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Comparative Study of Equivalent Static Analysis and Response spectrum analysis on conventional slab & Flat Slab with or without shear wall Using STADD. PRO

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Abstract – *As we know flat slab building structures are significantly more flexible than traditional concrete frame/wall or frame structures, thus becoming more vulnerable to seismic loading. To improve the performance of building having flat slabs under seismic loading, provision of flat slab with shear wall is proposed in the present work. In this paper a commercial building with G+5, G+10 and G+15 floors is considered for the seismic analysis using response spectrum method. The results are compared with equivalent static method. The software used for the analysis is STAAD. Pro V8I SS6. In this work the seismic zone is considered to be Zone III, soil type hard. The results generated from both the method were compared considering the parameters such as base shear, maximum displacement, maximum shear force and bending moment and storey drifts.*

Key Words: **Response spectrum, equivalent static analysis, STADD.Pro, Base shear, Flat slab, Shear wall, seismic loading.**

1. INTRODUCTION

Earthquake or seismic analysis is a subset of structural analysis which involves the calculation of the response of a structure subjected to earthquake excitation. Various seismic data are necessary to carry out the seismic analysis of the structures .The object of the present work is to compare the behavior of multi-storey buildings having flat slabs and flat slab with shear wall on the performance of these three types of buildings under seismic forces.

1.1 LITERATURE REVIEW

Anuja Walvekar, H.S.Jadhav (2015) Investigated the effect of flat slab building with and without shear wall and the seismic behavior of high rise building with different positions of shear wall. For that, 15 story models were selected and the effect of different locations of shear wall on high rise structure, linear dynamic analysis (response spectrum analysis) using software ETABs was carried out. Seismic parameters like time period, base shear, storey displacement and storey drift are checked out. [6]

Raghavendra Rao, Dr.M Rame Gowda (2015) Carried out the study of characteristic seismic behavior of flat slab buildings. a residential building with G+10 floors is considered for the seismic analysis using response spectrum method. The results are compared with equivalent static method. The software used for the analysis is ETABS 2015.0.0. Drift and displacement results obtained by ESA are greater than the results obtained by RSA. [10]

R.S.More, V. S. Sawant (2015) gave the guidelines for analysis of flat slab taking into account space crunch, height limitations and other factors, deviations from a regular geometry and regular layout and also behavior and response of flat slabs during earthquake. [9]

1.2 Method of seismic analysis

In the equivalent static method, the lateral force equivalent to the design basis earthquake is applied statically. The equivalent lateral forces at each storey level are applied at the floor level. The base shear ($V = VB$) is calculated as per Clause 7.5.3 of IS 1893: 2002.

$$V_B = A_h W \qquad A_h = \left(\frac{Z}{2}\right)\frac{I}{R}\frac{S_a}{g}$$

The response spectrum is a plot of the maximum response (maximum displacement, velocity, acceleration or any other quantity of interest) to a specified load function for all possible single degree-of-freedom systems. The abscissa of the spectrum is the natural period (or frequency) of the system and the ordinate is the maximum response. It is also a function of damping. Fig. 3.1 shows the design response spectrum given in IS 1893: 2002 for a 5% damped system. According to IS 1893: 2002, high rise and irregular buildings must be analyzed by the response spectrum method.

1.3 Objectives of the Present Work

i. To perform static and dynamic analysis of multi-storeyed RCC buildings in conventional slab, flat slab with shear wall& without shear wall (G+5, G+10, G+15 Storey) using Response Spectrum Analysis and Equivalent Static Analysis, considering earthquake Zones(III) as per the Indian Standard code of practice IS 1893-2002 part-I: Criteria for Earthquake resistant structure (Zone III).
ii. To find the relationship between Equivalent static analysis and Response spectrum analysis method.

1.4 Model Description

A building plan was taken in seismic zone III for seismic analysis of the building with conventional slab, flat slab and shear wall. Building details are given below.

