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Comparative Study between Kani's Rotational Contribution Method and FEM using STAAD.Pro in a G+3 Residential Flat

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Abstract

Structural Engineering plays a key role in accomplishing the need for ever increasing living space by analyzing and designing with economy and elegance to give a safe, serviceable and durable structure. The study investigates the effectiveness of Kani's Rotational Contribution Method and Finite Element Method (FEM) using STAAD.Pro in analyzing a G + 3 residential flat. Accordingly the critical portal frame was identified and analyzed for 4 cases (floor wise combinations) using above said two methods. The results had been compared and it was found that the mean variation for beam moments ranges from 2.74 % to 12.7 % and for column moments it varies from 6.92 % to 39.44 % for different floor combinations. Concisely, it can be inferred that more than 50 % of the end moments fall within 10 % variation category in beam moments for all cases and more than 40 % of end moments fall within 10 % variation classification in column moments for different floor combinations. In short both the methods are versatile on practical considerations. In case of smaller frames (2 to 3 floors) Kani's method is best suited for its flexibility, self correctiveness, faster convergence and simplicity. Alternatively for larger three dimensional frames it is suggested to go in for Linear Static Analysis using STAAD.Pro for its speed, adaptability, graphic interface and extendability.

Keywords: Kani's Method, Finite Element Method (FEM), Linear Static Analysis

1. INTRODUCTION

Buildings constitute an integral part of civilization. Ever since from ancient times, building science has become an indispensible component of design process. It is emphasized that any structure to be erected must satisfy the needs efficiently for which it is intended and shall be durable throughout its desired life span. Safety requirements must also be met so that a structure is able to serve its purpose with the minimum costs. Thus in Engineering and Architecture, a structure is the combination of two or more basic structural components connected together in such a way that they serve the user functionally and carry the loads arising out of self and super-imposed loads safely without causing any problem to utility. Migration to cities, population explosion and ever increasing land cost pose a threat to living space. Indirectly these factors pave way for vertical expansion and it is the responsibility of the Civil Engineers to cope with the current situation.

Rashmi Agashe et al [1] performed theoretical design and structural analysis of a G+4 residential building using IS Code Method and verified using STADD Pro. software. Potharaboyena Vinay et al [2] studied a portion of RCC building frame with Substitute Frame Method. The design part of the structure was done using Limit State Method. Chiranjeevi M et al [3] investigated a single bay portal frame using Moment Distribution Method and Kani’s Method for uniformly distributed loading conditions. Further the results were compared using STAAD.Pro. There is only a slight variation in the end moments among these methods. Kushal Shah et al [4] attempted to analyze and design a residential building of G+6 floors consisting of 5 apartments in each floor using the software package STAAD.Pro against all possible loading conditions. Balwinder Lallotra et al [5], considered different structural elements like fixed beam, column with point load, cantilever beam, portal frame etc., and analyzed them using softwares like STAAD Pro, ETABS and SAP-2000 and validated the results with manual design as per Indian Standards. In the case of portal frame the bending moment at one of the fixed end is more than 241.5% when compared to theoretical value. The variation is more than 542.21 % at the other end. Ashok Kumar N et al [6] analyzed and designed a G+3 hospital building using Substitute Frame Method and STAAD Pro V8i. There is only minor difference between manual and software results obtained. Syed Faheemuddin et al [7] has taken a G+2 building with 3 bays for the study. Linear Static Analysis has been done using Kani’s Method and SAP2000 V17.3. There is only 5.2 % variation for column moments and 4.1 % variation in the beam moments between the two methods. In column axial loads the variation is 5.1 %. In short SAP 2000 V17.3 gives a higher variation when compared to manual methods.

2. NEED FOR THE STUDY AND APPROACH

There are three approaches to the analysis viz.,the mechanics of materials approach (strength of materials), the elastic theory approach, and the finite element approach. The first two make use of analytical formulations which apply mostly to simple linear elastic models leading to solutions that can often be solved by hand. The finite element approach is actually a numerical method for solving differential equations generated by theories of mechanics such as elastic theory and strength of materials. However the finite element method depends heavily on the processing power of computers and is more applicable to structures of arbitrary size and complexity.

The present study was initiated with the aim to analyse a portal frame using both manual and software oriented Finite Element Method (FEM). Based on space constraint, cost issues and on the gaps identified in the earlier investigations the following objectives are set for the present study.

1. To identify the critical portal frame in a G+3 residential flat and analyse manually for Bending moment and Shear forces using Kani's Rotational Contribution Method under vertical loading conditions.
2. To conduct Linear Static Analysis by FEM using STAAD Pro.V8i and compare the results obtained from both methods.

