Seismic Vulnerability of Multistoried Buildings With Ground Soft Story and With Infills

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***Abstract* — Multistory buildings with open (soft story) ground floor are inherently vulnerable to collapse due to seismic loads, their constructions is still widespread in develop nations. Social and functional need to provide car parking space at ground level far out weights the warning against such buildings from engineering community. In this study, 3D analytical model of multistory buildings have been generating for different buildings models and analyzing using structural analysis tool 'ETABS'. To study the effect of ground soft, infill, and models with ground soft during earthquake, seismic analysis both linear static, linear dynamic (response spectrum method) as well as nonlinear static (pushover) procedure have to be perform. The analytical model of building includes all important components that influence the mass, strength, stiffness of the structure. The deflections at each story have to be compare by performing equivalent static, response spectrum method as well as pushover have also be perform to determine capacity, demand and performance level of the considering models. Numerical results for the following seismic demands considering the inelastic behavior of the building, ductility coefficients of structures**

Keywords— Soft Story,Ductlity,Outweights,Stifness, linear static, linear dynamic (response spectrum method), nonlinear static(pushover)

1. INTRODUCTION

The capacity of structural members to undergo inelastic deformations governs the structural behavior and damageability of multi-storey buildings during earthquake ground motions. From this point of view, the evaluation and design of buildings should be based on the inelastic deformations demanded by earthquakes, besides the stresses induced by the equivalent static forces as specified in several seismic regulations and codes. Although, the current practice for earthquake-resistant design is mainly governed by the principles of force-based seismic design, there have been significant attempts to incorporate the concepts of deformation-based seismic design and evaluation into the earthquake engineering practice. In general, the study of the inelastic seismic responses of buildings is not only useful to improve the guidelines and code provisions for minimizing the potential damage of buildings, but also important to provide economical design by making use of the reserved strength of the building as it experiences inelastic deformations. Pushover methods are becoming practical tools of analysis and evaluation of buildings considering the performance-based seismic philosophy. Pushover curve represents the lateral capacity of the building by plotting the nonlinear relation between the base shear and roof displacement of the building. The intersection of this pushover curve with the seismic demand curve determined by the design response spectrum represents the deformation state at which the performance of the building is evaluated.

2. NECESSITY OF THE STUDY

1. To study the effect of infill walls and without infill walls on structure.
2. To study of natural frequency of the structure.
3. To study the performance level of the structure

3. DIFFERENT METHODS OF SEISMIC EVALUATION STUDIES

3.1 LINEAR STATIC ANALYSIS

In linear static procedures the building is modeled as an equivalent single-degree of freedom (SDOF) system with a linear static stiffness and an equivalent viscous damping. The seismic input is modeled by an equivalent lateral force with the objective to produce the same stresses and strains as the earthquake it represents. Based on an estimate of the first fundamental frequency of the building using empirical relationships or Rayleigh's method

3.2 LINEAR DYNAMIC ANALYSIS

In a linear dynamic procedure the building is modeled as a multi-degree-of-freedom (MDOF) system with a linear elastic stiffness matrix and an equivalent viscous damping matrix. The seismic input is modeled using either modal spectral analysis or time history analysis. Modal spectral analysis assumes that the dynamic response of a building can be found by considering the independent response of each natural mode of vibration using linear elastic response spectra. Only the modes contributing considerably to the response need to be considered. The modal responses are compared using schemes such as the square-root-sum-of-squares (SRSS). Time-history analysis involves a time step- by-step evaluation of building response, using recorded or synthetic earthquake records as a base motion input. In both cases the corresponding internal forces and displacements are determined using again linear elastic analyses.

3.3 NONLINEAR STATIC ANALYSIS

Pushover Analysis is a nonlinear static method of analysis. This analysis technique, also known as sequential yield analysis or simply "Pushover" analysis has gained significant popularity during past few years. It is one of the three analysis techniques recommended by FEMA 273/274 and a main component of Capacity Spectrum Analysis method (ATC-40).

