EFFECT OF PATTERN LOADING ON SEISMIC BEHAVIOUR OF STRUCTURES BY CONSIDERING INFILLED EFFECT

R.JAIPAL
M.Tech Student, Department of Civil,
Bharath Institute of Engineering &
Technology, Hyderabad, India, 500070
E-mail: jaipalcivil.jntu@gmail.com

Y.VARUN KUMAR
Assistant Professor ,Department of Civil,
Annamacharya Institute of Technology &
Sciences, Hyderabad, India, 501512
Email: varunchary12@gmail.com

ABSTRACT
The accurate estimation of design actions on the structure is very important in structural design as it significantly affects the final design and objectives. Any error in the estimation of design actions may lead to wrong results of structural analysis on the structure and lead to the unrealistic sizing of its structural members or even collapse of the structure. Therefore it is important to account for the most adverse effects of live loads on the structure. The consideration of pattern loading depends on the ratio of dead to live load and the type of structural member.

These days most of the engineers are not considering the different live load patterns to get the adverse effect of the structure. Considering the live load to all the slab panels may not appropriate to estimate the design parameters. In this context, an attempt is required to see the effect of pattern live load on the structure under seismic loads. The effect of pattern load may be different from bare frame structure and also infill structures. For the present work a regular symmetrical building will be chosen and the structure is loaded with different pattern live loading is analyzed for seismic load case with and without infill walls. Different dead loads to live load ratios are also considered as a parameter.

Index Terms—Live load patterns, pattern loading, infill walls

I. INTRODUCTION

Generally the structural deisgn of individual members are designed for the critical values of analysis results. Identifying worst analysis results estimation with different load combinations are crucial for any designer to avoid the failure of members or structure as whole. The loads on any structure are fixed or movable. Self weight of members are in fixed loads category where as live loads such as human occupancy floor loads can be placed in various ways are in the category of movable loads. The live loads position have influence on behaviour of structure. Hence live load position need to be consider in analysing the sturctures. such live load positions are known as live load pattern. Assuming the patterns of live load for worst response of the structure is more crucial and difficult in multi dimensional systems. Such situations required number of trails to be attempted. Conventionally dead loads, live loads, earthquake loads and wind loads are the primary load types used to analyze a structure for various parameters like span moments, end moments, shear, thrust or deflections. The Muller Breslau Principle for influence lines is an effective way to obtain critical load patterns. Realizing the fact that the efforts required in solving large structures is too much and such efforts further increase as design demands multiple analysis of the structure. In a way, such conventional analysis tools prove to be realistic only in a qualitative sense. Further, combining load combinations and load patterns requires the engineer to do multiple iterations of structural analyses in order to capture the critical scenario. Apart
from being an impractical task in most situations, it is impossible at times. In fact for Simplicity standard structural engineering codes of practice have suggested several critical load patterns.

The objective of present study is to understand the behaviour of a symmetrical building of G+9 stories under static and seismic loads for different live load patterns. It is to check importance of considering live load patterns for the analysis of structures.

II. LITERATURE REVIEW

ASCE 7-05 Section 4.6 states "The full intensity of the appropriately reduced live load applied only to a portion of a structure or member shall be accounted for if it produces a more unfavorable effect than the same intensity applied over the full structure or member." What this means is that it is need to arrange the live load so as to cause maximum effect in members. The design of structural elements must have sufficient strength to support all possible arrangements of live load. Consequently the analysis needs to provide with envelope diagrams for each member. Envelope diagrams are internal force diagrams that envelop all the possible values of force at each location along the member. So examples are used below to explain method for determining envelopes. This can seem daunting task as designer need to do multiple load cases to account for the various loadings on your structural system. For statically determinate structures, it is often easy to establish critical loading scenarios for shear, moment, reactions, and deflection. Unfortunately for continuous, statically indeterminate structures this is not so obvious and the use of influence lines becomes extremely useful.

Furlong R.W (1981) worked on rational analsysis of multistory concrete structures. Problems to be faced in analysis of structures considering effect of live load patterns. In the work, furlong approached the problem of solving the structures for different live load patterns as a practical designer and claimed that all possible live load combinations do not have to be considered for the following reasons. 1. As the number of load cases increases, the probability of occurence of the most critical combinations decreases. 2. Member forces are not very sensitive to loading not adjacent to such members. 3. Linear elastic analysis is just an approximation for reinforced concrete structures in which I and E change due to cracking and creep. Considereing these important points, Furlong proposed simple live load arrangments which he claimed would yield reasonable values for shear and bending moment in beams and columns.

