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Effect of Rapid Transit Vibrations on a G+2 Storied Residential Building Located in Delhi

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Abstract—*Vibrations generated by metro train running on underground tracks transfer their effect through the ground into surrounding residential and other commercial buildings. Traffic induced vibrations produce undesirable impacts on the nearby structures which can significantly lower the quality of life and the working conditions of the people. In this paper, an effort is made to study the effect of traffic induced vibrations on the surrounding buildings. The study is divided into two phases. The first phase of the study involves collection of vibration data for two residential locations alongside the Central Secretariat - Mandi House corridor of Delhi Metro. The second phase involves the analysis of a G+2 storeyed building being modelled in SAP 2000 and Linear dynamic analysis (Response Spectrum Analysis) has been carried out on the model to observe displacements at each joint of the structure. A comparison is made between the displacements generated in the building with and without inducing the effect of vibrations. It was concluded that the displacement at each joint has increased significantly after inducing the effect of vibrations on the building. The percentage increase in the displacements came out to be almost 45-55 %. However, these effects can be minimized by using latest techniques including the use of Rubber bearing isolators, mass suspension system and the use of new technology materials.*

Keywords: *Metro trains, Response spectra, Displacements, Rubber bearing isolators.*

1. INTRODUCTION

Ground-borne vibrations due to railway traffic have become important environmental issues, which are particularly critical when new rail infrastructure is introduce in an existing urban environment. Ground-borne vibrations can be controlled at different levels along the transmission path between the source and the receiver. A number of different issues are associated with the generation and propagation of vibration from traffic. Low frequency vibration from heavy traffic is perceived as whole body vibration Vibrations induced by rapid transit is a common concern in cities in India and worldwide. House owners may complain about annoyance and building damage. There may be concern about the possibility of adverse long-term effects of vibrations on residential buildings, especially those in a weak condition. Traffic induced vibrations, which are transmitted through the ground, may interfere with the proper operation of vibration sensitive equipments and cause nuisance on local population. Influence of these vibrations on surrounding buildings and sensitive devices play an important role on acceptance of the projects.

[3.6]Structural fatigue can be defined as the process of accumulation of damage due to application of time varying stress. It can be expected to occur whenever a structure is subjected to time varying loads and in many situations may govern the design. Each time a load cycle is applied, an incremental amount of damage occurs. This damage is cumulative in nature and accumulation continues till the failure occurs. If fatigue cracks are detected early, then repair may be possible. If not detected and properly repaired, the results may be disastrous failures.

1.1 Factors Influencing Ground-Borne Vibration

[1]The important physical parameters can be divided into the following four categories:

i. **Operational and Vehicle Factors:** This category includes all of the parameters that relate to the vehicle and operation of the vehicles. Factors such as high speed, stiff primary suspensions on the vehicle, and flat or worn wheels will increase the possibility of problems from ground-borne vibration.
ii. **Flyover:** There is relatively low damping associated with the steel superstructure specially with welded joints. Here, directly radiated noise is usually the dominant problem, although vibration can be a problem. For rubber-tired systems, the smoothness of the roadway/guide way is the critical factor.
iii. **Geology:** Soil and subsurface conditions are known to have a strong influence on the levels of ground-borne vibration. Among the most important factors are the stiffness and internal damping of the soil and the depth to bedrock. Experience with ground-borne vibration is that vibration propagation is more efficient in stiff clay soils, and shallow rock seems to concentrate the

vibration energy close to the surface and can result in ground-borne vibration problems at large distances from the track or bridges. Factors such as layering of the soil and depth of water table can have significant effects on the propagation of ground-borne vibration.

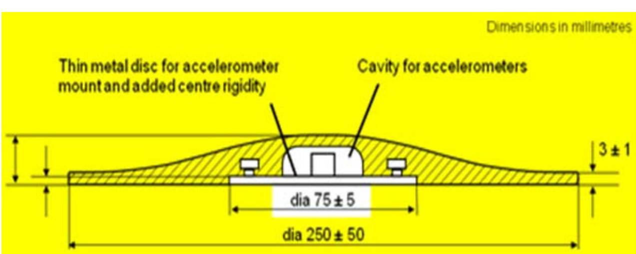
iv. **Receiving Building:** The receiving building is a key component in the evaluation of ground-borne vibration since ground-borne vibration problems occur almost exclusively inside the buildings. The vibration levels inside a building are dependent on the vibration energy that reaches the building foundation, the interaction of the building foundation with the soil, and the propagation of the vibration through the building.