3. METHODOLOGY

Kani's Rotational Contribution Method is an iteration method for analyzing statistically indeterminate structures in which the contribution of rotation moments are distributed till the desired degree of accuracy is achieved. Framed structures are rarely symmetric and subjected to side sway hence Kani's Method is best suited and much simpler than other methods like Moment Distribution Method, Slope Deflection Method etc. However it is only an approximate method that can save a great deal of time when compared to Moment Distribution Method, especially when considering structural floors with a couple of stories or more. The most significant feature of Kani's method is that process of iteration is self-corrective. Any error at any stage of iterations is corrected in subsequent steps. Thus skipping a few steps either by over sight or by intention, does not lead to error in final end moments.

Any structure's response includes internal processes, moments, and inherent stresses that are used in the design process. Usually in finite element based structural analysis as contemplated in STAAD.Pro, the unknown displacement/moments are obtained from equilibrium equations of actual system and then the external and internal forces /stresses are calculated from structure's global equilibrium equations. For this reason FEM is the best option of discretization of complicated structural system where basic equilibrium equations are readily acquired from the principle of virtual work. In this way STAAD.Pro looks into each and every aspect of structural engineering starting from analysis, design, validation, model evolution and visual display on the basis of concurrent engineering. Further STAAD.Pro provides a complete insight in getting precise results like nodal displacements, support reactions, axial forces, beam deflections, base shear, storey shear, mode shapes etc., especially in Linear Static Analysis which is an important subject now a days because of practical considerations, time and safety features as the structural requirements are examined upto collapse. However this study is confined to finding variation in beam and column end moments only between Kani's Rotational Contribution Method and FEM using STAAD.Pro.

4. PLANNING AND SIZING OF STRUCTURAL ELEMENTS

A typical architectural floor plan for a G + 3 residential flat has been proposed in Figure 1. Each floor consists of two types viz., 'A' and 'B' with common parking area in ground floor. Both types consist of living, 3 bed rooms, kitchen, dining, toilet and utility area. Also a balcony has been provided for first, second and third floors. A slab thickness of 150 mm was adopted for living rooms, parking and balconies. For all other rooms 120 mm thickness had been provided. Two cross sections for beams viz., 230 mm × 350 mm and 230 mm × 400 mm, depending upon the spans were adopted for all the floors. Similarly two cross sections for the columns viz., 230 mm × 230 mm and 230 mm × 350 mm were adopted depending on the loading conditions throughout the structure. A wall height of 3 m was provided for all the floors. For the analysis purpose the critical frame with 9 bays has been identified in the middle of the structure so as to support maximum loads from the floors transferred to this frame in the "X" direction. All loading conditions on slabs, supporting beams and columns have been calculated as per IS 875 Part 1 and 2. Further the loads on beams supporting the slabs are uniformly distributed in accordance with Clause 24.5 of IS 456: 2000. The frame configuration and loadings on critical frame are presented in Figures 2 and 3.