Ugur Ersoy (1992) worked on live load arrangements for multi-story frame analysis. He mentioned that 'Code require analyses based on live load arrangements producing the most unfavorable effects. This requirment leads to hundreds of cases in the analysis of multi-story structures which is neither feasible (even with the use of computer) nor sensible (due to the approximations involved). A reasonable number of cases should be analysed to obtain sufficiently accurate results'.

Kulkarini J.G, Kore P.N., S.B.Tanawade (2013) studied the analysis of multi story building frames subjected to gravity and seismic loads with varying inertia. his paper presents an elastic seismic response of reinforced concrete frames with 3 bay, 5 bay and 7 bay 9 storey structures which have been analyzed for gravity as well as seismic forces and their response is studied as the geometric parameters varying from view point of predicting behavior of similar structures subjected to similar loads or load combinations.

III. MODELLING AND ANALYSIS

In the present study a G+9 floors symmetrical building is chosen as shown in figure 1. Building is having plan dimension of 30 m ×30m, Six bays in each direction and each bay of 5 m. In all the models dead is considered full which includes self weight of the slab, beams, columns, floor finishes and wall loads. There are Eight different live load patterns are considered for the study viz., loading is in alternate bays, chess board kind of pattern, live load only at the corners panels, loading is only in central panels, full live load in all panels etc. as shown in figure 2a and figure 2b.

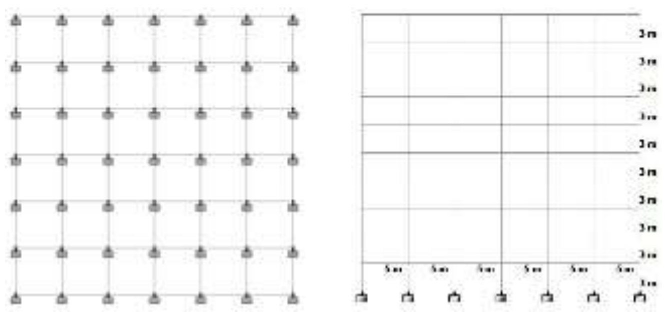
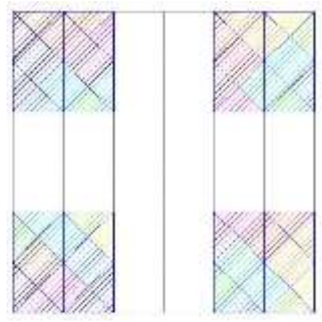
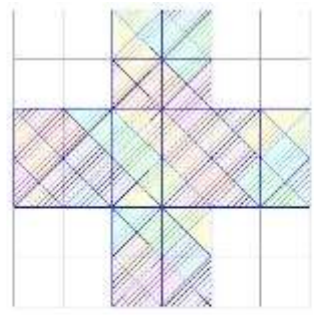


Fig. 1 Plan and Elevation of building considered for the design



Pattern 1



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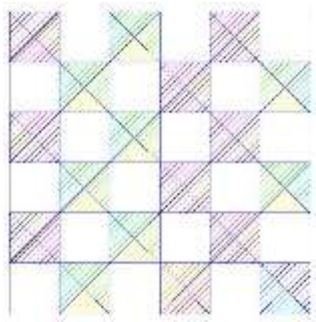
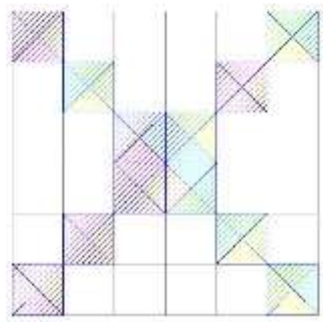


