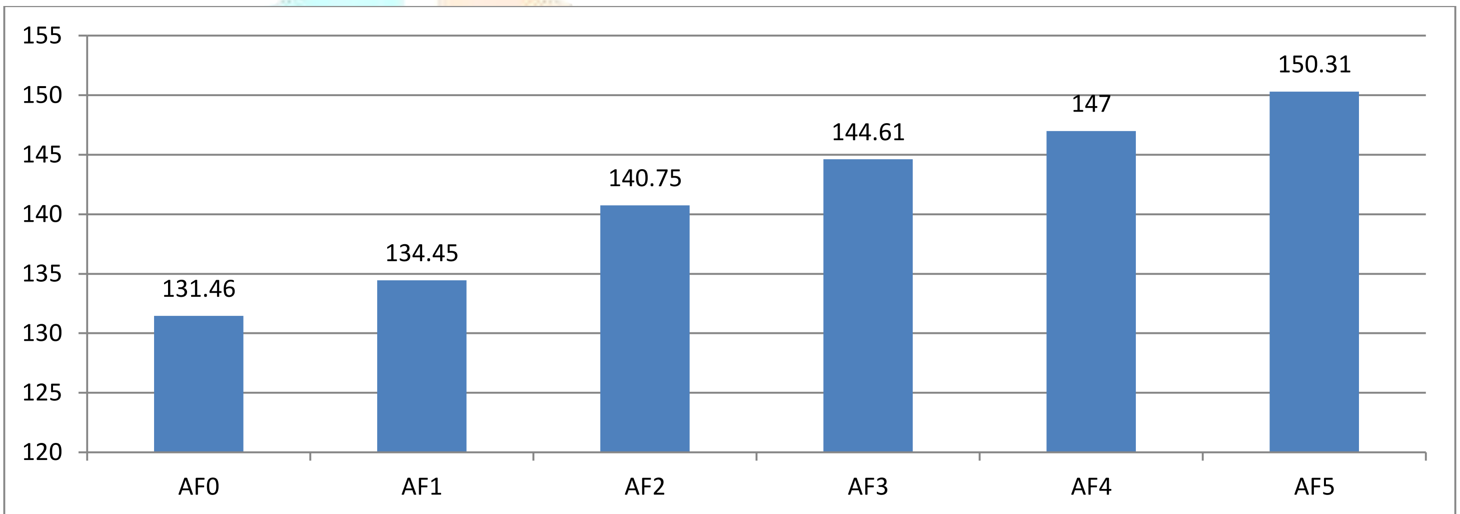
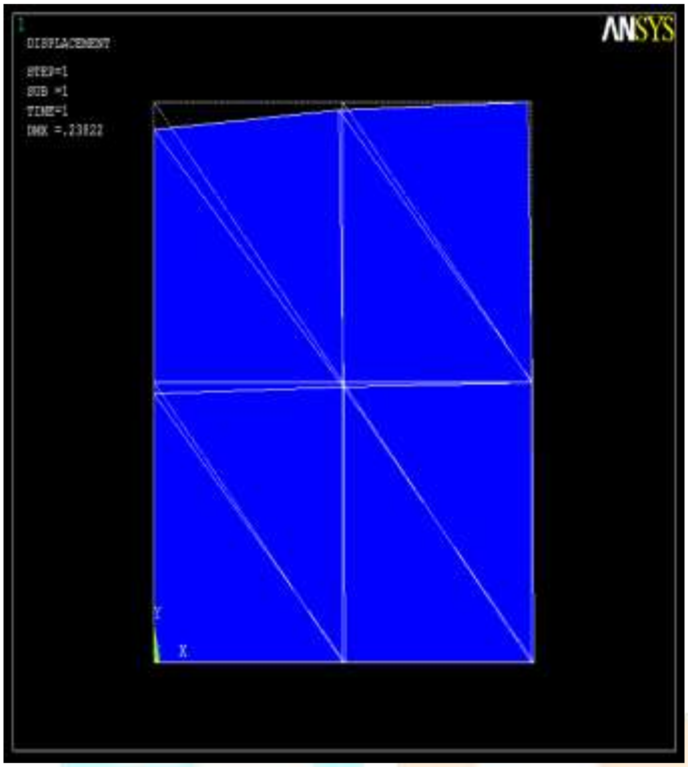
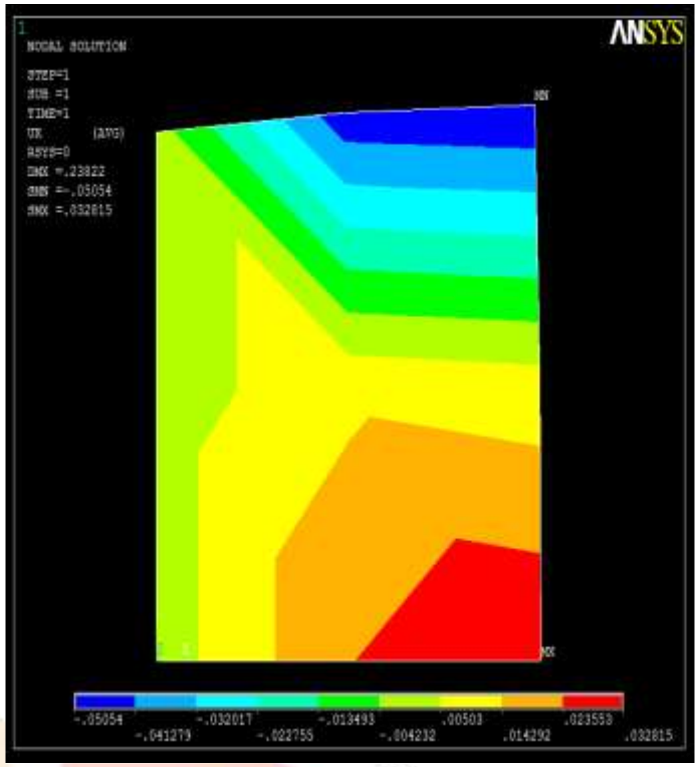


