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Static and Dynamic Behavior of Reinforced Concrete Framed Building: A Comparative Study

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Abstract: *Reinforced concrete frame buildings are most common type of construction in urban India, which is subjected to several types of forces during their life time such as static forces and dynamic forces due to wind and earthquakes. The static loads are constant with time, while dynamic loads are time varying, causing considerable inertia effects .It depends mainly on location of building, importance of its use and size of the building. Its consideration in analysis makes the solution more complicated and time consuming and its negligence may sometimes becomes the cause of disaster during earthquake.*
So it is growing interest in the process of designing civil engineering structures capable to withstand dynamic loads . The behavior of building under dynamic forces depends upon its mass and stiffness properties, whereas the static behavior is solely dependent upon the stiffness characteristics.
Key Words:*Static Analysis, Dynamic Analysis, Natural Period of Vibration.*

I. Introduction

Dynamic analysis is a time consuming process and requires additional inputs related to its mass of the structure and an understanding of structural dynamics for interpretation of analytical results.
For the earthquake resistant design, we should try to minimize the mechanical energy in the structure. It is very clear that rigid structure will have only kinetic energy and zero strain energy. A structure cannot fail if it has zero strain energy
Comparison of static and dynamic behavior of a six storey's building is considered here in this paper and it has analyzed by using computerized solution available in all four seismic zones i.e. II,III,IV, and V.
The total design lateral force[1] or design seismic base shear (V_b) along any principal direction shall be determined as a following expression
Base shear $V_b = A_h W$ Where
A_h = design horizontal acceleration spectrum as mentioned in (I) above
W = seismic weight of the building which the sum of the seismic weight of all the floors. Imposed load on roof level need not be considered.
$A_h = Z/2 \times I/R \times Sa/g$ ------------ (I)
Z = Zone factor as per seismic II, III, IV, and V varies from o.1 to o.36.
I = Importance factor depending upon the functional use of the structures.
R = Response reduction factor depending on the perceived seismic damage performance of the structure.
Sa/g = Average response acceleration coefficient for the rock or soil sites.
The approximate fundamental natural period of vibration (Ta) in seconds of moments resisting frames building without brick infill panels may be estimated by the empirical expression.
$T_a = 0.075\, h^{0.75}$ for RC frame building
$= 0.085\, h^{0.75}$ for steel frame building
h = height of building in meter this excludes the basement storey, where basement walls are connected with the ground floor deck or fitted between the building columns but it includes the basement storey when they are not so connected.
The calculated base shear is distributed[5] along the height of the building. The shear force at any level depends on the mass at that level and deforms shape of the structure.
The vertical distribution of base shear to different floor levels will as per following expression:
$Q_i = V_b W_i h_i^2 / \sum W_i h_i^2$
Q_i = Design lateral force at floor i.
W_i = Seismic weight of floor i.
h_i = Height of floor I measured from base
n = Number of story's in the buildings is the number of levels at which the masses are located.
There are four seismic zones[1] which depends upon the seismic hazard associated with different regions and code also recommends different analytical methods depending upon the height[7], location and configuration of

buildings, zone and height of the building under which allows equivalent static method of analysis (ESMA) is used.

The International Building Codes (IBC) allows equivalent static method of analysis (ESMA) for regular and slightly irregular buildings consisting of only 2 to 3 stories even in lower seismic zones, these being the most stringent requirements among the national codes worldwide . Thus where we can use the ESMA as per the different national countries Codes has mentioned in the following Table.

