Life John, Dr. M G Rajendran / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 3, Issue 2, March -April 2013, pp.764-769

Comparative Studies on Exact and Approximate Methods of Structural Analysis

Life John*, Dr. M G Rajendran **
*(Department of Civil Engineering, Karunya University, Coimbatore)
** (Department of Civil Engineering, Karunya University, Coimbatore)

ABSTRACT

The safety and serviceability of a structure is dependent on how accurately the forces and the response associated with it are determined Many precise methods of analysis have been well documented in the literature for structural analysis. Computer programs provide results with good cost and time efficiency. The main problem is that structural engineers are using these softwares as black box and gross errors are left undetected. This problem can be overcome by using fast and efficient methods which yield results which are approximate and acceptable. These methods are called approximate methods and they have been used successfully for the analysis of the structures. An overview of various such approximate methods is briefly done in this paper. This paper also intends to compare revised method of structural analysis to the values obtained from STAAD.pro.

Keywords – Approximate Methods, Split frame analysis, Revised Method of analysis

1. INTRODUCTION

The development of modern technology has made exact structural analysis very easy. High speed computers are now capable of solving large number of equations and results can be obtained quickly. But these methods do have the following limitations:

a) It is easy for structural engineers to lose the “feel” for how structures respond to loads in computer methods.
b) It is possible that gross errors in the sophisticated computer analysis go undetected
c) It is very useful in client, architect meetings where a quick check on structure might be necessary.
d) Error in the computer program “NASTRAN” lead to underestimation of loads acting on an offshore platform Sleipner A. The requirement that “hand Calculation groups” Check to computer Calculations was Instituted

2. REVIEW OF LITERATURE

2.1 Jinghai Wu[1] has carried out Approximate analysis of building frames for vertical loads. Approximate methods are useful in preliminary design, and also provide the analyst and the designer with a rapid means of rough checking "exact" solutions.

The approximate analysis of building frames for vertical loads is covered in several papers and textbooks. The existing story wise summation method is complicated in computation, and the other approximate methods usually have poor accuracy. This paper presents the simplified storywise summation method, which may be summarized as follows:

(I) divide a building frame into many single-story frames whose number equals the number of stories of the building frames;
(2) Approximately analyze each single-story frame; and
(3) Sum the single-story frames. The method is almost as accurate as the existing story wise summation method, and may provide better accuracy than the other approximate methods. The intent of this paper is to develop an approximate analysis of building frames for vertical loads, which may involve less labour in computation than the existing story wise summation method.

First of all a building frame is divided into many single-story frames whose number equals the number of stories of the building frame. Each single-story frame is approximately analyzed in the following steps:

1. Determine the location of inflection points of each beam (Epstein 1988).
a. Find the location of the inflection points in the loaded beam assuming both ends are fixed against rotation (unless one end is actually pinned).
b. If only one end needs to be released, the near inflection point, originally aL from that end, is moved to a new location, *x*, from that end, found from the following:

$$\frac{x}{l} = \left(\frac{1-d}{\beta-\alpha d}\right)\alpha\beta$$

c. If both ends need to be released, move each inflection point as if only the end nearest to it is released.
d. If there are loads on the adjacent beam at the released joint, a modified moment distribution factor *d'*

e. If there is an inflection point in an unloaded beam, it moves from an original location corresponding to 01. = 1/3. Find the new location by substituting b= 2/3 and the appropriate *d* into (1).
2. Determine the end moments of beams and their unbalanced moment at each rigid joint by statics.
3. The unbalanced moment at each rigid joint is distributed to the column framing at the joint in the proportion of their stiffness factors; thus the near-end moment of each column is obtained.
4. The far-end moment of a column is equal to its near-end moment multiplied by its carryover factor.
The final end moments of a beam are equal to the end moments of the beam calculated from the single-story frame that includes the beam. The final end moments of a column are equal to the summation of the end moments of the column calculated from the upper single-story frame and the end moments of the column calculated from the lower single-story frame; both the upper single-story frame and the lower single-story frame include the column.

