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Application of Finite Element Method in Engineering- A Brief Review

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Abstract*— Finite Element Method (FEM) is a numerical method of stress analysis having large complexities of the problems like, varying shape, boundary conditions and loads. It is also powerful technique for stress analysis in aircraft, large machine body and large structural elements. This paper reviews the recent development of FEM and its application in science and technology fields for sustainable and computerized development of engineering fields. In this method the whole elements are divided in to various elements with numbers of nodes and calculation and analyzed separately and designing it. The high performance computing facilities and advanced finite element programs are now available for research and development activities in many universities in collaboration with industries. Basically STAAD.Pro, GT STRUDEL, NASTRAN, NISA and ANSYS etc. computer software are used for analysis and solving the many complex structures. Now days this method is used not only for the analysis in solid mechanics, but even in the analysis of fluid flow, heat transfer, electric and magnetic fields and many others. In civil engineering, this method extensively for the analysis of beams, space frames, plates, shells, folded plates, foundations, rock mechanics problems and seepage analysis of fluid through porous media. Both static and dynamic problems can be handled by finite element analysis. This method is also used extensively for the analysis and design of ships, aircrafts, space crafts, electric motors and heat engines.

***Keywords*— Finite Elements Method, Structural Engineering, Nodes, Elements**

I. INTRODUCTION

The various Engineers, scientist and mathematicians have invented finite element analysis independently in 1943 Courant made an effort to use piecewise continuous functions defined over triangular domain. After a decade various developers are introduced the concept of applying principle of structural analysis problems and development the name of Finite Element Method. Finite elements play an important role in providing accurate and reliable results, since it would impact important decisions which are taken based on the FEA result.
The several researchers are research on this topic and finalized the elementary analysis of structures and they are idealized the problems and limitations of finite element formulation of different elements had been identified when assuming a displacement function and when obtaining the stiffness matrix. Problems can be occurred due to the assumption of lower order displacement polynomial function and use of a numerical integration to obtain stiffness matrix.

II. LITERATURE REVIEW

Walls *et.al,* (2019) studied a nonlinear finite element with variable, eccentric neutral axis. This paper conducted a thorough study on beam finite element and analysis methodology for structures with variable, eccentric neutral axis. The shift of neutral axis occurs due to non-linear material behavior (softening, cracking, etc.). This analysis is used to the non-linear analysis of structures such as wind towers and bridge decks where the position of the neutral axis in a beam section changes due to material nonlinearity. The case studies provide the influence of cross-sectional distortion and its affect on internal force distributions. For the analysis cantilever beam with material non-linearity is analyzed by applying a moment of 30 kNm. The NA shifts upwards by 12.7mm for E_0 = 200 GPa and 3.3mm for E_1 = 20 GPa. The maximum difference between solutions when the NA does shift is 0.5%. The Abacus model and the FBE formulation predict very similar deflections, differing by a maximum of 1.0% and 1.9% at maximum load for material E_0 and, with the FBE formulation predicting lower deflections.

Naveen *et.al,* (2019) studied finite element analysis of natural fiber-reinforcement polymer composites. This paper conducted experimental and numerical studies infinite element analysis of natural fiber-reinforced polymer composites. The principal objectives of this research are to model 1D, 2D, 3D structure by assigning suitable material property, elements, meshing, and applying proper structural boundary conditions. ANSYS is used for analysis software. In the case of micromechanical simulation the models were created by assuming uniform material properties in the cross-section and the gradient properties of the material in the axis. Natural fibre-based polymer composites are widely used in many industries due to their light weight, eco-friendliness, low cost, and higher mechanical properties. The interfacial damage analysis of fibre reinforced polymer composites is done by applying a perfect bonding to the boundaries of the fiber/matrix interface, and then a frictional contact is implemented on the fiber/matrix interface to model the mechanical properties. It is found that the representative volume element method is the most popular homogenization-based multi scale constitutive method used in finite element modeling to evaluate the impact of microstructures on the mechanical and thermal properties of NFRPC.

Yanga et.al, (2019) studied automatic finite element modeling for deformation analysis of composite structures. This paper focused their research on deformation analysis of composite structures by finite element method. This paper combines the three-dimensional laser scanning technology and finite element method (FEM) to investigate the deformation mechanism of arched structures. The deformation behavior of arched structures is analyzed based on ANSYS simulation and prediction with the calibration of TLS measurement. The experimental results show that the theoretical model presented is effective for the prediction of carrying capacity, deformation character and mechanical properties of arched structures, which indicates that the dynamic model is valid and the simulation analysis is reliable.

