International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 05, May-2019

STUDY THE IMPACT OF METRO RAIL INDUCED VIBRATION ON STRUCTURES

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Abstract: Vibrations induced by rail and road traffic is of great concern in urban cities which reduce useful life of structure. The present work discusses the measurement of level of vibration during construction stage of underground metro rail and correlate with vibration criteria given by codes of various country. Metro rail generate vibration at time of construction and operation stage which propagate in soil eventually reaching the foundation of building and causing them to vibrate. Metro rail induced vibration create long term effect on structure which include fatigue and settlement of foundation. This vibration can be controlled at various level along transmission path between source and receiver. Level of vibrations are measured at several location along the metro route. Study carried out for vibrations induced at time of operation stage. A combine effect of metro rail vibrations road traffic vibrations considered in research work.

Key word: metro rail, ground borne vibration, elevated, traffic

1. Introduction

Vibration is define as an oscillation of particle about its mean position. There are many source of vibration like earthquake, railway, road traffic, pile driving operation, wind, etc. Ground-borne vibrations have dire environmental issues, which are particularly critical when new rail infrastructure is introduced in an existing urban environment. The ground borne vibration is one of the major factor that affect sensitive equipment, cause discomfort to people and create fatigue effect in building. There may be concern about the possibility of adverse long-term effects of vibrations on residential buildings, especially those in weak condition. There vibration may concern sensitive instruments in hospital like Cyclotron, Endodontics, Tattoo removal machine, etc. has accuracy up to 0.5 - 1mm and instruments in research laboratory like electron microscope, Nano drop Spectrophotometer etc. requires high accuracy up to 0.1 to 0.2mm. Factor influencing ground borne vibration are type of vehicle, geology condition of site and type of building. This vibration can be controlled at different level along transmission path between source and receiver. Prediction of traffic vibration is not easy due to many unknown factor are affecting like soil condition, soil type, site topography, etc.

Figure 1 (A) Ahmedabad metro rail

Figure 1 (B) Elevated section of metro rail

Note that mainly two type of damage may be occur in buildings: 1) structural damage & 2) Architectural damage. Architectural damage include cosmetic damage or minor cracks of building which do not affect the strength of building. But continuous vibration may cause the long term structural damage to the building which include fatigue and settlement of foundation. This may concern regarding safety of building.
In this paper, metro generated vibration is taken as source of vibration. Vibrations are generate at time of construction stage as well as operation stage of metro rail. Here, identification of level of vibration is carried out at time operation stage of Ahmedabad metro rail. Vibration induce at time of train running on rail due to interface between wheel and rail. This vibrations are transferred to building on close proximity via substructure of bridge and ground. Study carried out to

measure maximum level of vibration. Level of vibration induced due to operation of metro rail is transferred to building analytically. Also Level of vibration is measured at structural component of building due to road traffic. A combine effect of metro rail vibration and traffic vibration is analysed. This level of vibrations are compared with limiting criteria given by codes of various country. Study of Level of vibration was carried out for engineer buildings only.

2. Metro rail vibration

Effect of vibration include three path: source, transmission path and receiver.

1) Vibration source: it is place where waves are generated due to road traffic, rail traffic, at time of tunnelling process, etc. Irregularities and unevenness on road and rail also induce vibration. In rail traffic, level of vibration may be different at different speed of train.
2) Transmission path: waves generated at source propagate through ground and reach the receiver. Intensity of vibration is dependent on transmission path. Type of soil, soil strata, stiffness of soil, damping, distance between the source and receiver also affect the level of vibration.
3) Receiver: Waves propagate through ground to reach foundation of building and inducing vibration in the structure. This will depend on type of wave and vibration susceptibility of building components. Vibration create architectural and structural damage to the building.

3. Modelling & Analysis

A computer software CSi Bridge is used to determine the level of vibration due to metro train. Three span of viaduct is consider to analyse the bridge. Each span is 25m long supported on pier size 2.0 m diameter. The bridge deck accommodate two metro rail track. Each track is 1.676m wide. The centre to centre distance between two tracks is 4.2m. The viaduct was made of prestressed post-tensioned RCC box type girder. Dimension of Box girder is top width is 8.4m with soffit width of 4m. The metro train is electric operated B.G. train. The super structure is simply supported on bearing size 700 x 600 x 175mm.

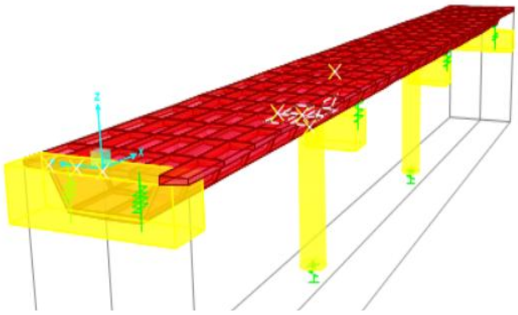

Figure 2 Modelling of bridge deck in CSi Bridge.