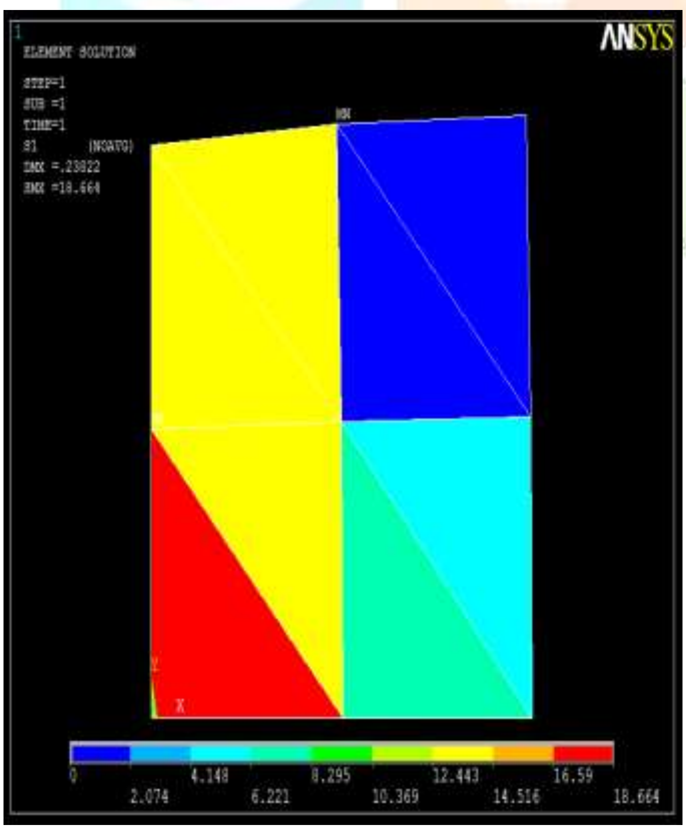
Figure 8.Minor Principal Stress (Compressive –ve) after 28 Days Curing