Pushover analysis provides information on many response characteristics that cannot be obtained from an elastic static or elastic dynamic analysis. These are [30];

- Estimates of inter story drifts and its distribution along the height.
- Determination of force demands on brittle members, such as axial force demands on columns, moment demands on beam-column connections.
- Determination of deformation demands for ductile members.
- Identification of location of weak points in the structure (or potential failure modes).
- Consequences of strength deterioration of individual members on the behavior of structural system.
- Identification of strength discontinuities in plan or elevation that will lead to changes in dynamic characteristics in the inelastic range.
- Verification of the completeness and adequacy of load path.

3.4 NON-LINEAR DYNAMIC ANALYSIS

In nonlinear dynamic procedure the building model is similar to the one used in non-linear static procedures incorporating directly the inelastic material response using in general finite elements. The main difference is that seismic input is modeled using a time history analysis, which involves time-step-by-time-step evaluation of the building response.

3.5 ADVANTAGES OF INELASTIC PROCEDURE OVER ELASTIC PROCEDURES.

Although an elastic analysis gives a good understanding of the elastic capacity of structures and indicates where first yielding will occur, it cannot predict failure mechanisms and account for redistribution of forces during progressive yielding. Inelastic analyses procedures help demonstrate how buildings really work by identifying modes of failure and the potential for progressive collapse. The use of inelastic procedures for design and evaluation is an attempt to help engineers better understands how structures will behave when subjected to major earthquakes, where it is assumed that the elastic capacity of the structure will be exceeded. This resolves some of the uncertainties associated with code and elastic procedures.

4.0 ANALYSIS OF MULTISTORIED BUILDINGS WITH GROUND SOFT STORY AND WITH INFILLS

4.1 DESCRIPTION OF THE SAMPLE BUILDING

The plan layout for all the building models are shown in figures

SYMMETRIC BUILDING MODELS:

Model 1: Twelve stoteyed Building with full infill masonry wall (230 mm thick) in all storeys.

Model 2: Twelve storeyed Building (ground soft story) no walls in the first storey and full brick infill masonry walls (230 mm thick) in the upper storeys.

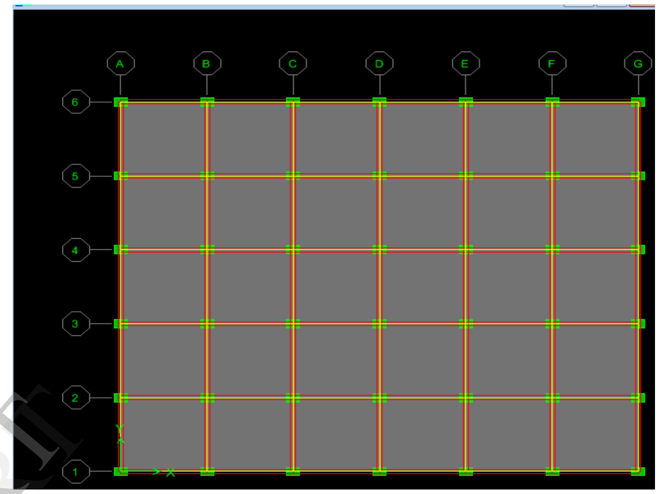

Figure:4.1 Plan Layout

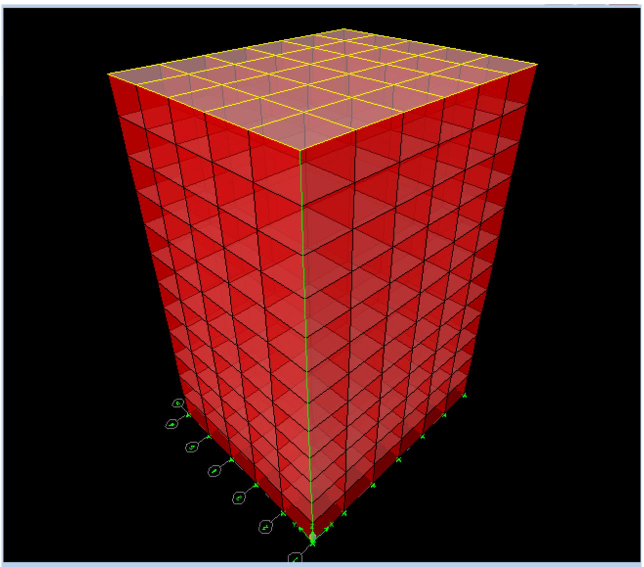

Fig:4.2 Elevation of twelve storeyed Building Model 1 (full infill)