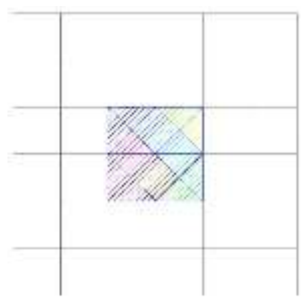
Pattern 3



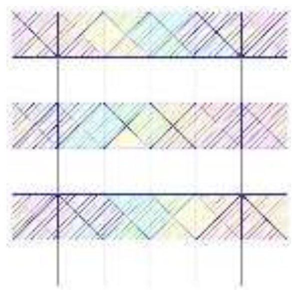
Pattern 4

Fig.2a. Live load patterns considered for the present study

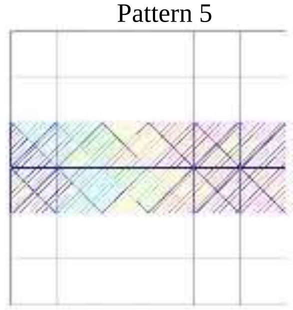
he study is conducted in two phases. In the first phase the models are analyzed for static load condition and in second phase study the models are analysed for seismic load conditions. Columns and beams are identified for the study and shown in figure 3. A finite element software STAAD Pro is used for the analysis



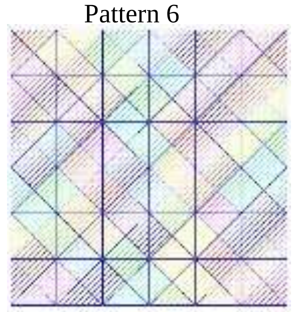
Pattern 5



Pattern 6



Pattern 7



Pattern 8

Fig.2b. Live load patterns considered for the present study

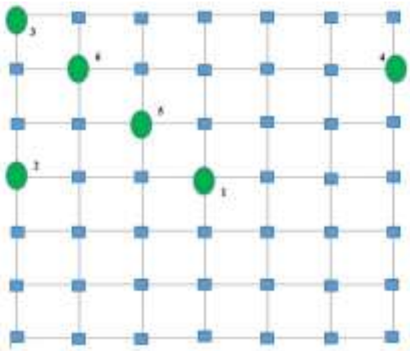
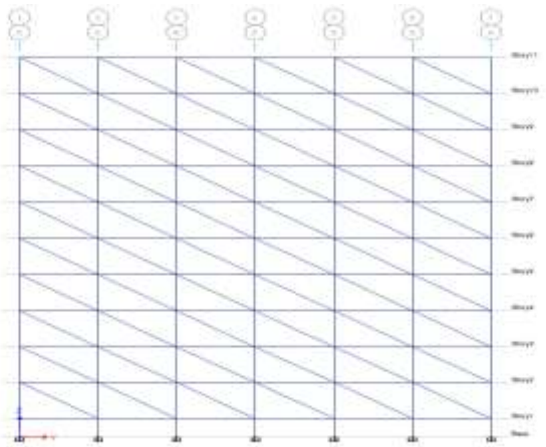
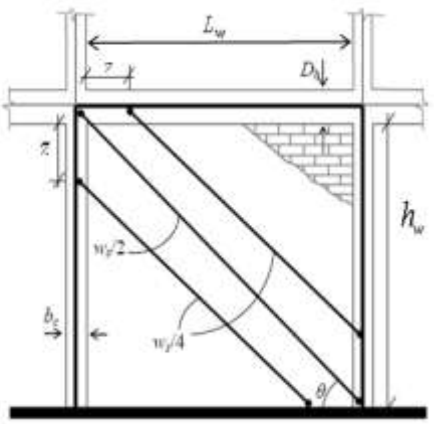
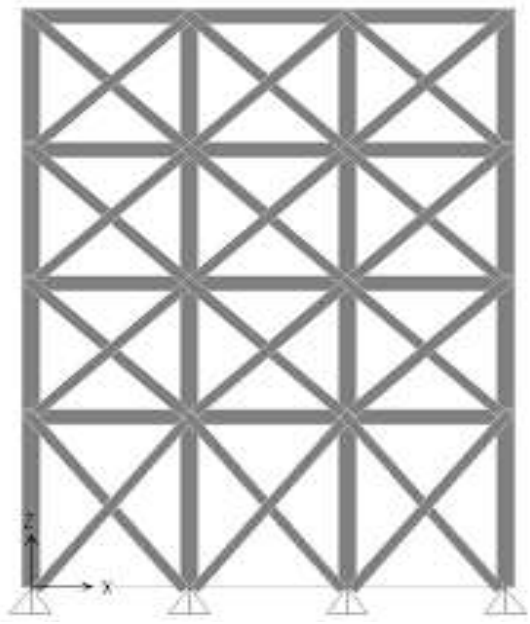


Fig.3. Identified columns considered for the present study

ELEVATION OF FRAME MODEL WITH INFILL







Infill models

Influence of infill wall on bare frame structure depends on height of the wall, thickness of wall, width of the wall, young's modulus of wall. There are number of models are proposed by various researchers.