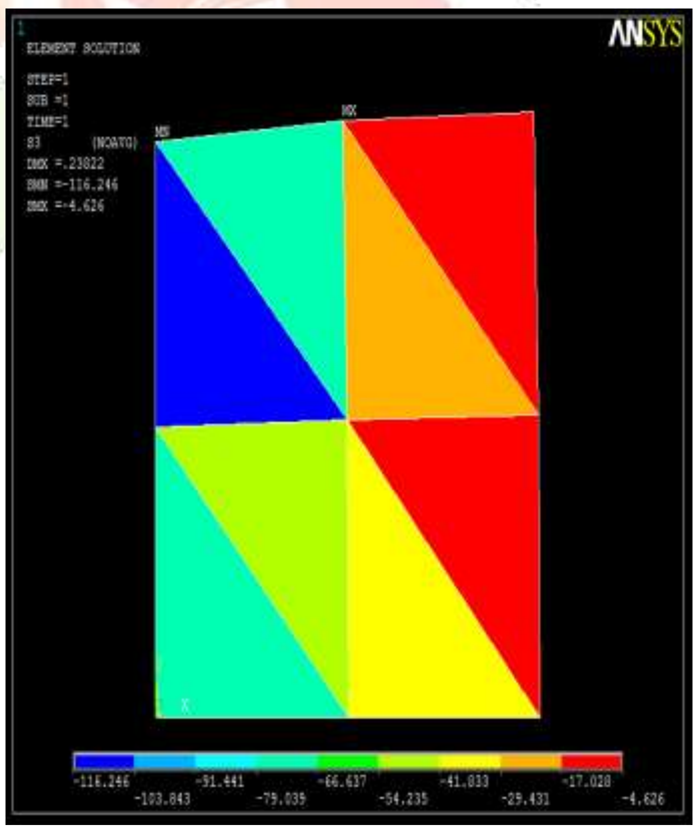
9a) Displacement Diagram



9b) Contour of Nodal Displacement

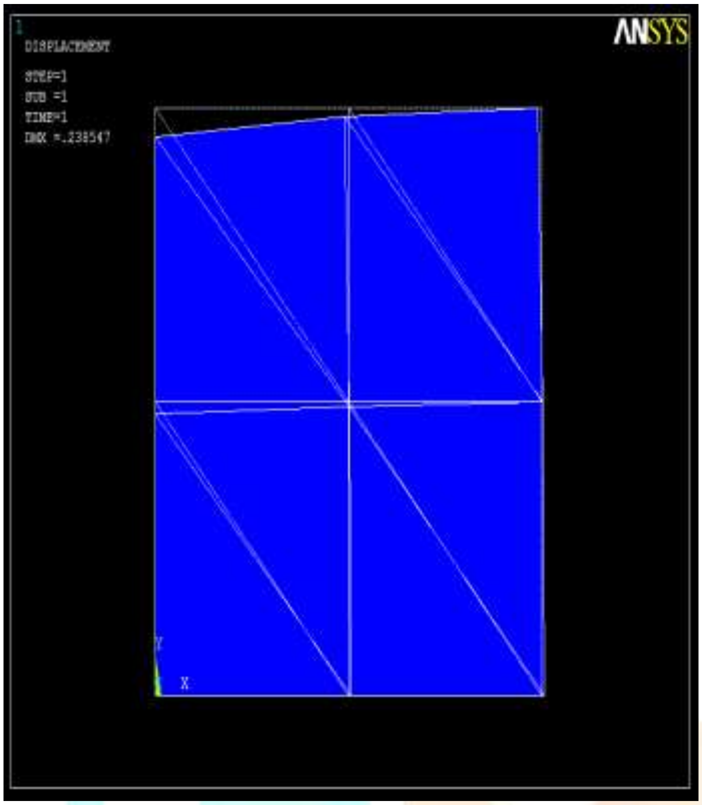


9c) Max Major Principal Stress @Element6