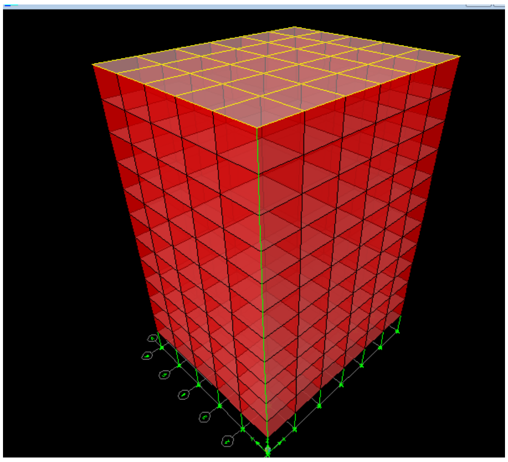

Fig:4.3 Elevation of twelve storeyed Building Model 2 (ground soft)

4.2 DESIGN DATA:

Material properties:

Young's modulus of (M25) concrete, E = 25.000x10^6 kN/m²
Young's modulus of (M20) concrete, E= 22.360x10^6 kN/m²
Density of Reinforced Concrete= 25kN/m³
Modulus of elasticity of brick masonry= 3500x10³kN/m²
Density of brick masonry= 19.2 kN/m³
Assumed Dead load intensities
Floor finishes= 1.5kN/m²
Live load= 4 KN/ m²

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Assumed Dead load intensities
Floor finishes = 1.5kN/m²
Live load = 4 KN/ m²
Member properties
Thickness of Slab= 0.125m
Column size for twelve storeyed = (0.6m x 0.6m)
Column size for nine storeyed = (0.45m x 0.6m)
Beam size of twelve storeyed = (0.375m x 0.6m)
Beam size of nine storeyed =(0.375m x 0.6m)
Thickness of wall= 0.230m
Thickness of shear wall =0.30m
Earthquake Live Load on Slab as per clause 7.3.1 and 7.3.2 of IS 1893 (Part-I)- 2002 is calculated as:
Roof (clause 7.3.2) = 0
Floor (clause 7.3.1) = 0.5x4=2 kN/m2
IS: 1893-2002 Equivalent Static method
Design Spectrum
Zone –V
Zone factor, Z (Table2) – 0.36
Importance factor, I (Table 6) – 1.5
Response reduction factor, R (Table 7) – 5.00
Vertical Distribution of Lateral Load, $f_i = V_B \frac{w_i h_i^2}{\sum_{j=1}^{n} w_j h_j 2}$

IS: 1893-2002 Response Spectrum Method: Spectrum is applied from fig.2 of the code corresponding to medium soil sites. The spectrum is applied in the longitudinal and transverse directions.

4.3 Manual Calculation

Natural periods and average response acceleration coefficients:

For twelve-storeyed frame building:

Fundamental Natural period, longitudinal and transverse direction, Ta=0.075*$36^{0.75}$=1.102sec

For medium soil sites, Sa/g = 1.36/T=1.36/1.102=1.234

For twelve-storeyed brick infill's buildings:

Fundamental natural period longitudinal direction,

Ta= $\frac{0.09x36}{\sqrt{25}} = 0.66$ sec

For medium soil sites, Sa/g = 1.36/0.66=2.060

Fundamental Natural period, transverse direction,

T_a= $\frac{0.09x32}{\sqrt{20}} = 0.643$ sec

For medium soil sites, Sa/g = 1.36/0.643=2.11

Design horizontal seismic coefficient,

$$A_h = \frac{Z}{2} x \frac{I}{R} x \frac{Sa}{g}$$

Ah= (0.36/2) x (1.5/5) x 2.060 =0.11124 in longitudinal direction.

