THE INTERNATIONAL JOURNAL OF
SCIENCE & TECHNOLEDGE

Modeling of Staircase and Its Effect on the Seismic Performance of RCC Building

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Abstract:
A stair is a convenient means of access between the floors of a building. It is constructed to provide ready, easy, comfortable and safe ascent/descent with series of steps that are neither laborious nor difficult to climb within an enclosure called stairwell (staircase). The main objectives of the stair is that it Should be constructed of materials that are capable of maintaining strength and stability for a period of time sufficient to escape to the outside and able to support for movement between floors, including dead and imposed load. The proper protection and design of stairs is necessary to avoid earthquake hazards resulting from their failure. The work presents simple analysis methods that guides about the failure mechanisms, type of damages, and comparison of results for both the buildings i.e. with and without staircase models. On the basis of results obtained and comparing them for both the buildings it is concluded that proper emphasis should be given to stair modelling and its detrimental effects to avoid complete stair failure or serious damages to its component parts.

Keywords: *Base shear, response spectrum method, staircase, storey drift*

1. Introduction

Stairs, in a unique way, are like bridges. They join certain location to differing ones, enabling people to go from one place to another and back. They make two ends get together, being a series of steps between one height to another, or from one floor to another. Stairs makes the construction of skyscrapers and multiple story houses and dwellings possible, saving real property space on the ground and creating huge room- space upward, even until the top floors soar above the clouds. Elevators may take the place of stairways, but they cannot quite replace them in function and effectiveness. Emergency stairs, for instance, are essential and requirement of any building code anywhere in the world, have been rendered necessary by threats of electrical power outages fires, earthquakes, and other natural calamities or emergencies. Notwithstanding their common function of providing the means on which to walk, or run, up and down elevated structures in case problems and for safety.

2. Theoretical Background

2.1. Stair Classification

From the early beginning of the use of reinforced concrete (RC), different types of stair have been designed. According to the literature, the existing stairs can now be classified into two main categories depending on the static behavior of the stair steps: (i) stairs with steps performing as cantilever beam, (ii) stairs with simply supported steps.

In side these two categories three principal types of stairs can be distinguished:

1) Stair type A (see Figure 1) – The stair structure is composed of: 1) columns, at least four columns are located at the side of the staircase (generally at its four corners), but in some cases they can be located internally to the substructure “stair”; 2) beams that connecting the columns (storey beam and inter-storey beam); 3) beams supporting the flight steps (elementbs1-bs2-bs3 in Figure 1). In particular, storey and inter-storey landings are supported respectively by elements bs1 andbs3, while steps are cantilever beams constraint into the inclined part of the beam bs2. Three types of beam configurations can be distinguished, depending on the presence of bs1 and bs3.

2) Stair type B (see Figure 1) – The stair structure is composed by: 1) columns (at least four); 2) beams connecting the columns, storey beam and inter-storey beam; 3) the slab constraint at the beams at each storey and inter-storey. This slab has two horizontal parts (s1-s3) and one inclined to the horizontal (s2). On this cranked element the steps are simply supported, they are made contemporary or successively to the slab. The slab can be made of only reinforced concrete or of brick and joist.

3) Stair type C – The staircase is composed of reinforced concrete walls, and the steps, having a cantilever behavior is fully constraint in these RC walls.

Generally the stair type B and C are used worldwide, in Europe and USA, while the stair type A, with cranked beams, are much more adopted in Europe