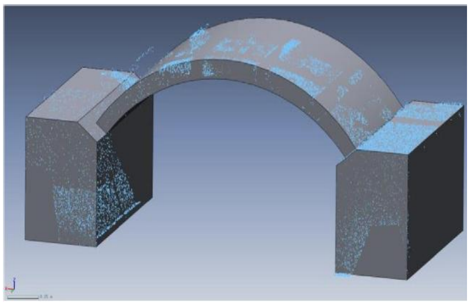

Fig.1: FEM model of the arch [3]

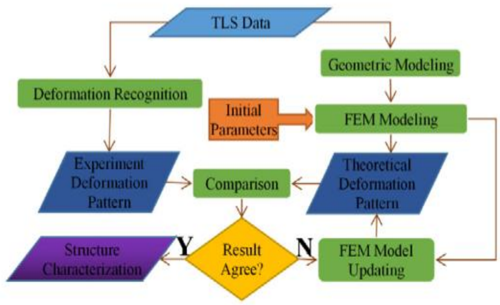

Fig.2: Work-flow of the FEM model [3]

Parisi *et.al,* (2017) investigated structural failure through probabilistic nonlinear finite element analysis: Methodology and application. This paper conducted research on structural failure investigations through probabilistic nonlinear finite element analysis. Structural failure investigations are strongly influenced by high levels of uncertainty in modeling parameters. In this study, a failure investigation methodology including uncertainty characterisation, modelling and propagation is presented and applied to a historic piper no stone balcony, collapse of which caused four casualties. Based on field inspections, laboratory surveys and experimental testing, a three dimensional finite element (FE) model with four alternative restraint conditions was developed and material properties were statistically characterised. It conclude that by applying proper material and loading condition in model, pre determination of failure of model can be effectively evaluated by the finite element method.

Table 1: Peak load capacity and corresponding vertical displacement of the balcony [4]

Restraint condition								
Statistic	RC1		RC2		RC3		RC4	
	F_{max}(kN)	□Fmax (mm)	F_{max}(kN)	□Fmax (mm)	F_{max}(kN)	□Fmax (mm)	F_{max}(kN)	□Fmax (mm)
Mean	170.39	3.05	115.34	3.10	81.79	2.90	10.76	0.54
CoV	14.95%	27.21%	11.51%	23.23%	7.68%	21.38%	2.04%	7.41%

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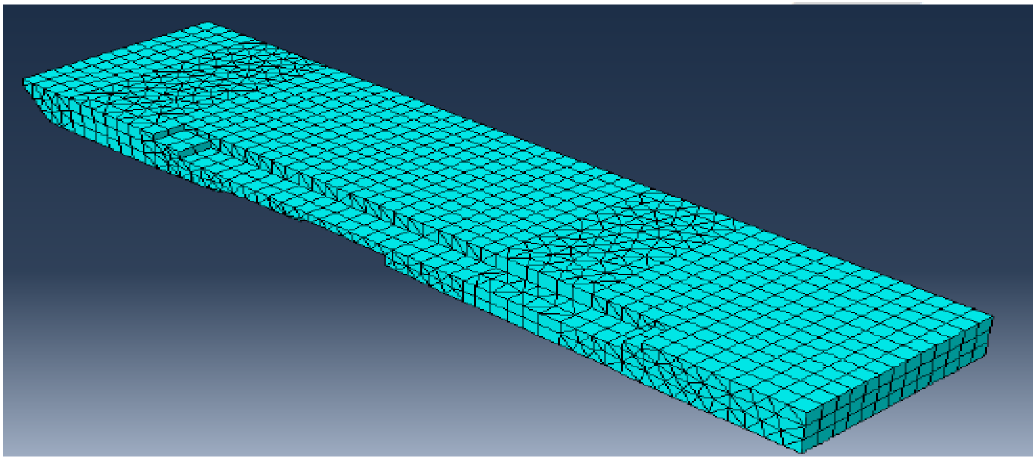

Fig.3: FEM model of the balcony [4]

Adan ***et.al,*** **(2017)** constrained shell Finite Element Method, Part 2: application to linear buckling analysis of thin-walled member's .This paper conducted an investigation on the buckling analysis of thin-walled members by finite element method. A general FEM is notable to separate the various buckling modes, so we can't directly use it in standard capacity calculations. Here member is discredited both in the transverse and longitudinal directions, and the longitudinal base functions are modified from the trigonometric functions of FSM to polynomial functions. A column of 500 mm long, doubly symmetrical I-shaped cross section (40×10 mm flanges, 200×4 mm web) is used for analysis. The result of analysis show global buckling solutions are in accordance with the expectations: the first mode is a minor-axis flexural buckling with one single longitudinal wave, the second mode is a pure tensional mode with one single wave, while higher modes consist of multiple waves along the member length.