2.2 Dr. Terje Haukaas[(2)] has discussed the following two Approaches :
1. Rough assessment of span-to-depth ratios based on experience
2. Guess the location of Inflection points in beams and columns

TYPICAL SPAN-TO-DEPTH RATIOS

The ratio of the Span length, *L*, and the Cross-section height (depth), *d*, of structural components is a useful but approximate Indicator of Whether a Design is efficient. The following tables are obtained by considering a variety of "normal" situations, in which both ultimate and serviceability limit-states are considered.

Table 1: Timber

	L [m]	*L/d*
Lumber joist floors	2-7	15-25
I-joist floors	5-10	15-25
Timber beams	3-10	10-20
Glulam beams	6-25	15-20
CLT floors	?	20-30
CLT roofs	?	30-40
Roof trusses, pitched	10-40	2-8
Roof trusses, flat	10-40	8-15

Table 2: Steel

	L [m]	*L/d*
Wide-flange beams	3-20	15-25
Plate (high web) girders	10-25	15-20
Trusses	10-50	8-16

Table 3: Reinforced concrete

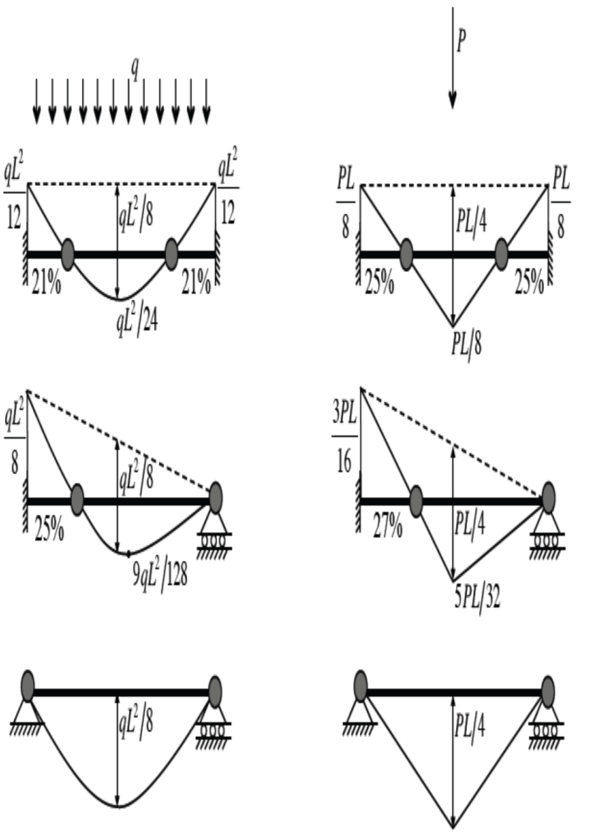
	L [m]	*L/d*
Slabs	3-8	30-35
T-beams	3-15	8-14

Table 4: Pre-stressed concrete

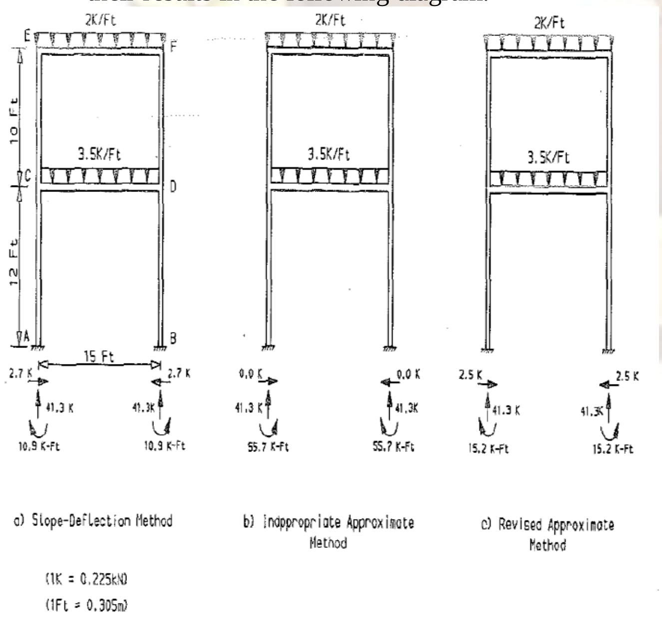
	L [m]	*L/d*
Slabs	6-10	40-44
Beams	8-20	16-28
Double tees (Ts)	8-30	24-36

