Analysis of Buildings with Slab Discontinuity

Babita Elizabath Baby[1], Sreeja S[2]

[1]M Tech Student, ICET, Muvattupuzha, India

[2]Assistant Professor, ICET, Muvattupuzha, India

Abstract: ***Openings are common in buildings nowadays. When subjected to lateral loads , buildings with slab openings are often vulnerable to damages. Correct location of openings can offer efficient strength and serviceability to the structure. Slab openings are provided for lighting purpose, architectural beauty etc. In the present work slab openings are provided as discontinuity at different locations such as at center, at corners and at periphery. In each case linear and nonlinear analysis(push over analysis) are done in ETABS software.***

Keywords: Seismic analysis, diaphragm discontinuity, nonlinear analysis, pushover analysis, Response spectrum analysis

1. Introduction

In multi-storeyed framed building, damages from earthquake generally initiates at locations of structural weaknesses. Openings present in slab are often providing discontinuities in distribution of load. But when these openings are provided at suitable locations the vulnerability of structure to damage can be avoided. Structural engineers have developed confidence in the design of buildings. In the present work openings enclosed by shearwalls are placed at different locations.The effect of location of slab openings on the seismic response of a multistoreyed building is studied.

2. Literature Review

This literature review focuses on recent contributions related to diaphragm and past efforts most closely related to the needs of the present work.

Smith, B.S. and A. Coull. (1991) states that, the provision of adequate lateral stiffness is a major consideration in the design of a tall building in seismic zone. Firstly, deflection must be maintained at a sufficiently low level for the proper functioning of non-structural components such as elevators and doors. Secondly, it must be limited to prevent excessive cracking and consequent loss of stiffness, and to avoid any redistribution of load to non structural elements such as partitions, infill, cladding or glazing. Thirdly, the structure must be sufficiently stiff to prevent dynamic motions becoming large enough to cause discomfort to occupants, prevent delicate work being undertaken or affect the sensitive equipments.

Basu (2004), Jain (1984) and Tao (2008) had analyzed differing kinds of structures starting from formed, -shaped to long and slenderbuildings. Although these studies proved to be contributing to understanding the dynamics of such style of structures, they didn't address the effects of diaphragm openings.

Itani and Cheung (1984) introduced a finite element model to research the non-linear load deflection behavior of incased wood diaphragms. The model is general and is in sensible agreement with experimental measurements. Nonetheless it is will not deal with openings and however to extend the developed model to account for them. Pudd and Fonseca (2005) developed a replacement progressive analytical model for sheathing-to-framing connections in wood shear walls and diaphragms. Though the new model is not like previous analytical models, being appropriate for each monotonic and cyclic analysis, it didn't account for the consequences of openings on neither shear walls nor diaphragms.

Kim and White(2004) proposed a linear static methodology applicable solely to buildings with flexiblediaphragms. The procedure is predicated on the idea that diaphragm stiffness is tiny compared to the stiffness of the walls, which flexible diaphragms within a building structure tend to respond independently of one another. Though the proposed approach gave insight into the restrictions of current building codes, it did not deal with diaphragm opening effect.

3. Scope and Objective

In the present study, a typical multi storeyed building will be analyzed using commercial software ETABS for nonlinear static (pushover) and dynamic (response spectrum) analysis. All the analyses will be carried out considering the diaphragm discontinuity and the results so obtained will be compared. Diaphragm discontinuity is in the form of slab openings.This study is done for RC framed multistoreyed building (G+10) with fixed support conditions. Fom the present thesis we may know the best location of openings.

The salient objectives of the present study are as follows:

- To investigate the seismic performance of a multi-storeyed building with slab openings.
- To investigate the suitable location of openings.
- To compare the results obtained through various analysis.

4. Methodology

One of the objectives of this model designing is to ensure that the models represent the characteristics of apartment buildings. A hospital building(G+ 10) having the base dimension 25.48m × 20.53m having floor height 4m is modelled. The super structure is modelled using the software ETABS. The end nodes at the bottom of the structure is modelled as fixed supports due to rigid connection of the columns with pile at the foundation level. The columns will also be inter-connected at the plinth beams to increase the stability of the structure, wherever necessary. All slabs are modelled as membrane.Shearwalls are modelled as shells.