2. METHODOLOGY

In this paper, an attempt is made to study the effect of traffic induced vibrations on the residential buildings. The study is being carried out in two phases. The first phase of the study involves collection of vibration data for two residential locations alongside the Central Secretariat- Mandi House corridor of Delhi Metro. The second phase of the project involves the analysis and design of a G+2 storeyed building using SAP 2000. Static and dynamic analysis (Response Spectrum Analysis) for medium soil condition has been carried out on the model to observe the displacements at each joint of the structure.

3. INSTRUMENT USED

Data required for response spectra analysis is collected by using triaxial accelometer and soundbook. Fig. 1 shows the picture of triaxial accelometer and Fig. 2 shows the soundbook. Vibration data was collected at each site using these instruments.



[1] **Fig. 1: Basis model of Triaxial Accelerometer**

Fig. 2: Sound book for vibration monitoring

4. MODELING AND ANALYSIS

A G + 2 storey building (10.5 m height)is analysed and modeled in SAP 2000 with and without ground borne vibrations. Fig. 3 shows the RC framed structure. The size of beams and columns taken for this model are shown in table number 1. Grade of concrete and steel is M 20 and Fe 415 respectively. Initially dead load and live loads are considered using IS 875 Part 1 and Part 2. The building is then analyzed and checked for the displacements at each joint. The dynamic analysis of the building is done by using response spectra obtained from traffic induced vibrations as shown in Fig. 4. The displacement at each joint is checked again including the effect of response spectra.

Table 1: Size of structural members

S. NO	MEMBER	SIZE
1	BEAM	300mm x 230mm
2	COLUMN	450mm x4 50mm
3	SLAB	125 mm

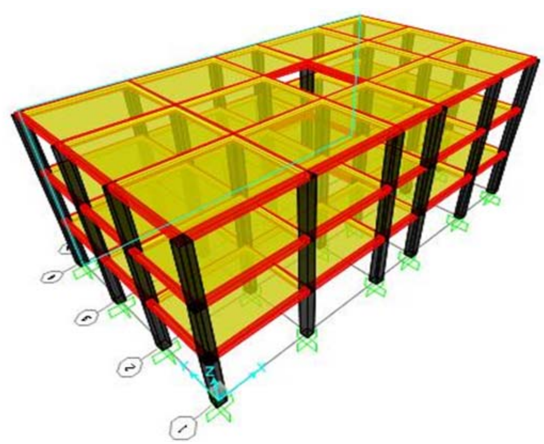


Fig. 3: G+2 storey building modeled in SAP 2000 (Extrude view).

5. RESULTS AND DISCUSSIONS

After carrying out the dynamic analysis, the deformations of the various structural members can be visibly seen in the Fig. 5. The displacements have taken place in opposite directions of x, y and z- directions. A comparison is made between the displacements before and after inducing vibrations. Table number 2 and 3 shows the comparison before and after the effect of traffic induced vibrations. The displacements have been compared with and without vibrations at each storey level that is at 3.5 m, 7 m and 10.5 m. In this paper, the displacements at the joint number 97, 73 and 1 in X, Y and Z directions are checked for the effect of vibrations. The negative sign indicates that the displacements are in opposite direction of x, y and z.

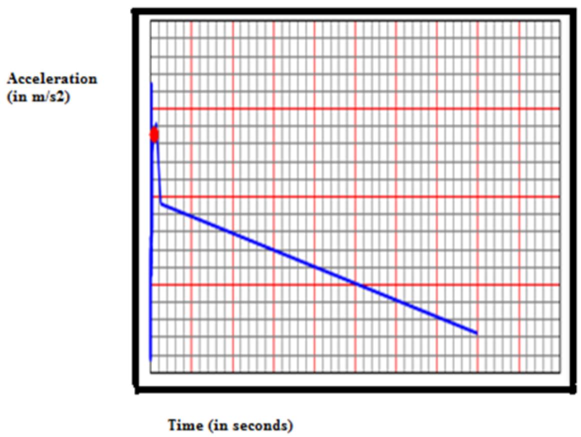


Fig. 4: Response spectra for metro induced vibration generated by Sap 2000.