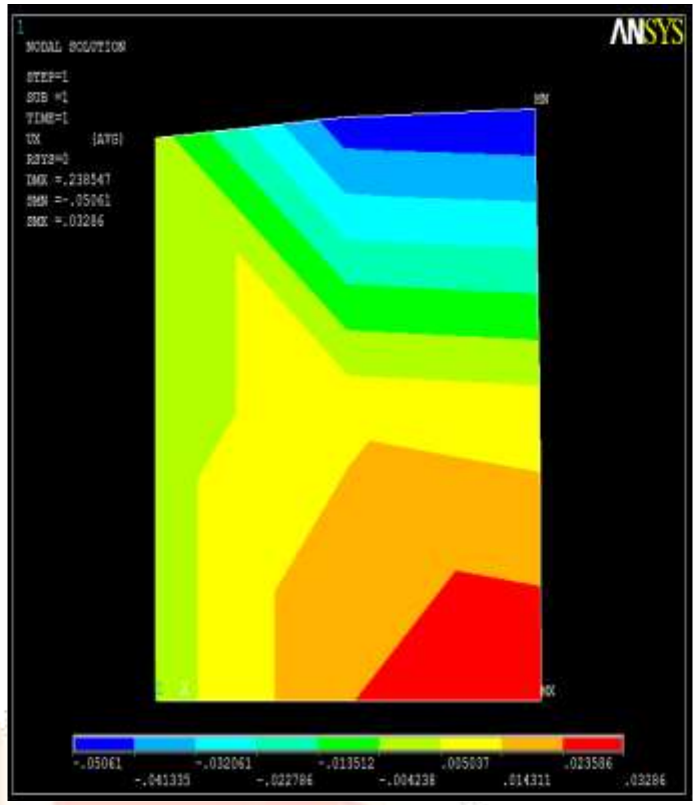


9d) Max Minor Principal Stress @Element 2

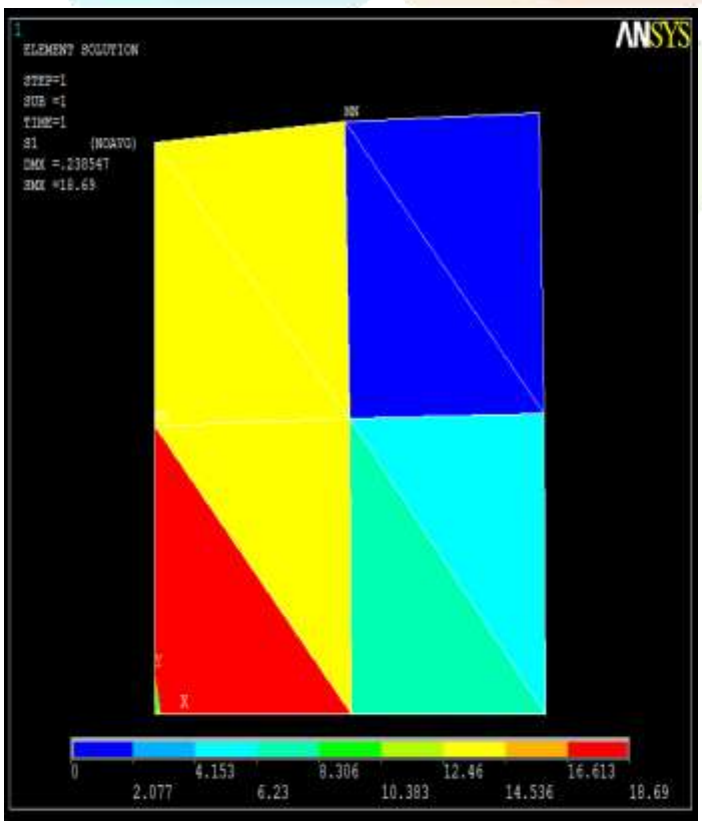
Figure 9. Stress Contour of Concrete Mix after 7 Days Curing