LOCATION OF INFLECTION POINTS IN BEAMS AND COLUMNS

To make good guesses about the location of inflection points and end-moment values it is necessary to relate them to known reference cases. Figure shows six beam cases that are particularly useful; three with distributed load and three with a point-load at mid-span.



2.3 R. A. Behr et all[3]. have brought out potential errors in approximate methods of structural analysis. They have reviewed the existing methods of approximate structural analysis described in various literatures and compared with Slope deflection method, Conventional approximate method and Revised approximate method. They have presented their results in the following diagram.



2.4 R.A. Behr et all.[4] have also suggested some assumptions in selection of point of inflection in beam and column so as to obtain values closer to the exact method.

The assumptions used for continuous loading are:

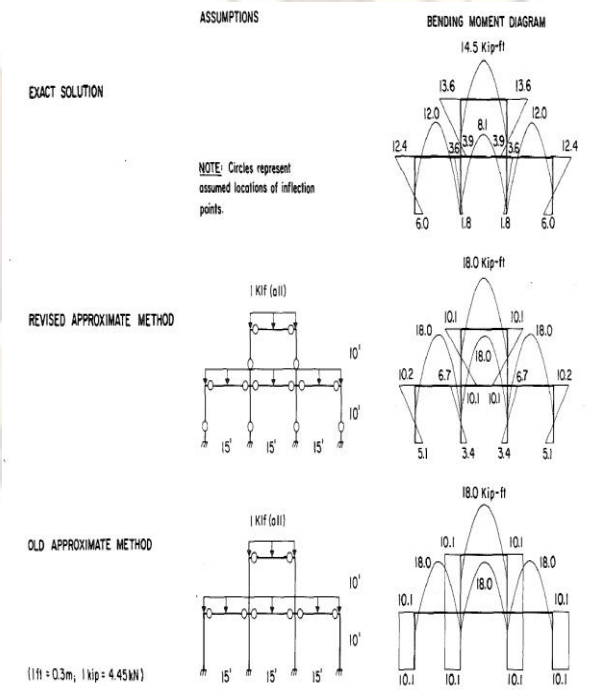
1. Points of inflection exist in girders at 0. 1L and 0.9L. (In the case of flexible girders and stiff columns, points of inflection can be moved closer to the 0.21L and 0.79L marks; for stiff girders and flexible columns, points of zero moment can be located closer to the ends of the girder.)

2. A point of inflection exists in each column. The location of the inflection point is determined by the position of the column within the structure, i.e.

a. First-story columns with fixed base supports are assumed to have a point of inflection at 0.33H from the column base, where *H* is the height of the column. A similar suggestion is made by Wang and Salmon (1984). If a hinge exists at the column base, then the point of inflection should be located there.

b. Top-story columns are assumed to have points of inflection at 0.4H, again measured from the base of the column.
c. Intermediate columns are assumed to have points of inflection at mid height.

The results obtained from the above analysis are compared with slope deflection and conventional approximate method as shown below.



3. COMPARISON OF EXACT AND APPROXIMATE METHOD FOR A MUTISTORIED BUILDING

For the comparison of a values obtained by approximate method and exact method, the method adopted in reference 4 is used. For the above comparison a four storied building is chosen and the plan of the building is as shown in figure 8.

