Effect of Diaphragm Openings in Multi-storeyed RC framed buildings using Pushover analysis

P.P. Vinod Kumar [1], Dr. V.D. Gundakalle [2]

[1] *M.Tech Student, Civil Engineering, KLEMSSCET - Belagavi, Karnataka, India.*
[2] *Professor, Civil Engineering, KLEMSSCET - Belagavi, Karnataka, India.*

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Abstract - ***Earthquakes are natural hazards under which disasters are mainly caused by damage or collapse of buildings. In the present scenario, most of the buildings are designed and constructed on the basis of aesthetics which happens to ignore the basic principles of earthquake resistant structure, where we come across many buildings having irregular configurations both in elevation and plan. Openings in the floors are common for many reasons like staircases, lighting, architectural and etc. these openings develop stresses at discontinuities.***

This present paper makes a humble effort to portrait the behavior of multi storeyed buildings with diaphragm openings under non-linear static (pushover) analysis using ETABS – 2013. To achieve this objective various models with varying percentages of diaphragm openings were analyzed and compared for seismic parameters like maximum dead load, base shear, maximum storey drifts, modal time period and pushover results.

Key Words: *Diaphragm Discontinuity, Pushover Analysis, Maximum Dead Load, Base Shear, Maximum Storey Drifts, Modal Time Period and Pushover results.*

1. INTRODUCTION

1.1 General

The recent earthquake including the last Nepal earthquake (2015) in which many reinforced concrete structures have been severely damaged or collapsed, have indicated the need for evaluating the seismic adequacy of existing buildings. In multi-storeyed framed building, damages from earthquake generally initiate at locations of structural weaknesses present in the lateral load resisting frames. This behavior of multi-storeyed framed buildings during strong earthquake motions depends on the distribution of mass, stiffness, strength in both horizontal and vertical planes of buildings. In few cases, these weaknesses may be created by discontinuities in stiffness, strength or mass along the diaphragm.

1.2 Significance of the Present Study

This study is conducted to evaluate problems in structural behavior of buildings during earthquake. An assumption is made in the seismic analysis that all the structures behave linearly elastic during seismic excitations which intern does not clear the non-linearity of the structure. So in order to understand better the non-linear response of the structures this study would be useful. In the mentioned seismic analysis, the building will be analyzed for linear static, linear dynamic and non-linear static methods.

1.3 Concept of Diaphragm Discontinuity

Diaphragm discontinuity includes those having openings greater than 50% of the total diaphragm area or changes in the effective diaphragm stiffness of more than 50% from one story to the next story. Discontinuities in the lateral stiffness of the diaphragm are due to openings, cut-outs, adjacent floors at different levels or change in the thickness of diaphragm. Floor diaphragm openings are typically for the purpose of stairways, shafts or other architectural features.

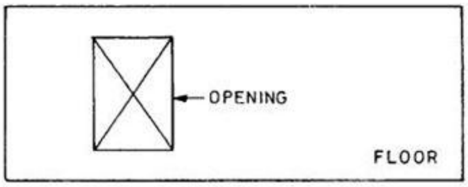


Fig. 1: Diaphragm discontinuity

Diaphragm is used for reducing the degree of freedom of building. Use of diaphragm constraint for building structures eliminates the numerical accuracy problems. Assigning diaphragm is also useful in the lateral dynamic analysis of buildings. After assigning diaphragm constraint at each story, only three DOF's are considered; lateral displacement in two principal directions and one rotation. Diaphragm's can be modeled into three basic actions namely, rigid action, semi-rigid action and flexible action.

1.4 Pushover Analysis

A pushover analysis is performed by subjecting a structure to a monotonically increasing pattern of lateral loads, representing the inertial forces which would be experienced by the structure when subjected to ground shaking. Under incrementally increasing loads various structural elements may yield sequentially. Consequently, at each event, the structure experiences a loss in stiffness. Using a pushover analysis, a characteristic non linear force displacement relationship can be determined.

After pushover analysis, the results obtained in terms of demand, capacity and formation of plastic hinges will give the clear insight into the real behavior of the structure.