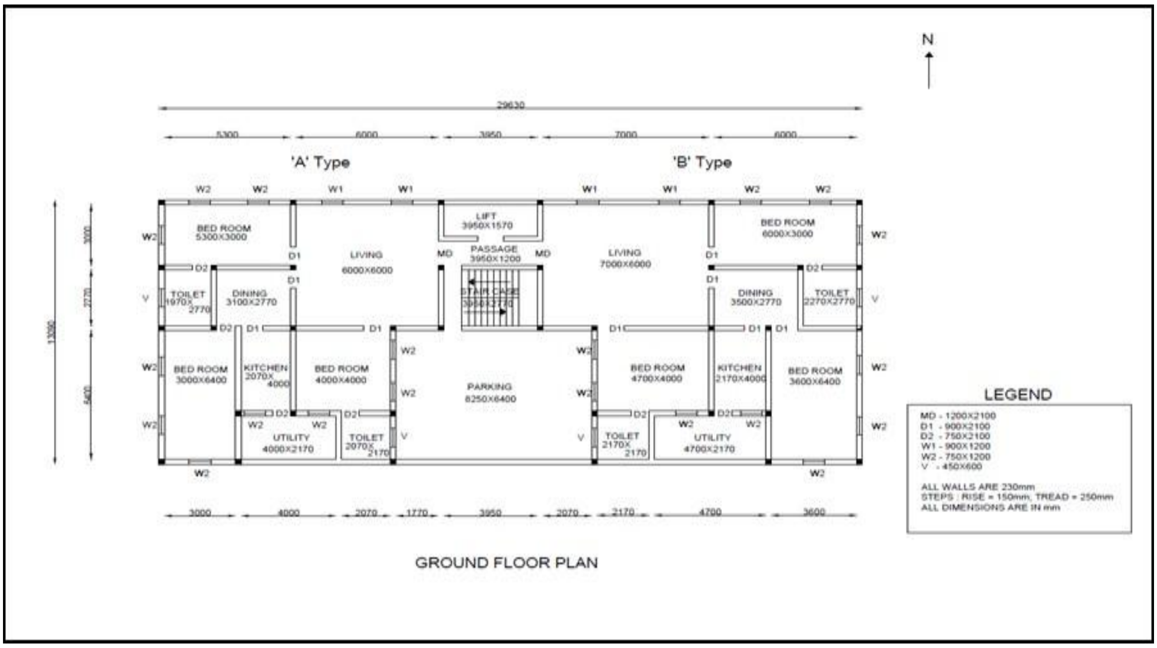

Figure 1: Typical Floor Plan

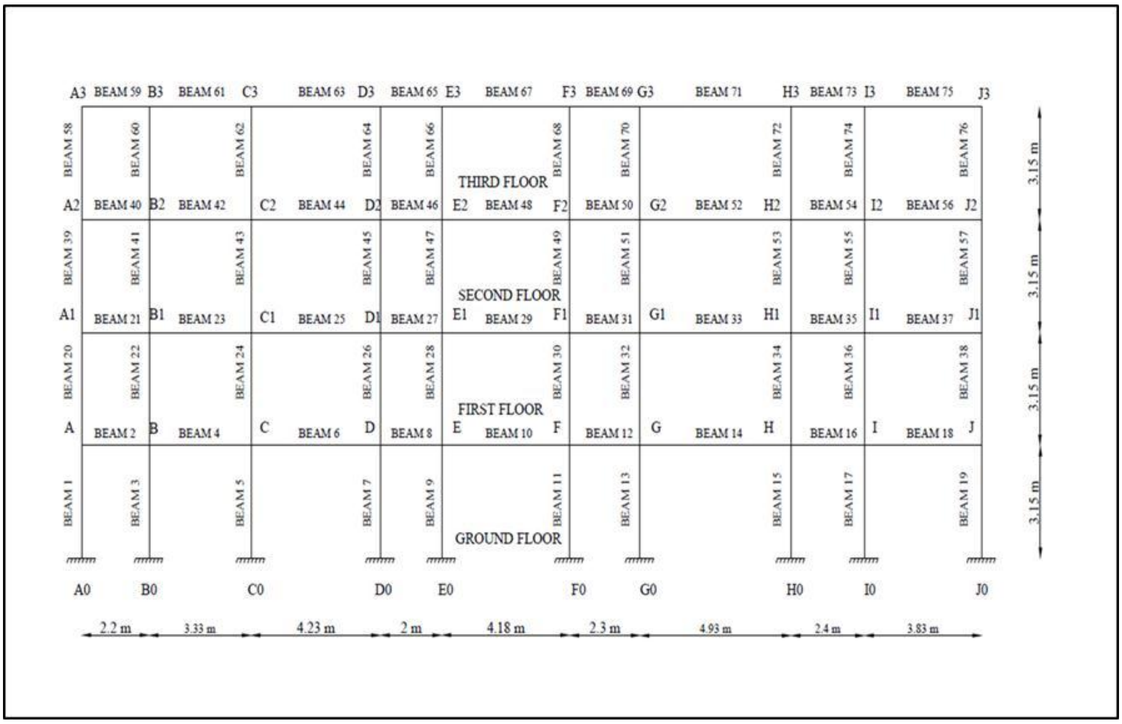

Figure 2: Critical Frame Configuration in 'X' Direction

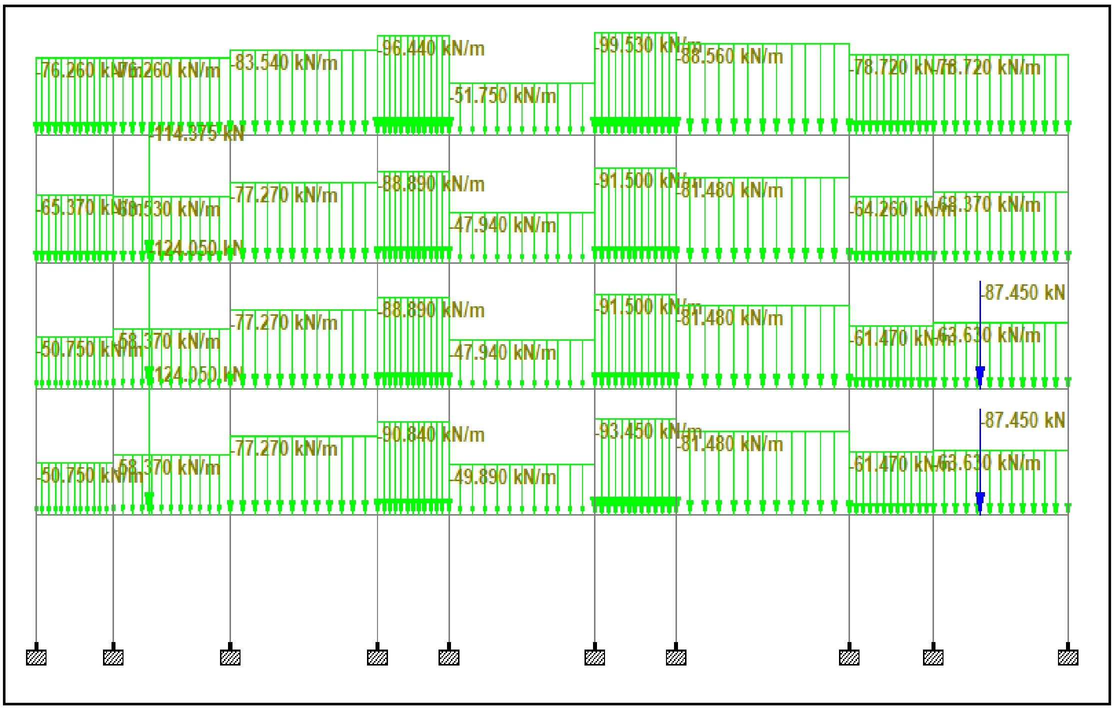

Figure 3: Loadings on Critical Frame

5. APPROACH

The same loading details / pattern of the critical frame as depicted in Figure 3 were treated as inputs for both the methods. As the loading pattern is different for each floor it was decided to analyse the structure with different floor combinations for both methods as follows:

Case 1: Ground Floor (GF)

Case 2: Ground Floor + First Floor (GF+FF)

Case 3: Ground Floor + First Floor + Second Floor (GF+FF+SF)

Case 4: Ground Floor + First Floor + Second Floor + Third Floor (GF+FF+SF+TF)

As discussed earlier relative stiffness, distribution factors and rotational contribution factors were evaluated. Fixed end moments for each structural element have been computed based on various load combinations including point load. The iteration was started in topmost left corner and proceeded in a cyclic manner. Four iteration cycles were completed as portrayed in Figure 4 and the values had almost converged. Further the final moments obtained with Kani's method has been presented in Figure 5. Similarly for the same loading conditions the results were obtained for Linear Static

Analysis using STAAD.Pro. For illustration purposes a portion of the portal frame has been considered and the results obtained for respective beam and column moments only for the joints E0,E,E1,E2,E3,F0,F,F1,F2 and F3 for all the four cases for both the methods and the percentage variations are presented in Table 1.

