Analysis of Space Frame under Pattern Loading

Vishal Yadav and Vivek Garg

Department of Civil Engineering, M.A.N.I.T., Bhopal, India

Abstract- The use of reinforced concrete buildings has become a general scene in the contemporary world. The analysis, design and construction processes have been idealized through various building design codes and design philosophies. Buildings are designed to withstand all the loads that may occur with a certain degree of probability during its entire lifetime. Different categories of loads have been classified by codes in accordance with the purpose and location of the structure. Among all the loads, imposed load has the moving tendency and can translate from one span to the other forming different patterns of loading. In present study, a G+1 storey, 5 bay x 5 bay frame subjected to an imposed load of 5 kN/m^2 located in seismic zone II, has been taken as a base frame and analysis is done using STAAD Pro software. The member forces of a building are compared between conventional loading (i.e. seismic and all span gravity loading) and pattern loading (i.e. conventional loading plus 5 patterns of imposed load) to determine the necessity of pattern loading. In beam members the values of bending moment are significantly higher for pattern loading as compared with conventional loading. This increase in moment is found more in beam sagging moment compared to hogging moment. The effect of pattern loading is felt more on the upper storey exterior beams compared to the lower storey beams. Pattern loading causes insignificant changes in the beam shear force and column axial force.

Keywords- Imposed load; Conventional loading; Pattern loading; STAAD Pro etc.

1. INTRODUCTION

A structure can be defined as a body which can withstand the applied loads without any appreciable deformations. Civil engineering structures are created to serve some specific functions like human transportation, human habitat, bridges etc. in a safe and economical way. A structure is an assemblage of individual elements like truss elements, beam elements, columns, shear walls, slabs, cable or arch. Structural engineering is concerned with the planning, designing and the construction of structures. Structure analysis involves in determining the forces and displacements that are caused due to various forces on the structures or components of a structure. Analysis is performed to calculate the response of a structure to applied external loads. Building standard codes recommends that arrangement of imposed load should be such that the values of critical forces at all sections in the structure can be evaluated and accounted for in the design. However there are numerous pattern by which live load may be subjected on a structure, evaluating all those patterns is practically not possible. So various approaches have to be developed to limit the loading arrangements to such cases which can be handled easily and also at the same time provide rational and realistic values of the forces generated in the structure.

1.1 Literature Review

Many researchers have presented work on different arrangements of live load and how to minimize the number of patterns to find the critical pattern. Such works have been discussed in chronological order in this section.

Large (1950) presented a method which is mainly based on the concept of influence lines diagrams. According to this method the number of live load combinations required to obtain support moments are equal to the number of beam-column joints. Additionally, two load combinations are required to obtain the span bending moments. However it can be clearly seen that this method is time consuming as it requires a large number of loading arrangements to be considered also the number of these arrangements will go on increasing with increase in number of storey and bays.

Furlong R.W. (1981) approached this problem as a practical designer and claimed that all possible live loads combinations do not have to be considered for the following reasons. The probability of occurrence of the most critical combination decreases with increase in load combinations. Member forces are not sensitive to loading for members to adjacent to such members. Linear elastic analysis is just an approximation for reinforced concrete structure in which I and E change due to cracking and creep. Considering these points, Furlong proposed some simple imposed load arrangements which he claimed would give reasonable values for shear and bending moment in beams and columns. The live load arrangement proposed by Furlong is shown in figure, for a five bay, five storey frames. Furlong gave the following equation for determining the no of loading patterns which is dependent on the no bays of the structure. No of load combinations = 2+ (m-1), where m is the no of spans in a multistory frame structure.

Ugur E. (1992) gave a method where no. of loading cases is constant and is always equal to 5 irrespective of no of storey's and bays. Apart from some specified points, his results were comparable to that of Furlong. Ersoy proposed two different arrangements for frames for maximum and minimum span moments which results in simple checker board loading. For maximum support moments and shears in beams the basic loading is shown in figure. Other patterns consist of continuous loaded members leaving one unloaded span in between. On each storey the basic train loading is shifted one bay to the right as compared to the storey above. This arrangement will also yield maximum moments for some of the frame columns. In figure the loading arrangements proposed by the author are applied to the frame shown. As may be observed, the number of live load arrangements is independent of the number of bays and is five for all cases.

Quimby (2002) proposed the method of influential superposition which is based on the concept of superposition and hence is valid for linear systems. In this method unit loads of the same nature as the real live loads are applied individually on the

ISSN 2250-3153
spans of the structure forming different loading cases, number of which are equal to the number of spans in the structure and the effects are determined at points of interest for each case of loading.

Akiner M.E. (2012) has based the work on the previous works done by ERSOY and Furlong and developed his third approach called approach no 3 using genetic algorithm. Genetic algorithms are search algorithms based on the mechanics of natural selection and natural genetics. Their basic idea is what lies behind the nature itself, "Survival of the Fittest". A third approach was presented which required analysis of five cases irrespective of the no of storey's and bays. The aim of approach no3 (AN3) is as the aim of Furlong approach and Ersoy approach, to obtain sufficiently accurate results with a reasonable number of loading cases. First two loading cases are Classical Checkerboard Loading and as same as first two loading case of Ersoy approach. Loading cases for finding maximum negative moments are different than Furlong and Ersoy approach in AN3, starting from the first beam, at the upper left, two adjacent beams are loaded and third one is unloaded. This loading continues until all beams are dealt with.

