

# Review on Finite Element Modeling of RC Beam with addition of Fly ash & M-Sand in Concrete

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**ABSTRACT:** The buildings are composed of various structural units like column, beam and wall. The experimental study to understand the strength behavior of such component is widely developed by various researchers. On the other hand, to make the safe, durable and efficient structure some important modeling aspect is also required. Finite element analysis based software ANSYS is based suitable to determine the deformation, equivalent elastic stress and equivalent elastic strain. In the present study a RC beam is modeled and the cement & sand quantity is replaced by fly-ash in the varying percentage from 0% to 60%. The results of the study are revealed that the total deformation and maximum deformation is decreased with the effect of fly-ash. The obtained results indicated that the 50% fly-ash content is best suitable based on the deformation parameter in concrete mixture.

**KEYWORDS:** ANSYS 15.0, DEFORMATION, EQUIVALENT ELASTIC STRAIN, EQUIVALENT STRESS, FLY ASH, M-SAND.

## I. INTRODUCTION

Finite Element Analysis (FEA) was developed by R. Courant in 1943; it was depended on the RITZ methods. FEA is used for numerical analysis and minimization of error in calculation. Manually calculation is very much typical to do so that there are so many analytical methods to solve it in a very fast and easy way. FEA is using widely in now a day mostly in structural engineering and aircraft engineering. Here is a software ANSYS that can be used to create a model on it and analyze it in a very fine manner. ANSYS create mesh on the model and accurately calculate all the parameter using FEA phenomenon. FEA can be divided into four generations from 10 to 15 years. Now there are some changes in the direct stiffness method from 1934 to 1970. In fig 1, discretized element of a model is showing, how a large element can divide into small parts like a mesh. From finite element analysis, the complicated problem can be solved easily. It can be numerical and the analytical method is a very much long and time-consuming method as compare to the analytical approach.

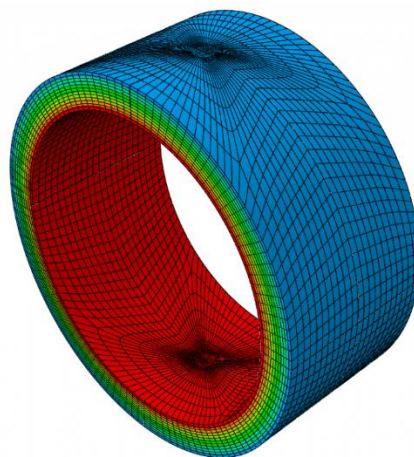


Fig. 1 Meshing of discretized element

[Source file:- <https://tortuetec.com/en/ref-proj/fea-pp-pipe-imperfection/>]

The replacement of material in concrete, beneficial for high rise building and bridge structure because the strength of concrete increased and density of concrete mix decrease. Replacement of material in the concrete mix, it's not a new technique, already various experimental studies carried out according to parameters and as per the properties of the material (Mohamed, Heba et al., 2011, Huang, Chung-Ho et al., 2013, Mengxiao, Shi, et al., 2015, Rao, S. Krishna, et al., 2016, Singh Sarbjeet, et al., 2016, Sonnenschein et al., 2016, Hama, Sheelan M., and Nahla N. Hilal 2017, Zhang, Yuliang, et al., 2018, Agrawal, U. S., et al., 2019, Khan, Mehran, et al., 2019, Zhou, Hongyu, and Adam L. Brooks, 2019). So in this study an analytical approach is used to find out certain important parameters which are unable to determine in the laboratory.

### 1.1. Finite element Method

Generally, the finite element method is also known as finite element analysis, in this method normally finding the approximate solution by using the numerical technique with the help of partial differential equations and sometimes also uses an integral equation. The finite element method is working on the built-up algorithm in which it divides all parts into many small numbers of elements and then analyze the elements with making the relationship between these elements. FEM is using the Galerkin method to solve the equation. In this method, some polynomial approximation function is also working to solve. In this method, the spatial derivatives are changed to a partial differential equation by eliminating the spatial derivatives.