Table No.1 Conditions on use of ESMA in various national Codes[7]

Country	Maximum building height (m) Regular	Irregular	Seismic zones	Soil profile	Ta(S)
India	40 90	12 40	Higher Lower	- -	- -
USA(IBC)	2-3 stories	-	Lower	-	<3.5Ta
Euocodes-8	-	-	-	-	<2or 4Ta
Columbia	60 -	- 18	- -	Not on soft soil -	<0.7 -
Israel	80 - - -	- 80 5-storey 20	All Lower Lower All	- - For building with a soft storey For building with plan irregularities	<2.00 <2.00 - -
The Philippines	70	20	-	Soft clay <12m Thick	<0.7
New Zealand	15 -	- 15	- -	- -	<2.0(regular) <0.45(irregular)
Algeria	65 30 -	- 8-23 All	Lower Higher Lowest	- - -	- - -
Costa Rica	30	-	-	-	-
Iran	50	-	-	-	-
Nepal	40	-	Lower	-	-
Venezuela	-	60	-	For building with plan irregularities	-

Note:-1.Typical storey height in building is about 3.0 to 3.50 m

T_a is the natural period corresponding to the beginning of velocity- sensitive region on the response spectrum.

The main purpose of linear dynamic analysis is to evaluate the time variation stresses and deformation in structures caused by arbitrary loads by solving Eigen value problems. The building can vibrate into different mode shapes .There can be as many mode shapes possible as no of dynamic degree of freedom in building. Dynamic degree of freedom system in a structure is the no of independent coordinate in which the structure can undergo motion under dynamic forces; depending upon the building type only the first few modes may govern the response of the building.

The lateral displacement (u) at any point on the building during earthquake can be expressed as linear combination of all the modes shapes of the building. In short building, the first vibration mode may only governing mode with more than 90-95 % participation factor. With increasing number of floors, flexibility of building increases bringing higher modes effects in to the picture.

DESIGN BRIEF

Here in this paper a six story RC frame building is analyzed using computerized solution of analysis with the following assumption.

1. Type of structure-- Multistory rigid jointed plane frames
2. No of storey-- G+5, six stories
3. Seismic Zones- II, III, IV and V (4-Zones)
4. Floor height-- 3.6m.

4b. Depth of foundation 2.4m

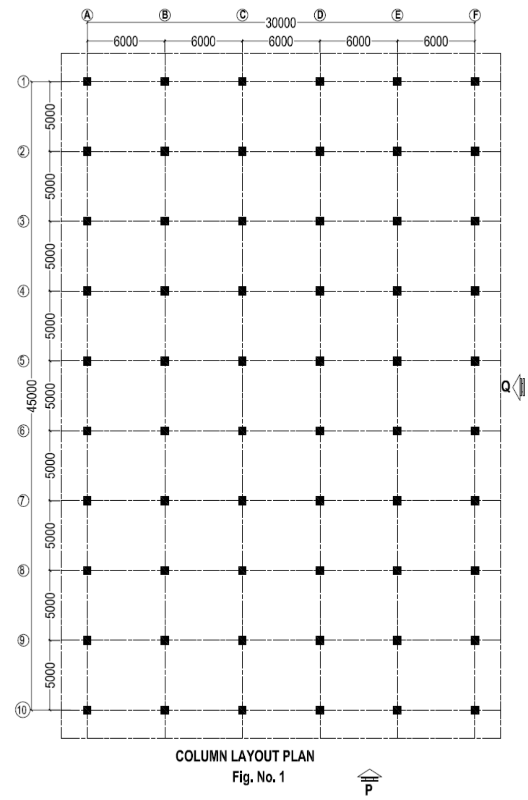
5. Building height-- 21.60m
6. Plan size-- 45.30 x 30.60m
7. Total area-- 1386.18sq.m
8. Size of columns-- 0.30m x 0.60m
9. Size of beams-- 0.30m x 0.60m
10. Walls- (a) External- 200 mm
    (b) Internal 100 mm