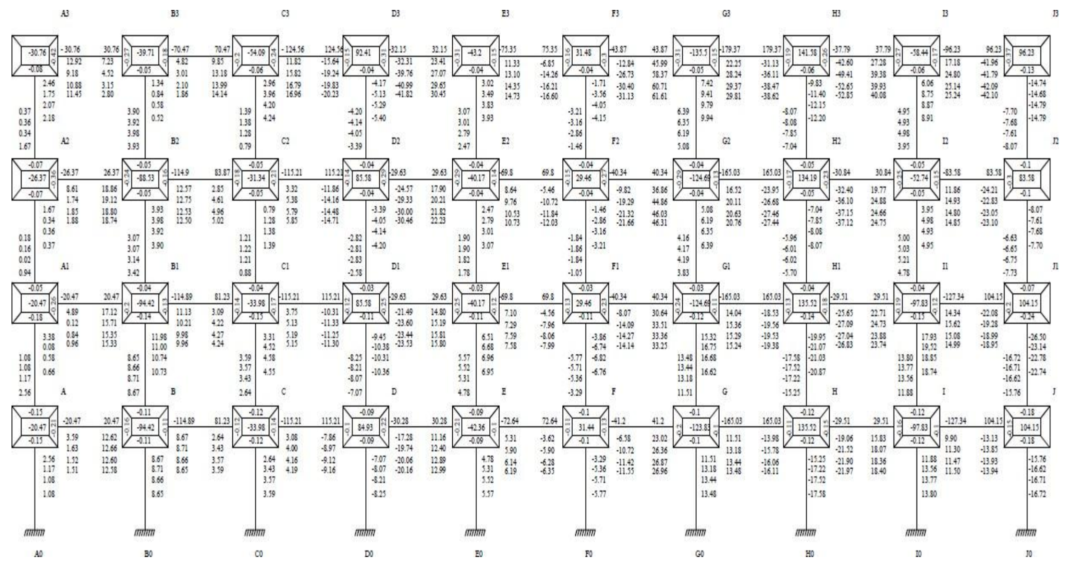

Figure 4: Kani's Iterative Cycle (G+3)

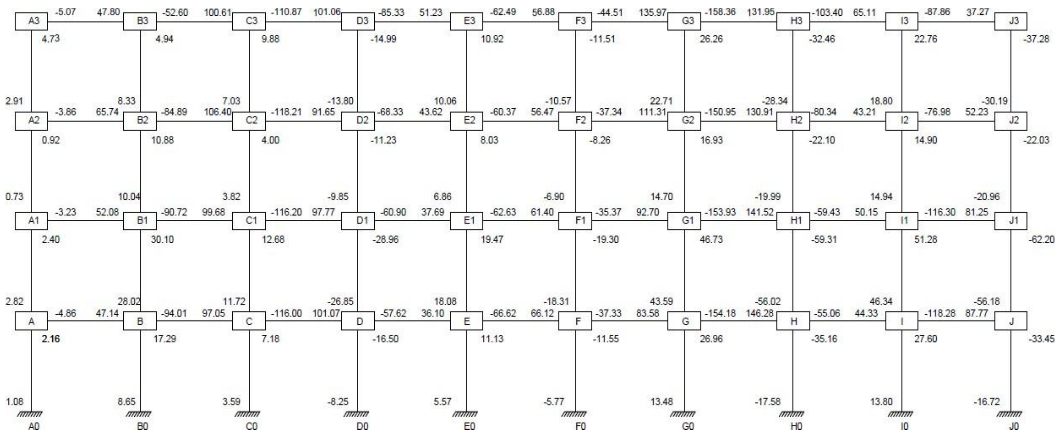

Figure 5: Kani's Final End Moments (G+3)

Table 1: Beam and Column moments

CASE	BEAMS						COLUMNS					
	JOINT	MEMBER	BEAM	END MOMENTS (KNm)		% VARIATION	JOINT	MEMBER	COLUMN	END MOMENTS (KNm)		% VARIATION
				KANI's	STAAD					KANI's	STAAD	
Case 1 (GF)	E	ED	BEAM 8	44.03	45.73	3.72	E-E0	E0E	BEAM 9	9.08	9.3	2.37
		EF	BEAM 10	62.45	63.7	1.96		EE0	BEAM 9	18.17	17.98	1.06
	F	FE	BEAM 10	60.81	61.2	0.64	F-F0	F0F	BEAM 11	10.41	7.53	38.25
		FG	BEAM 12	37.82	44.23	14.49		FF0	BEAM 11	20.82	16.97	22.69
Case 2 (GF+ FF)	E1	E1D1	BEAM 27	39.91	45.74	12.75	E0-E	E0E	BEAM 9	5.45	4.38	24.43
		E1F1	BEAM 29	60.83	62.4	2.52		EE0	BEAM 9	10.89	9.31	16.97
	F1	F1E1	BEAM 29	60.27	62.69	3.86	E-E1	EE1	BEAM 28	18.64	15.01	24.18
		F1G1	BEAM 31	37.53	46.18	18.73		E1E	BEAM 28	20.94	16.66	25.69
	E	ED	BEAM 8	35.78	42.3	15.41	F0-F	F0F	BEAM 11	5.48	4.63	18.36
		EF	BEAM 10	66.57	66.61	0.06		FF0	BEAM 11	10.97	8.92	22.98
	F	FE	BEAM 10	66.63	68.3	2.45	F-F1	FF1	BEAM 30	19.59	14.47	35.38
		FG	BEAM 12	37.12	44.91	17.35		F1F	BEAM 30	22.73	16.51	37.67
Case 3 (GF+FF+SF)	E2	E2D2	BEAM 46	49.46	54.74	9.65	E0-E	E0E	BEAM 9	5.66	4.11	37.71
		E2F2	BEAM 48	58.05	60.67	4.32		EE0	BEAM 9	11.32	9.05	25.08
	F2	F2E2	BEAM 48	52.23	60.53	13.71	E-E1	EE1	BEAM 28	17.54	12.01	46.04