### 1.2. ANSYS

ANSYS markets and develops finite element analysis software used to solve complicated technical problems. This software creates imitative computer models of electronics, machine or structures, components to calculate fluid flow, toughness, temperature, strength, distribution, electromagnetism, elasticity, and other properties. ANSYS is used to determine how can create and test on a specimen on their different specifications, without doing any building test and without conducting a crushing test, etc. For example, this ANSYS software can use to show how a bridge can be stand after years for traffic, how to design a slip made from less material without any safety issue.

#### 1.2.1. Structural Analysis with ANSYS

ANSYS is the structural analysis software can solve complex structural engineering problems and make faster & better design decisions. With the finite element analysis (FEA) many tools are available in the software, you can customize and find solutions for your structural & mechanics problems and characterize them to analyze multiple or more than one design model. You can connect easily one analyze to other physics analysis tools. ANSYS is mechanical & structural analysis software used in whole the engineering industry to reduce the costs of testing & optimize their product designs.

## II. MATERIALS USED

**Cement:** According to IS-8112 (1989), simple portland cement of 43 grade available in the local market is used in the investigation. The specific gravity of cement is 3.15.

#### **Fly ash:**

Fly ash used in this SCC is from Vijayawada Thermal Power Station. This is a waste product, which is produced by combustion of coal. Fly ash reduces pollution even compared to cement. Low heat of hydration is produced by adding mineral reagents like fly ash.

#### **Fine aggregate:**

All is well in SCC. Overall size and upgrades play a major role in making self-compacting concrete. In the field of IS 383: 197, the locally available river basin is used.

#### **Coarse aggregate:**

In this SCC small size and limited thick set should be used so that internal stress can be reduced due to interruption. The size of the coarse total in this mixture was 10mm, 12.5mm and 20mm.

**Water:** The water used was fresh, colorless, and tasteless. In this experiment, portable water is used free of organic compounds

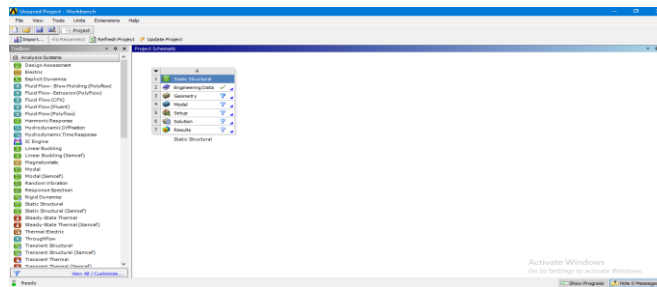
**Super plasticizer:** Super-plasticizers and viscosity modified agents available in the market names of Master Gelenium Sky 8630 are used as a chemical mixture to increase paste flow and prevent isolation.

**M-Sand**

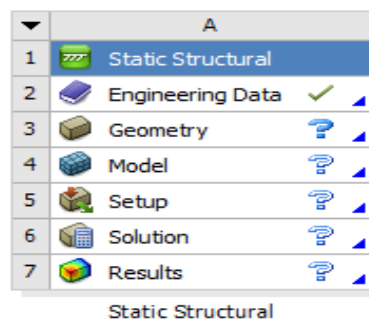
It is an alternative replacement of river sand because according to growing in construction industry increased the demand of sand. More uses of river sand are destroying the nature so replace the river sand in construction material. M-sand have many advantage as compare river sand, it's cost effective as material and as transportation of material also reduce the cost. Manufactured sand, manufacture at industry from crushed hard rock and easily available near at the construction site. Due to the M-sand reduce the construction cost and main advantage of m-sand is, can easily controlled the size of sand so get the exact grading of sand as require of the construction. Figure 1.3, showing a picture of M sand.