The properties of various frame member sections such as cross sectional dimensions of the slab, beams, columns, shear walls etc. and material property were defined and assigned.

A. Slab
Slab thickness is 0.1m

B. Beams
The dimensions of beams are
B1 – 0.2 × 0.4m
B2 – 0.2 × 0.6m

C. Column
The dimensions of columns are
C_1 – 0.3m ×0.6m
C_2 - 0.4m × 0.45m

D. Shearwall
Thickness of shearwall is 0.2m

E. Slab opening
5% of the floor area is provided as opening

F. Loading
Dead load and live load as per IS 875:1987 part I and part II respectively. Earthquake load as per IS 1893: 2002.

G. Load Combination
As per IS 456: 2000 , load combinations provided are:
1) DL+LL
2) 1.5 (DL + LL)
3) 1.2 (DL + LL + EL_x)
4) 1.2 (DL + LL +EL_y)
5) 1.2 (DL + LL – EL_x)
6) 1.2 (DL + LL – EL_y)
7) 1.5 (DL + EL_x)
8) 1.5 (DL +EL_y)
9) 1.5 (DL – EL_x)
10) 1.5 (DL +EL_y)
11) 0.9 DL + 1.5 EL_x
12) 0.9 DL +1.5 EL_y
13) 0.9 DL -1.5 EL_x
14) 0.9 DL - 1.5 ELy
15) DL + EQx
16) DL + EQy
17) DL –Eqx
18) DL –EQy
19) DL + 0.8 LL + 0.8 EQx
20) DL + 0.8 LL+ 0.8 EQy
21) DL + 0.8 LL – 0.8EQx
22) DL + 0.8 LL -0.8 EQy

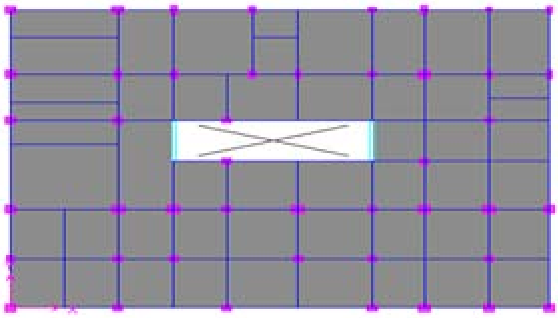

Figure 1: Model 1- Opening at center

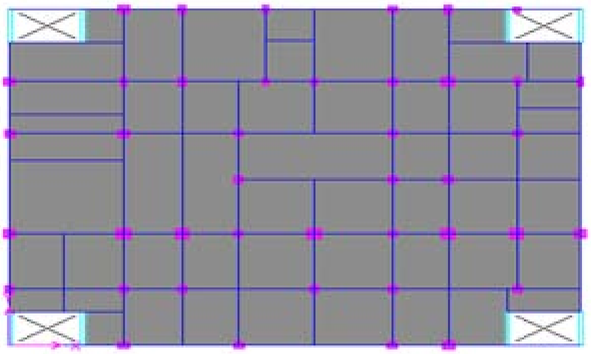

Figure 2: Model 2- Opening at corners

5. Result Summary

Analysis Results of Various Models using Linear Static Method

Table 1: Maximum Story Drift at Roof Level

	Load Combination	*Model 1*	*Model 2*	*Model 3*
X-Direction	Envelope	0.00522	0.004109	0.00357
Y-Direction		0.00311	0.00288	0.00255