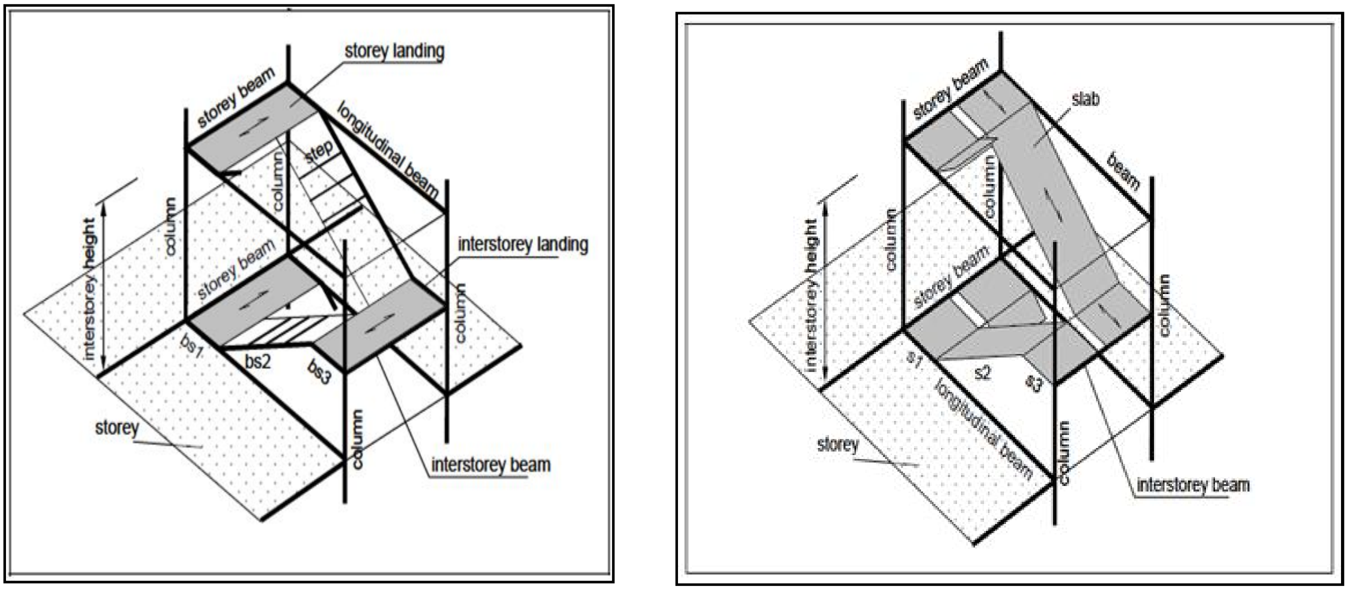

Figure 1: stairs with simply supported steps

3. Modelling and Analysis

Structural modeling of the buildings has been prepared as per the geometrical plans configuration in Fig. 1 by SAP 2000 Version 14.0.0. Beams and columns have been modeled as 3-D frame elements. In the modeling process, the properties assigned to the frame elements include geometric dimension, reinforcement detail, and the type of material. The models have been assumed to be fixed supports at the pedestal top of the foundation at a depth of 1.5 m from the plinth beam.

Building details are as follows

1. Grade of concrete used is M30 and grade of steel is Fe 500
2. Floor to floor height is 3.3 m
3. Slab thickness is 125 mm
4. Size of column 600X600 mm and size of beam 400X300 mm
5. Live load on floors is as per IS 875:1987
6. Site located in Seismic zone V
7. Building is resting on medium soil
8. Take importance factor as 1
9. Density of concrete is 25kN/m^2
10. Density of masonry wall is 20kN/m^2
11. Floor finish assumed as 1 kN/m^2.
12. Roof treatment load taken as 1.5 kN/m^2
13. Waist slab thickness 230 mm
14. Rise -150 mm, Tread - 250 mm
15. Building is G+3 storied