11 Thickness of slab- 150mm

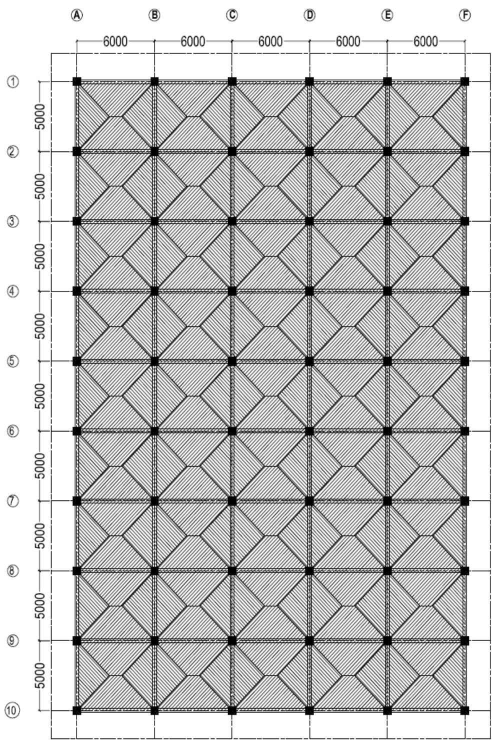
12. Imposed load[4] - 4.00kN/ m^2

13. Floor finish - 1.00kN/ m^2
14. Water proofing- 2.500kN/ m^2
15. Specific wt. of RCC-- 5.00 kN/ m^3
16. Specific wt of infill - 20.00 kN/ m^3
17. Material used Concrete M-25 and Reinforcement Fe-415.
18 Earthquake load - As per IS-1893-2002
19 Type of soil - Type -II, Medium soil as per IS-1893
20 Ec - 5000√fck N/ mm^2
(Ec is short term static modulus of elasticity[3] in N/ mm^2)
21 Fcr = 0.7√fc k N/ mm^2
(Fck is characteristic cube strength of concrete in N/ mm^2)
22 Static analysis - Equivalent static lateral force method.
23 Dynamic analysis - Using Response spectrum method
24 Software used - STAAD-Pro for both static and dynamic analysis[8]
25 Fundamental natural period of building
Ta = 0.075 $h^{0.75}$ for moment resisting RC frame building without infill
Ta = 0 .09 h /√d for all other building
i/c moment resisting RC frame building with brick infill walls, Where h = height of building
d = base dimension of building at plinth level in m along the considered direction of lateral forces.
26 Zone factor Z--- as per IS-1893-2002 Part -1 for different zones as per clause 6.4.2.

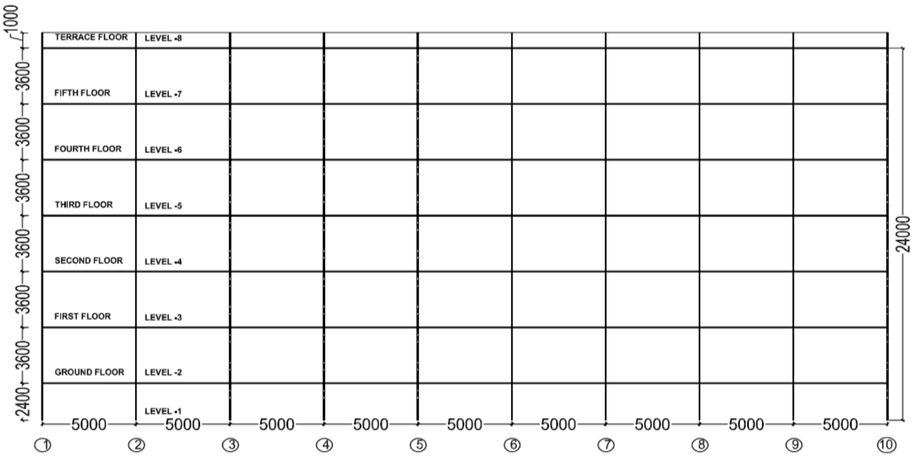
The static and dynamic analysis has been done using the above parameters for different zones and the post processing results obtained has summarized in the succeeding tables.