The substructure is singe cast in-situ RCC pile of diameter 2.1m. Height of pier and grade of concrete are consider as 20m and M40 respectively. A pier is supported on mono pile with pile cap dimension 2.5m x 2.5m. The modulus of subgrade reaction is 10 kg/m^3 considered for analysis.

The maximum operating speed of train is 80 kmph. Axel load of metro train is considered as 18T. Maximum number of successive car in train is 4. To calculate maximum level of vibration, train running on both track and impact factor of 1.4 is considered for dynamic loading.

In Analysis, to measure maximum level of vibration following two cases are considered. 1) Train running in only one lane, 2) Train running in opposite direction on both lane. Maximum level of vibration induced due to metro rail at ground level was measured.

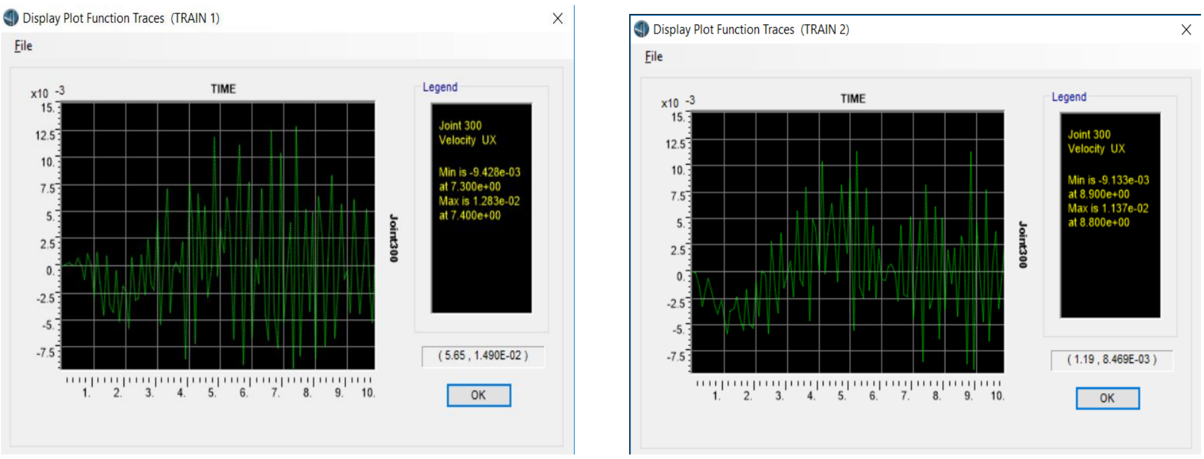

Figure 3 Result of maximum level of vibration at ground level.

4. Instrument and data acquisition

Level of vibration generally measure in peak particle velocity (PPV) in mm/s to predict damage of building. For vibration induced in building: 1) frequency range is normally from 4Hz to 80Hz; sometimes up to 125Hz. And 2) amplitudes are generally range from 0.005m/s^2 to 2m/s^2 for acceleration and 0.05 mm/s to 25mm/s for velocity. OROS make analyzer OR36 was used to measured level of vibration. It contains transducer for collection data and NVGate software for real time and post analysis data.

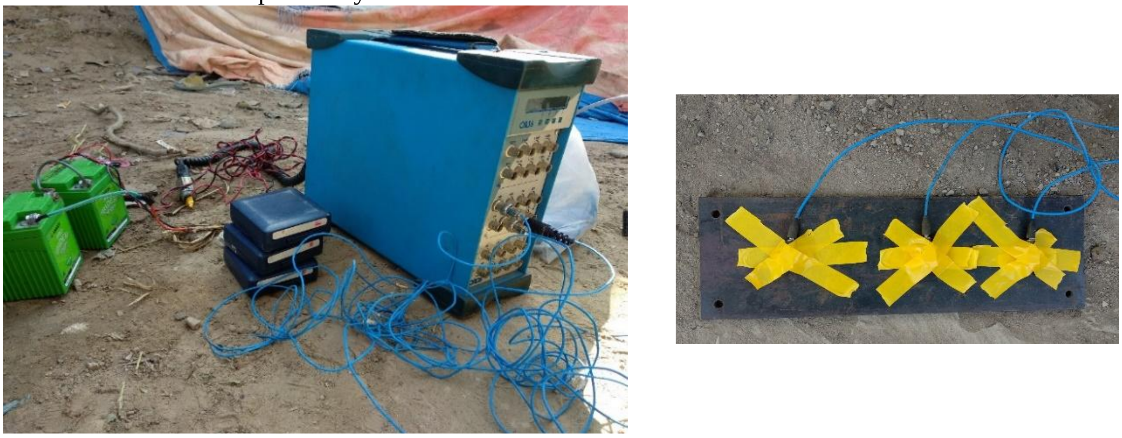

Figure 4 Instrument setup: OROS OR36 Analyzer

5. Methodology of measurement

There is a standard format to measure the level of vibration on site.

i. Vibration analyzer was used to carry out data collection.
ii. Piezoelectric accelerometer were used to measure the vibration which fixed either on metal plate or directly on structural member of building with adhesive and connect to analyzer.
iii. The metal plate was fixed on plane ground and levelled.
iv. Analyzer is connected with computer.
v. Results analysis was carried out with help of NVGate software.