2. MODELLING AND ANALYSIS

Table - 1: Seismic Parameters

Particulars	Details
No. of floors	G+15
Zone factor	IV
Building type	SMRF
Response reduction factor	5
Plan irregularity	Diaphragm Discontinuity
Soil type	Medium (type – II)
Concrete grade	M25
Steel grade	Fe415
Importance factor	1

Table – 2: Modeling details

Plan	40x40 m
Typical story height	3.2 m
Total building height	51.2 m
Grade of concrete	M25
Grade of steel	Fe415
Beam dimension	500x350 mm
Column dimension	700x700 mm
Slab thickness	150 mm

Table – 3: Types of models

Model no.	Opening Percentage
Model 1	0 %
Model 2	12.5 %
Model 3	25 %
Model 4	37.5 %

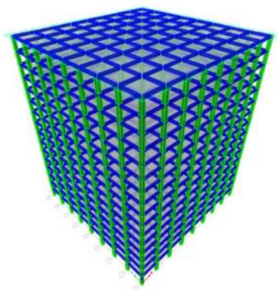


Fig. 2: Typical 3D view

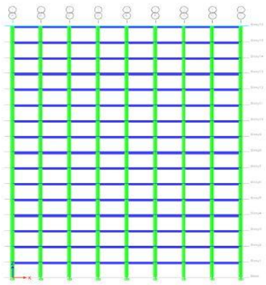


Fig. 3: Typical elevation

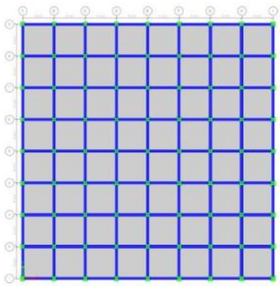


Fig. 4: Plan (Model 1)

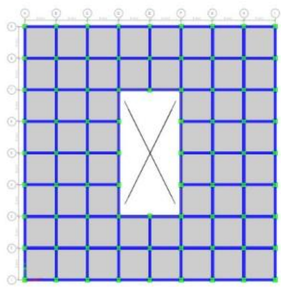


Fig. 5: Plan (Model 2)

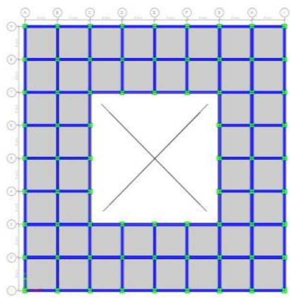


Fig. 5: Plan (Model 3)

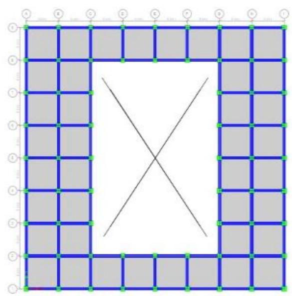


Fig. 6: Plan (Model 4)

3. RESULTS AND DISCUSSIONS

Results discussed in the present study are in terms of;

1. Maximum Dead Load
2. Base Shear
3. Maximum Storey Drifts
4. Modal Time Period
5. Pushover Results

3.1 Maximum Dead Load

Table – 4: Maximum Dead Load (self weight)

Model no.	Dead Load (Max) - kN
Model 1	197203.2
Model 2	179821.6
Model 3	159158.4
Model 4	138495.2

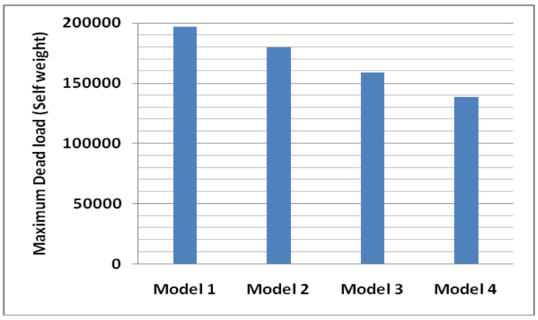


Fig. 7: Maximum dead load (self weight)

3.2 Base Shear

Table – 5: Base shear along X direction

Model No.	EQ X	SPEC X	PUSH X
Model 1	9900.9	4490.99	14459.53
Model 2	9036.12	4101.46	13348.37
Model 3	7993.38	3674.15	12069.89
Model 4	6950.63	3182.56	10485.03

Table – 6: Base shear along Y direction

Model No.	EQ Y	SPEC Y	PUSH Y
Model 1	9900.9	4490.99	14558.58
Model 2	9036.12	4165.17	13257.07
Model 3	7993.38	3674.15	11949.89
Model 4	6950.63	3247.16	10745.58