Contd.,

CASE	BEAMS						COLUMNS					
	JOINT	MEMBER	BEAM	END MOMENTS (KNm)		% VARIATION	JOINT	MEMBER	COLUMN	END MOMENTS (KNm)		% VARIATION
				KANI's	STAAD					KANI's	STAAD	
		F2G2	BEAM 50	41.79	55.12	24.18		E1E	BEAM 28	18.1	11.67	55.10
	E1	E1D1	BEAM 27	21.64	47.11	54.06	E1-E2	E1E2	BEAM 47	7.33	4.87	50.51
		E1F1	BEAM 29	70.75	63.65	11.15		E2E1	BEAM 47	9.06	5.92	53.04
	F1	F1E1	BEAM 29	58.48	67.14	12.9	F0-F	F0F	BEAM 11	5.8	5.54	4.69
		F1G1	BEAM 31	33.37	51.42	35.1		FF0	BEAM 11	11.61	8.5	36.59
	E	ED	BEAM 8	37.59	45.27	16.96	F-F1	FF1	BEAM 30	18.24	12.37	47.45
		EF	BEAM 10	65.82	63.33	3.93		F1F	BEAM 30	19.07	11.67	63.41
	F	FE	BEAM 10	66.32	68.95	3.81	F1-F2	F1F2	BEAM 49	7.51	4.04	85.89
		FG	BEAM 12	37.69	48.09	21.63		F2F1	BEAM 49	9.59	5.41	77.26
Case 4 (GF+FF+SF+TF)	E3	E3D3	BEAM 65	51.23	62.36	17.85	E0-E	E0E	BEAM 9	5.57	3.75	48.53
		E3F3	BEAM 67	62.49	67.31	7.16		EE0	BEAM 9	11.13	8.44	31.87
	F3	F3E3	BEAM 67	56.88	70.45	19.26	E-E1	EE1	BEAM 28	18.08	10.67	69.45
		F3G3	BEAM 69	44.51	67.02	33.59		E1E	BEAM 28	19.47	10.07	93.35
	E2	E2D2	BEAM 46	43.62	56.25	22.45	E1-E2	E1E2	BEAM 47	6.86	3.07	123.45
		E2F2	BEAM 48	60.37	63.86	5.47		E2E1	BEAM 47	8.03	3.23	148.61
	F2	F2E2	BEAM 48	56.47	67.44	16.27	E2-E3	E2E3	BEAM 66	10.06	4.37	130.21

Contd.,

CASE	BEAMS						COLUMNS					
	JOINT	MEMBER	BEAM	END MOMENTS (KNm)		% VARIATION	JOINT	MEMBER	COLUMN	END MOMENTS (KNm)		% VARIATION
				KANI's	STAAD					KANI's	STAAD	
		F2G2	BEAM 50	37.34	61.83	39.61		E3E2	BEAM 66	10.92	4.95	120.61
	E1	E1D1	BEAM 27	37.69	51.05	26.17	F0-F	F0F	BEAM 11	5.77	4.23	36.41
		E1F1	BEAM 29	62.63	64.19	2.43		FF0	BEAM 11	11.55	7.72	49.61
	F1	F1E1	BEAM 29	61.4	68.26	10.05	F-F1	FF1	BEAM 30	18.31	10.87	68.45
		F1G1	BEAM 31	35.37	55.96	36.79		F1F	BEAM 30	19.3	9.66	99.79
	E	ED	BEAM 8	36.1	47.5	24	F1-F2	F1F2	BEAM 49	6.9	2.64	161.36
		EF	BEAM 10	66.62	66.61	0.02		F2F1	BEAM 49	8.26	2.77	198.19
	F	FE	BEAM 10	66.12	69.48	4.84	F2-F3	F2F3	BEAM 68	10.57	2.84	272.18
		FG	BEAM 12	37.33	50.89	26.65		F3F2	BEAM 68	11.51	3.43	235.57

Note: GF- Ground Floor, FF-First Floor, SF- Second Floor, TF- Third Floor

6. RESULTS AND DISCUSSIONS

For the study purposes only the final beam and column moments were compared for all the four cases. From the results it is observed that the percentage variation shows a higher value only in the joints A, A1, A2, and A3. But for these joints the percentage variation is relatively less when compared to all other joints. This may be due to change in the rigidity of the joints at the end of the portal frame thereby making it unstable at the joints A, A1, A2 and A3 as the degrees of freedom are available in more than one direction. A consolidated statement showing minimum, maximum, mean percentage variation in end moments is indicated in Table 2. Further for all the four cases the variation in end moments were classified into four categories viz a) < 5 % b) 5 to 10 % c) 10 to 20 % and d) > 20 %. This categorization of beam and column moment percentage variation is also provided in Table 2.