Ansari and Garg (2016) presented a journal on Structural behaviour of building frame under pattern loading. The loading patterns considered were similar to that of Ugur Ersoy on a two dimensional building frame and compared the results with that of the conventional loading pattern with all spans loaded. It was concluded that the values of bending moment are significantly higher for pattern loading as compared with conventional loading for both beam and column members. The effect of pattern loading is felt more on interior beam members as compared with the exterior beam members of the same floor also it is observed that pattern loading effects the top floors interior beam the most as compared with any other beam member. The effect of pattern loading is more on beam sagging moment as compared to hogging moment.

2. PROPOSED WORK

The present study investigates the structural behavior of an RC frame (G+1 Commercial building) under pattern loading. The base frame under consideration is used for storage purpose. An Imposed load of 5 kN/m^2 is considered on floors of the building. The slab weight is taken as 3 kN/m^2. A wall load of 7 kN/m is considered on the outer periphery of first floor whereas a load of 3 kN/m for parapet wall is considered on the outer periphery of second floor. The structure is analyzed for two loading cases. In first case (Conventional loading) structure is analyzed for seismic forces and all span gravity loading and in second case (Pattern loading) structure is analyzed for conventional loading plus five different loading patterns. The analysis is performed by using structural analysis software i.e. STAAD Pro. The analysis results of structure for conventional and pattern loading are compared to evaluate the effect of pattern loading on the RC structure.

The geometrical and seismic parameters used for modelling of proposed problem are shown in Table 1 and Table 2. Isometric view and plan of proposed structure under consideration is depicted in Fig.1 and Fig.2. Column and beam member numbering is shown in Fig.3 to Fig.10. Loading patterns considered in the study is shown in Fig.11.

Table 1 Geometric Parameters

Sr. No.	Parameters	Values
1.	No. of storey's	2
2.	No. of span in X-direction	5
3.	No. of Span in Y-direction	5
4.	Floor to Floor height	3.5m
5.	Span length in X and Y-direction	4m
6.	Size of beam	0.2m x 0.3m
7.	Size of column	0.25m x 0.25m
8.	Slab thickness	0.120m

Table 2 Parameters for Seismic load

	Parameter	Value

Sr. No.		
1	Location (ZONE II)	Zone Factor = 0.10
2	Response reduction factor (Ordinary RC Moment Resisting Frame)	RF = 5
3	Importance factor (All General Building)	I = 1
4	Rock and soil site factor (Medium soil)	SS = 2
5	Type of structure (RC Frame Building)	ST = 1
6	Damping ratio	DM = 0.05