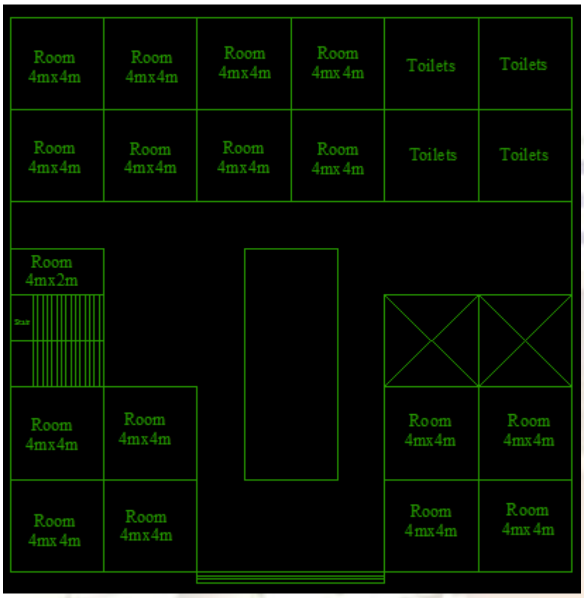


Figure.8 typical Plan of four storied building.

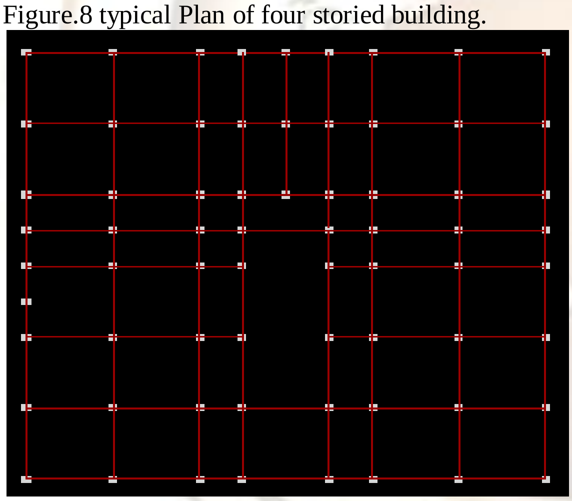


Figure 9. Column and Beam Layout.

The columns were suitably arranged as shown in figure 9 and a preliminary design was carried out. After fixing the dimensions of the members, a model was created in STAAD.pro and the dead loads and live loads were applied as per IS 875 Part I and Part II. Figure 10, 11 shows the plan and 3D model of the structure created in STAAD.