Parameters & structure configuration

In the first phase study

Type of frame: Ordinary RC moment resisting frame
Support conditions: fixed at the base.
Number of storey: 10 story (G+9).
Floor height: 3.0 m.
Depth of Slab: 175 mm.
Size of beam: (300 × 550) mm.
Size of column: 550 × 550 mm.
Spacing between frames: 5 m in both X and Y directions
Materials: M 30 concrete
Fe 415 steel
Thickness of wall: 230 mm.
Unit weight of Concrete 24 kN/m^3
Unit weight of RCC: 25 kN/m^3
Unit weight of infill: 19 kN/m^3

Loadings:

The loads are considered as per IS 875 (part-1) for dead loads, IS 875 (part-2) for live loads
Live load on floor: 3 kN/m^2 (Commercial building)
Exterior Wall load: 12 kN/m
Parapet Wall load: 4 kN/m (Applied only on roof)
Dead load from slab: 0.175×25=4.375 kN/m^2
Floor finish: 1.0 kN/m^2
Ratio of Dead Load to Live load = 3.39

In the second phase study

In the second phase, in addition to the phase 1 study properties the following seismic parameters are considered.
Seismic zone (Z5): V, Seismic Zone factor, Z = 0.36
Soil type = III (Soft soil)

Importance factor, I = 1
Response Reduction factor, R = 3 (Ordinary moment resisting frame)
Damping of structure: 5 percent (Concrete)

In the third phase study

In addition to the phase I and II study properties the additional property considered is infill property. Infill is modelled as a compressive strut between panels. The width of the infill is considered based on Paulay and Priestly infill model.

Width of infill is W=0.25 d_z, where d_z is the diagonal length of infill strut.
In our models dz is 4.94m
therefore width of strut is 0.25×4.94 =1.23 m.
Thickness of infill is 0.23m.

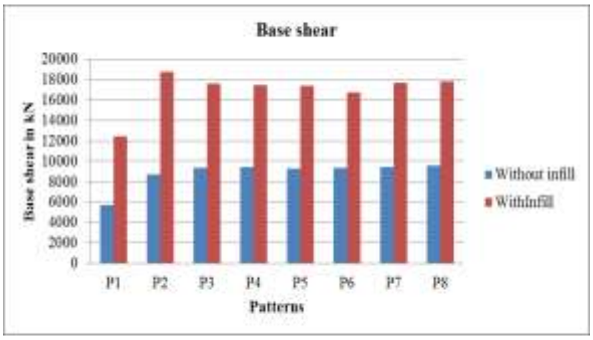
IV. RESULTS AND DISCUSSION

Generally structures are subjected to dead and live loads. Dead loads are constant through out of the life of the Structures where as imposed loads or live loads vary time to time and position to position within the structure. Live loads position influences the design forces in different elements of the structure. In the present study a G+9 floors symmetrical building is chosen as shown in figure and plan, elevation and isometric view respectively. Building is having plan dimension of 30 m ×30m, Six bays in each direction and each bay of 5 m. In all the models dead is considered full which includes self weight of the slab, beams, columns, floor finishes and wall loads. There are Eight different live load patterns are considered for the study viz., loading is in alternate bays, chess board kind of pattern, live load only at the corners panels, loading is only in central panels, full live load in all panels etc. as shown in figure. In this chapter a detailed report is given which includes models, loading patterns, identified columns, beams bars for the study, parameters considered for the design. The study is conducted in three phases. In the first phase the models are analyzed for static load condition, in the second phase study the models are analysed for seismic load conditions without considering infills. In the third phase study the models are analysed for seismic load by considering infills. In seismic analaysis response spectrum method has been used in phase 2 and phases 3 study. Columns and beams are identified for the study and shown in figure. A finite element software ETABS is used for the analysis.