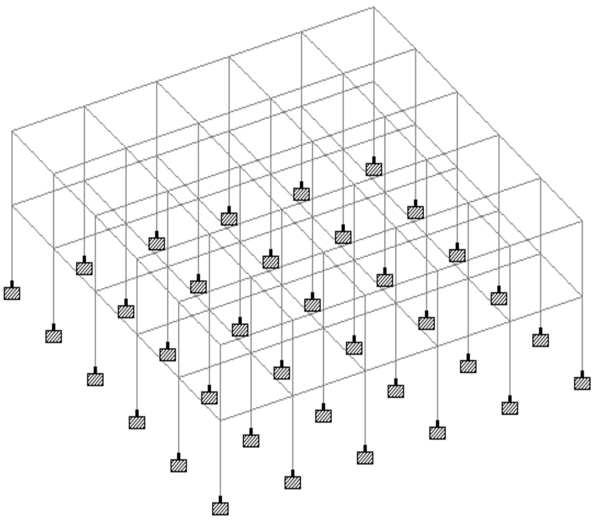


Fig 1 Isometric view of proposed structure

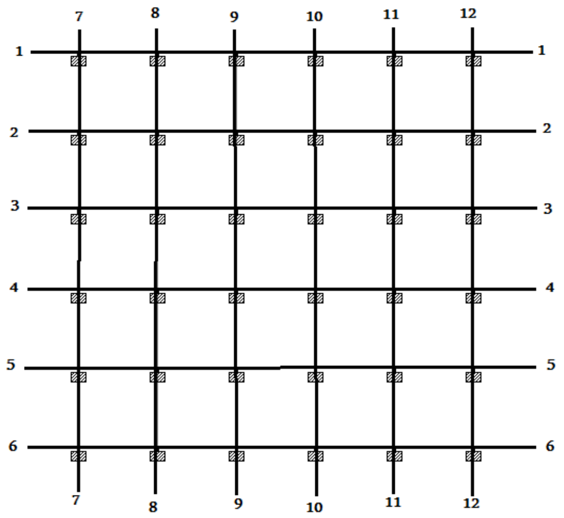


Fig 2: Plan of base frame

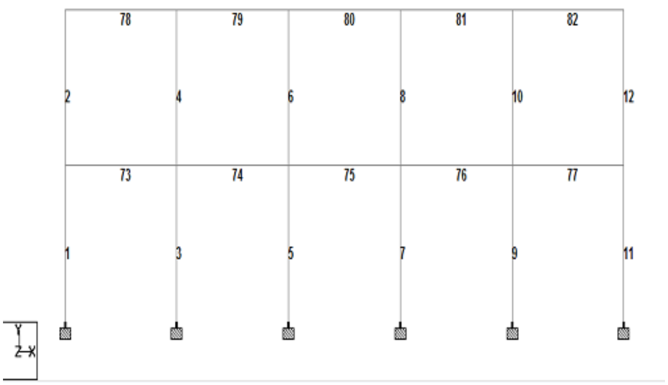


Fig 3: Section 1-1

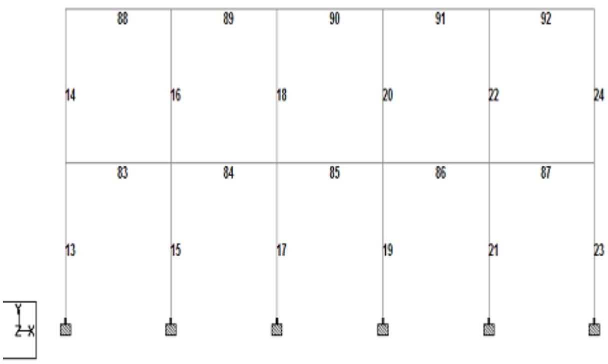


Fig 4: Section 2-2

ISSN 2250-3153

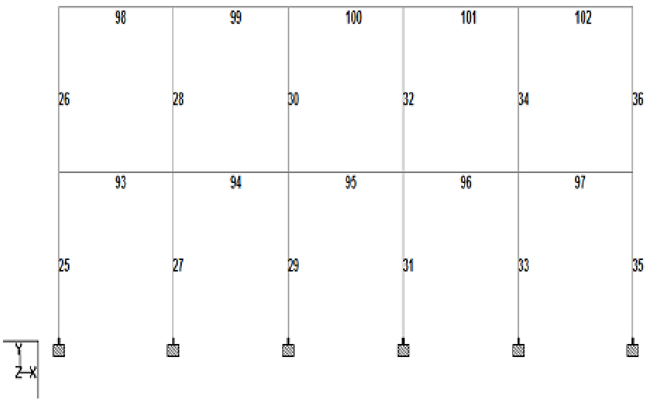


Fig 5: Section 3-3

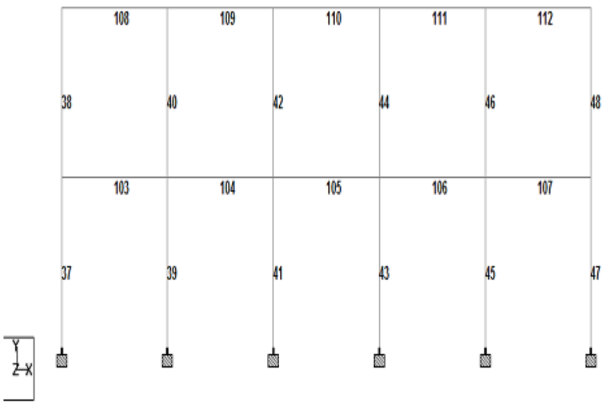


Fig 6: Section 4-4

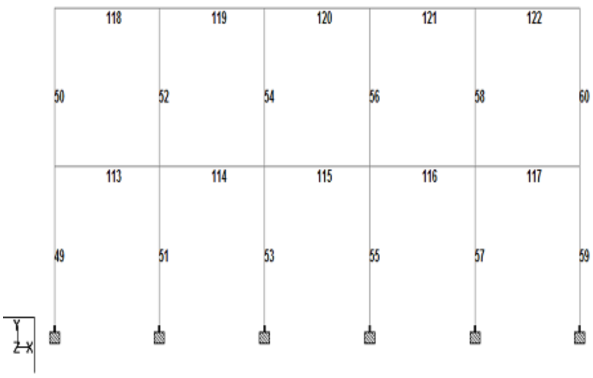


Fig 7: Section 5-5

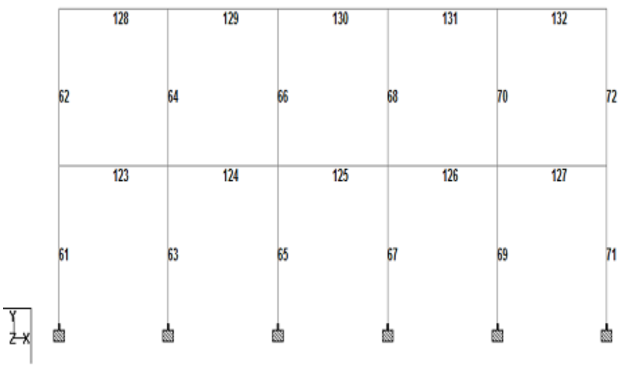


Fig 8: Section 6-6

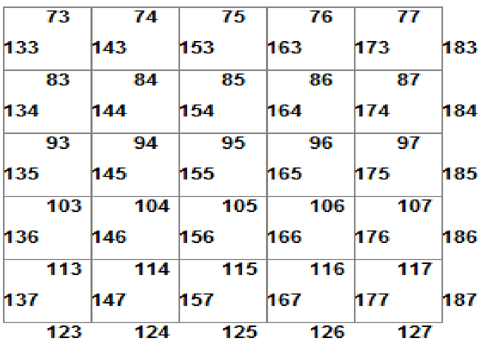


Fig 9: Beam numbering at first floor

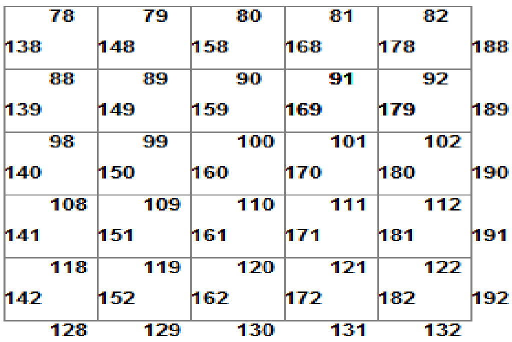


Fig 10: Beam numbering at top floor

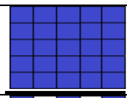
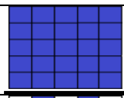
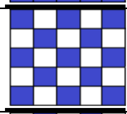
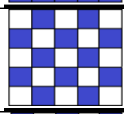
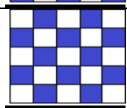
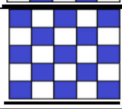
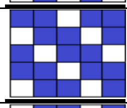
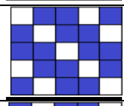
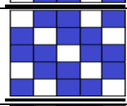
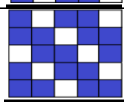
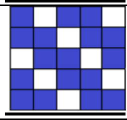
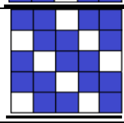
LOADING TYPE	SECOND FLOOR	FIRST FLOOR
CONVENTIONAL LOADING		
PATTERN 1		
PATTERN 2		
PATTERN 3		
PATTERN 4		
PATTERN 5		

Fig 11: Loading patterns on G+1 storey structure

2.2 Load cases and combinations

Primary loads and their combinations considered in the study area as follows:

Primary loads
LC 1:- EQ X = EQ in +X direction
LC 2:- EQ Z = EQ in +Z direction
LC 3:- DL = Dead load
LC 4:- Conventional load
LC 5:- Pattern 1
LC 6:- Pattern 2
LC 7:- Pattern 3
LC 8:- Pattern 4
LC 9:- Pattern 5

Load Combinations

LC 10:- LC 3*1.5 + LC 4*1.5
