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Study the impact of underground metro rail induced vibration

Suryanshu Dahisaria[1], Major Dr. C.S. Sanghvi[2]

[1]*P.G. Student, Applied Mechanics Department, L.D. College of Engineering, Ahmedabad, Gujarat, India.*
[2]*Professor, Applied Mechanics Department, L.D. College of Engineering, Ahmedabad, Gujarat, India.*

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 at different depth from ground level and the prevalent soil strata is sandy silt. Impact of road traffic vibration is also considered in research work.***

Key word: metro rail, ground borne vibration, underground

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 0.02mm 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.

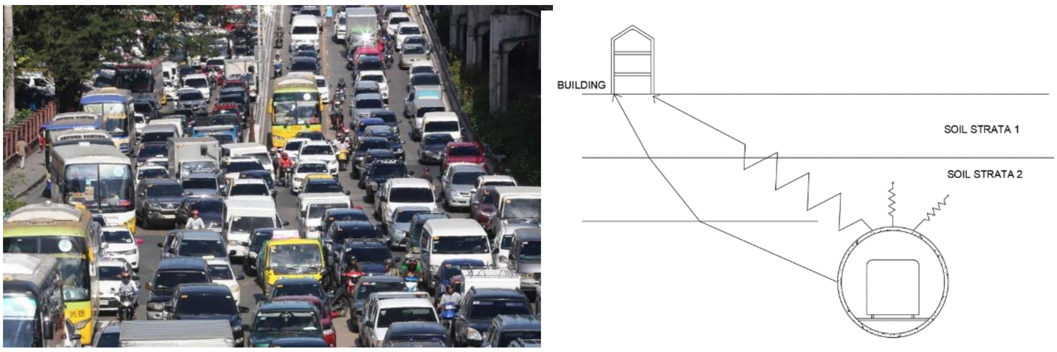

Figure1 (A) Traffic vibration (B) underground metro rail construction vibration

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. Level of vibration is measured on ground level during the tunnelling process of construction of underground metro rail. When Tunnel Boring Machine (TBM) is running and construction of tunnel is going on, vibration produced and propagate in soil and eventually reach the foundation of building and causing them to vibrate. Level of vibration is measured in two direction: longitudinal and transverse the direction of tunnelling. Level of vibration measured at time of construction along with road traffic. Intensity of road traffic was moderate with average speed of vehicle is 30 to 40 km/hr. 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. 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. The measurements were perform on five different location as shown in map.

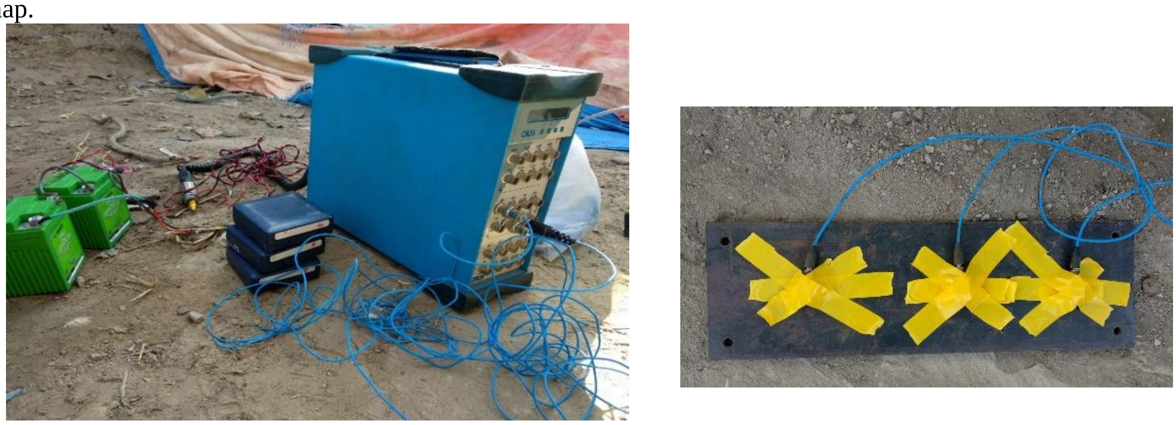

Figure 2 Instrument setup: OROS OR36 analyzer

4. 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 on metal plate 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.

5. 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

6. Measurement

Traffic vibration

Level of vibration was measured due to road traffic at Kalupur Circle, Ahmedabad. Site for measurement was selected on basis of maximum intensity of traffic and underground section passing through it. Level of vibration was measured at time of maximum and minimum traffic.

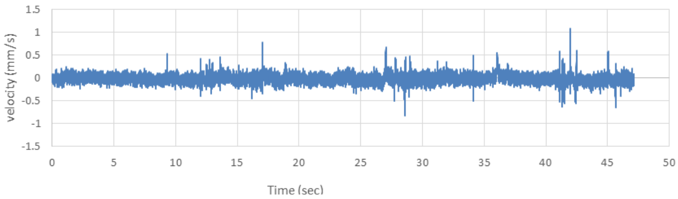

Figure 3 Velocity vs Time for traffic vibration

Maximum level of vibration noticed was 0.34mm/s at time of minimum road traffic and 1.23mm/s at time of maximum intensity of road traffic.

Construction stage vibration

Level of vibration was measured at five location as shown in figure. Measurements were taken parallel and perpendicular direction of tunnelling. This level of vibration enhance in level of vibration induced during tunnelling.

Figure 4 Location of measuring point on surface above underground section

7. Result table

Location	Depth of tunnel from ground level	Max. PPV (mm/s) at surface due to tunnel construction		Max. PPV (mm/s) due to tunnel construction	Max. PPV (mm/s) due to combined road traffic and tunnel construction
		Perpendicular direction	Parallel direction		
1	11.67 m	0.15	0.21	0.21	1.44
2	11.93 m	0.18	0.21	0.21	1.44
3	12.05 m	0.13	0.13	0.13	1.36
4	12.00 m	0.11	0.12	0.12	1.35
5	12.05 m	0.25	0.22	0.25	1.48

8. Observation

A field investigation was carried out to determine impact of metro rail induced vibration during construction stage on structures. Sensors were arranged on ground level along metro rail path. Level of vibration was measured during tunnel construction with traffic vibration. Study of investigation show that max PPV is 1.48 mm/s with moderate traffic condition.

9. Conclusion

From the field investigation, the following conclusion can be drawn:

Maximum peak particle velocity at time of construction stage of metro rail is 1.48mm/s. Therefore structures are safe against structural damage as values are within permissible limit. There may be a possibility of cosmetic damage in future. Range of vibration will affect sensitive instrument in hospital and research laboratory nearby metro route, therefore accuracy of the instrument will be affected.

10. 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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