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NUMERICAL ANALYSIS OF FRAME USING APPLIED ELEMENT METHOD

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Abstract-Numerical methods are playing a predominant role in structural analysis. Though there are many numerical methods, some are time taking and some are less accurate when compared to other methods. Methods like finite element are accurate in the results but the efficiency in showing stresses anywhere on the structural element is very low, it can calculate only in high stressed areas and it cannot show failure of the element or structure. In this study an effective Applied Element Method is used which gives accurate results and can show the stresses at any point of the structural element and complete failure criteria can be observed. From the initial point till the separation of elements, the complete process can be seen and data at each point can be gathered.

A linear static analysis of 1 bay 1 storied RC frame is done using two methods, one with displacement control and other with load control. Displacement control is done while permitting the frame to have a maximum displacement (in two cases) 0.01 m and 0.02m which is done in 100 increments. Similarly, in load control case, the maximum loads given to the frame are 5 &10KN which are applied to frame in 100 increments. The complete analysis of frame is done using Compaq visual fortran5.5, which is a compiler that shows graphical and numerical data as output for the given input resource files (inpmesh, bcdata , lddata). The data for each increment is considered, results are discussed by comparing both control cases. The behavior of the frame from initial increment to final increment and also failure of springs at each increment also plotted.

Keywords- Applied Element Method, springs, elements, load, displacement

I. Introduction

Numerical methods for structural analysis can be classified into two categories:

Continuum model:

The FEM is typical example of this category. Analysis of structures, especially concrete structures can be performed at most before failure. The FEM can answer only the following question which is “will the structure fail or not? “Unfortunately, it is very difficult to use FEM for the second important question “how does the structure collapse?”

Discrete model:

These category techniques can follow the structural behaviour from zero loading and up to collapse of the structure. However, the accuracy of EDEM is small, deformation range is less than that of the FEM. Hence the failure, load cannot be predicated accurately using EDEM.

This is where Applied Element Method has an edge over other numerical analysis.

The Applied Element Method (AEM) is a numerical analysis used in predicting the continuum and discrete behaviour of structures

II. Literature Review

“Hatem tageldin: AEM program 1st born at the University of Tokyo as a part of Professor Hatem Tagel Din's research studies on the analysis of structures subjected to the extreme loading conditions generated during a seismic loading. Since 1995 the research of AEM has been an ongoing project, with many validation tests being conducted and research papers published certifying the results achieved by the Applied Element Method. Research verified its accuracy for elastic analysis, crack initiation and propagation. estimation of failure loads for reinforced concrete structures; reinforced concrete structures under cyclic loading; buckling and post-buckling behavior; nonlinear dynamic analysis of structures subjected to severe earthquakes; fault-rupture propagation; nonlinear behavior of brick structures; and the analysis of glass reinforced polymers (GFRP) walls under blast loads.”

“KimiroMeguro: he done a vast research in applied element method and published many research papers like Applied element simulation of RC structures under cyclic loading, large displacement structural analysis, simulation of non linear theory, Dynamic large deformation analysis using applied element method, applied element simulation for collapse analysis of structures, simulation of brick masonry wall behaviour using applied element method etc and many conclusions were given on accuracy and efficiency of applied element method over other methods.”

“Ramancharlapradeep: A reverse dip-slip fault zone is modelled numerically to study the influence of dip angle, bedrock displacement and the thickness of the soil deposit on the length of effected zone. A parametric study has been carried out to show the relationship between the bedrock displacement and influence length using two different dip angles (90' and 45').he has done an extensive work on faults.”

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"Paola Applied element method analysis on unreinforced masonry structures has been done & analysis is done using two different springs brick& brick motor springs are used to model the model the masonry anisotropy and model was validated with shear wall experiment data and conclusions were given and a good agreement was found in force and deformation curves.

"Bishnupandey: The main stream of research has been done on brick masonry wall and analysis has been done on the Simulation of Brick Masonry Wall Behaviour under In- Plane Lateral Loading Using Applied Element Method."

"Archanaadongre: Behaviour of RC framed brick masonry wall has been studied in different loading conditions and proved the importance of providing external reinforcement to increase the strength and stiffness. "A comparative study of inelastic behaviour of rc frame with and without brick infill" study has been done & behaviour of different types of structures has been studied with the effect of reinforcement proved that RC framed infill wall shows a good ductile behavior with good strength and stiffness due to which damage to the wall is minimum."

III.Methodology

A linear static analysis is done on a single frame using Applied Element Method, in this method a structure is divided into small elements (for example say square), the division of elements depends on symmetry of structure. The modelling of objects in AEM is very similar to modelling objects in FEM. Each object is divided into a series of elements connected and forming a mesh. The main difference between AEM and FEM, however, is how the elements are joined together. In AEM the elements are connected by a series of non-linear springs representing the material behaviour.