LC 11:- LC 3*1.5 + LC 5*1.5
LC 12:- LC 3*1.5 + LC 6*1.5
LC 13:- LC 3*1.5 + LC 7*1.5
LC 14:- LC 3*1.5 + LC 8*1.5
LC 15:- LC 3*1.5 + LC 9*1.5
LC 16:- LC 3*1.2 + LC 4*1.2 + LC 1*1.2
LC 17:- LC 3*1.2 + LC 4*1.2 + LC 2*1.2
LC 18:- LC 3*1.2 + LC 4*1.2 – LC 1*1.2
LC 19:- LC 3*1.2 + LC 4*1.2 – LC 2*1.2
LC 20:- LC 3*1.5 + LC 1*1.5
LC 21:- LC 3*1.5 + LC 2*1.5
LC 22:- LC 3*1.5 - LC 1*1.5
LC 23:- LC 3*1.5 - LC 2*1.5
LC 24:- LC 3*0.9 + LC 1*1.5
LC 25:- LC 3*0.9 + LC 2*1.5
LC 26:- LC 3*0.9 - LC 1*1.5
LC 27:- LC 3*0.9 - LC 2*1.5

3. RESULTS AND DISCUSSION

In the present study, a G+1 building has been modeled and the values of member forces generated by conventional loading (i.e. all span load plus seismic load) have been compared to the forces generated in the members being subjected to pattern

ISSN 2250-3153
loading (i.e. conventional loading along with the set of 5 different pattern loads). Pattern/Conventional ratio is determined to evaluate the impact of pattern loading.

3.1 Effect of pattern loading on column forces

In this section the effect of pattern loading on the columns of base frame is studied and the results have been tabulated. Bending moment (M_z) and axial forces (F_x) in the column members are analyzed and compared for conventional and pattern loading to evaluate the effect of pattern loading on column members. Effects of pattern loading on column forces are shown in Table 3.

3.1.1 Effect on Bending moment

Table 3 indicates that there is no increase in bending moment values for pattern loading in comparison to conventional loading for all column members. This implies that the lateral loads applied have greater impact than pattern gravity loads in generating critical bending moments in column members.