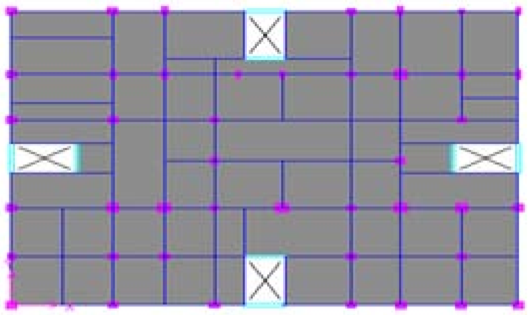

Figure 3: Model 3- Opening at Periphery

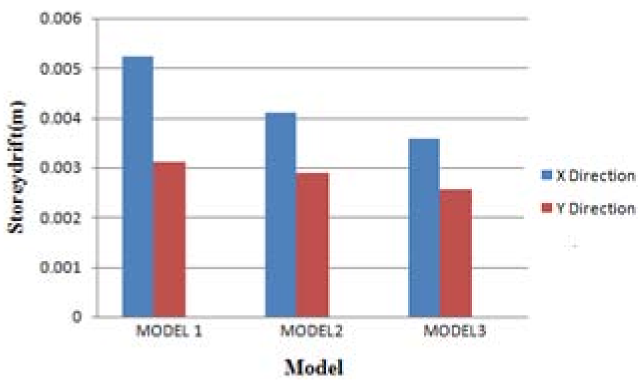

Figure 4: Graph for Maximum Storey Drift at Roof level

Table 2: Maximum Bending Moment and Shear Force For Beam No: 25.For Model 1

Load Combination	*At Support*	*Mid-Span*	*Shear Force*
DL+EQX	50.29	39.817	80.83
DL+0.8LL+0.8EQX	55.02	47.64	91.83
DL+0.8LL-0.8EQX	37.97	52.453	85.05
ENVELOPE	370.43	131.70	254.08

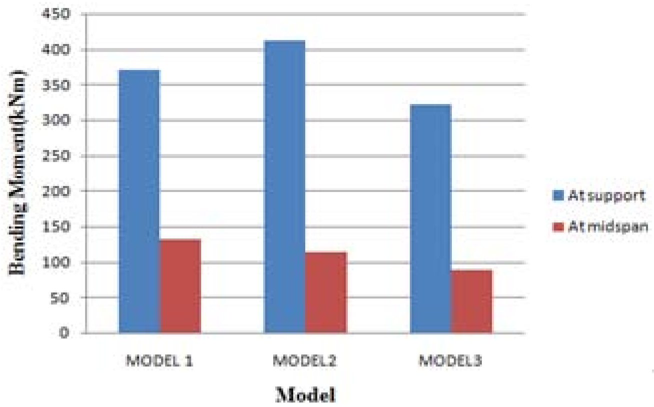

Figure 5: Variation of Maximum Bending Moment at Ground level

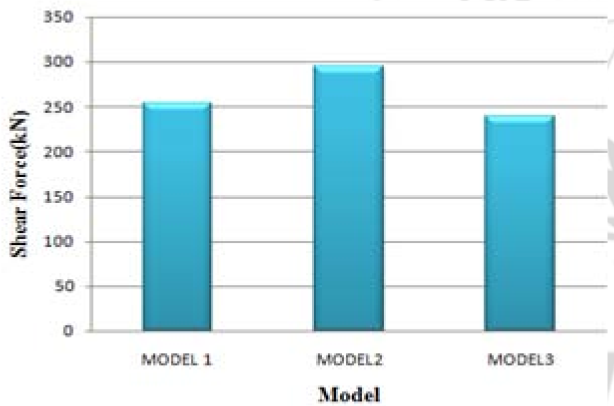

Figure 6: Variation of Shearforce at Ground level

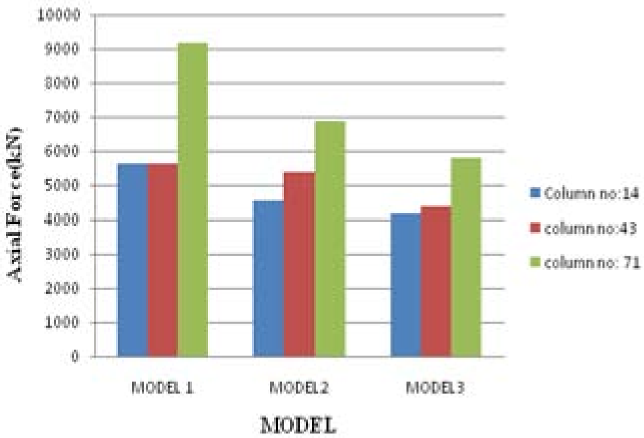

Figure 7: Variation of Axial force for column no: 14, 43 and 71

6. Analysis Results of Various Models Using Response Spectrum Method

Table 3: Maximum Story Drift at Roof Level

	Load Combination	Model 1	Model 2	Model 3
X-direction	ENVELOPE	0.00529	0.00420	0.00364
Y-direction		0.00312	0.00288	0.003367