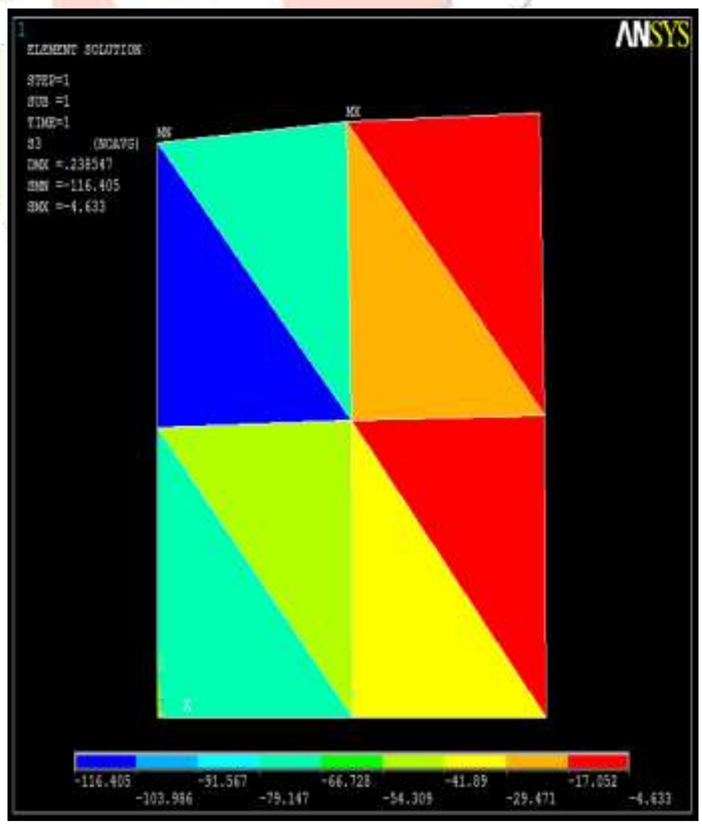
10a) Displacement Diagram



10b) Contour Of Nodal Displacement

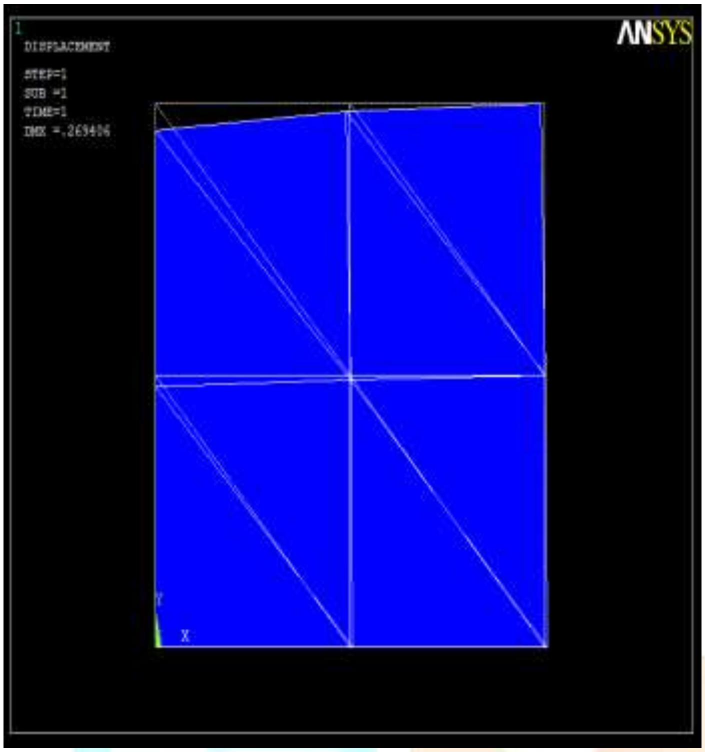


10c) Max Major Principal Stress @Element 6