3.1.2 Effect on Axial force

The highest value of Pattern/Conventional ratio for axial force is 1.04 as shown in table 3. The maximum variation is observed in the member nos. 2, 6, 8, 12, 26, 36, 38, 48, 62, 66, 68 and 72 which are upper storey exterior columns. This indicates despite the increase in value of axial force, the effect of pattern loading is insignificant. It is observed that the exterior columns in the central bay are more affected by pattern loading as compared to the interior columns. The effect of pattern loading can be seen more on upper storey columns as compared to the lower ones.

Table 3: Comparison of forces in columns between conventional and pattern loading.

Column No.	Max/Min Values	Pattern Loading		Conventional loading		Pattern/Conventional ratio	
		Bending Moment (kN-m)	Axial force (kN)	Bending Moment (kN-m)	Axial force (kN)	Bending Moment	Axial force
1	Max +ve	13.87	174.84	13.87	173.02	1.00	1.01
	Max –ve	-14.24	*	-14.24	*	1.00	**
2	Max +ve	18.77	76.82	18.77	74.05	1.00	1.04
	Max –ve	-16.50	*	-16.50	*	1.00	**
3	Max +ve	12.07	291.54	12.07	291.54	1.00	1.00
	Max –ve	-12.58	*	-12.58	*	1.00	**
4	Max +ve	10.89	136.02	10.89	133.01	1.00	1.02
	Max –ve	-9.68	*	-9.68	*	1.00	**
5	Max +ve	12.14	281.96	12.14	281.96	1.00	1.00
	Max –ve	-12.06	*	-12.06	*	1.00	**
6	Max +ve	9.06	132.79	9.06	127.74	1.00	1.04
	Max –ve	-9.32	*	-9.32	*	1.00	**
7	Max +ve	12.06	281.96	12.06	281.96	1.00	1.00
	Max –ve	-12.14	*	-12.14	*	1.00	**
8	Max +ve	9.32	132.70	9.32	127.74	1.00	1.04
	Max –ve	-9.06	*	-9.06	*	1.00	**
9	Max +ve	12.58	291.54	12.58	291.54	1.00	1.00
	Max –ve	-12.07	*	-12.07	*	1.00	**
10	Max +ve	9.68	135.75	9.68	133.01	1.00	1.02
	Max –ve	-10.89	*	-10.89	*	1.00	**
11	Max +ve	13.87	174.57	13.87	173.02	1.00	1.01
	Max –ve	-14.24	*	-14.24	*	1.00	**
12	Max +ve	18.77	76.82	18.77	74.05	1.00	1.04
	Max –ve	-16.50	*	-16.50	*	1.00	**
13	Max +ve	15.40	291.54	15.40	291.54	1.00	1.00
	Max –ve	-14.61	*	-14.61	*	1.00	**
14	Max +ve	24.92	135.80	24.92	133.01	1.00	1.02
	Max –ve	-20.47	*	-20.47	*	1.00	**
15	Max +ve	13.77	455.51	13.77	455.51	1.00	1.00
	Max –ve	-14.06	*	-14.06	*	1.00	**
16	Max +ve	12.84	230.40	12.84	230.40	1.00	1.00
	Max –ve	-11.22	*	-11.22	*	1.00	**
17	Max +ve	13.72	443.50	13.72	443.50	1.00	1.00
	Max –ve	-13.67	*	-13.67	*	1.00	**
18	Max +ve	10.78	222.91	10.78	222.91	1.00	1.00
	Max –ve	-11.09	*	-11.09	*	1.00	**
19	Max +ve	13.67	443.50	13.67	443.50	1.00	1.00