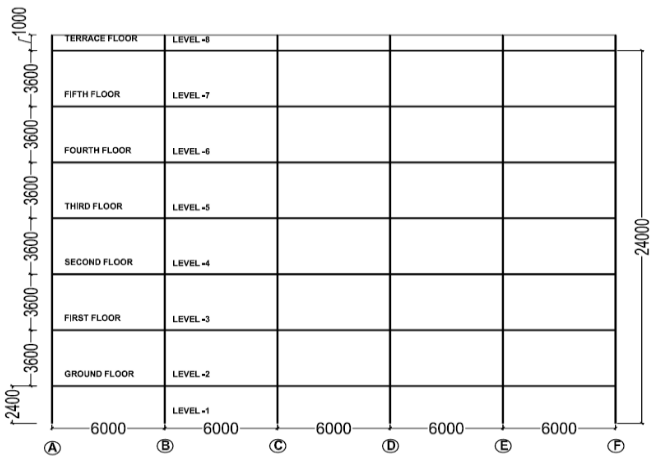
COLUMN LAYOUT PLAN
Fig. No. 1



LOAD DISTRIBUTION
Fig. No. 2



ELEVATION 'Q'
Fig. No. 3



ELEVATION 'P'

Fig. No. 4

II. Results:

Table No.2 NODAL FORCES AND SEISMIC SHEAR FORCES AT VARIOUS LEVELS (ZONE - II) STATIC ANALYSIS

Time Period =	0.3922 Sec	S_a/g = 2.5	Z=0.10	I=1.5	R=5	
			Base Shear in kN =		3716.78	
Floor	W_i (kN)	h_i (m)	$W_ih_i^2$	$W_ih_i^2/\sum W_ih_i^2$	Q_i	Total Shear (kN)
8	11913.00	24.00	6861888.00	0.29	1076.83	1076.83
7	16766.00	20.40	6977338.56	0.29	1094.94	2171.77
6	16766.00	16.80	4732035.84	0.20	742.59	2914.36
5	16766.00	13.20	2921307.84	0.12	458.44	3372.80
4	16766.00	9.60	1545154.56	0.07	242.48	3615.28
3	16766.00	6.00	603576.00	0.03	94.72	3710.00
2	7500.00	2.40	43200.00	0.00	6.78	3716.78
Total	103243.00		23684500.80	1.00		

Table No. 3 NODAL FORCES AND SEISMIC SHEAR FORCES AT VARIOUS LEVELS (ZONE - III) STATIC ANALYSIS						
Time Period =	0.3922 Sec	S_a/g = 2.5	Z=0.16	I=1.5	R=5	
			Base Shear in kN =		5946.84	
Floor	W_i (kN)	h_i (m)	$W_ih_i^2$	$W_ih_i^2/\sum W_ih_i^2$	Q_i	Total Shear (kN)
8	11913.00	24.00	6861888.00	0.29	1722.92	1722.92
7	16766.00	20.40	6977338.56	0.29	1751.91	3474.83
6	16766.00	16.80	4732035.84	0.20	1188.15	4662.98
5	16766.00	13.20	2921307.84	0.12	733.50	5396.48
4	16766.00	9.60	1545154.56	0.07	387.97	5784.44
3	16766.00	6.00	603576.00	0.03	151.55	5935.99
2	7500.00	2.40	43200.00	0.00	10.85	5946.84
Total	103243.00		23684500.80	1.00		

Table No. 4 NODAL FORCES AND SEISMIC SHEAR FORCES AT VARIOUS LEVELS (ZONE - IV) STATIC ANALYSIS						
Time Period =	0.3922 Sec	S_a/g = 2.5	Z=0.24	I=1.5	R=5	
			Base Shear in kN =		8920.26	
Floor	W_i (kN)	h_i (m)	$W_ih_i^2$	$W_ih_i^2/\sum W_ih_i^2$	Q_i	Total Shear (kN)
8	11913.00	24.00	6861888.00	0.29	2584.38	2584.38
7	16766.00	20.40	6977338.56	0.29	2627.87	5212.25
6	16766.00	16.80	4732035.84	0.20	1782.22	6994.47
5	16766.00	13.20	2921307.84	0.12	1100.25	8094.72
4	16766.00	9.60	1545154.56	0.07	581.95	8676.67
3	16766.00	6.00	603576.00	0.03	227.32	8903.99
2	7500.00	2.40	43200.00	0.00	16.27	8920.26
Total	103243.00		23684500.80	1.00		