Base shear :

Table(a) : Base shear in kN for different pattern loading

Patterns	Without infill	With infill
P1	5658.6	12455.22
P2	8704	**18722**
P3	9332.4	17588.3
P4	9421.3	17453.19
P5	9288.8	17398.81
P6	9332	16766
P7	9455.7	17702.69
P8	**9582.63**	17784.07



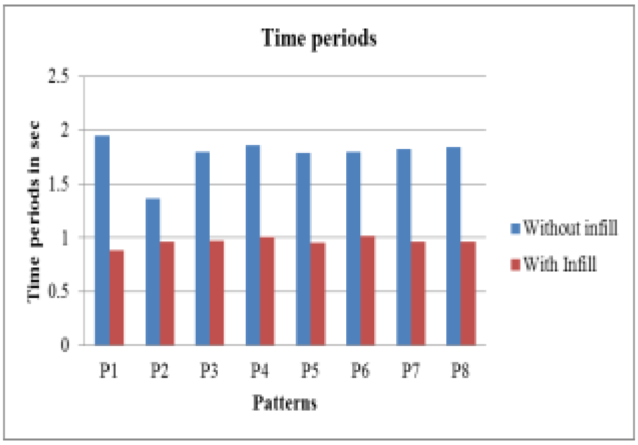
Base shear values in phase 2 and phase 3 studies

The base shear values of considered structure with and without infill walls are presented in table 4.1 and depicted in figure 4.1. In the model without infill the maximum shear is in pattern 8, i.e. live load in all panels. In this, full load is considered in all panels therefore the total mass of the structure increased in turn base shear also increases. The base shear values are higher in structure with infills and lower in without infill structure. If infills are considered, the structure time period will be decreased and S_a/g value increases (depending upon time period in response spectrum). In this case the variation is almost two times from without infill structure to with infilled structure. In the structure with infill, the maximum base shear is in pattern 2.

Time periods

Table (b): Time periods in phase 2 and phase 3 study

In dynamic analysis of bare frame structure (phase 2 study) and infill frame structure (phase 3 study) , time periods are presented in Table 4.6 and figure 4.6. Time periods are more in bare frame compared to infill frame structure as the stiffness increases time period of the structure decreases. In bare frame structure, pattern 1 loading model having more time period than pattern 8 loading model. In case of infill frame structure, pattern 6 loading model having more time period than pattern 8 loading model.



Absolute Maximum bending moments in columns

Absolute Maximum bending moments in phase 1 study

Patterns	C1	C2	C3	C4	C5	C6
P1	48.78	42.25	40.57	44.58	42.98	44.78
P2	52.48	48.57	46.65	45.65	44.56	44.89
P3	60.79	56.66	52.64	48.65	46.06	44.16
P4	59.27	54.53	50.87	48.83	47.62	46.13
P5	59.42	56.17	52.63	49.03	46.71	45.18
P6	62.74	58.69	53.29	48.94	45.44	43.28
P7	61.85	57.93	54.33	50.77	48.77	46.74
P8	**67.23**	**64.68**	**59.80**	**55.18**	**52.20**	**50.05**

In three phases of study, the absolute maximum bending moments and shear forces are studied. Phase 1 study results are presented in table and figure . The notations and position of columns are shown in figure.

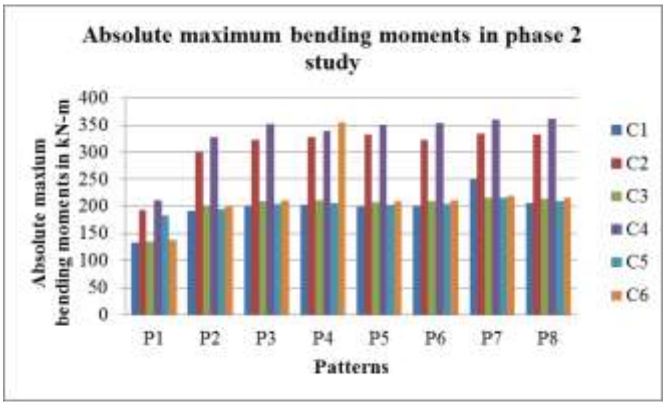
Absolute maximum bending moments in kN-m in columns

The absolute Maximum bending moment in phase 1 studyis influenced by only pattern 8 (all panels loaded).