	Max –ve	-13.72	*	-13.72	*	1.00	**
20	Max +ve	11.09	222.91	11.09	222.91	1.00	1.00
	Max –ve	-10.78	*	-10.78	*	1.00	**
21	Max +ve	14.06	455.51	14.06	455.51	1.00	1.00
	Max –ve	-13.77	*	-13.77	*	1.00	**
22	Max +ve	11.22	230.40	11.22	230.40	1.00	1.00
	Max –ve	-12.84	*	-12.84	*	1.00	**
23	Max +ve	15.40	291.54	15.40	291.54	1.00	1.00
	Max –ve	-14.61	*	-14.61	*	1.00	**
24	Max +ve	24.92	135.75	24.92	133.01	1.00	1.02
	Max –ve	-20.47	*	-20.47	*	1.00	**
25	Max +ve	15.75	281.96	15.75	281.96	1.00	1.00
	Max –ve	-15.27	*	-15.27	*	1.00	**
26	Max +ve	25.52	132.87	25.52	127.74	1.00	1.04
	Max –ve	-20.84	*	-20.84	*	1.00	**
27	Max +ve	14.58	443.50	14.58	443.50	1.00	1.00
	Max –ve	-14.86	*	-14.86	*	1.00	**
28	Max +ve	13.51	222.91	13.51	222.91	1.00	1.00
	Max –ve	-11.79	*	-11.79	*	1.00	**
29	Max +ve	14.51	431.11	14.51	431.11	1.00	1.00
	Max –ve	-14.46	*	-14.46	*	1.00	**
30	Max +ve	11.40	215.04	11.40	215.04	1.00	1.00
	Max –ve	-11.72	*	-11.72	*	1.00	**
31	Max +ve	14.46	431.11	14.46	431.11	1.00	1.00
	Max –ve	-14.51	*	-14.51	*	1.00	**
32	Max +ve	11.72	215.04	11.72	215.04	1.00	1.00
	Max –ve	-11.40	*	-11.40	*	1.00	**
33	Max +ve	14.86	443.50	14.86	443.50	1.00	1.00
	Max –ve	-14.58	*	-14.58	*	1.00	**
34	Max +ve	11.79	222.91	11.79	222.91	1.00	1.00
	Max –ve	-13.51	*	-13.51	*	1.00	**
35	Max +ve	15.75	281.96	15.75	281.96	1.00	1.00
	Max –ve	-15.27	*	-15.27	*	1.00	**
36	Max +ve	25.52	132.70	25.52	127.74	1.00	1.04
	Max –ve	-20.84	*	-20.84	*	1.00	**
37	Max +ve	15.75	281.96	15.75	281.96	1.00	1.00
	Max –ve	-15.27	*	-15.27	*	1.00	**
38	Max +ve	25.52	133.06	25.52	127.74	1.00	1.04
	Max –ve	-20.84	*	-20.84	*	1.00	**
39	Max +ve	14.58	443.50	14.58	443.50	1.00	1.00
	Max –ve	-14.86	*	-14.86	*	1.00	**
40	Max +ve	13.51	222.91	13.51	222.91	1.00	1.00
	Max –ve	-11.79	*	-11.79	*	1.00	**
41	Max +ve	14.51	431.11	14.51	431.11	1.00	1.00
	Max –ve	-14.46	*	-14.46	*	1.00	**
42	Max +ve	11.40	215.04	11.40	215.04	1.00	1.00
	Max –ve	-11.72	*	-11.72	*	1.00	**
43	Max +ve	14.46	431.11	14.46	431.11	1.00	1.00
	Max –ve	-14.51	*	-14.51	*	1.00	**
44	Max +ve	11.72	215.04	11.72	215.04	1.00	1.00
	Max –ve	-11.40	*	-11.40	*	1.00	**
45	Max +ve	14.86	443.50	14.86	443.50	1.00	1.00
	Max –ve	-14.58	*	-14.58	*	1.00	**
46	Max +ve	11.79	222.91	11.79	222.91	1.00	1.00
	Max –ve	-13.51	*	-13.51	*	1.00	**
47	Max +ve	15.75	281.96	15.75	281.96	1.00	1.00
	Max –ve	-15.27	*	-15.27	*	1.00	**
48	Max +ve	25.52	132.79	25.52	127.74	1.00	1.04
	Max –ve	-20.84	*	-20.84	*	1.00	**
49	Max +ve	15.40	291.54	15.40	291.54	1.00	1.00
	Max –ve	-14.61	*	-14.61	*	1.00	**

50	Max +ve	24.92	136.48	24.92	133.01	1.00	1.03
	Max –ve	-20.47	*	-20.47	*	1.00	**
51	Max +ve	13.77	455.51	13.77	455.51	1.00	1.00
	Max –ve	-14.06	*	-14.06	*	1.00	**
52	Max +ve	12.84	230.40	12.84	230.40	1.00	1.00
	Max –ve	-11.22	*	-11.22	*	1.00	**
53	Max +ve	13.72	443.50	13.72	443.50	1.00	1.00
	Max –ve	-13.67	*	-13.67	*	1.00	**
54	Max +ve	10.78	222.91	10.78	222.91	1.00	1.00
	Max –ve	-11.09	*	-11.09	*	1.00	**
55	Max +ve	13.67	443.50	13.67	443.50	1.00	1.00
	Max –ve	-13.72	*	-13.72	*	1.00	**
56	Max +ve	11.09	222.91	11.09	222.91	1.00	1.00
	Max –ve	-10.78	*	-10.78	*	1.00	**
57	Max +ve	14.06	455.51	14.06	455.51	1.00	1.00
	Max –ve	-13.77	*	-13.77	*	1.00	**
58	Max +ve	11.22	230.40	11.22	230.40	1.00	1.00
	Max –ve	-12.84	*	-12.84	*	1.00	**
59	Max +ve	15.40	291.54	15.40	291.54	1.00	1.00
	Max –ve	-14.61	*	-14.61	*	1.00	**
60	Max +ve	24.92	136.02	24.92	133.01	1.00	1.02
	Max –ve	-20.47	*	-20.47	*	1.00	**
61	Max +ve	13.87	175.18	13.87	173.02	1.00	1.01
	Max –ve	-14.24	*	-14.24	*	1.00	**
62	Max +ve	18.77	77.11	18.77	74.05	1.00	1.04
	Max –ve	-16.50	*	-16.50	*	1.00	**
63	Max +ve	12.07	291.54	12.07	291.54	1.00	1.00
	Max –ve	-12.58	*	-12.58	*	1.00	**
64	Max +ve	10.89	136.48	10.89	133.01	1.00	1.03
	Max –ve	-9.68	*	-9.68	*	1.00	**
65	Max +ve	12.14	281.96	12.14	281.96	1.00	1.00
	Max –ve	-12.06	*	-12.06	*	1.00	**
66	Max +ve	9.06	133.06	9.06	127.74	1.00	1.04
	Max –ve	-9.32	*	-9.32	*	1.00	**
67	Max +ve	12.06	281.96	12.06	281.96	1.00	1.00
	Max –ve	-12.14	*	-12.14	*	1.00	**
68	Max +ve	9.32	132.87	9.32	127.74	1.00	1.04
	Max –ve	-9.06	*	-9.06	*	1.00	**
69	Max +ve	12.58	291.54	12.58	291.54	1.00	1.00
	Max –ve	-12.07	*	-12.07	*	1.00	**
70	Max +ve	9.68	135.80	9.68	133.01	1.00	1.02
	Max –ve	-10.89	*	-10.89	*	1.00	**
71	Max +ve	13.87	174.84	13.87	173.02	1.00	1.01
	Max –ve	-14.24	*	-14.24	*	1.00	**
72	Max +ve	18.77	76.82	18.77	74.05	1.00	1.04
	Max –ve	-16.50	*	-16.50	*	1.00	**
						Bending Moment	**Shear Force**
Maximum variation						**1.00**	**1.04**