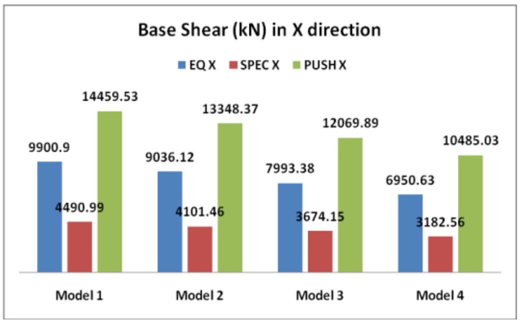


Fig. 8: Base Shear in X direction for all cases

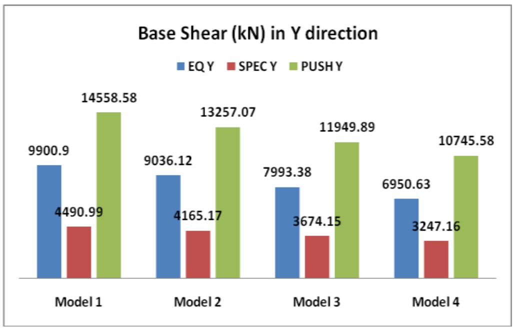
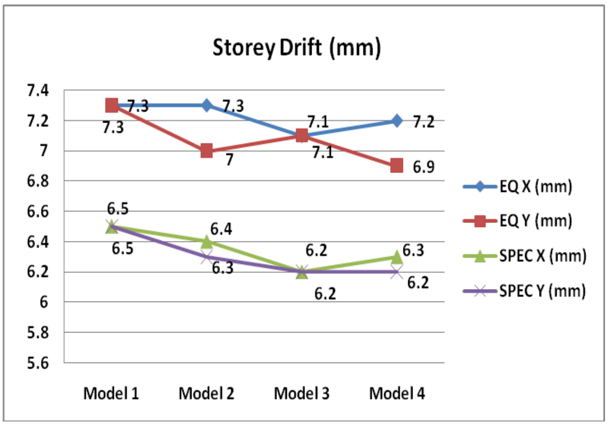


Fig. 9: Base Shear in Y direction for all the cases

3.3 Maximum Storey Drifts

Table – 7 and Fig. 10: Maximum Storey Drifts for Equivalent static and Response spectrum Analysis

Model No.	EQ X (mm)	EQ Y (mm)	SPEC X (mm)	SPEC Y (mm)
Model 1	7.3	7.3	6.5	6.5
Model 2	7.3	7	6.4	6.3
Model 3	7.1	7.1	6.2	6.2
Model 4	7.2	6.9	6.3	6.2



3.4 Time Period

Table – 8: Modal Time Period in seconds

Model No.	Mode 1	Mode2	Mode 3
Model 1	2.81	2.81	2.601
Model 2	2.808	2.763	2.591
Model 3	2.772	2.772	2.571
Model 4	2.784	2.724	2.537