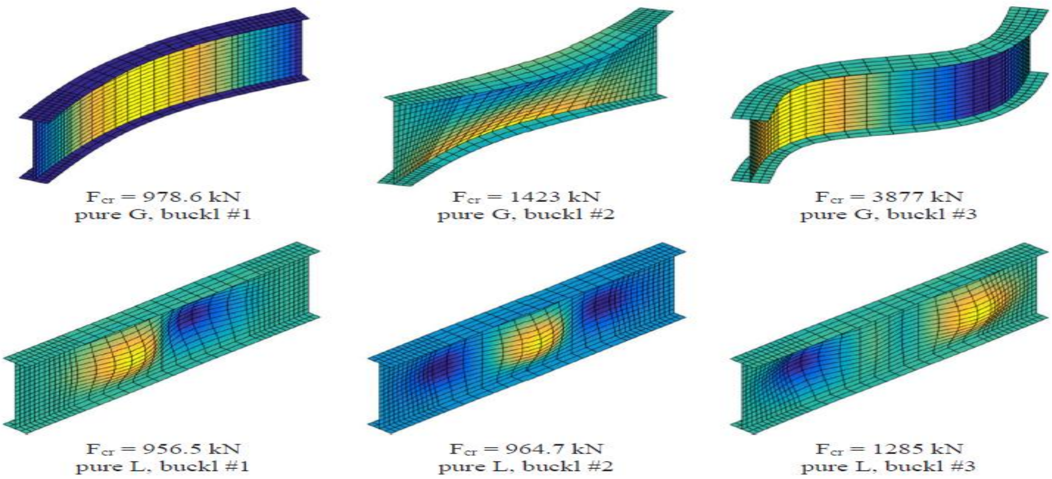

Fig.4: Global and Local Buckling [5]

Chakrabarty ***et.al,*** **(2016)** studied finite element analysis in process safety application. This paper conducted a thorough study of finite element analysis in process safety application. Finite element analysis is powerful in process safety applications and can address a diverse set of problems, including fluid dynamics. The dispersion modeling and problems dealing with both fluid flow and structure, such as for studying interaction between fire and structure can also be analyzed. The finite element analysis can handle structural response, damage detection and mechanical failure due to stress in the structure. The failure of the structure on the various physical, loading and environmental conditions can be effectively studied by finite element analysis.

David *et.al,* (2016) investigated practical Application of the Stochastic Finite Element Method. This paper focused their research on the stochastic finite element method. It is an extension of the FEM that considers the uncertainty of a system which arises through variations in initial conditions, materials or geometry.This paper introduces the most commonly used techniques: direct Monte Carlo simulation, the perturbation method and the spectral stochastic finite element method. It then looks at the currently available software for the SFEM and provides examples from the disciplines of materials science, biomechanics and engineering to illustrate different procedures by which the SFEM is practically used. The SFEM is also used to the effective elastic Young's Modulus and Coefficient of Thermal Expansion (CTE).

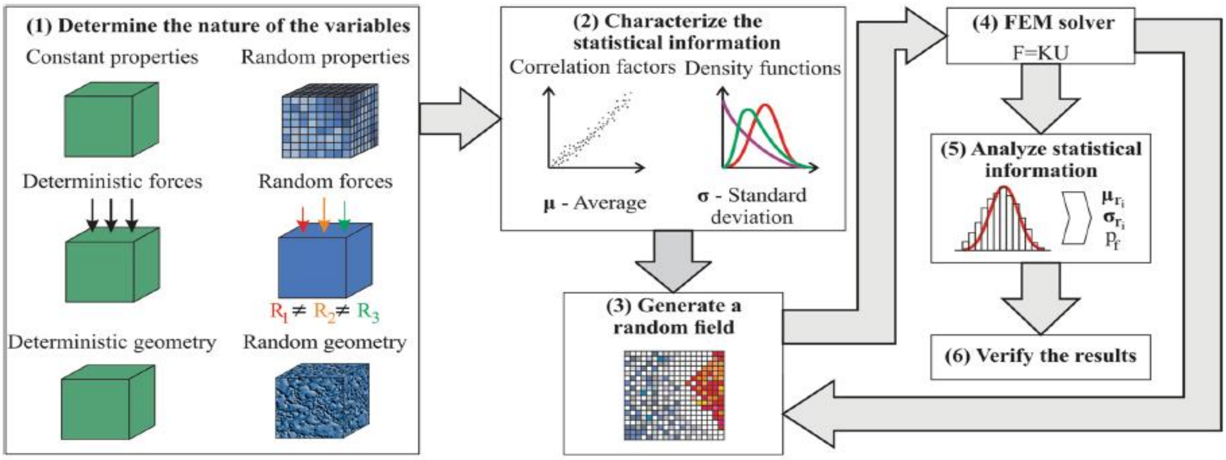

Fig.5: Schematic of the general procedure of the stochastic finite element method [7]

III. CONCLUSIONS

The above study shows that there is wide range of application of finite element method. It can be used to find the material properties, response of structure, and failure prediction of structure, damage assessment, and behavior of structure in different environment. It can be effectively used in analysis of fiber polymer composite and the buckling behavior of thin walled section. Deformation analysis of composite structures, heat conduction and seepage through porous media can be also analyzed. It is the most commonly used process for the stress and deformation calculation, So FEM is the strongest and reliable tool for analysis various physical and mechanical properties and it has multi range application.

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