Every two consecutive elements are connected with two types of springs.

1. Normal spring 2. Shear spring, this two springs are placed inrespective directions (Normal spring in normal direction & shear spring in shear direction).As we know the elements and springs play a major role in results, some examples from previous studies are provided describing the effect of element size and no of springs.

Effect of element size on results: Adjustment of element size in the analysis is very important. Simulation of structures using elements of large size leads to increasing the structure stiffness and failure load of structure. This means that the calculated displacements become smaller and the failure load gets to be larger than the actual one.

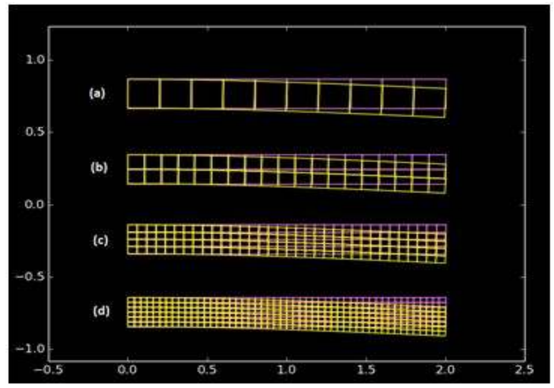


Fig1. Member with varying element sizes

Model	Total no. of elements	No. of elements per section	using FEM		using AEM	
			Displacement	Percentage Error	Displacement	Percentage Error
a	10	1	-0.0448225	99.71%	-0.000131577	1.13%
b	38	2	-0.000172269	24.40%	-0.00013108	0.76%
c	136	4	-0.000138103	5.80%	-0.00013087	0.60%
d	300	6	-0.000133241	2.37%	-0.000130843	0.58%

Table (1). The above table shows error % with FEM and AEM

To discuss the effect of the number of connecting springs, analyses were performed by TAGEL DIN HATEM using two models with 20 and 10 springs connecting each pair of adjacent elements faces for each case of different element size. It is proved t that increasing the number of base elements leads to decreasing the error but increasing the CPU time. Use of only one element at the base leads to about 30% error in the theoretically calculated displacement. This error reduces to less than 1%when the number of elements at the base increases to 5 or more.However, the CPU times increases. When we compare the results, although the accuracy of the results of 10 springs model is same as that in case of 20 springs, the CPU time in case of 10 springs is almost half of that in case of 20 springs. It can be concluded that usage of large number of elements together with relatively few number of connecting springs leads to very high accuracy in reasonable analysis time

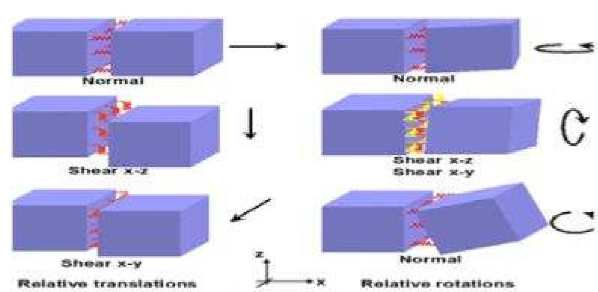


Fig2. Springs connectivity and relative rotations and translations.

No of springs	2	4	6	8	10	20
Error ratio	25%	6.3%	2.8%	1.6%	1%	0.25%

Table 2. The above table shows variation in error ratio with number of springs.

IV.Modeling And Analysis

The application of Applied Element Method is illustrated through static analysis of portal frame subjected to lateral load. Geometrical data Material properties, End conditions and type of loading conditions are as follows

Frame data:

Column spacing = 4000 mm c/c

Storey height = 4000 mm

Width of beam and column = 300 mm

Depth of beam and column = 300 mm

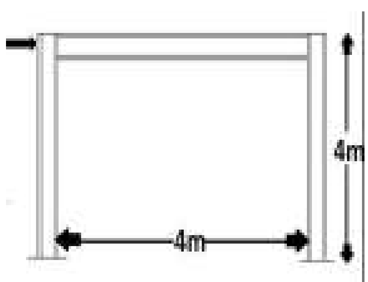
E =30000.00N/mm^2

Poisson's ratio of concrete = 0.15

Shear modulus G = 3750 N/mm2

Moment of inertia (I) = 5.4 x109 mm4.

Support condition = Fixed at base.



Input files details:

1. Load data [Ld Data]
2. Inpmesh data [Inp Data]
3. Boundary condition data [Bc Data]

Load data:In load data the complete load profile, type of loading, increments of loading, at what point the load has tobe given will be used to create the load resource file (say ld data)

Inpmesh data: In inpmesh data the geometry of the structure or the structure element, reinforcement, reinforcement properties, and other data provided to the structure will be used to create inpmesh.