Ah= (0.36/2) x (1.5/5) x 2.11 =0.1139 in transverse direction

Table 4: Deign Seismic Based Shear for twelve storeyed buildings

Table 4.1: Distribution of Lateral Seismic Shear force for twelve storeyed building for Model 1

Level	$(Q_i)_x$(KN)	$(Q_i)_y$ (KN)
12	1840.97	1840.97
11	3877.20	3877.20
10	5578.70	5578.70
9	6889.70	6889.70
8	7977.55	7977.55
7	8758.57	8758.57
6	9400,12	9400,12
5	9790.63	9790.63
4	10097.46	10097.46
3	10236.46	10236.46
2	10264.82	10264.82
1	10264.82	10264.82

Table 4.2: Distribution of Lateral Seismic Shear force for twelve storeyed building for Model 2

Level	$(Q_i)_x$(KN)	$(Q_i)_y$ (KN)
12	1810.69	1810.69
11	3813.42	3813.42
10	5459.50	5459.50
9	6776.37	6776.37
8	7846.32	7846.32
7	8669.36	8669.36
6	9297.92	9297.92
5	9657.01	9657.01
4	9931.36	9931.36
3	10041.10	10041.10
2	10095.97	10095.97
1	10095.97	10095.97

Figure 4.4: Shear diagram for twelve storeyed Model 1 along longitudinal and transverse direction

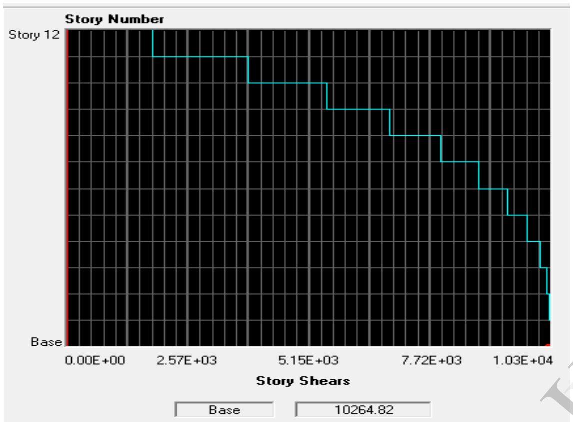
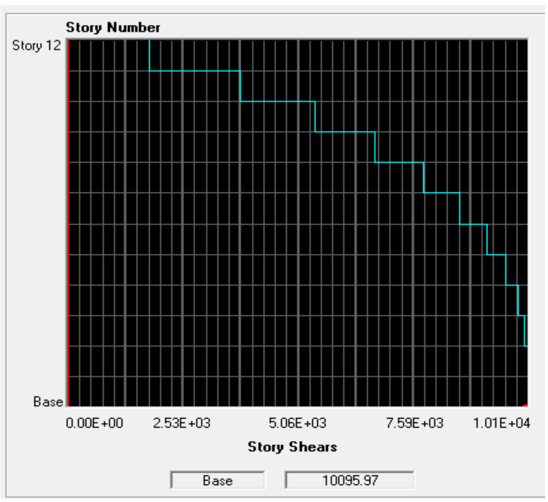


Figure 4.5: Shear diagram for twelve storeyed Model 2 along longitudinal and transverse direction



5. RESULTS AND DISCUSSIONS

Equivalent Static Method:

As compared to Model 1, Model 2 has 3.68% of less displacement than Model 1, in longitudinal direction and 3.49% less in transverse direction.

Response Spectrum Method:

As compared to Model 1, Model 2 has 7.33% of less displacement than Model 1, in longitudinal direction and 5.42% less in transverse direction.

Pushover Analysis:

In Pushover Analysis different building Models have pushed to its failure and correspondingly displacement is noted.

From the displacement table 5.1 to 5.2 and graphs 5.1-5.6.As compared to Model 1, Model 2 have 62.033% of more displacement than Model 1, in longitudinal direction and 15.59% more in transverse direction.

DISPLACEMENTS						
STOREY NO'S.	EQUIVALENT STATIC METHOD		RESPONSE SPECTRUM METHOD		PUSH OVER ANALYSIS	
	UX	UY	UX	UY	UX	UY
STORY12	15.6774	16.8968	11.1648	11.9447	78.3627	48.0587
STORY11	14.8334	15.8834	10.6235	11.2863	73.8908	44.4746
STORY10	13.7835	14.6708	9.9596	10.5086	69.0147	40.7936
STORY9	12.5598	13.2915	9.1799	9.6202	63.7169	37.0101
STORY8	11.2031	11.7879	8.2994	8.6381	57.9746	33.1076
STORY7	9.7531	10.2011	7.3347	7.5809	51.7636	29.0399
STORY6	8.2477	8.5715	6.3039	6.4687	45.0679	24.7732
STORY5	6.723	6.9376	5.2264	5.3225	37.9316	20.4227
STORY4	5.2128	5.3361	4.123	4.1649	30.4994	16.033
STORY3	3.7485	3.8014	3.0157	3.0194	22.7503	11.5995
STORY2	2.3598	2.3666	1.9293	1.9123	15.0849	7.4868
STORY1	1.0654	1.0536	0.8834	0.8649	7.6206	3.8314

TABLE 5.1 DISPLACEMENTS OF 12 STOREY INFILL STRUCTURE IN MM.