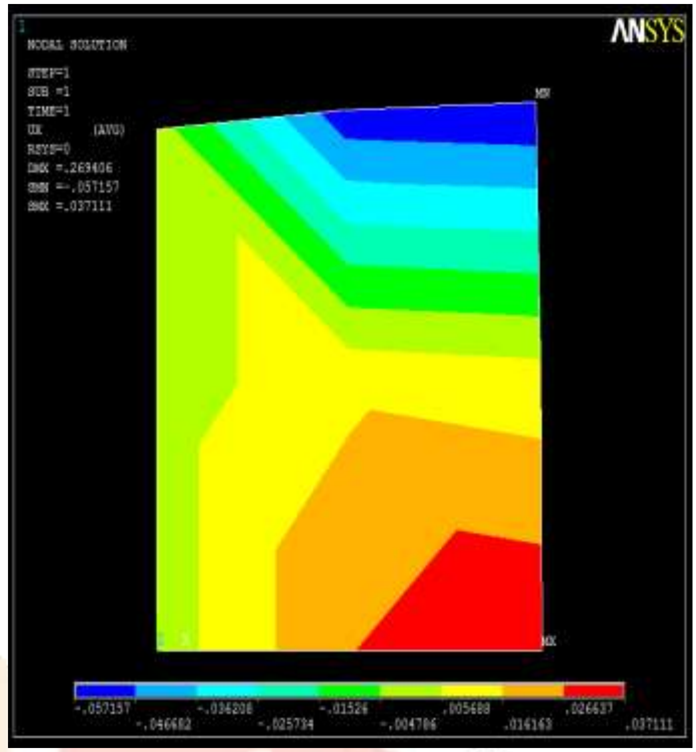


10d) Max Minor Principal Stress @Element 2

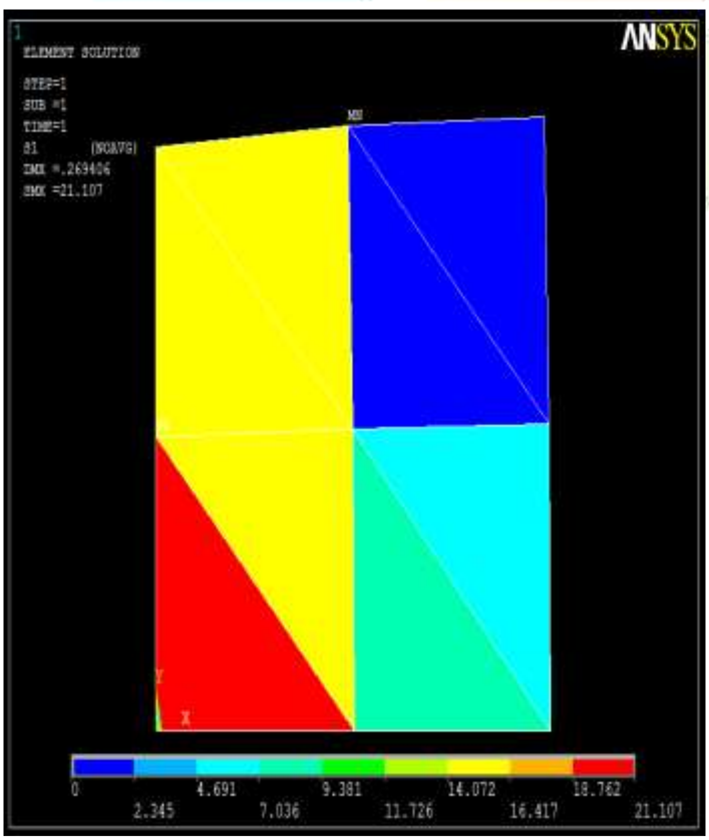
Figure 10. Stress Contour of Concrete Mix with 5% Alccofine after 7 days Curing