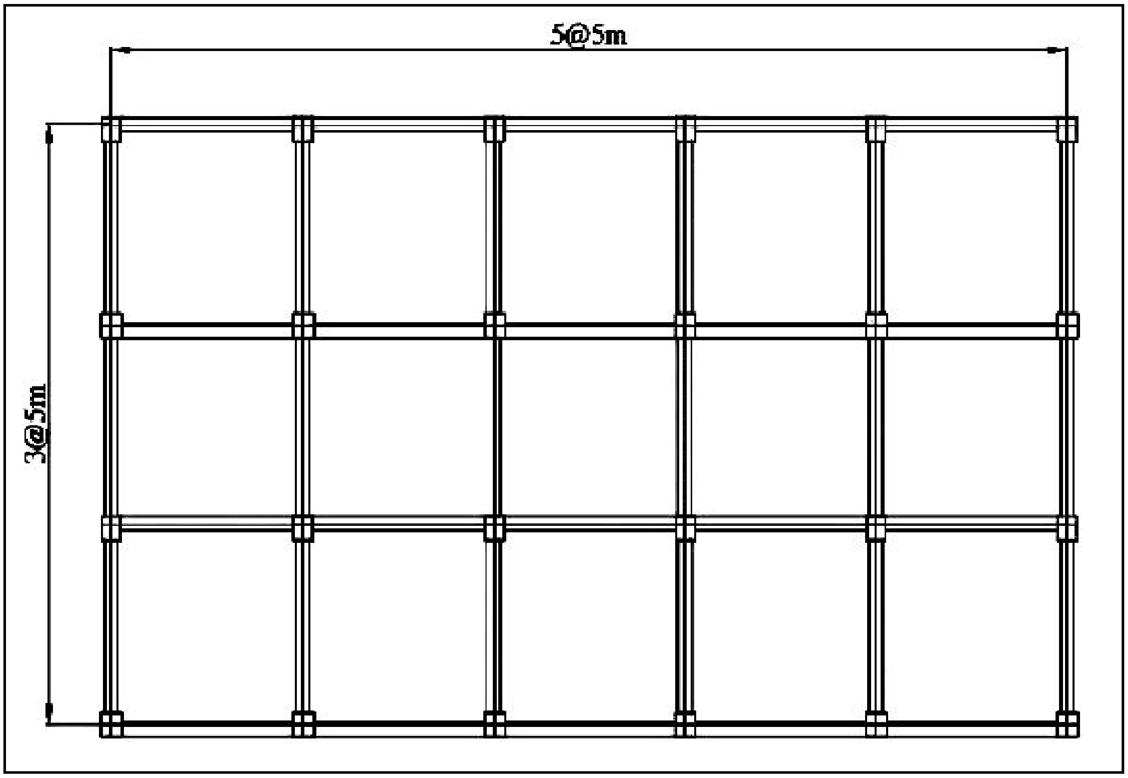

Figure 2: Building plan for modelling

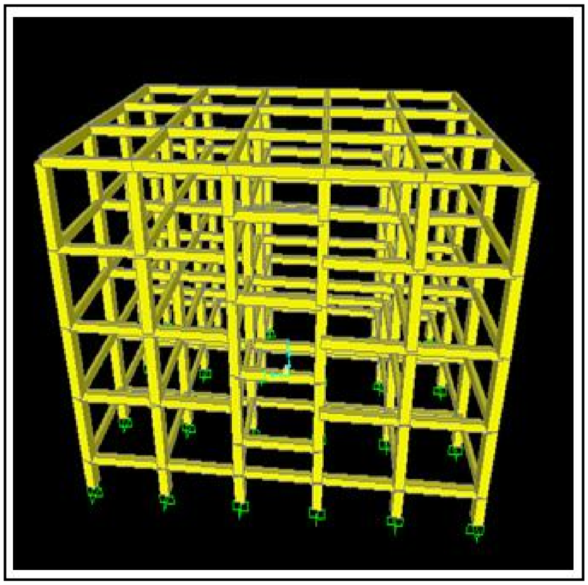

Figure 3: Building without staircase modelling

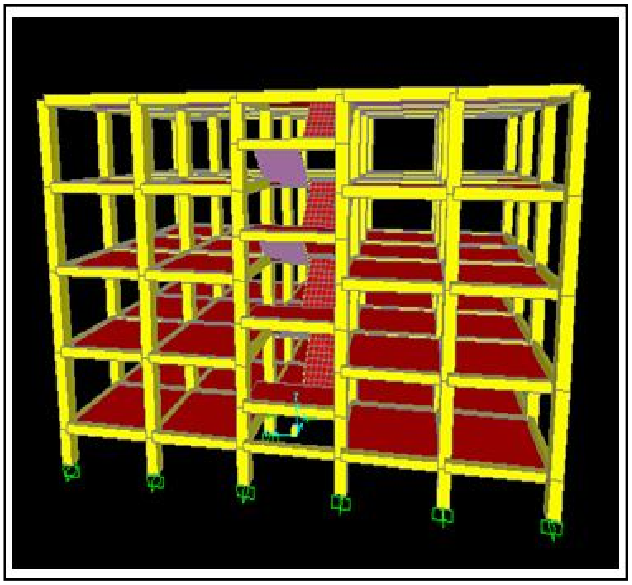

Figure 4: Building with staircase modelling

4. Result and Discussions

4.1. Performance of Buildings without Staircase Model

In engineering practice, the modeling of staircase is not considered in the modeling of the structure. The staircase has been assumed to be simply supported and the dead load and live load reactions on the landing beams are calculated. And results of analysis are summarized as follows.