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DISPLACEMENTS						
STOREY NO'S.	EQUIVALENT STATIC METHOD		RESPONSE SPECTRUM METHOD		PUSH OVER ANALYSIS	
	UX	UY	UX	UY	UX	UY
STORY12	15.1808	16.3081	11.9841	12.5928	48.362	55.5552
STORY11	14.523	15.5009	11.5506	12.0556	47.3685	54.1117
STORY10	13.7127	14.544	11.0281	11.4308	46.3549	52.5761
STORY9	12.7733	13.4615	10.4193	10.7225	45.3207	50.946
STORY8	11.7352	12.2852	9.7327	9.9411	44.2664	49.2249
STORY7	10.6274	11.0458	8.9786	9.0985	43.1931	47.4177
STORY6	9.478	9.7735	8.1618	8.2079	42.1018	45.5314
STORY5	8.3136	8.4972	7.314	7.2838	40.9941	43.5743
STORY4	7.1591	7.2444	6.4299	6.3416	39.8721	41.5567
STORY3	6.0365	6.0396	5.5294	5.3968	38.7367	39.4882
STORY2	4.9818	4.9215	4.6421	4.4801	37.6031	37.4108
STORY1	3.8222	3.7209	3.6045	3.434	36.2993	34.952

TABLE 5.2 DISPLACEMENTS OF 12 GROUND SOFT STOREY STRUCTURE IN MM.

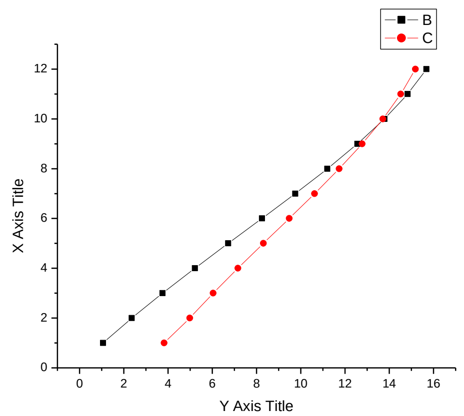

Fig 5.1 displacement of linear static analysis of 12th storey buildings in x – direction.

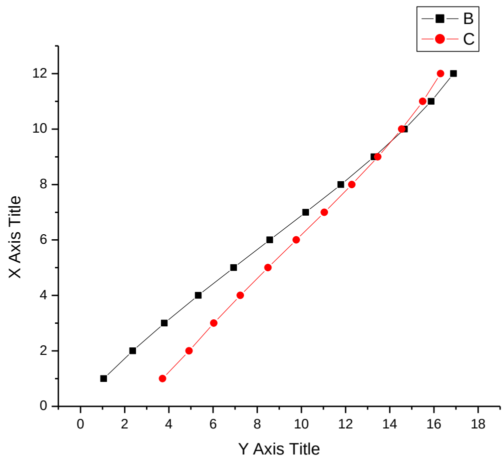

Fig 5.2 displacement of linear static analysis of 12th storey buildings in y – direction.

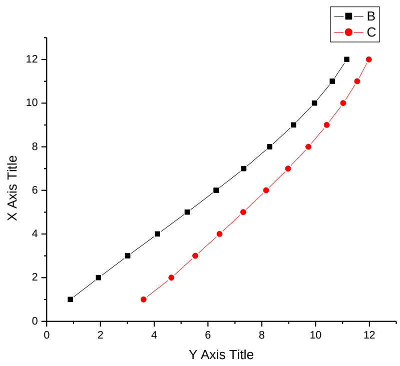

Fig 5.3 displacement of linear dynamic analysis of 12th storey buildings in x – direction.