6. Limiting criteria for building for continuous vibration

Permissible peak particle velocity(mm/s)					
Content/country	India	Germany	Australia	Switzerland	Hungry
Historic building and important structures	2	3	2	3	2
Domestic house and low rise building	10	5	10	5	5
Offices and industrial building	15	20	25	8	10

Table 1 permissible PPV for various structure

Permissible peak particle velocity(mm/s)	
Content	Permissible limit
Architecture damage to building	0.1-0.75 mm/s as per Chinese criteria (GB/T50452-2008)
Human Comfort	0.2 mm/s for residential area to 2.5 mm/s for factory and industrial place.

Table 2 permissible PPV for Architectural Damage and Human comfort

7. Measurement

Measurement of Level of vibration is carried out on various structures in close proximity to metro rail route. Operation of Ahmedabad Metro rail was started from Vastral Gam to Apparel Park. Level of vibration measured on various buildings along this route as shown in figure. Site for measurement was selected on basis of importance of structure. It include load bearing structures and RCC frame structure. Level of vibration measure only on engineer buildings.

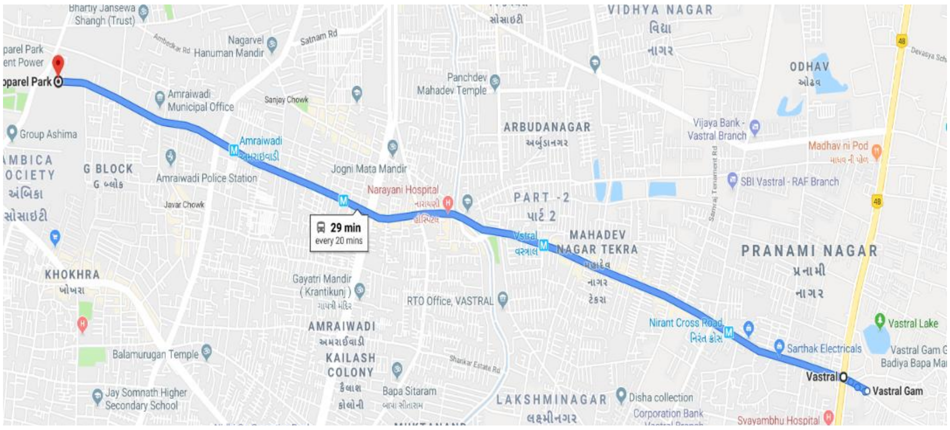

Figure 5 Ahmedabad Metro route from Vastral Gam to Apparel Park

8. Result table

Sr No.	Name of site (Distance from source)	PPV(mm/s) due to Traffic	PPV(mm/s) due to Metro Rail	Max. PPV (mm/s) due to combine metro and traffic vibration.
1	Tej English School	0.034	0.227	0.261
2	Rudra Business Park (Hospital)	0.015	0.145	0.160
3	Municipal water tank	0.013	0.184	0.197
4	Khushi pathology laboratory	0.015	0.280	0.295
5	Hiraba School Campus	0.028	0.300	0.328
6	Riddhi Siddhi Bike Showroom	0.042	0.364	0.405
7	RCC G+2 Building	0.013	0.518	0.530
8	G+1 Load bearing building	0.029	0.356	0.385
9	Pushpak Residency	0.023	0.132	0.155

Table 3 Result Table of combine metro rail and road traffic vibration

9. Observation

A field investigation was carried out to determine impact of metro rail induced vibration during operation stage on structures. Sensors were arranged on structural member of building in close proximity to metro rail path. Level of vibration was measured during train running at maximum speed with road traffic vibration. Study of investigation show that max PPV is 0.530 mm/s with moderate traffic condition.

10. Conclusion

From the field investigation, the following conclusion can be drawn:
Maximum peak particle velocity at time of construction stage of metro rail is 0.530mm/s. Therefore structures are safe against structural damage as values are within permissible limit. There may be a possibility of cosmetic damage in building as per Chinese criteria for vibration.
As limiting value for human comfort is 0.2mm/s, this level of vibration also affect human comfort and annoy people.
Range of vibration will affect sensitive instrument in hospital and research laboratory nearby metro route, therefore accuracy of the instrument will be affected.

11. Remedial measures

Vibration produced during construction stage can be reduced at source, transmission path and at receiver. Control of vibration can be achieved at any one stage or multiple stages. Reduction in amplitude and frequency of vibration can be achieved by controlling train speed, by using floating slab system, using ground barrier, by improving soil strata, by controlling sufficient distance between building and rail line, by screening of vibration in ground, building isolate system, etc.
Level of vibration in building can also be reduced by using damper or by taking extensive care that the vibration frequency do not match the resonance frequency. The behaviour of vibration can be changed by changing stiffness of building component or by providing flexible support. However this is only possible in new construction, in existing building it is not practical.

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