Effect of Underground Metro on Historical Monuments in Delhi

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Abstract: *Today, traffic induced vibration control is a frequently used concept for enhancing the living standard in residential apartments along railway lines. Vibrations generated by metro train running on underground tracks transfer through the ground into surrounding structures. These traffic induced vibrations usually cause no threat to the safety of the structures, but their undesirable impacts can significantly lower the quality of life and the working conditions of these structures.*

Traffic induced vibration in the buildings due to metro trains have been analyzed by using 1/3 octave analyzer. The results obtained were compared with Federal Transport Authority guidelines and its effects on nearby structure have been investigated.

This study involved collection of vibration data for five historical monument located just above the metro tunnel on the corridor of Delhi Metro. It was concluded that the vibration level (VdB) at each location is well above the permissible level of vibration recommended by various standard authority. The maximum value out of five historical monuments found at Darya Ganj was 104.6 VdB.

Index terms: *Vibration, Metro rail, Monuments, Vibration decibel.*

I. INTRODUCTION

Vibrations generated due to mass rapid transport system (MRTS) have become important for nearby historical monuments, 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. There may be concern about the possibility of adverse long-term effects of vibrations on old buildings and historical monuments along metro corridors, especially those in a weak condition. The literature concerning vibration effects on historic buildings is not common, especially that relating to permissible and safe vibration levels, and conclusive studies of damage from vibrations are rare.

In this paper, an attempt is made to study the effect of traffic induced vibrations on the historical monument. The study involves collection of vibration data for five historical monuments located alongside the Delhi Metro corridors and also compares these values of vibration with FTA guidelines.

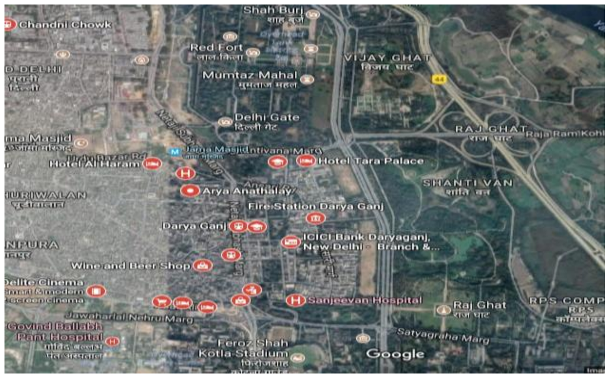

Figure 1: Location of historical monuments for Collection of data

[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.

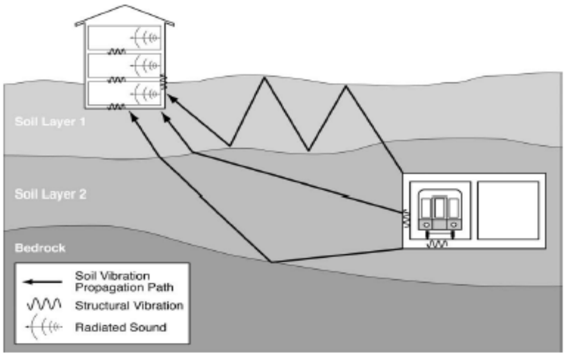

Figure 2: Propagation of ground borne vibration.

1.1 Factors Influencing Ground-Borne Vibration

[1]The important physical parameters can be divided into the following three 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. **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.

iii. **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.

II. INSTRUMENT USED

Data required to study the impact of vibration on historical monument was collected by using triaxial accelometer and sound book. Vibration data was collected at each site using these instruments.

Figure 3: Triaxial accelometer and sound book for Collection of data.

III. METHODOLOGY

Some standard guidelines as per FTA manual for collection of data as per site conditions and nearby features of location.

1 Vibration measurements were carried out at selected historical sites.

2 Tri axial accelometer was used to carry out data at each location.

3 Measurements were made of vibration on the ground near the structure. Area near the sensors would have needed to be vacated in order to control adverse effects from internal vibrations such as footfalls.

4 The measurement locations were chosen with consideration of both technical and practical issues. The vibration transducer needed to be placed in such way, that vibration on structure in all direction can measure easily.

5 Tri-axial transducers were used to measure the vibrations. The transducer was fixed on metal plate having size of 10 cm × 30 cm × 0.5 cm with help of adhesive material.

6 The plate having the transducer was placed simply on the plane ground and plate was leveled using level tube.

7 The values of accerlation/velocity was converted into VdB (vibration Decibal) by using relation

$$\mathbf{VdB = 20log_{10}\frac{Vm}{Vr}}$$

where:
Vm = measured vibration velocity
Vr = international reference 1 x 10^{-6} cm/sec (rms) or .394 x 10–6 in/sec(rms)

IV. RESULTS

S.No	Site	Sample	VdB (Vibration decibel)			Avg.
			X	Y	Z	
1	Darya Ganj	S1	71.5	73.7	73.7	64.5
		S2	71.9	72.8	85.3	65.3
		S3	104.5	112.1	120.3	103.9
		S4	89.7	86.9	104.0	88.2
		S5	94.4	91.7	96.9	75.5
2	Delhi Gate	S1	76.8	78.3	84.6	67.5
		S2	93.8	92.3	89.7	67.0
		S3	89.8	83.6	84.0	67.9
		S4	103.7	97.1	97.3	82.7
		S5	100.8	90.9	93.0	66.5
3	Lal Quila	S1	73.3	78.7	82.2	65.0
		S2	85.4	81.2	75.4	64.8
		S3	82.7	78.6	95.5	63.7
		S4	101.1	99.6	94.0	74.2
		S5	106.2	104.	106.0	80.4
4	Khooni Darwaza	S1	98.5	87.3	91.4	65.4
		S2	83.6	81.1	77.9	65.0
		S3	83.3	78.9	85.6	65.1
		S4	101.1	99.6	94.0	74.2
		S5	106.2	104.	106.0	80.4
5	Kashmiri Gate	S1	83.7	85.4	87.3	66.5
		S2	81.7	83.0	86.7	69.7
		S3	86.1	83.6	84.1	66.3
		S4	75.8	76.3	82.6	65.5
		S5	92.8	90.3	86.7	66.0

CONCLUSION

Studies were carried out at different historical monuments in Delhi capital city like DARYA GANG, DELHI GATE, LAL QUILA, KASHMIRI GATE and KHOONI DARWAZA at each location five sample were taken. From study of different vibration criteria we used VdB value as safe limit criteria for historical and fragile buildings for continuous traffic vibration from federal transport authority manual. Maximum average value of vibration founded at DARYA GANG, DELHI GATE and LAL QUILA was 103.9, 82.5 and 80.4 From above result we can conclude ,these values were well above permissible value as per FTA guidelines for three locations and for two locations i.e KASHMIRI GATE , KHOONI DARWAZA below permissible value and also historical structures where testing has been done are safe from structural & architectural damage due to metro vibration. But, due to continuous metro vibration, cosmetic damage to these historical structures is possible in future and some remedial measures are required to protect these structures.

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