Table-1: Building details

Particulars	Details
Plan Size	43.840 m x 19.500m
Number of Floors	G+5, G+10, G+15
Building Type	COMMERCIAL
Storey Height	19.50m,37m,54.5m
Soil Type	Hard Soil (Type III)
Steel Grade	Fe 415
Concrete Grade	M 25
Seismic Zone	III
Response Reduction Factor	3
Importance Factor	1
Exterior Column Size	400mm x6500 mm
Interior Column Size	400mm x 500mm
Beam Size	300mm x 450 mm
Slab Thickness	150 mm
Slab Thickness	150 mm
Shear Wall thickness	230 mm
Live Load on floor	2 KN/m^2
Live Load on terrace	1.5 KN/m^2
Terrace finish	1KN/m^2
Floor Finish	1KN/m^2

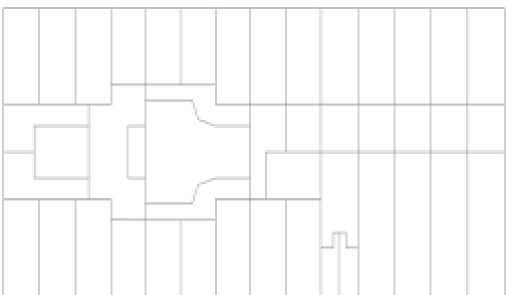

Fig. 1 Plan for building

Table -2: Details of Models

Model Number	Slab
Model 1	G+5 CS
Model 2	G+10 CS
Model 3	G+15 CS
Model 4	G+5 FS
Model 5	G+10 FS
Model 6	G+15 FS
Model 7	G+5 FS WITH SW
Model 8	G+10 FSWITH SW
Model 9	G+15 FS WITH SW

2. RESULTS AND DESCUSSION

The results obtained from the STAAD Pro. analysis of G+5, G+10 & G+15 model for ESA and RSA methods are tabulated and discussed for the parameters such as base shear, maximum storey drift, displacement, shear force and bending moment. The comparison between ESA and RSA methods are shown and reported.

2.1 Base shear

Base shear is the maximum expected lateral force that will occur due to seismic ground acceleration at the base of the structure. The base shear, or earthquake force, is given by the symbol "VB".

Table -3: Base shear for ESA and RSA method

MODELS	ESA	RSA
Model 1	1910 KN	1910 KN
Model 2	2182 KN	2160 KN
Model 3	2380 KN	2372 KN
Model 4	1809 KN	1809 KN
Model 5	2067 KN	2064 KN
Model 6	2255 KN	2248 KN
Model 7	1808 KN	1808 KN
Model 8	2072 KN	2069 KN
Model 9	2263 KN	2252 KN

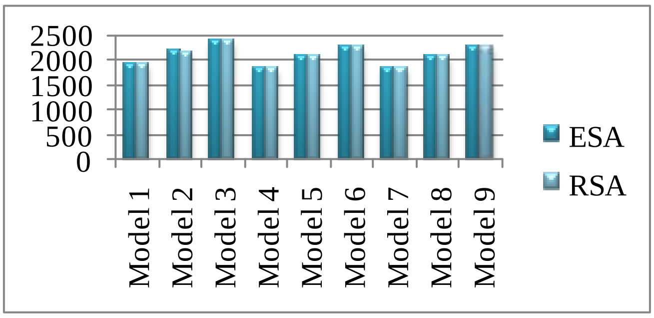

Chart -1: Base shear for ESA and RSA method

Base shear value for different slab condition (CS, FS, FSSW) in G+5, G+10 and G+15 are 0% to 1% less respectively, in RSA than ESA.

2.2 Story drift

Storey drift is the drift of one level of a multistory building relative to the level below. Inter-storey drift is the difference between the roof and floor displacements of any given story as the building sways during the earthquake, normalized by the story height. The factor is defined as the ratio of the story shear force when story collapse occurs to the story shear force when total collapse occurs. Through a series of dynamic analyses, simple equations are provisionally proposed to calculate the necessary story shear safety factor that can be used to prevent story collapse.