Boundary condition data:Boundary condition data is providing the file with the type of load control, load condition, no of elements both in x & y axis fixity conditions, material conditions are given as input.

After the resource files input is given and program is run in Visual Fortran Compiler ,the animations for given data will be shown from 0 to last increment and at every increment complete details like failure of springs both individual and cumulative, crack propagation, displacement, load taken. Every minute data is automatically saved at the resource file location itself. Since providing images at all increments is difficult one image for every 33 increments is provided for clear understanding

Displacement controls:

In displacement two cases are considered.

Case I : max displacement of 0.01m

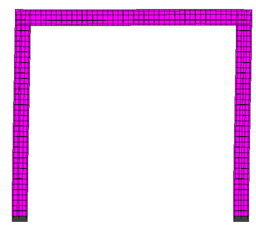


Fig4(a). The above figure shows animation at 1st increment.

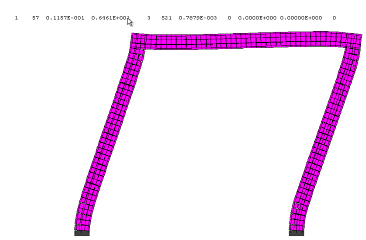


Fig4(b). The above figure shows animation at 30th increment

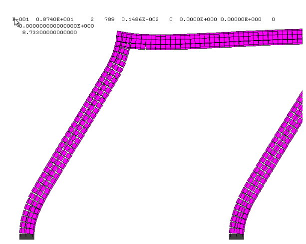


Fig4(c). The above figure shows animation at 99thincrement.

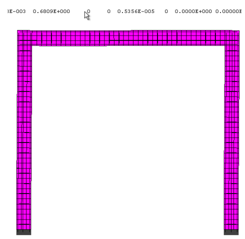


Fig4(d). The above figure shows animation at 1st increment.

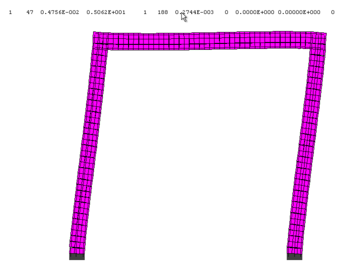


Fig4(e). The above figure shows animation at 30th increment

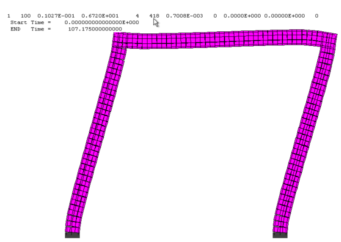


Fig4(f). The above figure shows animation at 99th increment

Load control.

In load control condition there are two cases one with

Case I: max load (lateral) of 5KN as shown in fig

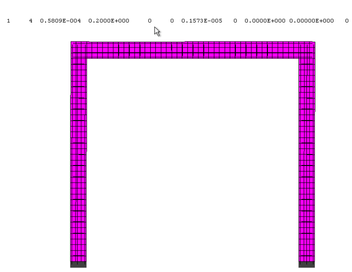


Fig4(g). The above figure shows animation at 1st increment.

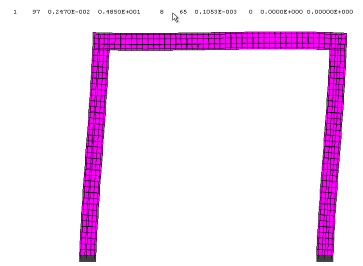


Fig4(h). The above figure shows animation at 30th increment.

Fig4(i). The above figure shows animation at 90th increment

Case II: max load (lateral) of 10KN as shown in fig

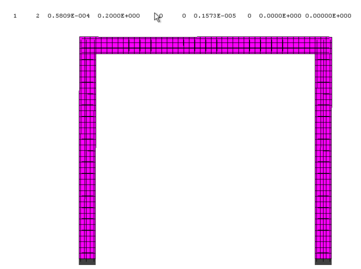


Fig4(j). The above figure shows animation at 1st increment.

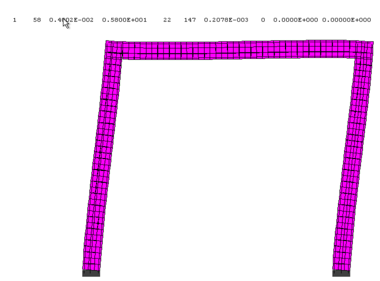


Fig4(k)The above figure shows animation at 30th increment.