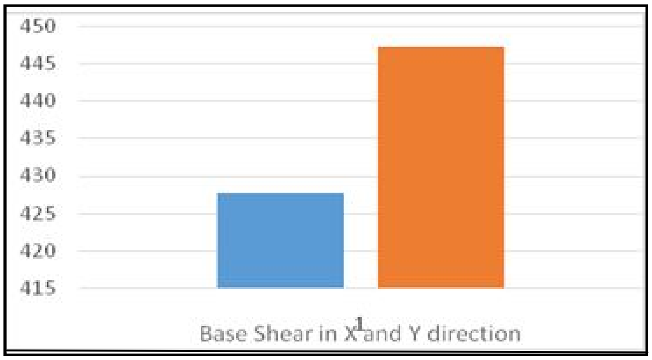

Figure 5: Base shear without staircase model (kN)

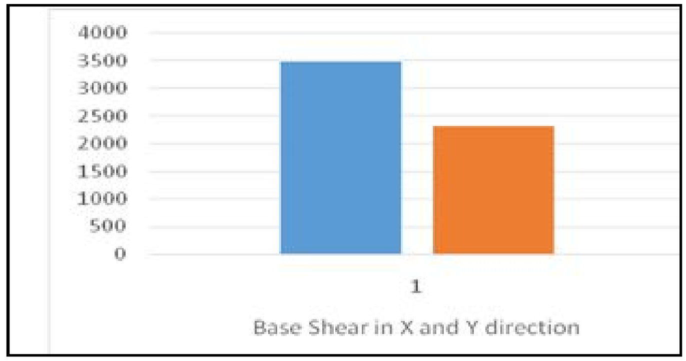

Figure 6: Base shear with staircase model (kN)

4.2 Comparison of Results

The performance of buildings designed without a stair model as discussed in 5 and with stair model in 6 have been compared. The effect of stair model on effects on landing beams and columns adjacent to the landing beams and the dynamic performance of the buildings has also been discussed.

4.2.1 Effects on the Landing Beams and Columns

It has been observed that the presence of staircase tremendously influence the peak value of response quantities of beams and columns around staircase. The landing beams and columns adjacent to staircase have been found to fail due to excessive demand imposed owing to the presence of the staircase. It has been observed that with the incorporation of stair model, columns touching the landing beam have been found to be subjected to an increase in axial force by an average of 20%. The lateral moment in such columns increased on average by 32%. Shear force in the landing beam increased by 36% on average. The torsional moment in the landing beam increased enormously.

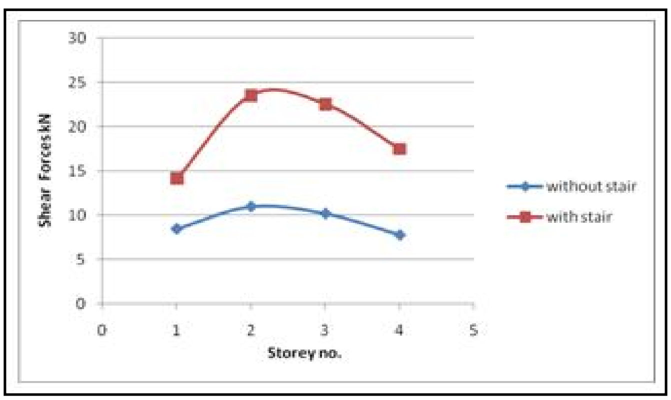

Figure 7: shear at each storey (landing beams)

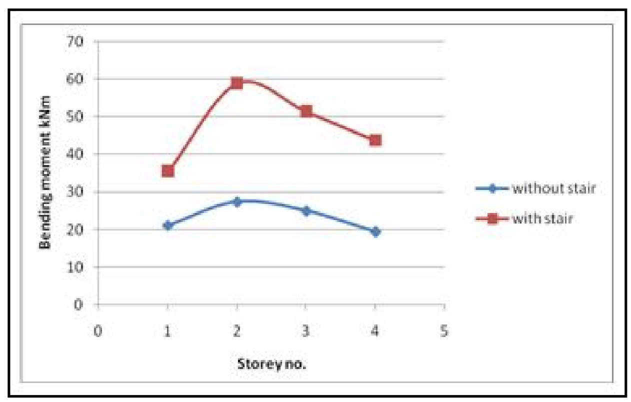

Figure 8: Bending moment at each storey (landing beams)

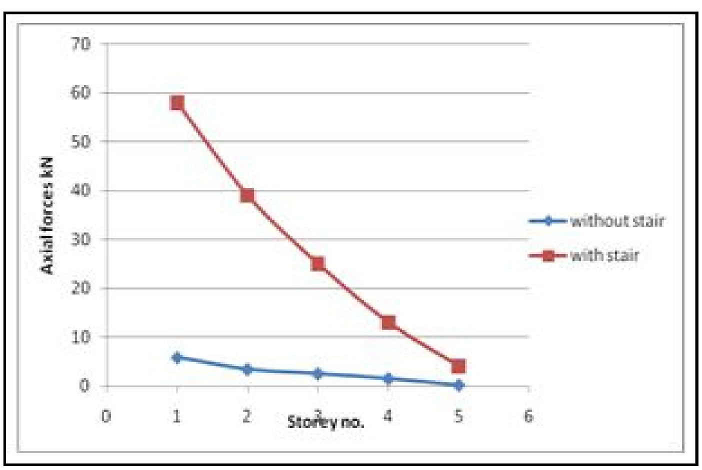

Figure 9: Axial forces at each storey (columns)