Table -4: Story drift for ESA and RSA method

MODELS	ESA		RSA	
	X(m)	Z(m)	X(m)	Z(m)
Models - 1	0.00028	0.00020	0.00019	0.00005
Models - 2	0.00034	0.00026	0.00030	0.00005
Models - 3	0.00039	0.00032	0.00036	0.00010
Models - 4	0.00062	0.00072	0.00015	0.00004
Models - 5	0.00072	0.00098	0.00044	0.00013
Models-6	0.00076	0.00110	0.00064	0.00024
Models-7	0.00075	0.00140	0.00021	0.00009
Models-8	0.00040	0.00058	0.00032	0.00011
Models-9	0.00095	0.00357	0.00077	0.00101

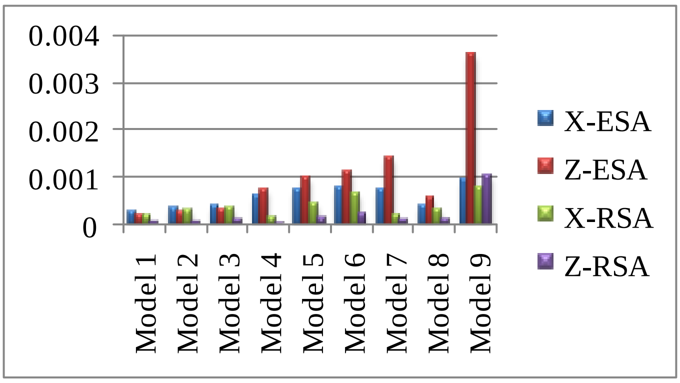

Chart -2: Story drift for ESA and RSA method

Storey drift value along x axis for G+5 with different slab condition (CS, FS, FSSW) are 32%, 76%& 72% less respectively, in RSA than ESA.

Storey drift value along z axis for G+5 with different slab condition (CS, FS, FSSW) are 75%, 81%& 69% less respectively, in RSA than ESA.

Storey drift value along x axis for G+10 with different slab condition (CS, FS, FSSW) are 76%, 39%& 16% less respectively, in RSA than ESA.

Storey drift value along z axis for G+10 with different slab condition (CS, FS, FSSW) are 94%, 87%& 78% less respectively, in RSA than ESA.

Storey drift value along x axis for G+15 with different slab condition (CS, FS, FSSW) are 72%, 20%& 19% less respectively, in RSA than ESA..

Storey drift value along z axis for G+15 with different slab condition (CS, FS, FSSW) are 94%, 81%& 72% less respectively, in RSA than ESA.

2.3 Shear force

Shearing forces are unaligned forces pushing one part of a body in one specific direction, and another part of the body in the opposite direction. When the forces are aligned into each other, they are called compression forces.

Table -5: Shear force for ESA and RSA method

MODELS	ESA		RSA	
	X(KN)	Z(KN)	X(KN)	Z(KN)
Model 1	240	22	210	9
Model 2	349	26	318	10
Model 3	416	30	370	11
Model 4	265	36	214	16
Model 5	436	59	326	14

Model 6	727	75	467	12
Model 7	753	47	649	30
Model 8	1307	87	1278	31
Model 9	1505	107	1497	34

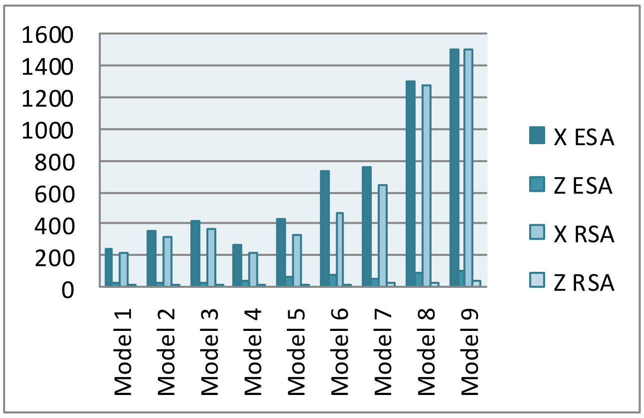

Chart -3: max. shear force for ESA and RSA method

Shear force value along x axis for G+5 with different slab condition (CS, FS, FSSW) are 13%, 19%& 14% less respectively, in RSA than ESA.