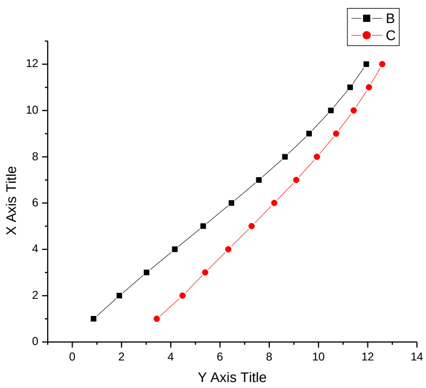

Fig 5.4 displacement of linear dynamic analysis of 12th storey buildings in y – direction.

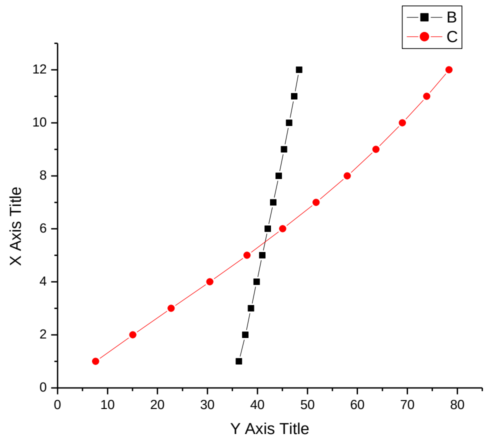

Fig 5.5 displacement of linear non static analysis of 12th storey buildings in x – direction.

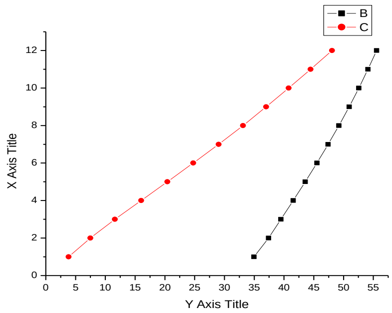

Fig 5.6 displacement of linear non static analysis of 12th storey buildings in y – direction.

6. SUMMARY AND CONCLUSION

The present work attempts to study the seismic response and performance level of different RC buildings located in seismic zone-V. In this study all important components of the building that influence the mass, strength, stiffness and deformability of the structure are included in the analytical model. To study the effect of infill and soft storey building models. The deflections at different storey levels and storey drifts are compared by performing response spectrum method as well as pushover method of analysis

It is essential to consider the effect of masonry infill for the seismic evaluation of movement resisting RC frames especially for the prediction of its ultimate state. Infill's increase the lateral resistance and initial stiffness of the frames they appear to have a significant effect on the reduction of the global lateral displacement.

Infill's having no irregularity in elevation having beneficial effects on buildings. In infilled frames with irregularities, such as ground soft storey, damage was found to concentrate in the level where the discontinuity occurs.

7. REFERENCES

1. Arlekar, N.J., Jain K.S., and Murthy, C.V.R. "Seismic Response of RC Frame Buildings with Soft First Storeys", Proceedings of the CBRI Golden Jubilee Conference on Natural Hazards in Urban Habitat, New Delhi, 1997.
2. Krawinkler, H., and Seneviratna, G.D.P.K. (1998): Pros & Cons of Pushover Analysis of Seismic Performance Evaluation.
3. Ashraf Habibullah, Stephen Pyle, "Practical three-dimensional non-linear static pushover analysis" Structure Magazsanine, Winter, 1998.
4. MOHAMED NOUR EL-DIN ABD-ALLA "Application of recent techniques of pushover for evaluating seismic performance of multistory buildings", Faculty of Engineering, Cairo University Giza, Egypt September 2007.
5. Kasım Armagan KORKMAZ, Fuat DEM_R and Mustafa S_VR_ "Earthquake assessment of R/C structures with masonry infill walls" Suleyman Demirel University, Civil Engineering Department, Cunur, Isparta, TURKIYE armagan@mmf.sdu.edu.tr. (Received: 06.08.2007; Accepted: 03.10.2007
6. IS: 1893 (Part-I) 2002 (2002): Criteria for Earthquake Resistant Design of Structures, Part-I General Provisions and Buildings, Fifth Revision, Bureau of Indian Standards, New Delhi
7. Kanitkar, R., and Kanitkar, V., "Seismic Performance of Conventional Multi-storey Buildings with Open Ground Storey for Vehicular Parking", Indian Concrete Journal, February 2004.

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