Determination of Modal Contribution Factor for Soft Storey Building

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Abstract-**In high rise building or multi storey building, soft storey construction is a typical feature because of urbanization and the space occupancy considerations. These provisions reduce the stiffness of the lateral load resisting system and a progressive collapse becomes unavoidable in a severe earthquake for such buildings due to soft storey. While damage and collapse due to soft story are most often observed in buildings, they can also be developed in other types of structures. Over the long years, the belief that the first mode of vibration governs the seismic response of shear-type frame structures has been widely accepted and proved to be effective for preliminary structural design. Indeed, most of the actual seismic design procedures are based on drift profiles which are typically an approximation of the shape of the fundamental mode of vibration. A new parameter, referred to as Seismic Modal Contribution Factor, which represents the contribution of the generic mode to the seismic response of the structure, is introduced for the analysis. With respect to the well-known Modal Contribution Factor, grounded on the concept of modal static response, the Seismic Modal Contribution Factor explicitly takes into account also the dynamic nature of the response due to earthquake excitation. So we have analysed 10 storey building with various soft storey levels as per Indian Standard codes which was situated in seismic zonev.**

Keywords: soft storey, seismic modal contribution factor, seismic response, modal static response.

I. INTRODUCTION

A. Background

The term "soft-story" refers to one level of a building that is significantly more flexible or weak in lateral load resistance than the stories above it and the floors or the foundation below it (70% or greater reduction from one floor to the next according to the modern, International Building Code (IBC) definition). According to IS 1873: (Part1) 2000, a soft storey has lateral stiffness less than 70% of that storey immediately above, or less than 80% of average stiffness of the three storeys above. Soft storeys are still having the problem of their lower seismic resistance under the earthquake forces. The belief that the large displacements occur at first storey level in soft storey building compared to other type of building i.e. bare frame and infill frame which was widely accepted and proved to be effective for preliminary structural design according to Danish Khan et al (2016) [2], but most of the design procedures are based on the drift profiles which was the shape of the fundamental modes of vibration which is the fundamental frequency. For the conventional five storey building, only three modes are enough to get the approximately accurateresults.

B. Scope andobjective

Study the dynamic properties of the building under vibrational excitation like modal shapes and natural time period and an evaluation of performance of intermediate soft storey building in terms of storey drifts, lateral displacements, lateral forces, storey stiffness, base shear and time period. In the modal analysis, of ten storey building by placing the soft storeys at third, sixth and tenth levels was done for knowing the number of nodes needed for the accurate results of contribution factor. It will help the safest construction at the future and avoid the vulnerability will cause by the earthquake.

II. BUILDINGCONFIGURATION

In the design of buildings, it is highly recommended that the geometry of the building to be regular and symmetric and for good reasons as per Adrian Fredrick C. Dyaa et al (2015) [1].The conventional ten storey model building with 35m height and 4m bay width and other three models having third soft storey, sixth soft storey and tenth soft storey are shown in fig 1.1 and 1. 2.

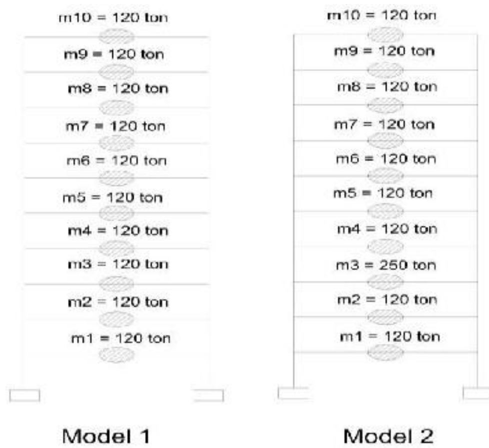

Fig1.1 Conventional and third level soft storey building

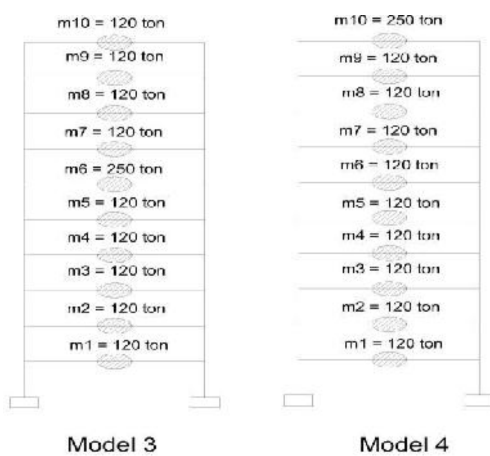

Fig1. 2 Sixth and tenth level soft storey building

The mass locations are designed by the mass irregularities of the building according to Indian Standard code IS 456-2000[5] and the Stiffness of the building remains same as 20000KN/m.