Shear force value along z axis for G+5 with different slab condition (CS, FS, FSSW) are 59%, 56%& 36% less respectively, in RSA than ESA.

Shear force value along x axis for G+10 with different slab condition (CS, FS, FSSW) are 9%, 25%& 2% less respectively, in RSA than ESA.

Shear force value along z axis for G+10 with different slab condition (CS, FS, FSSW) are 62%, 76%& 64% less respectively, in RSA than ESA.

Shear force value along x axis for G+15 with different slab condition (CS, FS, FSSW) are 11%, 36%& 1% less respectively, in RSA than ESA.

Shear force value along z axis for G+15 with different slab condition (CS, FS, FSSW) are 63%, 84%& 68% less respectively, in RSA than ESA.

2.4 Bending moment

Bending Moment is the torque that keeps a beam together. It is found by cutting the beam, then calculating the MOMENT needed to hold the left (or right) half of the beam stationary. If this is done for the other (left) side you should get the same answer - but opposite direction.

Table -6: Bending moment for ESA and RSA method

MODELS	ESA		RSA	
	X (KN-m)	Z (KN-m)	X (KN-m)	Z(KN-m)
Model 1	4	54	3	52
Model 2	5	65	4	62
Model 3	5	71	4	69
Model 4	14	70	12	66
Model 5	10	113	9	94
Model 6	7	152	6	107
Model 7	14	40	9	28
Model 8	12	79	11	65
Model 9	11	129	10	100

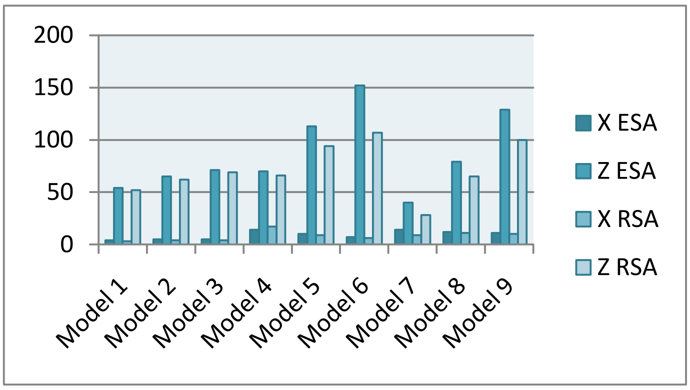

Chart -4: max. Bending moment for ESA and RSA method

Bending moment value along x axis for G+5 with different slab condition (CS, FS, FSSW) are 25%, 14%&36% less respectively, in RSA than ESA.

Bending moment Shear force value along z axis for G+5 with different slab condition (CS, FS, FSSW) are 4%, 6%& 30% less respectively, in RSA than ESA.

Bending moment value along x axis for G+10 with different slab condition (CS, FS, FSSW) are 20%, 10%& 8% less respectively, in RSA than ESA.

Bending moment value along z axis for G+10 with different slab condition (CS, FS, FSSW) are 5%, 17%& 18% less respectively, in RSA than ESA.

Bending moment value along x axis for G+15 with different slab condition (CS, FS, FSSW) are 20%, 36%& 1% less respectively, in RSA than ESA.

Bending moment value along z axis for G+15 with different slab condition (CS, FS, FSSW) are 3%, 30%& 22% less respectively, in RSA than ESA.