Absolute Maximum bending moments in phase 2 study

Phase 2 study results of column absolute maximum bending moments

Patterns	C1	C2	C3	C4	C5	C6
P1	133.7	192.8	135.0	211.3	184.2	137.9
P2	190.9	299.8	199.1	327.1	194.9	200.7
P3	200.7	322.8	208.7	351.3	203.9	210.2
P4	202.4	328.1	210.4	337.9	205.6	354.7
P5	199.9	331.4	208.1	350.4	203.2	209.0
P6	200.7	323.1	209.3	352.4	204.1	210.6
P7	**249.7**	**334.3**	**214.9**	359.6	**215.7**	**219.4**
P8	205.4	331.4	213.7	**360.5**	208.6	215.0



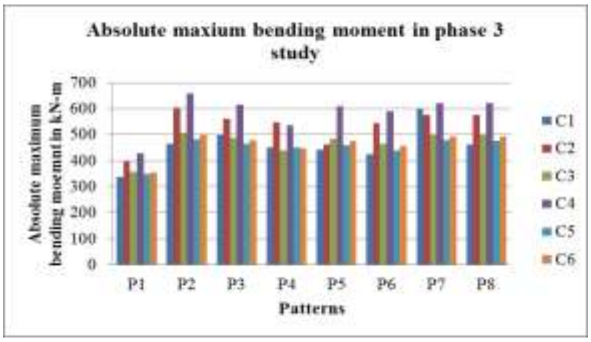
In interior column C1, the absolute maximum bending moment is maximum in pattern 7 compared to pattern 8. In C1 column, the maximum bending moment in pattern 7 is 21% more than pattern 8 loading. In intermediate column2, the absolute maximum bending moment is more in pattern 7 and is more than 1%. In corner columns C3 and C4 the absolute maximum bending moments in pattern 7 and pattern 8 are almost same. The difference is not more than 1%. Column C5 which is closer to interior column C1 is having maximum absolute bending moment is more in pattern 7 compared to pattern 8. The value is about 4% more in pattern7 than pattern8. The Column C6 which is closer to corner column C3 is having absolute maximum bending moment in pattern 7 is 2 % more than pattern 8.

Absolute Maximum bending moments in phase 3 study

Absolute maximum bending moments in kN-m in

Patterns	C1	C2	C3	C4	C5	C6
P1	337.93	397.31	359.11	429.31	349.12	354.61
P2	464.17	**604.91**	**508.4**	**657.97**	**480.99**	**498.43**
P3	499.5	561.18	488.99	614.48	464.2	479.9
P4	451.05	547.29	440.31	537.09	449.77	449.64
P5	444.01	463.64	484.21	609.63	460.6	475.63
P6	425.26	545.24	465.83	590.41	440.95	457.36
P7	**598.98**	574.82	500.6	620.71	478.5	492.81
P8	461.24	575.91	501.43	622.12	477.41	493.94

columns



In interior column C1, the absolute maximum bending moment is maximum in pattern 7 compared to pattern 8. In C1 column, the maximum bending moment in pattern 7 is 30% more than pattern 8 loading. In intermediate column2, the absolute maximum bending moment is more in pattern 2 and is more than 5%. In corner columns C3 and C4 the absolute maximum bending moments in pattern 2, 2% and 6% more than pattern 8 respectively. Column C5 which is closer to interior column C1 is having maximum absolute bending moment is more in pattern 2 compared to pattern 8. The value is about % more in pattern 2 than pattern 8. The Column C6 which is closer to corner column C3 is having absolute maximum bending moment in pattern 7 is 1 % more than pattern 8.

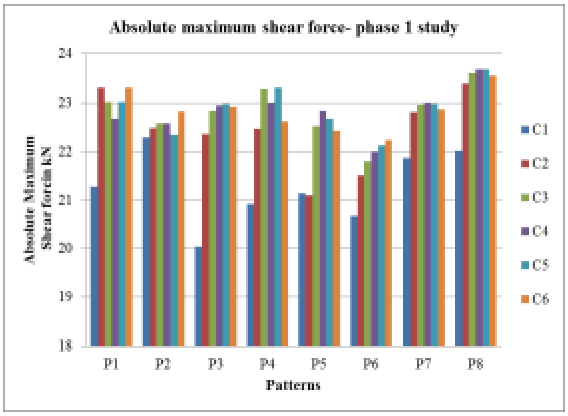
The absolute maximum bending moments are increased in all columns in phase 3 model when compared to phase 2 model studies. In all columns the moments are increased by 2 times and more.

Absolute Maximum shear forces in columns

Absolute Maximum shear forces in phase 1 study

The absolute maximum shear force in phase 1 study presented in figure 4.10 and table 4.10. The absolute Maximum shear force in phase 1 study is influenced by only pattern 8 (all panels loaded).