Table No. 5 NODAL FORCES AND SEISMIC SHEAR FORCES AT VARIOUS LEVELS (ZONE - V) STATIC ANALYSIS						
Time Period =	0.3922 Sec	S_a/g = 2.5	Z=0.36	I=1.5	R=5	
			Base Shear in kN =		13380.00	
Floor	W_i (kN)	h_i (m)	$W_ih_i^2$	$W_ih_i^2/\sum W_ih_i^2$	Q_i	Total Shear (kN)
8	11913.00	24.00	6861888.00	0.29	3380.20	3880.20
7	16766.00	20.40	6977338.56	0.29	3380.20	7760.40
6	16766.00	16.80	4732035.84	0.20	2676.00	10436.40
5	16766.00	13.20	2921307.84	0.12	1605.60	12042.00
4	16766.00	9.60	1545154.56	0.07	936.60	12978.60
3	16766.00	6.00	603576.00	0.03	374.30	13352.90
2	7500.00	2.40	43200.00	0.00	27.10	13380.00
Total	103243.00		23684500.80	1.00		

Table No. 6 NODAL FORCES AND SEISMIC SHEAR FORCES AT VARIOUS LEVELS (ZONE - II) DYNAMIC ANALYSIS						
Time Period =	0.3922 Sec	S_a/g = 2.5	Z=0.10	I=1.5	R=5	
Vb/VB = 3.0194			Base Shear in kN =		1230.97	
Floor	W_i (kN)	h_i (m)	$W_ih_i^2$	$W_ih_i^2/\sum W_ih_i^2$	Q_i	Total Shear (kN)
8	11913.00	24.00	6861888.00	0.29	356.64	356.64
7	16766.00	20.40	6977338.56	0.29	362.64	719.28
6	16766.00	16.80	4732035.84	0.20	245.94	965.22
5	16766.00	13.20	2921307.84	0.12	151.83	1117.05
4	16766.00	9.60	1545154.56	0.07	80.31	1197.35
3	16766.00	6.00	603576.00	0.03	31.37	1228.72
2	7500.00	2.40	43200.00	0.00	2.25	1230.97
Total	103243.00		23684500.80	1.00		

Table No. 7 NODAL FORCES AND SEISMIC SHEAR FORCES AT VARIOUS LEVELS (ZONE - III) DYNAMIC ANALYSIS

Time Period =	0.3922 Sec	S_a/g = 2.5	Z=0.16	I=1.5	R=5	
Vb/VB = 3.0194			Base Shear in kN =		1969.55	
Floor	W_i (kN)	h_i (m)	$W_ih_i^2$	$W_ih_i^2/\sum W_ih_i^2$	Q_i	Total Shear (kN)
8	11913.00	24.00	6861888.00	0.29	570.62	570.62
7	16766.00	20.40	6977338.56	0.29	580.22	1150.84
6	16766.00	16.80	4732035.84	0.20	393.51	1544.34
5	16766.00	13.20	2921307.84	0.12	242.93	1787.27
4	16766.00	9.60	1545154.56	0.07	128.49	1915.77
3	16766.00	6.00	603576.00	0.03	50.19	1965.96
2	7500.00	2.40	43200.00	0.00	3.59	1969.55
Total	103243.00		23684500.80	1.00		

Table No. 8 NODAL FORCES AND SEISMIC SHEAR FORCES AT VARIOUS LEVELS (ZONE - IV) DYNAMIC ANALYSIS

Time Period =	0.3922 Sec	S_a/g = 2.5	Z=0.24	I=1.5	R=5	
Vb/VB = 3.0194			Base Shear in kN =		2954.33	
Floor	W_i (kN)	h_i (m)	$W_ih_i^2$	$W_ih_i^2/\sum W_ih_i^2$	Q_i	Total Shear (kN)
8	11913.00	24.00	6861888.00	0.29	855.93	855.93
7	16766.00	20.40	6977338.56	0.29	870.33	1726.26
6	16766.00	16.80	4732035.84	0.20	590.26	2316.52
5	16766.00	13.20	2921307.84	0.12	364.39	2680.92
4	16766.00	9.60	1545154.56	0.07	192.74	2873.65
3	16766.00	6.00	603576.00	0.03	75.29	2948.94
2	7500.00	2.40	43200.00	0.00	5.39	2954.33
Total	103243.00		23684500.80	1.00		