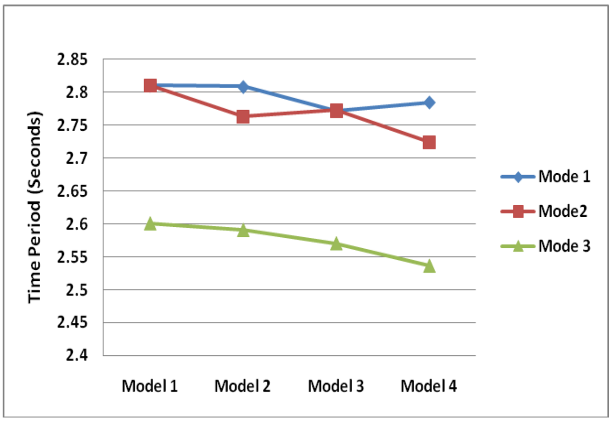


Fig. 11: Modal Time Period in seconds

3.5 Pushover results

3.5.1 Model 2 with 12.5% Opening

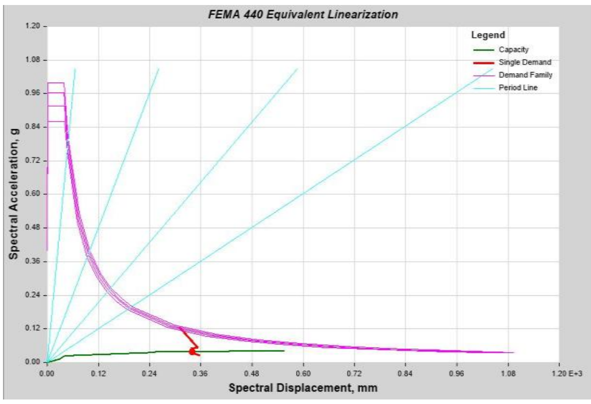


Fig. 12: Pushover curve in X direction for Model 2

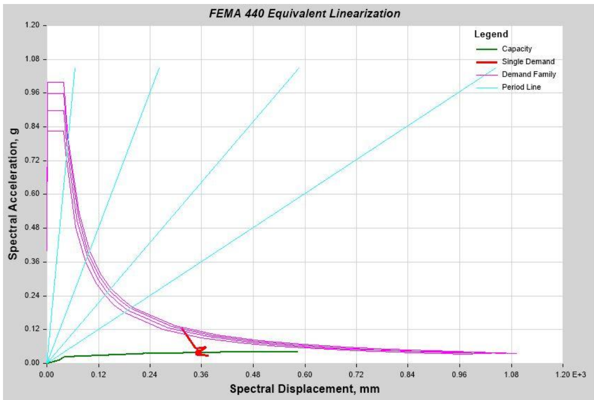


Fig. 13: Pushover curve in Y direction for Model 2

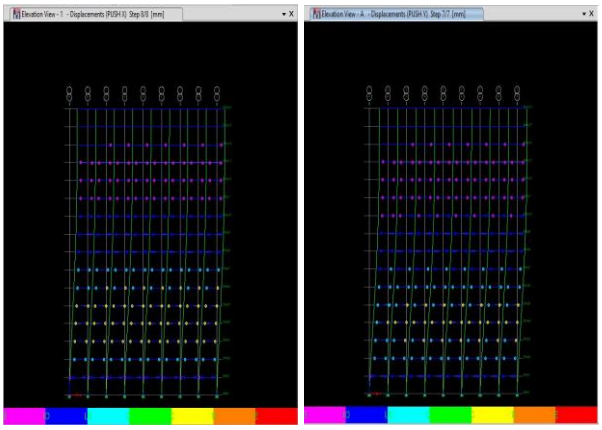


Fig. 14: Formation of hinges in X and Y direction

3.5.2 Model 4 with 37.5% Opening

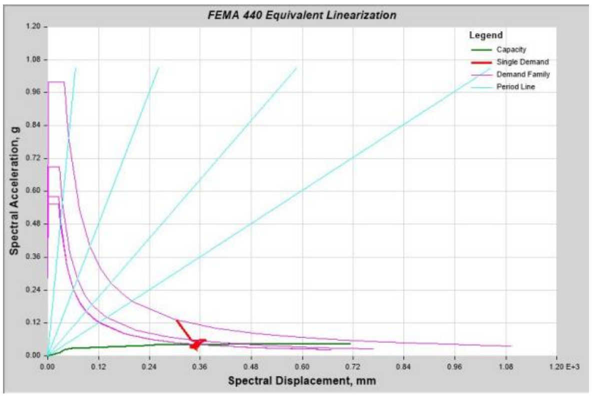


Fig. 15: Pushover curve in X direction for Model 4

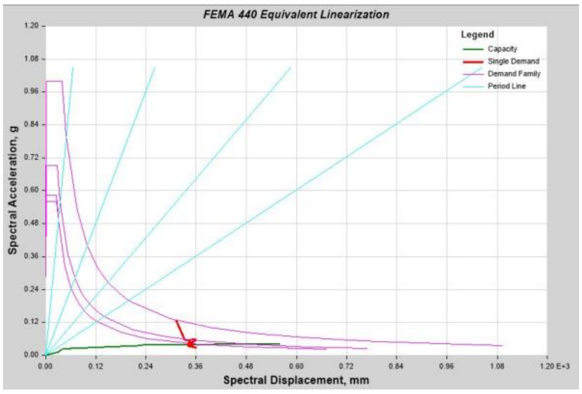


Fig. 16: Pushover curve in Y direction for Model 4

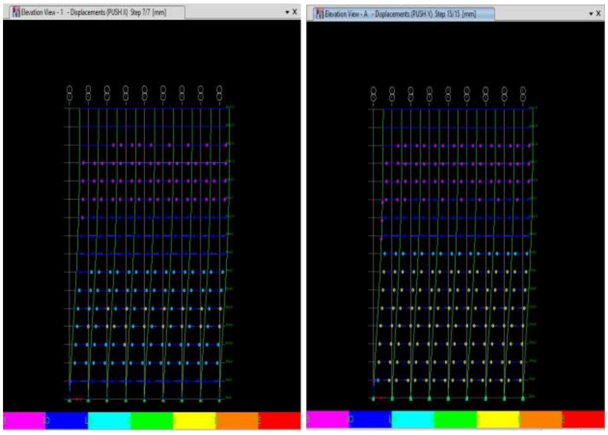


Fig. 17: Formation of hinges in X and Y direction

4. CONCLUSIONS

1. The influence of diaphragm openings on the seismic response of multi-storeyed buildings played a major role in reducing the base shear, hence attracting lesser seismic forces.
2. Provision of diaphragm opening alters the seismic behaviour of the buildings. Models with symmetrical opening in both directions expressed similar response for all the parameters while models with change in the symmetry behaved different.
3. For models 2 and 4, storey drifts have reduced and base shear has increased in Y direction, where the length of opening is more.
4. All the models nearly performed in the same range, the overall performance level of all the buildings is in between CP-C.
5. Hence according to this study, the building is merely safe and further it needs to be retrofitted.

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