Table 2: Consolidated % Variation

Beam Moment % Variation									
Case	**Number of Beam / Column Elements**	**Number of End Moments**	**Min**	**Max**	**Mean**	**< 5 %**	**5-10 %**	**10-20 %**	**> 20 %**
Case 1 (GF)	9	18	0.05	14.49	2.74	14	2	1	1
Case 2 (GF +FF)	18	36	0.06	21.57	5.37	24	3	6	3
Case 3 (GF+FF+SF)	27	54	0.37	54.85	10.01	30	3	9	12
Case 4 (GF+FF+SF+TF)	36	72	0.02	66.02	12.7	28	14	10	20
Column Moment % Variation									
Case 1 (GF)	10	20	0.27	38.25	6.92	10	6	0	4
Case 2 (GF +FF)	20	40	0.13	37.67	12.11	10	9	8	13
Case 3 (GF+FF+SF)	30	60	0.45	85.89	20.31	13	11	9	27
Case 4 (GF+FF+SF+TF)	40	80	0.05	272.2	39.44	7	10	18	45

Beam moments: In Case 1, 89 % of end moments fall within 10 % variation. Similarly for Case 4, 58 % of the end moments lies within 10 %. So it can be said that more than 50 % of the end moments fall within 10 % variation only.

Column moments: In Case 1, 80 % of end moments fall within 10 % variation. Similarly for Case 4, 22 % of the end moments lies within 10 %. Further for cases 1,2 and 3, more than 40% of the end moments fall in less than 10 % category. The classifications of percentage variation for all the four cases for beam and column moments are pictorially depicted in Figures 6 and 7. Further it is noticed that the percentage variation increases as the number of floors increases in both beam and column moments as may be seen from Table 2.