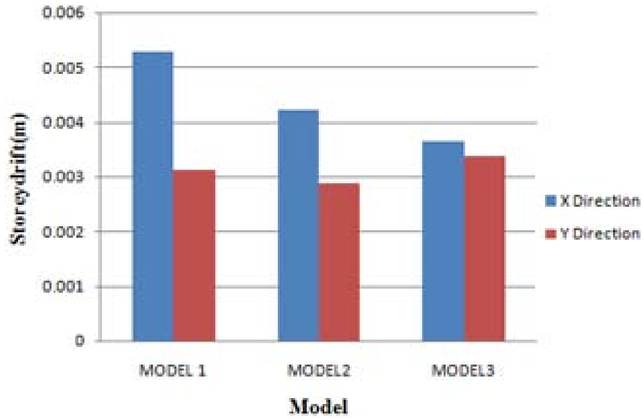

Figure 8: Graph for Maximum Storey Drift at Roof level

Table 4: Maximum Bending Moment and Shear Force for Beam No: 15.For Model 2

Load Combination	*At Support*	*MID-SPAN*	*Shear Force*
DL+EQX	48.12	16.05	73.83
DL+0.8LL+0.8EQX	55.3	28.16	85.58
DL+0.8LL-0.8EQX	70.1	63.34	166.8
ENVELOPE	413.43	123.8	301.2