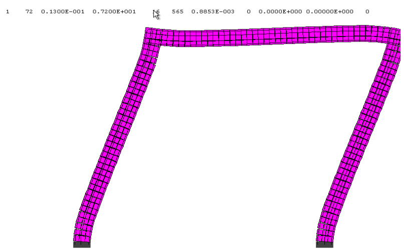


Fig3(l). The above figure shows animation at 90th increment

V.ResultsAnd Discussion

Displacement control:

Case I:In this case displacement control is taken and the maximum displacement applied is 0.01m which is taken in 100 increments

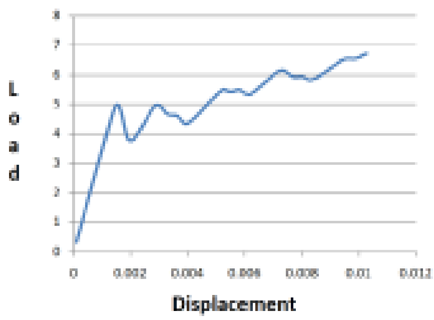


Fig6(a). Load vs displacement for displacement control case1

The displacement of 0.01m is applied in 100 increments and graph is plotted for the load Vs displacement. It is observed that the 1st peak behavior is observed at 3.164 KN for displacement of 0.0029 at this stage total no of 7 sprigs failed, due to failed spring strength carrying capacity is increasing but again with rearrangement of springs frame is still capable to take load till it reaches its ultimte capacity at around 6.7kN laod at 0.01m dispcament.

Case II: In this case of displacement control maximum displacement applied is 0.02m which is taken in 100 increments

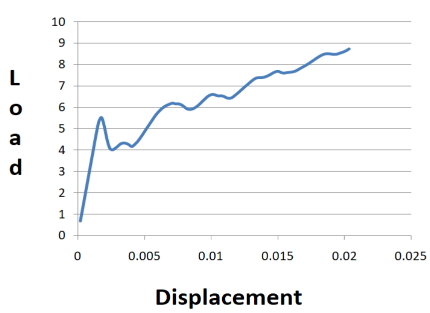


Fig6(b). The above graph shows load vs displacement for displacement control case2

The max displacement of 0.02m is taken in 100 increments and graph is plotted for the load Vs displacement. It is observed that the maximum strength is at 2.852KN for displacement of 0.002m and total no of 6 sprigs failed, after that the load vs displacement graph started to come down for the further values of displacement, but after 0.005m of displacement the load taken by structure is 2.852KN, there is continous increase in load carrying capacity of the frame.

Load control:

Case I: In this case load control is taken and the maximum load applied is 5KN which is taken in 100 increments

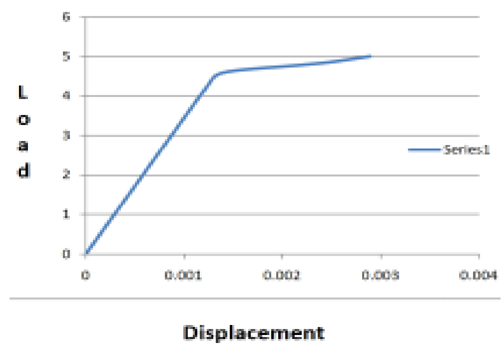


Fig6(c). The above graph shows load vs displacement for load control case1

The load 5 kN in 100 increments and graph is plotted for the load Vs displacement. It is observed that at 3kN of load 10 springs has failed, at this point the max displacement for the structure is 0.032m , after that the load Vs displacement graph started to gradually increase for every single increment load and displacement are proportional to each other till the 100th increment

Case II : In this load control case the maximum load applied is 10kN which is taken in 100 increments

For the load 10 kN in 100 increments, corresponding graph is plotted for the load Vs displacement. It is observed that at 3kN of load 6 springs has failed at this point the max displacement for the structure is 0.002m, after that the load Vs displacement graph started to gradually increase for every single increment of load and displacement is proportional to load till

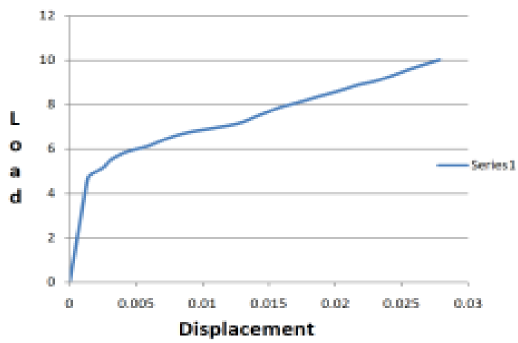


Fig6(d). The above graph shows load vs displacement for load control case2

VI. Conclusion

It is observed that while comparing both load control and displacement controls

1. Displacement control has given a much clearer response which is useful to understand the accurate behaviour of the structure.
2. In load control case, since load increases in perfect increments it is difficult to predict the displacement for the intermediate value (between increments) compared to displacement control case.
3. Structure showed its maximum strength before failure of springs.
4. After initial failure of springs structure is losing its stiffness gradually resulting in its ultimate failure.\

Future scope:There is lot of scope for further research

1. Research can be done by taking irregular sizes of elements.
2. Can be extended by taking different storeys and load conditions with 3D considerations

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