**III. MODELLING IN ANSYS**

In this Study, A model of beam is composed in ANSYS Software and analyzed. In which finite element analyses of a beam by adding fly ash & M-sand in concrete on difference percentage. This study is about analysis of beam by using different property of concrete by using fly ash & m sand percentage in concrete. Different range like 10%, 20%, 30%, 40%, 50%, 60% and 100% of fly ash used in concrete and similarly range is tested with M- sand for calculating some parameter like Total deformation, Equivalent elastic strain & Equivalent stress through ANSYS. These kinds of parameters are not possible to find in laboratory tests so here this study have the analytical solution of those parameter. For finite study of beam ANSYS workbench is under use which is basically the mechanical software but now days it is using in civil engineering also. Equivalent elastic strain, equivalent stress and total deformation of beam for every configuration have been calculated by using this analytical approach for analyses. The results obtained from solving different parameter have been compared with experimental data of same beam with same properties.



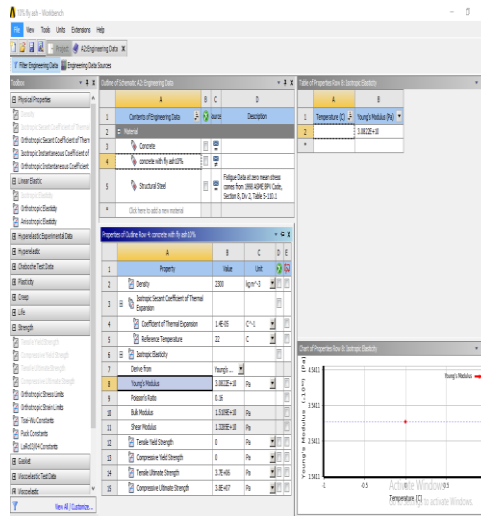
**Fig. 3.1 ANSYS Workbench Toolbox**



**Fig. 3.2 ANSYS Workbench Toolbox (Static Structural is selected)**

**Modeling of Beam**

There are so many kinds of parameters, which affect the non-linear behavior of a structure. In different load conditions, structure response and stiffness will be different. For structure engineering modeling static and dynamic structure is used in ANSYS. Here static structure has used for analyses. In static structure first it needs to take static structure and then give name to static structure then need to provide material properties for that it needs to use engineering data for adding new properties or edit old properties of materials. It can change physical property like isotropic, orthotropic, linear elastic, hyper elastic experimental data, plasticity, creep, life, strength, visco-elastic, damage, thermal, cohesive zone etc.



**Fig. 3.3** Toolbox shown in ANSYS window

Properties of Outline Row 4: concrete with fly ash 10%				
	A	B	C	D E
1	Property	Value	Unit	
2	Density	2300	kg m <sup>-3</sup>	
3	Isotropic Secant Coefficient of Thermal Expansion			
4	Coefficient of Thermal Expansion	1.4E-05	C <sup>-1</sup>	
5	Reference Temperature	22	C	
6	Isotropic Elasticity			
7	Derive from	Young's ...		
8	Young's Modulus	3.0822E+10	Pa	
9	Poisson's Ratio	0.16		
10	Bulk Modulus	1.5109E+10	Pa	
11	Shear Modulus	1.3285E+10	Pa	
12	Tensile Yield Strength	0	Pa	
13	Compressive Yield Strength	0	Pa	
14	Tensile Ultimate Strength	3.7E+06	Pa	
15	Compressive Ultimate Strength	3.8E+07	Pa	

**Fig. 3.4** Property window of 10% Fly ash used concrete

As figure 3.4 describe the window of properties of concrete by using 10% of fly ash in this. Similarly 20%, 30% 40%, 50%, 60% and 100% of fly ash and M sand use in concrete will show their properties, which will be defined in this table.