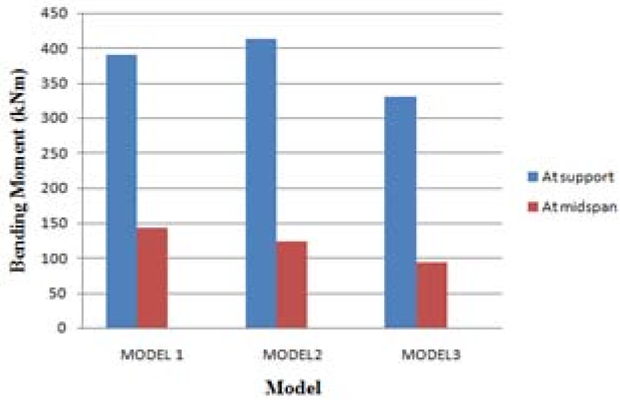

Figure 9: Variation of Maximum Bending Moment at Ground level

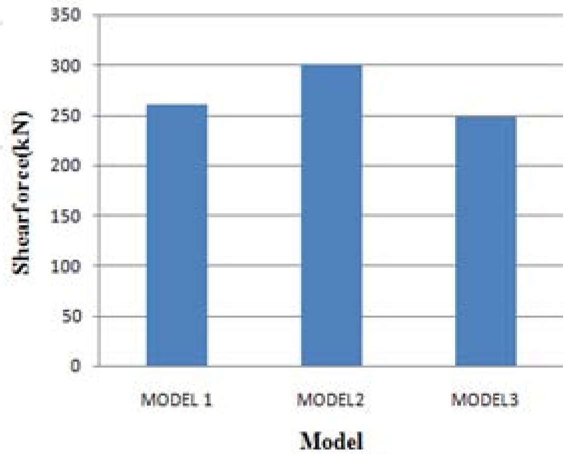

Figure 10: Variation of Shearforce at Ground level

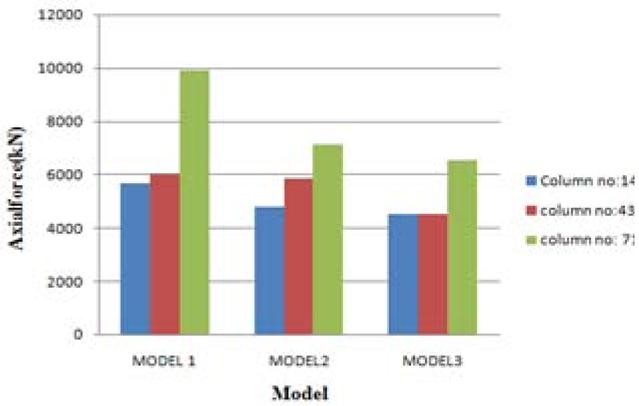

Figure 11: Variation of Axial force for column no: 14, 43 and 71

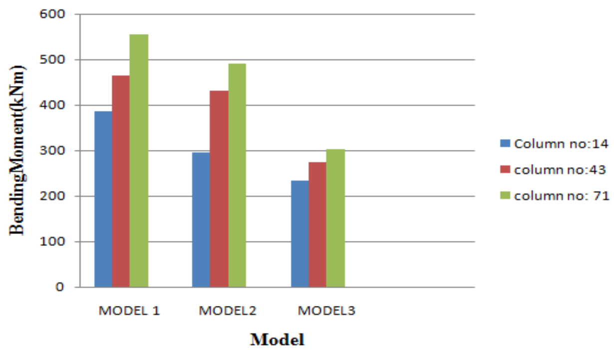

Figure 12: Variation of Bending Moment for column no: 14, 43 and 71

7. Analysis Results of Various Models Using Pushover Analysis

Table 5: Maximum Storey Drift At Roof Level

	Load Combination	*Model 1*	*Model 2*	*Model 3*
X-direction	PUSH 1	0.0052238	0.0042	0.0039
Y-direction	PUSH 2	0.003122	0.00301	0.0029

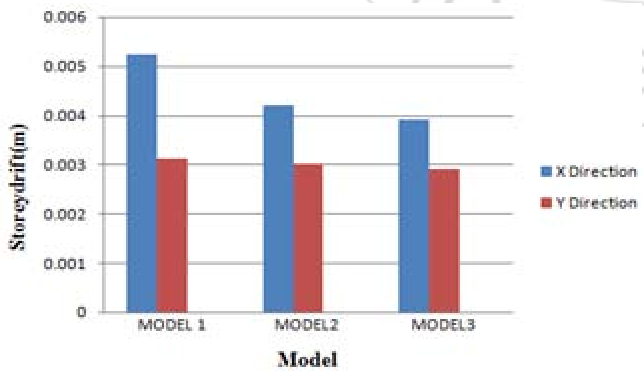

Figure 13: Graph for Maximum Storey Drift at Roof level

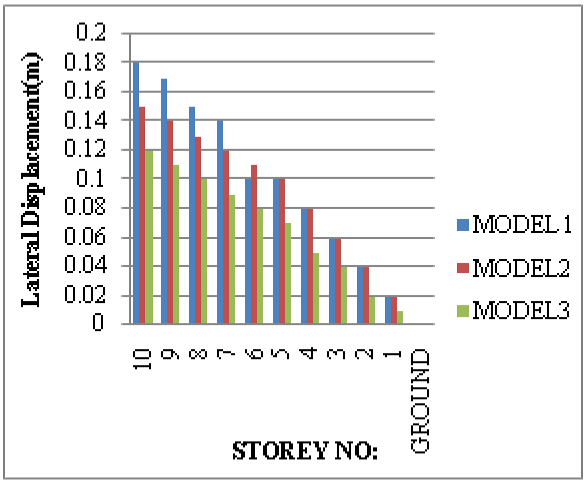

Figure 14: Variation of Lateral Displacement with Storeys

8. Comparitive Study Between Analysis Results

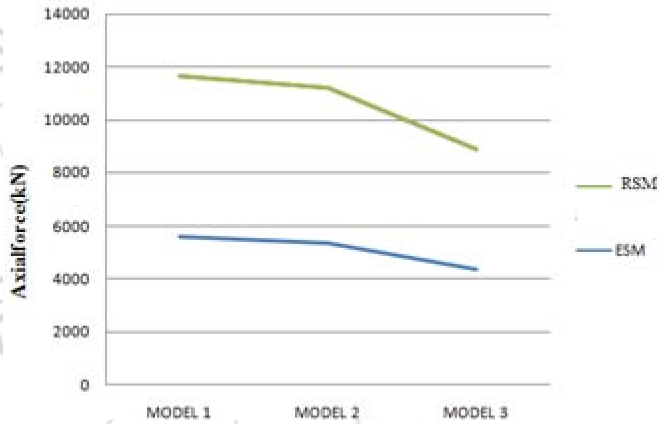

Figure 15: Graph for comparison of axial force using Equivalent static method and Response spectrum method