2.5 Storey Displacement

Storey displacement is displacement with respect to base of the structure.

Table -7: Story displacement for ESA and RSA method

MODELS	ESA		RSA	
	X(mm)	Z(mm)	X(mm)	Z(mm)
Model 1	14.097	10.023	12.612	1.777
Model 2	29.575	24.783	25.161	1.181
Model 3	48.397	42.561	38.885	1.247
Model 4	38.440	39.804	38.604	12.716
Model 5	68.184	97.552	59.994	12.797
Model 6	102.375	155.785	87.530	14.407
Model 7	31.100	38.964	26.143	23.176
Model 8	48.654	86.298	47.385	11.665
Model 9	74.475	126.093	69.127	9.068

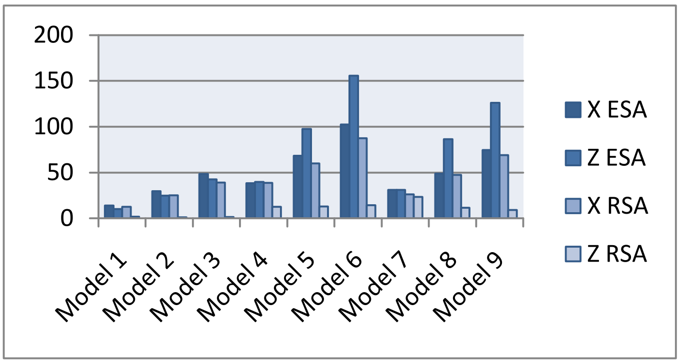

Chart -5: max. Displacement for ESA and RSA method

Storey displacement value along x axis for G+5 with different slab condition (CS, FS, FSSW) are 11%, 1%& 16% less respectively, in RSA than ESA.

Storey displacement value along z axis for G+5 with different slab condition (CS, FS, FSSW) are 82%, 68%&41% less respectively, in RSA than ESA.

Storey displacement value along x axis for G+10 with different slab condition (CS, FS, FSSW) are 15%,12%&3% less respectively, in RSA than ESA.

Storey displacement value along z axis for G+10 with different slab condition (CS, FS, FSSW) are 95%, 87%& 86% less respectively, in RSA than ESA.

Storey displacement value along x axis for G+15 with different slab condition (CS, FS, FSSW) are 20%, 15%& 7% less respectively, in RSA than ESA.

Storey displacement value along z axis for G+15 with different slab condition (CS, FS, FSSW) are 97%, 91%& 90% less respectively, in RSA than ESA.

(NOTE):

ESA = Equivalent Static Analysis

RSA = Response Spectrum Analysis

CS = Conventional slab

FS = Flat slab

FSSW=Flat slab with shear wall

3. CONCLUSIONS

From the results obtained as above, the following conclusions are drawn:

1. The seismic analysis of reinforced concrete frame structure is done by both static and dynamic analysis to determine and compare the base shear, it has been found that the difference between varies from 0-1%.
2. In buildings with flat slab, storey drift is significantly more as compared to CS slab buildings and approximately same as FS with shear wall which leads to the development of additional moment caused by drift which is also considered this while designing the columns.
3. The values of storey drift for all the stories are found to be within the permissible limit i.e. not more than 0.004 times to storey height according to IS 1893 : 2002 (Part I) .
4. Building saving flat slab with shear wall experience maximum force and bending moment as compared to respective buildings with only flat slab and conventional slab.
5. Compared to the building with flat slab, maximum displacement of CS and FS are less than that in the shear wall slab building.
6. Dynamic analysis gives lesser values for all parameters than static analysis. Hence, dynamic analysis is economical.
7. Drift and displacement results obtained by ESA are greater than the results obtained by RSA
8. From the analysis results for both ESA and RSA the storey displacement and storey drift is more along the shorter span i.e., in X-direction.
9. Base shear of conventional R.C.C building is greater than the flat slab building.

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