Table No. 9 NODAL FORCES AND SEISMIC SHEAR FORCES AT VARIOUS LEVELS (ZONE - V) DYNAMIC ANALYSIS

Time Period =	0.3922 Sec	S_a/g = 2.5	Z=0.36	I=1.5	R=5	
Vb/VB = 3.0194			Base Shear in kN =		13380.39	
Floor	W_i (kN)	h_i (m)	$W_ih_i^2$	$W_ih_i^2/\sum W_ih_i^2$	Q_i	Total Shear (kN)
8	11913.00	24.00	6861888.00	0.29	3876.58	3876.58
7	16766.00	20.40	6977338.56	0.29	3941.80	7818.37
6	16766.00	16.80	4732035.84	0.20	2673.33	10491.70
5	16766.00	13.20	2921307.84	0.12	1650.37	12142.08
4	16766.00	9.60	1545154.56	0.07	872.92	13015.00
3	16766.00	6.00	603576.00	0.03	340.99	13355.99
2	7500.00	2.40	43200.00	0.00	24.41	13380.39
Total	103243.00		23684500.80	1.00		

III. Summary:-

Reinforced concrete (RC) frame buildings are most common type of constructions in urban India, which are subjected to several types of forces during their lifetime, such as static forces due to dead and live loads and dynamic forces due to the wind and earthquake.

Performance of building largely dependents on the strength and deformability of constituent members, which is further, linked to the internal design forces for the members. The internal design forces in turn depend upon the accuracy of the method employed in their analytical determination.

Analyzing and designing buildings for static forces is a routine affair these days because of availability of affordable computers and specialized programs which can be used for the analysis. On the other hand, dynamic analysis is a time consuming process and requires additional input related to mass of the structure, and an understanding of structural dynamics for interpretation of analytical results.

IV. Conclusions:-

The Nodal forces and the seismic forces at various levels of storey has been tabulated for both the analysis and it is found that static shear force is nearly 3.01 times to the shear force obtained by dynamic analysis. It means the structure designed by static analysis will be much heavier and costly , But for the safety point of view , the static analysis should be done for the building heights mentioned in IS 1893:2002. Thus above conclusion is justifying the statement as per the code -1893-2002-Part -1 under clause 7.8.1.

1 Base shear in static analysis changes in the ratio of their zones factors, as the base shear is given by Z/2 x Sa/g x I/R, except Z all other parameter remains constant irrespective of seismic zone under which is designed. Therefore ratio of base shear in various earthquake zones are given by-Z_I: Z_{II}:Z_{III}:Z_{IV} = 1:1.6:2.4:3.6.

2. As described above beam ends forces are also varies as in the same i.e. Z_I: Z_{II}:Z_{III}:Z_{IV} = 1:1.6:2.4:3.6.

3. Similarly analyzing the building with same parameters in dynamic analysis, it is observed that parameters like base shear , nodal displacements and beam ends forces varies in the same ratio as described above, hence it is very important conclusion derived in the analysis that, if we design one building in one of the seismic zone, and if same building is likely to be constructed in another zone , than the different parameter can be worked out using these ratio, without going in to detailed analysis, provided all other parameter remain unchanged.

It is also observed that beam end forces in static analysis is coming more than the dynamic analysis which are nearly 13.66% higher with respect to dynamic analysis. This increase is nearly same in every zone i.e. II, III, IV, and V. Similarly it is also observed from the tables that the average variation in bending moment is also on higher side in static analysis than dynamic analysis it is nearly 1.029% above than dynamic analysis. This increase is nearly same in every zone i.e. II, III, IV, and V. It is also concluded that maximum shear is observed mainly at footing levels in X direction and the maximum bending moment is at first floor level.

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