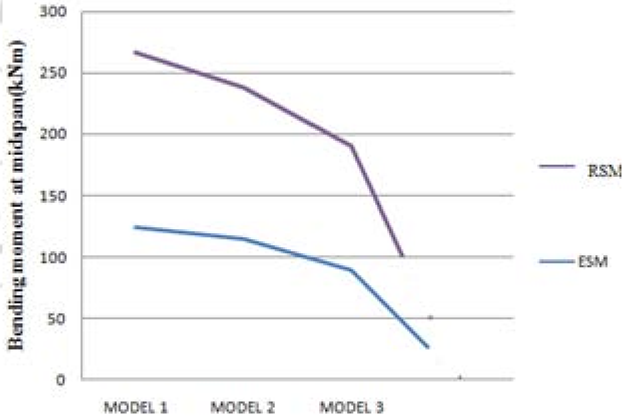

Figure 16: Graph for comparison of Bending Moment using Equivalent static method and Response spectrum method

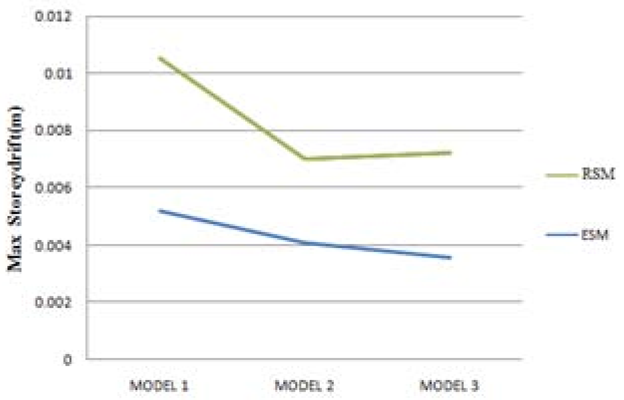

Figure 17: Graph for comparison of Storydrift in X direction using Equivalent static method and Response spectrum method

9. Conclusions

- From the graphical representation of axial forces for different load combinations , Model 3 having opening located at periphery are more effective for resisting lateral forces.
- Comparing on the basis of bending moments shear force and story drift also Model 3 is more effective than the other three models.
- Lateral displacement for model 3 is lesser compared to model 1 and model 2.
- So the openings are more effective to be located at periphery.
- Comparison has been done for the linear and nonlinear analysis. Around 4% variation has been shown for linear static analysis and response spectrum analysis.
- 7% variation has been shown for linear static analysis and pushover analysis.

References

[1] Aktan, A. E. and Nelsonl, G. E., (1988). "*Problems in Predicting Seismic Responses of RC Buildings*," J. Struct. Engrg. ASCE 114 (9), pp. 2036-2056

[2] Jain, S. K., (1984). "Seismic Response of Buildings with Flexible Floors," J. Engrg.Mech. ASCE 110 (1), pp. 125-129.

[3] Jain, S. K., and Jennings, P. C., (1984). "*Continuous Models for Frame and Shear-Wall Buildings with Flexible Floors*," 8 th World Conference on EQ. Eng., San Francisco, CA, Vol. 4, pp. 743-750

[4] Luttrell, L., (1996). "*Designing Roof and Floor Diaphragms*", Modern Steel Construction, Chicago, IL

[5] Nakashima, M., Huang, T. and Lu, L. W., (1984). "*Effect of Diaphragm Flexibility on Seismic Response of Building Structures*," 8th World Conference on EQ. Eng., SanFrancisco, CA, Vol. 4, pp. 735-742

[6] Tissell, J. R. and Elliott, J. R., (1993). "Plywood Diaphragms," Research Report 138,APA – The Engineered Wood Associates, Tacoma, WA.

[7] Ravikanth Chittiprolu, Ramancharla Pradeep Kumar, *Significance of Shear Wall in Highrise Irregular Buildings,* International Journal of Education and applied research, Vol. 4, Issue Spl-2, Jan - June 2014.

[8] M.D. Kevadkar, P.B. Kodag , *Lateral Load Analysis of R.C.C. Building,* International Journal of Modern Engineering Research (IJMER) Vol.3, Issue.3 May-June. 2013 pp-1428-1434

[9] Misam Abidi, Mangulkar Madhuri. N.*, Review on Shear Wall for Soft Story High-Rise Buildings,*International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-1, Issue-6, August 2012.

[10] Paulay, T. and M.J.N. Priestley. 1992. *Seismic design of reinforced concrete and masonry buildings*. John Wiley and Sons, Inc. USA.

[11] Varayani, U.H. 2002. *Structural design of multi-storeyed buildings.* 2nd ed. South Asian publishers, New Delhi