**Model generation**

When geometry is completed or finally generated then model window takes in use. In model window project is on top then model is under this. Geometry is in model folder which have solids or surface which user have created in geometry window. As shown in figure 3.5 here, window of model. In top of window file, edit, view, units, tools and help are menus of menu bar. On right side solve, show error, worksheet etc. are also useful option on model. Then selection point like selection by node, selection by edge, selection by face and selection by body or surface etc. in below bar show vertices, show mesh, wireframe such are some option used to show these kind of properties of model. Following are the options which can insert in the model:

- (1) Named selection
- (2) Construction geometry
- (3) Virtual topology
- (4) Symmetry

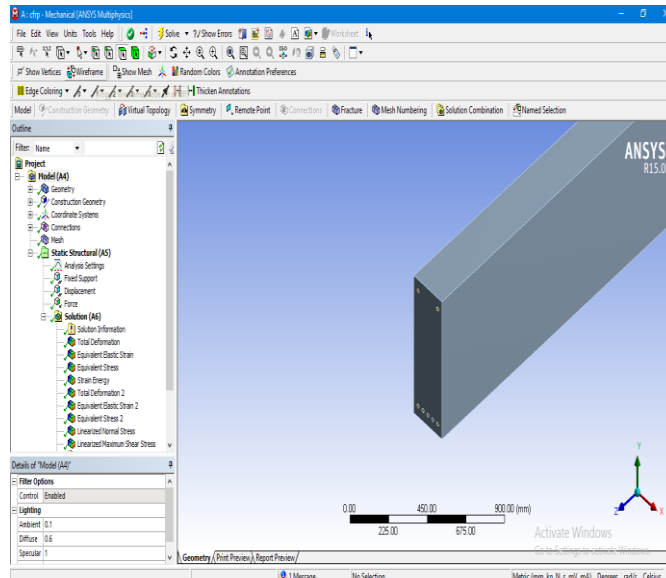


Fig. 3.5 Model window of ANSYS Workbench

Table 3.1 Properties of Fly Ash used in Concrete (M-30)

S. No.	Fly ash %	Concrete Properties		
		Compressive strength of cubes at 28 days (N/mm <sup>2</sup> )	Modulus of elasticity (E), (N/mm <sup>2</sup> )	Split tensile strength of cylinder at 28 days (N/mm <sup>2</sup> )
1	0%	39.58	31456.32	3.70
2	10%	38.00	30822.07	3.70
3	20%	39.00	31224.99	3.80
4	30%	40.00	31622.78	3.90
5	40%	41.00	32015.62	4.00
6	50%	42.82	32718.50	4.10
7	60%	41.00	32015.62	4.10

After changing the percentage of Fly ash & M sand, properties of concrete has been changed as described in table 3.1 & 3.2 respectively.

In this study, beam element is modeled by using solid body to make a simple model and less time consuming in analysis. Solid body is a 3-D element, where length of solid body is assigned by a command called extrude. ANSYS Workbench uses Extrude tab for making length of a body in which user can define length and unit of a surface created in geometry.

Table 3.2 Properties of M-Sand used in Concrete (M-60)

S. No.	M Sand %	Concrete Properties		
		Compressive strength of cubes at 28 days (N/mm <sup>2</sup> )	Modulus of elasticity (E) (N/mm <sup>2</sup> )	Split tensile strength of cylinder at 28 days (N/mm <sup>2</sup> )
1	0%	57.80	38013.16	3.20
2	10%	60.80	38987.18	4.03
3	20%	60.15	38778.22	4.17
4	30%	63.20	39749.21	4.17
5	40%	67.11	40960.35	4.51
6	50%	67.27	41009.15	4.73
7	60%	69.23	41602.28	4.83

**IV. RESULTS BASED ON MATERIAL PROPERTIES**

Following materials were used in the study:

- Fly ash
- M sand

Following results parameter are found on all five specimens:

- Total deformation
- Equivalent elastic strain
- Equivalent stress

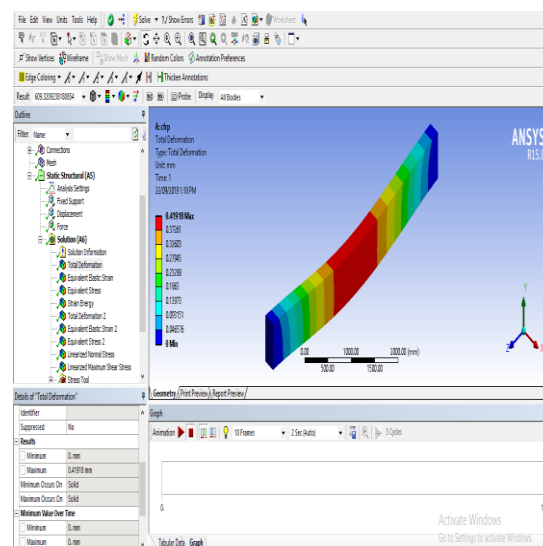


Fig 4.1 Total deformation on body due to Fly Ash

Colour describes the value like maximum deformation at the centre showing a red colour and blue colour describe the zero deformation. This total deformation is on the whole body defines in node numbers and deformation. Result data on all 145749 nodes are available in mm, it can easily export in excel sheet. That data cannot be shown in this study because of number of nodes are high in range. So at the time of modelling a path is created in construction geometry,

deformation on that path is defined on the length of the Then a length vs total deformation in mm graph is plotted. colour describe the range of deformation on defined path. Path is from one top edge to another top edge of the beam. specimen.

## V. CONCLUSIONS

The reviews of many research papers have been studied in the field of ANSYS, analytical & experimental approaches, to examine and determine the present and future scope of work. In a research, paper fly ash & M sand are used in a concrete for experimental approach to found, mechanical property, compressive strength, flexure strength, Hardness test, toughness test etc. An analytical, experimental and numerical approach was carried out in papers for different kind of material & test. Analysis of research was carried out in deep for a common finding of future work, strength, weakness, and gap was found to form new methodology for analyzing a beam with concrete property changes. Replacement of cement with Fly ash & replacement of sand with M sand has done in concrete beam then dissertation title is selected as-

### “Finite Element Modeling of RC Beam with addition of Fly ash & M-Sand in Concrete”

The first chapter was the introduction of ANSYS and also about the used parameters. The second chapter presented the review or study done for the dissertation. The third chapter mentioned the way of the process, how modeling and analysis were done & what kind of property taken. The fourth chapter gives the comparisons of the results in the form of a table, graph, and figures. The fifth chapter is about concluding all the studies.

Based on the analytical study of RC beam with the effect of addition of fly ash and M-Sand, following conclusion can be drawn:

- The maximum deformation obtained at 10% addition of fly ash further increase in the content of fly ash decreases the maximum deformation till 50% content, thereafter (at 60% fly ash content) content marginal increment is observed. The Maximum deformation decreases continuously till the addition of 60% M-Sand content. However, the reduction in deformation is more effective with the M-Sand as compare to fly ash.
- The addition of 10% fly ash increases the max equivalent elastic strain further addition of fly-ash reduces the results up to 50% fly ash content, after that minor increment is observed at 60% fly ash content. A continuous downtrend is observed with the effect of M-Sand content on maximum equivalent elastic strain. The comparative results elucidate that the M-Sand shows better control on equivalent elastic strain as compare with fly ash.
- On contrary, the maximum equivalent stress is reduced till the 10% content of M-Sand, further addition to 50% fly ash content increases the stress, thereafter an appropriate increment is observed at 60% fly ash content. A zig zag trend is observed with the effect of M-Sand content on max equivalent stress, so it was very difficult to predict the trend in this aspect.
- As per the obtained result it can be summaries that the 50% fly ash and 60% M-Sand addition on concrete mixture gives the suitable results based on the maximum deformation, equivalent elastic strain and equivalent stress. However, cost calculation and comparison with the experimental results are the limitation of this work, which is the part of the future study.

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