III. MODAL CALCULATIONS FOR TEN STOREY SHEARFRAME

The steps involved in the determination of the modal contribution factor of the ten storey shear frame done by the procedure. It will further helpful for the design of high rice building in earthquake prone areas.

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Mass Matrix, m= $$\begin{bmatrix} m_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & m_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & m_3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & m_4 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & m_5 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & m_6 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & m_7 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & m_8 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & m_9 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & m_{10} \end{bmatrix}$$

Stiffness Matrix, k= $$\begin{bmatrix} k_1+k_2 & -k_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -k_2 & k_2+k_3 & -k_3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -k_3 & k_3+k_4 & -k_4 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -k_4 & k_4+k_5 & -k_5 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -k_5 & k_5+k_6 & -k_6 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -k_6 & k_6+k_7 & -k_7 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -k_7 & k_7+k_8 & -k_8 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -k_8 & k_8+k_9 & -k_9 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -k_9 & k_9+k_{10} & -k_{10} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -k_{10} & k_{10} \end{bmatrix}$$

A. Natural frequencies and Modeshapes

By mat lab coding, the values of natural frequencies and mode shapes of the conventional and various soft storey buildings are obtained and tabulated below.

Table 3.1 Natural Frequencies Calculated from Matlab coding

For conventional building Tn(sec)	For 3rdlevel soft storey building Tn(sec)	For 6thlevel soft storey building Tn(sec)	For 10thlevel soft storey building Tn(sec)
3.256374	3.321266	3.45913	3.585129
1.093589	1.202414	1.1152	1.187705
0.666089	0.70028	0.726375	0.710026
0.486689	0.486689	0.486689	0.50984
0.390305	0.417119	0.42328	0.403128
0.331961	0.351531	0.336916	0.339144
0.294525	0.297814	0.307853	0.298418
0.270095	0.275558	0.277855	0.272035
0.25466	0.264473	0.257539	0.255454
0.246093	0.248466	0.251212	0.246287

IV. MODAL RESPONSECONTRIBUTIONS

An understanding of the relative response contributions of the various modes is developed in this section with the objective of deciding the number of modes to include in dynamic analysis.

A. Modal Expansion Of ExcitationVector p(t) =sp(t)

Consider a common loading case in which the applied forces (t) have the same time variation p(t), and their spatial distribution is defined by s, independent of time. Thus $(t) = (t)$ A central idea of this formulation, which we will find instructive, is to expand the vector sas

$$S = \Sigma SrNr{=}1 = \Sigma \Gamma r Nr{=}1 m\Phi r$$

Premultiplying both sides by ΦnT and utilizing the orthogonally property of modes give

$$\Gamma n{=}\Phi nTsMn$$

The contribution of the nth mode to s is

$$Sn{=}\Gamma nm\Phi n$$

which is independent of how the modes are normalized. This should be clear from the structure of Equations. Equation may be viewed as an expansion of the distribution s of applied forces in terms of inertia force distributions Sn associated with natural modes. This interpretation becomes apparent by considering the structure vibrating in its nth mode with accelerations.

The associated inertia forces are$(fI){=}-m\ddot{u}n(t){=}-m\Phi n\ddot{q}n$(t) and their spatial distribution, given by the vector mΦn, is the same as that of Sn.

The expansion has two useful properties:

(1) The force vector Sn p(t) produces response only in the nth mode but no response in any other mode.

(2) The dynamic response in the nth mode is due entirely to the partial force vector Sn p(t).

To study the modal expansion of the force vector s p(t) further, we consider the structure of a ten story shear building (i.e., flexurally rigid floor beams and slabs) with lumped mass m at each floor, and same story stiffness k for all stories.

Fig 4.1 Shows the variation of base shear and base moment with respect to the height of the conventional building.