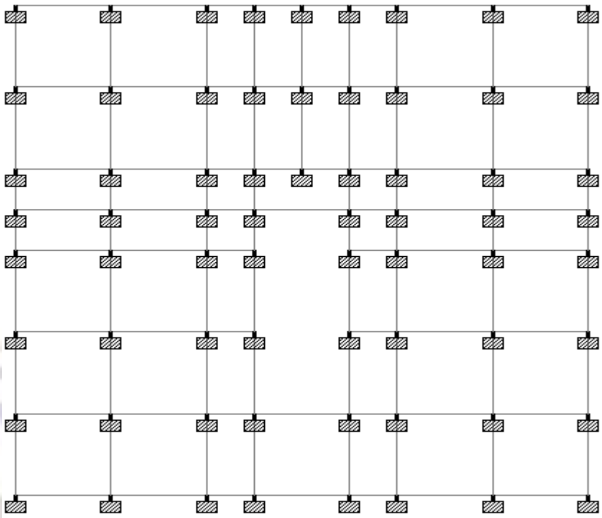


Figure 10. Plan view in STAAD.Pro

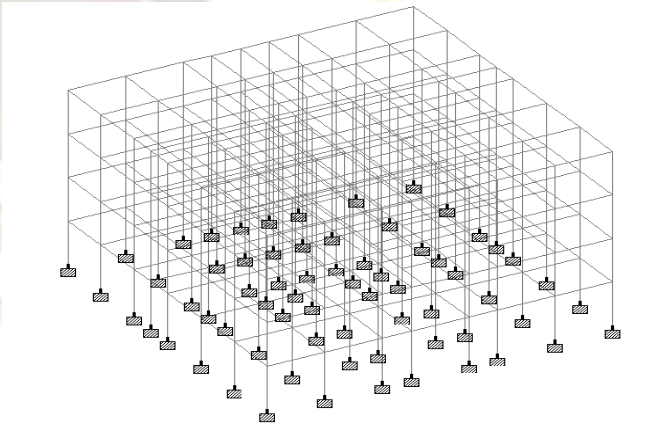
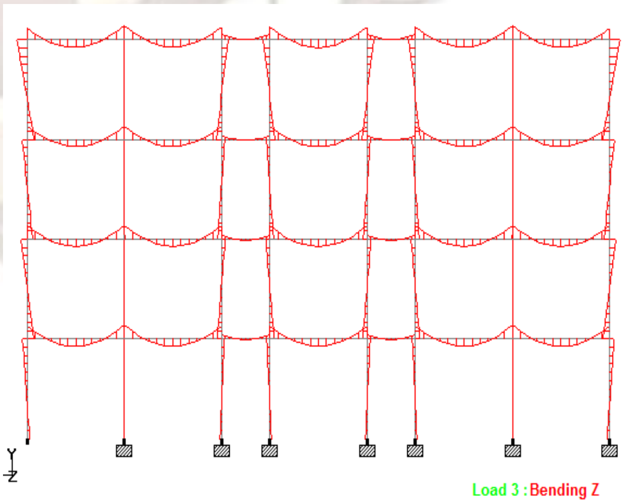


Figure 11. 3D View Of The Structure

The structure was analysed for a combination of dead load and live load and suitable factor was used. A sample bending moment diagram of the above analysis is shown in figure 12.



The values obtained from the above analysis are considered as the exact solution. Now each frame is analyzed manually using approximate method. Here points of contra flexure are fixed suitably using the following assumptions:

a. Point of contra flexure occurs in beams at a distance equal to 21 % of length on either side.
b. The moment in top story column has a point of inflection at 40 % height from base of column.
c. The moment in intermediate columns occur at 50 % of height from base of column.
d. The moment at bottom story column occurs at 33 % of height from base of column.

Using the above assumptions and equation of statics, each frame is analyzed and data obtained is compared with exact solution. The sample results of the comparison are tabulated below:

Sl. no	Beam	Calculated Value	Exact Value	Error	% Error
1	B1	49.084	45.892	3.192	6.96
2	B2	49.084	47.961	1.123	2.34
3	B3	49.084	49.958	-0.874	-1.75
4	B4	49.084	42.601	6.483	15.22
5	B5	49.084	50.585	-1.501	-2.97
6	B6	49.084	49.75	-0.666	-1.34
7	B7	49.084	48.883	0.201	0.41
8	B8	49.084	50.56	-1.476	-2.92
9	B9	12.35	16.202	-3.852	-23.77
10	B10	12.35	13.601	-1.251	-9.20
11	B11	12.35	11.44	0.91	7.95
12	B12	12.35	17.39	-5.04	-28.98
13	B13	12.35	12.47	-0.12	-0.96
14	B14	12.35	12.33	0.02	0.16
15	B15	12.35	12.23	0.12	0.98
16	B16	12.35	12.36	-0.01	-0.08
17	B17	12.35	12.32	0.03	0.24
18	B18	12.35	14.38	-2.03	-14.12
19	B19	12.35	16	-3.65	-22.81
20	B20	12.35	13.9	-1.55	-11.15
21	B21	12.35	12.36	-0.01	-0.08
22	B22	12.35	12.32	0.03	0.24
23	B23	12.35	14.38	-2.03	-14.12
24	B24	12.35	16	-3.65	-22.81
25	B25	49.084	46.625	2.459	5.27
26	B26	49.084	47.871	1.213	2.53
27	B27	49.084	48.827	0.257	0.53
28	B28	49.084	45.39	3.694	8.14
29	B29	49.084	50.665	-1.581	-3.12
30	B30	49.084	49.015	0.069	0.14
31	B31	49.084	47.811	1.273	2.66
32	B32	49.084	51.079	-1.995	-3.91
33	B33	49.084	45.918	3.166	6.89
34	B34	49.084	47.932	1.152	2.40
35	B35	49.084	49.72	-0.636	-1.28
36	B36	49.084	42.534	6.55	15.40
37	B37	49.084	49.723	-0.639	-1.29
38	B38	49.084	49.644	-0.56	-1.13
39	B39	49.084	49.217	-0.133	-0.27
40	B40	49.084	49.534	-0.45	-0.91
41	B41	49.084	50.469	-1.385	-2.74
42	B42	49.084	49.78	-0.696	-1.40
43	B43	49.084	49.237	-0.153	-0.31
44	B44	49.084	50.379	-1.295	-2.57
45	B45	12.35	16.23	-3.88	-23.91
46	B46	12.35	13.461	-1.111	-8.25
47	B47	12.35	11.24	1.11	9.88
48	B48	12.35	17.5	-5.15	-29.43
49	B49	12.35	12.23	0.12	0.98
50	B50	12.35	14.69	-2.34	-15.93
51	B51	12.35	16.612	-4.262	-25.66
52	B52	12.35	14.21	-1.86	-13.09
53	B53	49.084	46.926	2.158	4.60
54	B54	49.084	47.857	1.227	2.56
55	B55	49.084	48.82	0.264	0.54
56	B56	49.084	45.423	3.661	8.06
57	B57	49.084	45.904	3.18	6.93
58	B58	49.084	47.97	1.114	2.32
59	B59	49.084	49.853	-0.769	-1.54