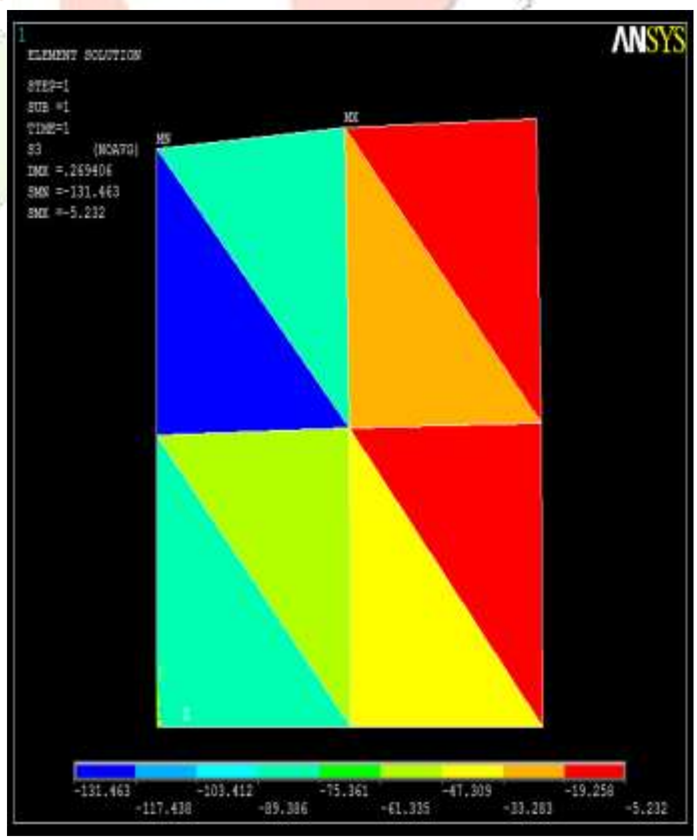
11a) Displacement Diagram



11b) Contour Of Nodal Displacement

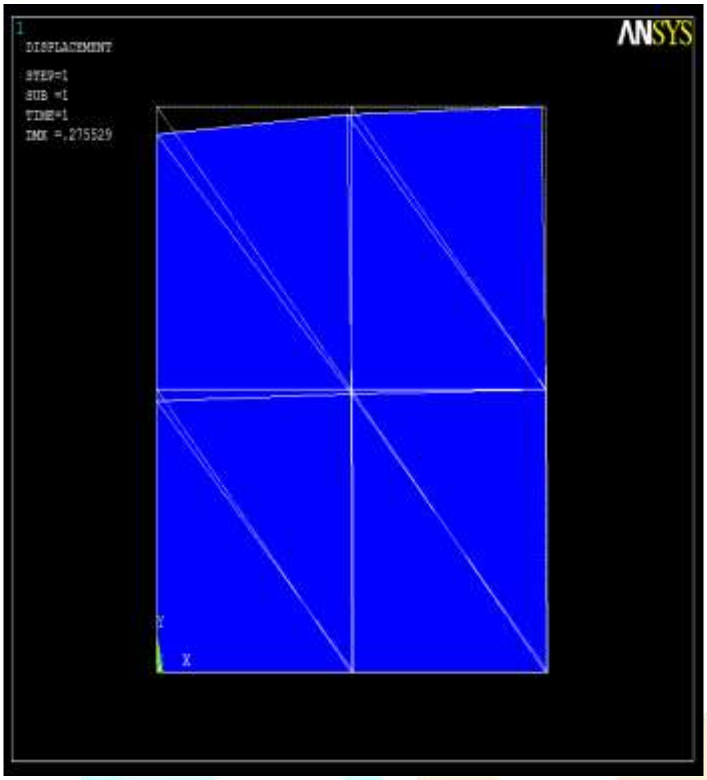


11c) Max Major Principal Stress @Element 6.