3.2 Effect of pattern loading on beam forces

Bending moment and shear force in beam members for conventional and pattern loading are compared to evaluate the effect of pattern loading on beam forces.

3.2.1 Effect on Bending moment

It has been indicated in table 4 that there is an increase hogging moment values for pattern loading in comparison to conventional loading for most of the beam members. The maximum Pattern/Conventional ratio for hogging moment is 1.12. The highest value of Pattern/Conventional ratio obtained for hogging moment is for top floor's exterior beam member (beam number 80, 130, 140 and 190).

Table 5 indicates that all the members are affected due to pattern loading and their sagging moment values increases. The maximum pattern/conventional ratio for sagging moment is found to be 1.25. The values of sagging moments are more affected as compared to hogging moment which is represented by higher values of Pattern/Conventional ratio. On every floor the exterior beam of central bay has higher value of Pattern/Conventional ratio than the interior beams. The values of Pattern/Conventional ratio follow an increasing trend from ground floor beams to top floor beams for both hogging and sagging moment. The highest value of Pattern/Conventional ratio obtained for sagging moment is for top floor's exterior beams which are adjacent to the beams having maximum hogging moment (beam number 79, 81, 129, 131, 139, 141, 189 and 191).

3.2.2 Effect on Shear force

The highest value of Pattern/Conventional ratio for shear force is 1.06. These values exhibit that the increase in values of shear force obtained through pattern loading are insignificant. The maximum value of Pattern/Conventional ratio is observed in exterior beam members of top storey (beam number 80, 81, 130, 131, 139, 141, 189 and 190). The Pattern/Conventional ratio for shear force follows an increasing trend from ground floor beams to the top floor beams.

Table 4: Beam members having Pattern/Conventional ratio for hogging moment greater than 1.06

Member No.	Max +ve Values	Pattern Loading (Critical) value	Conventional loading value	Pattern/Conventional ratio
		Bending Moment (kN-m)	Bending Moment (kN-m)	Bending Moment
130	Max +ve	32.11	28.67	1.12
140	Max +ve	32.11	28.67	1.12
80	Max +ve	31.65	28.67	1.10
190	Max +ve	31.65	28.67	1.10
129	Max +ve	33.16	30.51	1.09
141	Max +ve	33.16	30.51	1.09
75	Max +ve	39.67	36.80	1.08
185	Max +ve	39.67	36.80	1.08
79	Max +ve	32.68	30.51	1.07
191	Max +ve	32.68	30.51	1.07
125	Max +ve	39.37	36.80	1.07
135	Max +ve	39.37	36.80	1.07
76	Max +ve	40.36	37.86	1.07
184	Max +ve	40.36	37.86	1.07
126	Max +ve	40.13	37.86	1.06
134	Max +ve	40.13	37.86	1.06

Table 5: Beam members having Pattern/Conventional ratio for sagging moment greater than 1.13

Member No.	Max -ve Values	Pattern Loading (Critical) value	Conventional Loading value	Pattern/Conventional ratio
		Bending Moment (kN-m)	Bending Moment (kN-m)	Bending Moment
79	Max -ve	-19.70	-15.79	1.25
81	Max -ve	-19.70	-15.79	1.25
129	Max -ve	-19.70	-15.79	1.25
131	Max -ve	-19.70	-15.79	1.25
139	Max -ve	-19.70	-15.79	1.25
141	Max -ve	-19.70	-15.79	1.25
189	Max -ve	-19.70	-15.79	1.25
191	Max -ve	-19.70	-15.79	1.25
80	Max -ve	-20.35	-16.57	1.23
130	Max -ve	-20.35	-16.57	1.23
140	Max -ve	-20.35	-16.57	1.23
190	Max -ve	-20.35	-16.57	1.23
74	Max –ve	-22.88	-20.06	1.14
76	Max -ve	-22.88	-20.06	1.14
124	Max -ve	-22.88	-20.06	1.14
126	Max -ve	-22.88	-20.06	1.14
119	Max -ve	-27.63	-24.47	1.13
151	Max -ve	-27.63	-24.47	1.13
89	Max -ve	-27.62	-24.47	1.13
181	Max -ve	-27.62	-24.47	1.13
121	Max -ve	-27.59	-24.47	1.13
149	Max -ve	-27.59	-24.47	1.13
91	Max -ve	-27.58	-24.47	1.13
179	Max -ve	-27.58	-24.47	1.13