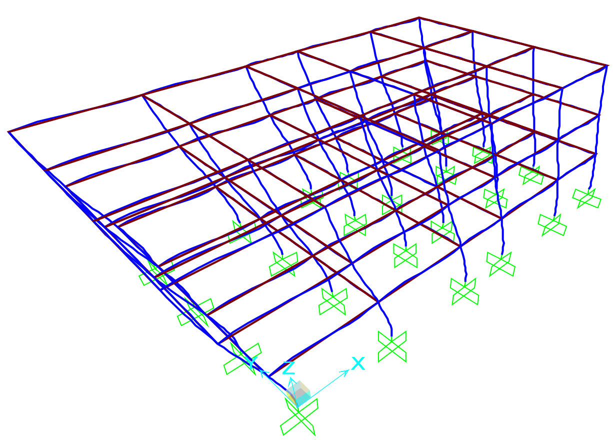


Fig. 5: Deformed shape of the model using SAP 2000.

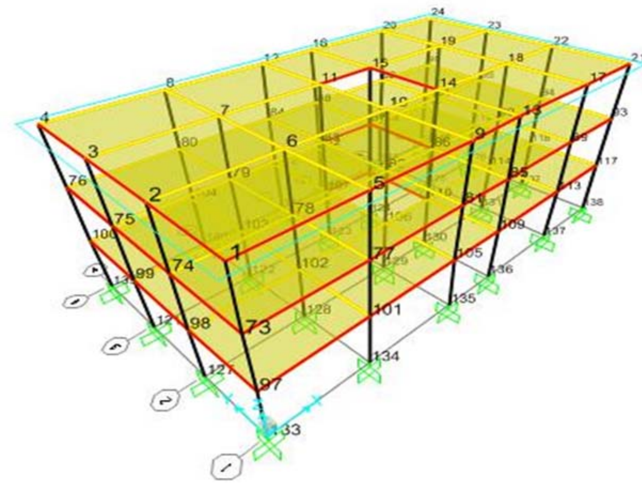


Fig. 6: G+2 storey building showing each joint. (Standard view)

Table 2: Displacement at various joints without traffic vibration.

S. no	Floor Height	Joint Number	Displacements in mm		
			X	Y	Z
1	3.5 m	97	-0.0018	-0.00013	-.087
2	7.0 m	73	-0.0068	-0.00026	-0.14
3	10.5 m	1	-0.011	0.00065	-0.17

Table 3: Displacement at various joints with traffic vibration.

S. no	Floor Height	Joint Number	Displacements in mm		
			X	Y	Z
1	3.5 m	97	-0.0036	-0.00026	-0.19
2	7.0 m	73	-0.012	-0.00058	-0.31
3	10.5 m	1	-0.022	.0012	-0.37

The displacements after the effect of vibrations have increased significantly The displacement of joint number 97 in X direction has increased from -0.0018 mm to -0.0036 mm after considering the response spectra.

Similarly, the displacement of joint number 97 in Y direction has increased from -0.00013 mm to -0.00026 mm after considering the response spectra. The displacement of joint number 97 in Z direction has increased from -0.087 mm to -0.19mm after considering the response spectra. The percentage increase has approximately come out to be 45-55 % after carrying out the dynamic analysis. Table number 4 shows the percentage increase in the values of displacements at the chosen joints 97, 73 and 1 in all the three directions. It can be concluded that these traffic induced vibrations may cause a long term fatigue in the nearby residential and commercial buildings. In addition to this, it causes annoyance and disturbance to the local residents of that particular area. There are various methods to minimize these effects. [9]The application of vibro isolation is a very efficient way to control the ground borne vibrations. Also, rubber bearing isolators and mass suspension system can be few measures to minimize these effects.

Table 4: Percentage increase in the values of displacements after the effect of traffic induced vibrations.

S. NO	Joint Number	Percentage increase in displacements after the effect of traffic induced vibrations		
		% increase in x-direction	% increase in y-direction	% increase in z-direction
1.	97	50	51.65	53.22
2.	73	43.55	55.44	53.54
3.	1	50	46.74	54.72

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