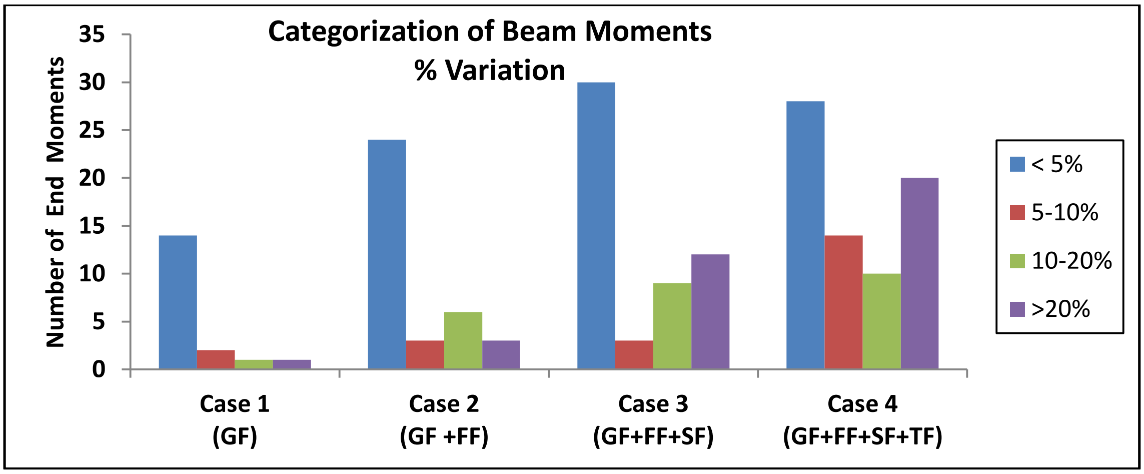

Figure 6: Classification of Beam Moments

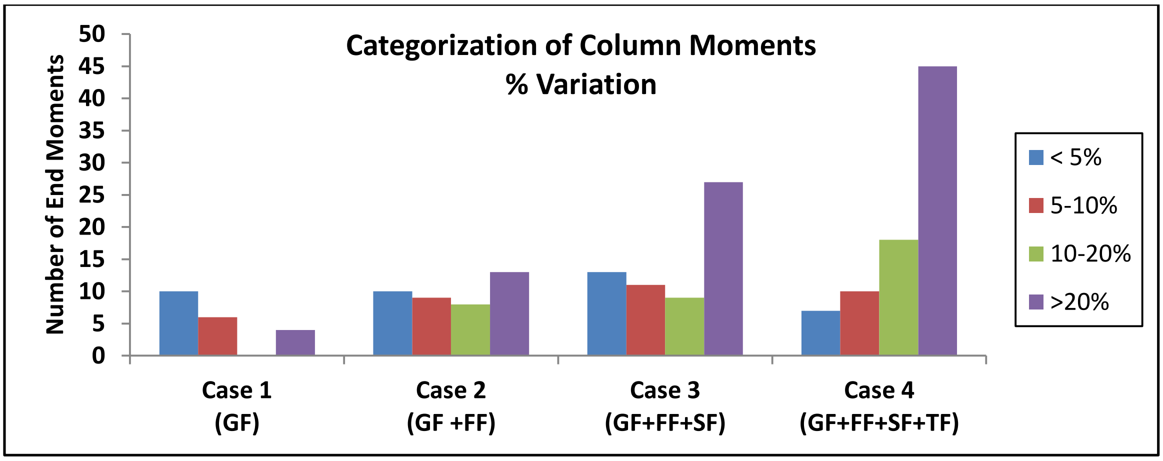

Figure 7: Classification of Column Moments

7. CONCLUSION

- The minimum variation is found in ground floor whereas the maximum variation occurs in the third floor for both beam and column moments.
- The variation among the four cases is from 2.74 % to 12.7 % in case of beam moments and it is from 6.92 % to 39.44 % in case of column moments.

- It is observed that the mean variation increases as the number of floors increases.
- The variation % is found to be more in column moments than in beam moments.
- It can be concluded that more than 50 % of the end moments fall within 10 % variation for all the four cases for beam moments and more than 40 % of the end moments lie within 10 % variation for the first three cases in column moments.
- In a nutshell, both the methods are adoptable for practical applications. However for smaller frames (2 to 3 floors) Kani's Method is suitable as it is less time consuming, flexible, self- corrective and easy. In case of larger three dimensional frames it is suggested to go in for Linear Static Analysis using STAAD.Pro as the analysis is extendable to push over non linear analysis, wind and seismic load combinations, graphic interface and design capabilities (Limit State Method based on IS 456-2000).

REFERENCES

[1] Rashmi Agashe, Marshal Baghele, Vaishanvi Deshmukh, Sharad Khomane, Gaurav Patle and Kushal Yadav (2020), "To Study, Analysis and Design of Multi-Storey Building using STAAD.Pro and Comparing with Manual Calculations", International Research Journal of Engineering and Technology (IRJET), Vol. No.7, Issue No 4.

[2] Potharaboyena Vinay and Kurimilla Srilaxmi (2018), "Structural Analysis and Design of Structural Elements of a Building", International Open Access Journal, Vol. No. 2, Issue No 3.

[3] Chiranjeevi M, Udaykumar A and Saikumar S V (2017), "Comparative Study on End Moments regarding Application of Analytical Methods and STAAD.Pro software", International Journal of Engineering, Science and Mathematics, Vol. No. 6, Issue No 8.

[4] Kushal Shahl, Pankaj Singh (2017), "Analysis of Loads for G+6 Residential Building using STAAD.Pro (v8i)", International Journal of Advance Research in Engineering, Science & Technology, Vol. No. 4, Issue No 7.

[5] Balwinder Lallotra, Dhirendra Singhal (2017), "A Compatability Study on Design and Analysis of Reinforced Concrete Structural Design using Software", International Journal of Engineering and Technology (IJET), Vol. No. 9, Issue No 2.

[6] Ashok kumar N, Navaneethan M, Naviya B, Gopalakrishnan D, Atun Roy Choudhury (2017), "Planning, Analysis and Design of Hospital Building using STAAD.Pro v8i", International Journal of Scientific and Engineering Research, Volume 8, Issue 4.

[7] Syed Faheemuddin, Mohammed Imran, Noman Fahad, Mohammed Hakeem Pasha (2016), "Analysis of Multi-Storeyed Building", International Journal for Innovative Research in Science and Technology (IJIRST), Vol. No. 3, Issue No 06.

[8] Ramamrutham S and Narayan R (2015), Theory of Structures, Edition 9, Dhanpat Rai Publishing Company.

[9] Punmia B C (1986), Strength of Materials and Mechanics of Structures, Vol. II Edition 7, Standard Publishers Distributors.

[10] IS 456:2000, Plain and reinforced concrete code of practice (Fourth revision).

[11] IS 875:1987 (Part 1), Code of practice for design loads (Dead load)

[12] IS 875:1987 (Part 2), Code of practice for design loads (Imposed load)

[13] SP 16:1978, Design Aids for reinforced concrete to IS 456:2000