4. CONCLUSION

In the present study the need of pattern loading in the analysis of building frames has been discussed by comparing the values of member forces obtained by conventional loading with that of pattern loading. The result indicates that the values of bending moment are significantly higher for pattern loading as compared with conventional loading for all beam members. This increase in moment is found more in beam sagging moment compared to hogging moment. The effect of pattern loading is felt more on the upper storey exterior beams compared to the lower storey beams. Pattern loading causes insignificant increase in beam shear force and column axial force. There is no impact of pattern loading on the bending moment of column members. This indicates that the conventional loading is adequate to design column members.

The summary of results obtained by the analysis to evaluate the need of pattern loading in the design of buildings has been tabulated in table 6.

Table 6: Summary of results for evaluation of need of pattern loading

Sr. No.	Particulars		Maximum values of Pattern/Conventional ratio
1	Beams	Hogging moment	1.12
		Sagging moment	1.25
		Shear force	1.06
2	Columns	Bending moment	1.00
		Axial force	1.04

REFERENCES

[1] Jirsa, J.O., Sozen, M.A. and Siess, C.P. (1969), "*Pattern Loading of Reinforced Concrete Floor Slabs*", Journal of the Structural Division, Vol-95, Issue-6, pp. 1117-1137.

[2] Jofriet, J.C. and Gregory, M.M (1971), "*Pattern Loading on Reinforced Concrete Flat Plates*", Journal Proceedings, Vol-68, Issue-12, pp. 968-972.

[3] Furlong R.W. (1981), "*Rational Analysis of multistory Concrete Structure*", Concrete International, American concrete Institute, Vol-3, no.6, pp 29-35.

[4] IS 875 (Part2)-1987, Code of practice for design loads (other than earthquake) for buildings and structures, Bureau of Indian standards, New Delhi.

[5] Nilson, A.H., and Winter, G. (1991), *Design of concrete structures*, McGraw-Hill, New York.

[6] Balfour, J.A.D. (1992), "*Computer Analysis of Structural Frameworks*", Blackwell Scientific Publications, Great Britain, pp. 254-325.

[7] Ugur E. (1992), "*Live load arrangements for multi storey Frame Analysis*", Digest 92 Teknik Dergi, pp. 163-170.

[8] Balfour, J.A.D. (1992), "*Computer Analysis of Structural Frameworks*", Blackwell Scientific Publications, Great Britain, pp. 254-325.

[9] Hassan, U.G. (1995), "*Interval Algebra to Deal with Pattern Loading and Structural Uncertainties*", Journal of Engineering Mechanics, Vol-121, no.11, pp. 1149-1157.

[10] IS 456:2000, Indian standard Plain and Reinforced concrete Code of practice (fourth revision), Bureau of Indian standards, New Delhi.

[11] Tsionis, G., Negro P., Molina, J., and Colombo, A. (2001), "*Pseudodinamic Tests on a 4-Storey RC Dual Frame Building*", Report EUR 19902, Ispra, Italy.

[12] Bartlett T.Q. (2002), "*Loads effect envelope for continuous structure by influential superposition*", University of Alaska Anchorage, School of Engineering, 3211 Providence drive, Anchorage, AK 99508.

[13] Agarwal P. and Shrikhande M. (2006), "Earthquake resistant design of structure", Prentice hall of India private limited, New Delhi, ISBN no. 81-203-2892-2.

[14] Duggal S.K. (2010), "Limit state Design of steel structures" in Tata McGraw hill education private limited New Delhi, ISBN no. 978-0-07-070023-9.

[15] Bhavikatti S.S. (2010), "Design of concrete structures" in I.K. International Publishing House Pvt. Limited, ISBN no 938057813X, 9789380578132.

[16] M.E. Akiner (2012), "*A New Approach on Pattern loading arrangement in frames*", Harran University, Turkey, International Journal of Advanced Engineering Application, Vol-5, Issue 3, pp 33-41.

[17] Hibbeler, R.C. (2015), Structural Analysis (sixth edition), Pearson publication.

[18] Ansari S., Garg V. (2016), "*Structural Behaviour of Building frame under pattern loading*", International journal of Science, Engineering and Technology, Vol-4, Issue 4.

AUTHORS

First Author: Vishal Yadav, P.G. Scholar in Structural Engineering, Department of Civil Engineering, Maulana Azad National Institute of Technology, Bhopal, Email: vishalyadav291@gmail.com

Second Author: Vivek Garg, Assistant Professor, Maulana Department of Civil Engineering, Maulana Azad National Institute of Technology, Bhopal, Email: vivek_garg5@yahoo.co.in