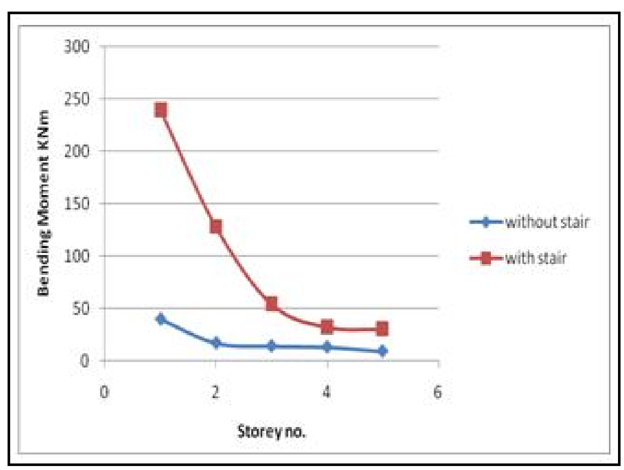

Figure 10: Bending moment at each storey (columns)

4.2.2. Effects on Inter Storey Drift

The effects on Inter storey Drift after the incorporation of stair model has been discussed in the section. The maximum Inter storey Drift from results of analysis of building has been found out and comparison has been shown in Fig.11 It has been observed from the buildings considered that the inter storey drift has been found to reduce by 40% on average on incorporation of stair model in a general trend expect in few cases.

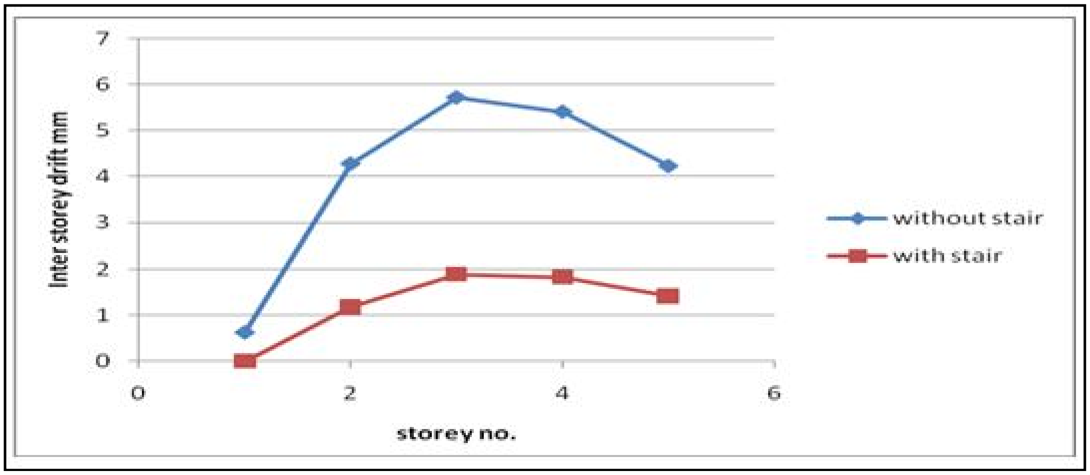

Figure 11: Inter storeys Drift at each storey

5. Conclusion

The work provides brief study of staircase influences on seismic performance of building. The following points can be considered as a concluding remark of the presented work.

1) It has been observed that the presence of staircase tremendously influence the peak value of response quantities of beams and columns around staircase. The landing beams and columns adjacent to staircase have been found to fail due to excessive demand imposed owing to the presence of the staircase.

2) Incorporating only weight of staircase and not stair element in computer model shall lead to under design as the codal design is inadequate to cater the additional demand imposed due to presence of staircase on landing beams and columns adjacent to staircase.

3) With incorporation of stair model, columns touching landing beam have been found to be subjected to an increase in axial force by an average of 20%. The lateral moment in such columns increased on average by 32%. Shear force in the landing beam increased by 36% on average.

4) The inter storey drift has been found to reduce by 40% on average on incorporation of stair model.

Non-incorporation of stair element in computer model may lead to failure of stair case under major earthquakes.

6. References

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