Sl.no	Column	Calculated Value	Exact Value	Error	% Error
1	C1	7.97	9.82	1.85	18.84
2	C2	32.73	26.303	6.427	24.43
3	C3	16.35	23.088	6.738	29.18
4	C4	32.24	28.807	3.436	11.93
9	C9	6.004	6.071	0.067	1.10
10	C10	24.25	18.23	6.01	36.01
11	C11	12.48	16.5	4.02	24.36
12	C12	24.48	21.57	2.91	13.49
19	C25	6.004	6.071	0.067	1.10
20	C26	24.25	18.232	6.018	33.01
21	C27	12.48	16.5	4.02	24.36
22	C28	24.48	21.597	2.883	13.35
23	C33	16.35	19.589	3.239	16.53
24	C34	32.73	24.873	7.857	31.59
25	C35	16.35	21.051	4.701	22.33
26	C36	49.084	42.601	6.483	15.22
27	C37	16.35	19.704	3.354	17.02
28	C38	32.73	24.783	7.947	32.07
29	C39	16.35	21.145	4.795	22.68
30	C40	49.084	42.534	-6.55	15.40

RESULT AND DISCUSSION

The various approximate methods of structural analysis for analysis of framed structures subjected to vertical and horizontal loads have been described above.

The comparison of moments in column has been done. The average variation being 20.92 %.

In beam the analysis is able to provide a reasonably accurate value in most of the cases. The average error % is 10.38 %.

From the above results, it can be concluded that further refinement is necessary and an analytical study is being carried out in the above field.

ACKNOWLEDGEMENT

The authors are thankful to the Management of Karunya University and the Director, School of Engineering for providing necessary facilities.

REFERENCES

1) JingHai Wu, Engr., Des. Inst. of Water Conservancy and Hydroelectric Power of Hehei Province. People's Republic of China.) "*Approximate analysis of building frames for vertical loads" - Journal of Structural Engineering,* Vol. 121. No.4. April. 1995.
2) Dr. Terje Haukaas, University of British Columbia,"*Lecture notes posted in "www.inrisk.ubc.ca."*
3) R. A. Behr, Member, ASCE, C. H. Goodspeed, and R. M. Henry, *"Potential errors in approximate methods of structural analysis" , Journal of Structural Engineering, Vol. 115, No. 4, April, 1989*
4) R. A. Behr, E. J. Grotton, and C. A. Dwinal *"Revised method of approximate structural analysis", Journal of Structural Engineering, Vol. 116, No. 11, November, 1990*
5) Manicka Selvam V.K , Bindhu, K.R, *"Split frame method for lateral load analysis of short frames", International Journal of Civil and Structural Engineering Volume 1, No 4, 2011*
6) C.K Wang, *"Intermediate Structural Analysis"* Mc Graw –Hill Publications 5th edition 1988.