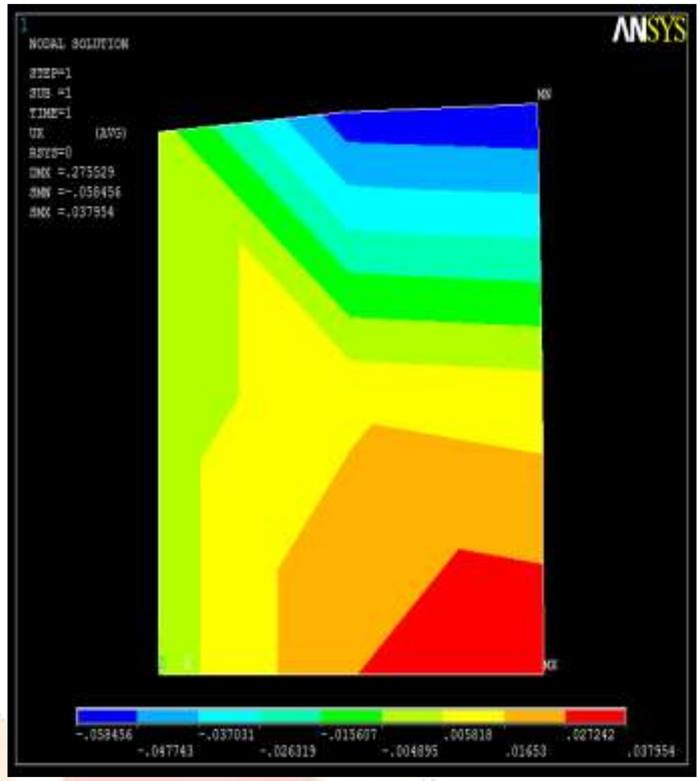


11d) Max Minor Principal Stress @Element 2

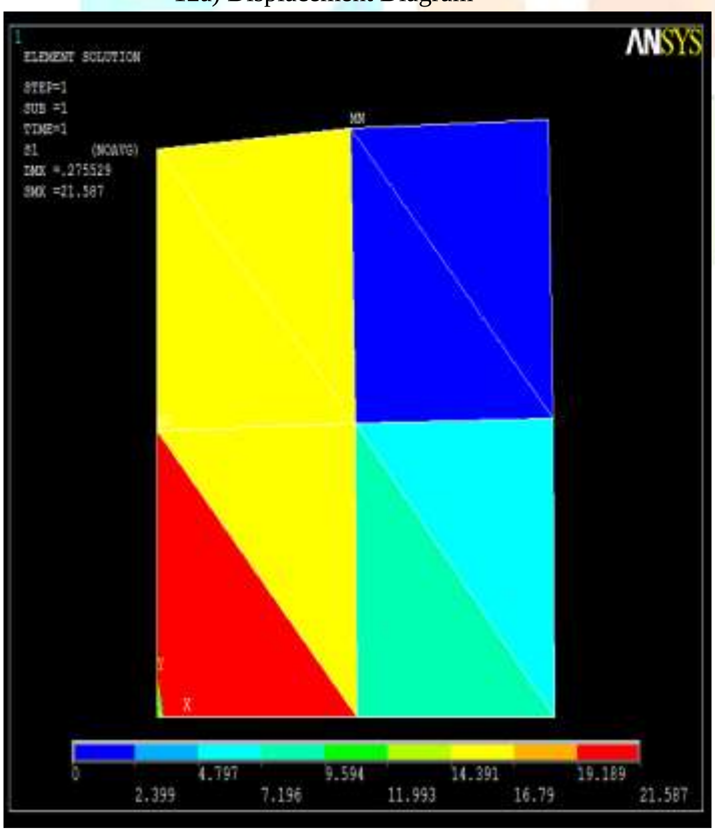
Figure 11. Stress Contour of Concrete Mix after 28 Days Curing



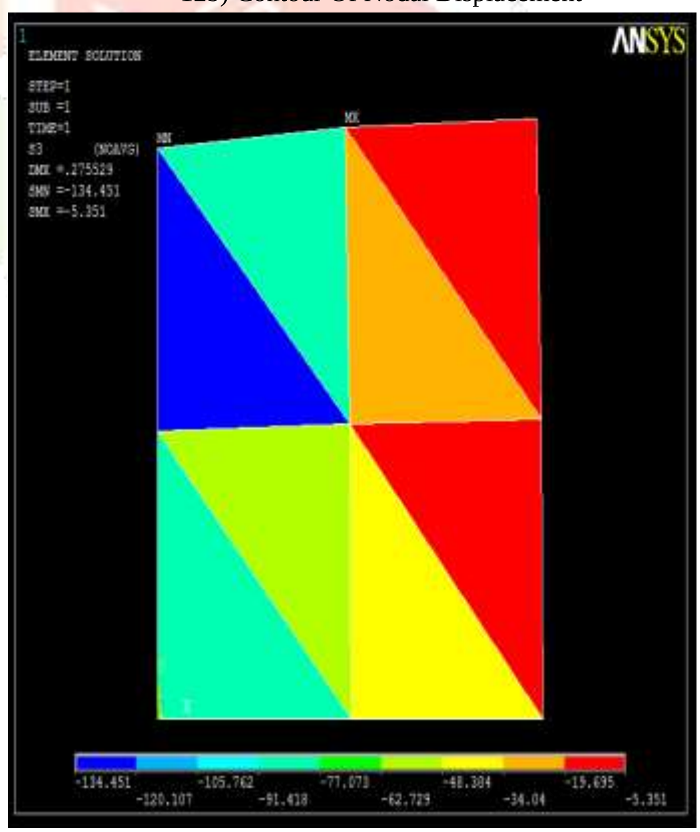
12a) Displacement Diagram



12b) Contour Of Nodal Displacement



12c) Max Major Principal Stress @Element 6.



12d) Max Minor Principal Stress @Element 2

Figure 12. Stress Contour of Concrete Mix With 5% Alccofine after 28 Days Curing

VI. CONCLUSION

The following points areaddressed in consequence of the experimental test results.

1. Alccofine powder reduces the workability of concrete on increasing its volume in the concrete mix it was found that slump value decreases for concrete mixes with alccofine when compared with reference concrete mix.
2. Due to inherent property of ultrafine powder, it enhances the compressive strength of concrete mix even at early stages. The compressive strength for reference mix 38.9 N/mm^2 and 44 N/mm^{2}after 7 and 28 days curing respectively. Lower concrete mix AF1 has higher strength than reference mix after 7 days and 28 days curing. On further increasing volume of Alccofine, compressive strength increases up to 43.4 N/mm2 after 7 days curing and increases up to 50.3 N/mm^{2}after 28 days curing.From the developed best fit models, compressive strength can be predicted with 99% accuracy prior to conducting experimentswith Alccofine concrete mix after 7 and 28 days curing.
3. For the experimental compressive loads, various plots for displacement, stress contours,major and minor principal stresses are exhibited for Alccofine concrete mixes after 7 days and 28 days curing by finite element analysis.

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