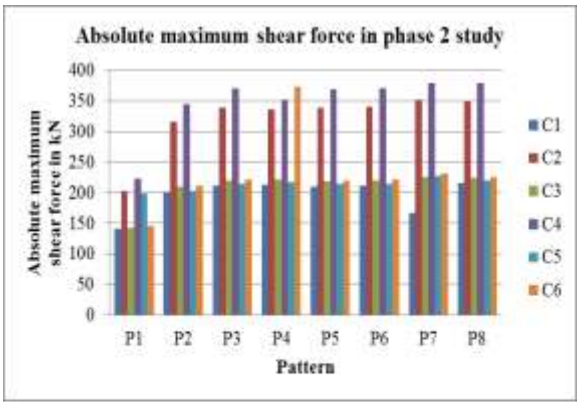
Patterns	C1	C2	C3	C4	C5	C6
P1	21.2	23.3	23.0	22.6	23.0	23.3
P2	22.2	22.4	22.5	22.5	22.3	22.8
P3	20.0	22.3	22.8	22.9	22.9	22.9
P4	20.9	22.4	23.2	23.0	23.3	22.6
P5	21.1	21.1	22.5	22.8	22.6	22.4
P6	20.6	21.5	21.8	21.9	22.1	22.2
P7	21.8	22.8	22.9	23.0	22.9	22.8
P8	**22.0**	**23.4**	**23.6**	**23.6**	**23.6**	**23.5**



Absolute Maximum shear forces in phase 2 study

Absolute maximum shear forces of phase 2 study are shown in table 4.11 and figure 4.11. In interior column C1, the absolute maximum shear force is maximum in pattern 8. It is not influenced by any other load pattern. In intermediate column2, the absolute maximum shear force is more in pattern 7 and is more than 1%. In corner columns C3 and C4 the absolute maximum shear force in pattern 7 and pattern 8 are almost same. The difference is not more than 1%. Column C5 which is closer to interior column C1 is having maximum absolute shear force is more in pattern 7 compared to pattern 8. The value is about 4% more in pattern7 than pattern8. The Column C6 which is closer to corner column C3 is having absolute maximum shear force in pattern 4 is 64 % more than pattern 8.

Pattern	C1	C2	C3	C4	C5	C6
P1	140.7	202.9	142.9	222.4	198.5	144.9
P2	201.0	315.4	209.6	344.6	202.1	211.3
P3	211.3	339.7	219.	369.8	214.7	221.2
P4	213.0	335.4	221.7	351.5	216.4	**373.3**
P5	210.4	338.4	219.1	368.9	213.9	220.0
P6	211.3	340.1	220.3	371.0	214.9	221.6
P7	166.5	**351.9**	**226.3**	378.6	**227.0**	230.9
P8	**216.2**	348.8	224.9	**379.8**	219.6	226.3



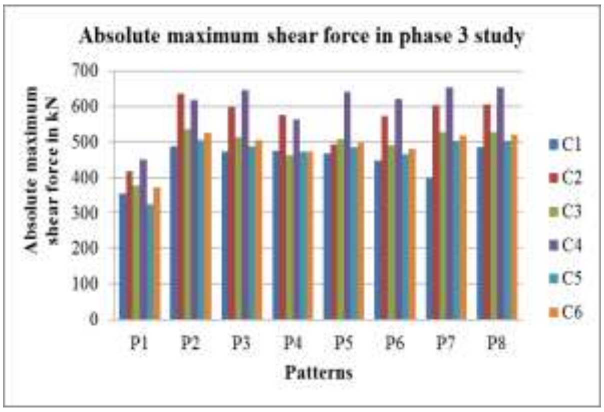
Absolute Maximum shear forces in phase 3 study

Absolute maximum Shear force in kN in columns

Absolute maximum shear forces of phase 3 study are shown in table 4.10 and figure 4.10. In interior column C1, the absolute maximum shear force is maximum in pattern 2 compared to pattern 8. The difference is less than 1%. In intermediate column2, the absolute maximum shear force is more in pattern 2 and is more than 5% when compared to pattern 8. In corner columns C3, the absolute maximum shear force is maximum in pattern 2. It is 1.5% more than pattern 8. In column C4, the absolute maximum shear force is more in pattern 2, and is 1.5% more than pattern8. Column C5 which is closer to interior column C1 is having maximum absolute shear force is more in pattern 2 compared to pattern 8. The value is about 1% more in pattern 2 than pattern8. The Column C6 which is closer to corner column C3 is having absolute maximum shear force in pattern 2 is 1 % more than pattern 8.