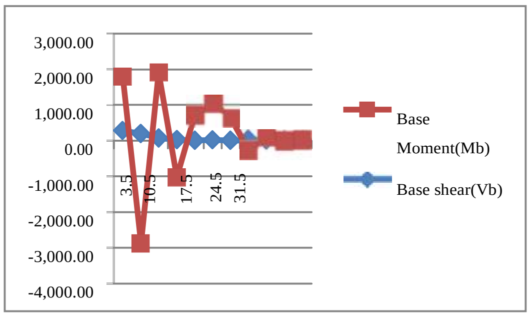

Fig 4.1 Base shear and base moment for the conventional building.

Fig 4.2 Shows the variation of base shear and base moment with respect to the height of the third soft storey building.

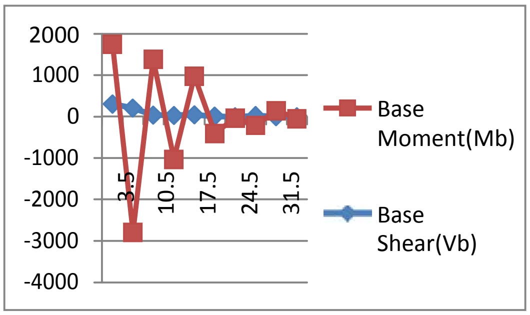

Fig 4.2 Base shear and base moment for the third soft storey building.

Fig 4.3 Shows the variation of base shear and base moment with respect to the height of the sixth soft storey building.

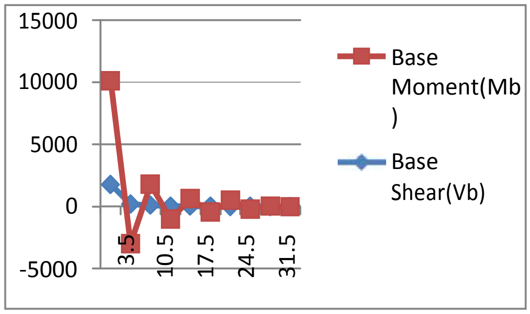

Fig 4.3 Base shear and base moment for the sixth soft storey building

Fig 4.4 Shows the variation of base shear and base moment with respect to the height of the tenth soft storey building.

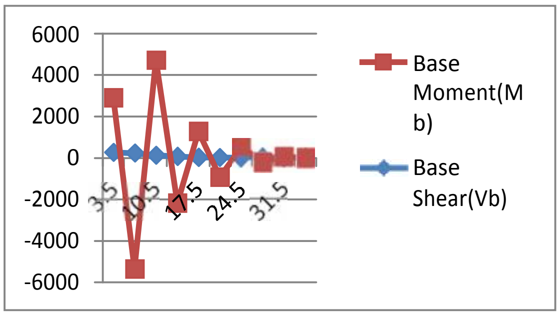

Fig 4.4 Base shear and base moment for the tenth soft storey building

B. Story Displacement under EarthquakeForces

The contribution of high modes varies with the structural response in consideration. It was indicated that the higher-mode response has greatest influence on the top storey shear and least influence on the floor displacements of building structure according to Meng-Hao Tsai et al(2002)[15]. The difference of an influence of higher modes in conventional building and various soft storey located buildings are discussed.

Table 4.1 Displacement values for the conventional, third, sixth and tenth soft storey buildings.

Displacement value for conventional building	**Displacement value for third level soft storey building**	**Displacement value for sixth levelsoftstorey building**	**Displacement value for tenth level soft storey building**
96.98	95.96	10.66	97.57
-22.48	-18.82	-24.19	-22.57
4.82	0.05	5.28	140.46
-1.47	-1.47	-1.47	-68.65
0.68	1	0.66	38.21
-0.61	-0.36	-0.34	-28.92
0.33	-0.02	0.27	15.49
-0.13	-0.11	-0.11	-6.55
0.03	0.06	0.01	1.03
-0.01	-0.02	-0.01	-0.98

V. RESULTS

The required number of modes for the analysis of ten storey conventional building was compared to the three models of soft storey building which are having the soft storey at third, sixth and tenth storey level are discussed and the results are givenbelow.

From this analysis, we concluded that the storeys below the soft storey levels having the major contribution to the base shear, base moment as compared to the conventional ten storey building. The storey displacement always higher in the roof level i.e the tenth storey of thebuilding.

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