The absolute maximum shear forces are increased in all columns in phase 3 model when compared to phase 2 model studies. In all columns the moments are increased by 2 times and more.

Patterns	C1	C2	C3	C4	C5	C6
P1	355.7	417.1	378.0	450.8	325.1	373.2
P2	**488.6**	**635.0**	**535.1**	619.4	**506.3**	**524.6**
P3	473.1	597.1	513.3	645.8	488.6	505.1
P4	474.7	575.6	463.3	562.7	473.4	473.3
P5	467.3	493.3	509.0	640.9	484.2	500.6
P6	447.7	572.4	490.3	620.5	464.1	481.4
P7	399.9	604.1	526.9	652.4	503.6	518.7
P8	485.5	604.9	527.8	**653.6**	502.5	519.4



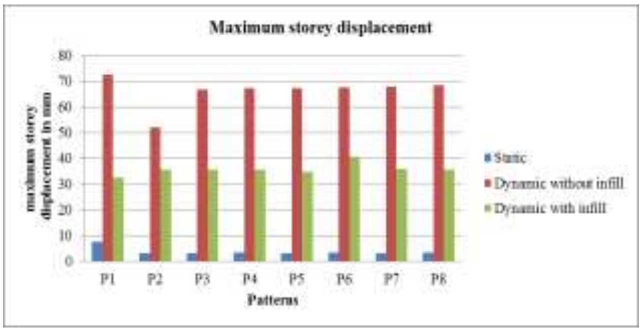
Maximum storey displacement

The maximum storey displacement is observed in one corner of the top storey. The results are presented in table 4.11 and figure 4.11. In phase 1 study, the maximum storey displacement is more in pattern 1 (corner panels loading) and is 2 times more than pattern 8. In phase 2 study, pattern 1 has 6% more storey displacement when compared to pattern 8. In phase 3 study, the storey displacement in top storey is 14% more than the pattern 8.

The storey displacements are more in phase 2 model (dynamic analysis of bare frame) when compared to phase 3 model. The maximum value of phase 2 studies is around 80% more than the phase 3 study. For lower values of displacement of phase 3 model for lateral loads indicate higher stiffness than phase 2 model.

Maximum storey displacement in mm in top storey

Patterns	Static	Without infill	With Infill
P1	**7.5**	**72.75**	32.59
P2	3.2	51.99	35.63
P3	3.1	66.83	35.68
P4	3.4	67.40	35.67
P5	3.02	67.42	34.83
P6	3.51	67.50	**40.67**
P7	3.02	67.95	35.95
P8	3.5	68.47	35.60



V.Conclusions

1. Phase 2 models (bare frame) is not influenced by pattern loading where as phase 3 model influenced and the variation is 5% when compared to full loading pattern. This is due to stiffness variation in the structure.
2. The stroey shears are more in phase 3 models when compared to phase 2 models. The values are increased more than 60%. There is no influence of pattern load for storey shear in phase 2 model but it is influenced by pattern loading in phase 3 model.
3. Storey drifts are influenced in both phase 2 and phase 3 models. Storey drifts values are considerably decreased in phase 3 model. As infills increases the stiffness the deformations and drifts decreases.
4. Time periods are also influenced by pattern loading. The variation is about 5 % compared to full loading i.e. pattern 8. Time periods depends on mass and stiffness of the structure, therefore infill structures have less time period when compared to bare frame structures.
5. The columns absolute maximum bending moments are not influenced by pattern loading in phase 1 study (static analysis of bare frame).
6. Interior columns of absolute maximum bending moments are influenced by the pattern loading in phase 2 study, where as exterior columns have very minimal influence of pattern loading on absolute maximum bending moments.
7. Phase 3 models of absolute maximum bending moments have influenced by the pattern loading and magnitudes are

more than 2 times of absolute maximum bending moments of phase 2 model.

8. Absolute maximum shear forces in columns are not influenced by pattern loading in phase 1 study (static analysis of bare frame).

9. Phase 2 and phase 3 columns of absolute maximum shear forces are influenced by pattern load but the influence is nominal.

10. Maximum displacement of top storey is also influenced by pattern loading. Phase 3 model displacements are less than phase 2 model. As the stiffness increases displacements decreases.

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Author[1]
R.Jaipal
Jaipalcivil.jntu@gmail.com
9849992298

Author[2]
Y.Varun Kumar
Varunchary12@gmail.com
8801814368