Study on amplitude reduction factor of fly ash infilled barrier using vibration sensor

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Abstract. Vibrations are phenomenon caused due to cyclic motion caused by certain amplitude and frequency. The ground borne vibrations hinder the building stability and durability. In the present study, the impact of vibrations is reduced with fly ash Infilled barrier. Different soils samples are collected and density is determined using standard compaction test. Density and vibration waves are inversely proportional to each other, that is higher the density of soils lower the propagation of vibration waves and vice versa. After the determination of density, the soils are tested by using vibration sensor in two cases. One is without placing fly ash barrier and the other is by placing fly ash barrier. The output is monitored in the Arduino software and amplitude rection factor and frequency reduction ratio are determined to identify the efficiency of fly ash barrier.

1 Introduction

Generally, vibration analysis or seismic analysis is calculated during the design stage of the structure. Vibrations are not only the problem for newly constructed buildings but also for the existing buildings as well, high level of vibrations can cause cracks, loose bolts, or even failure, large amplitude vibrations can be very destructive and even if the amplitudes are not very high prolonged exposure can lead to fatigue failures. There are few techniques to minimise the effects of vibrations on structures, for instance installation of isolation mounts or motion-arresting pads and increasing the floor loading within the building is one of cost-efficient methods. Structural vibration control is to control the vibrations caused by earthquake and wind by changing stiffness, damping, mass and shape of building and providing a certain amount of passive or active reaction forces.

2 Literature Review

According to studies, various kinds of vibrations show different types of effects on the structures [1]. The comparative study on ground borne vibrations produced by road traffic and railway traffic is observed and concluded that road traffic causes more negative impact on the building, The vibrations produced by road vehicles lie from 0.1 to 1.0m/s with frequency of 40Hz to 100Hz, and rail traffic have 40Hz to 80Hz which is comparatively low [2]. The vibration caused by the man-made activities like, tunnel blasting which causes severe

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ground borne vibrations when MEMS (Micro electromechanical system) is used, in which a network of sensors is deployed to monitor the effects of vibration caused by blasting and their frequency and amplitude [3].

Another method to counteract the vibrations is digging open trenches The use of fly ash in noise reduction, generally, fly ash is a coal combustion residual used as landfills and has low density, about 60% of the total weight of Portland (25% wt.), vermiculite (25%), and polypropylene fibers (0.5%) are used to create a non-acoustic material and used for noise isolation. Most vibration prone areas are railways and highways. The use of trenches around the buildings constructed or situated near the railway tracks, as the rail and road traffic is increasing at very rapid rate posing threat to the existing structures, thus use of open and infilled trenches are constructed various materials suitable to be used in filling the trenches which are of low density. The polyurethane foam trenches are used in mitigating the vibrations caused by the harmonic loads, which shows great efficiency with increase in the movement of the train [4].

There are few design techniques for vibration resistant structures. The vibration tests were conducted at undamaged state and after damage appeared to some extent [5]. The test results showed that the even limited reduction in frequency of vibration indicate major structural problem, although frequencies of both the buildings decreased with increase in damage, retrofitted buildings decreased with less damage [6]. The necessity of vibration analysis as there is a rapid growth in construction of high-rise buildings and to ensure the safety of buildings under multiple possible hazards that may occur to achieve the system level performance [7]. The classification of damages to the civil engineering structures by earthquake by using the machine learning technology. Using machine learning, the previous data is analyzed and the output displays a model of possible damages which can be incurred [8]. By conducting assessment to find the critical vibration values of structure based upon the bifurcation approach in automated geotechnical systems [9]. The dynamic behavior of structure under the application of loads and effect of earthquake and wind load is analyzed [10].

3 Methodology

3.1 Material used

3.1.1 For circuit

The software, sensors and essentials required for the study are mentioned below.

1. SW 420 Vibration sensor
2. Arduino UNO
3. Jumper wires
4. Bread Board
5. USB Cable
6. Arduino IDE software version (1.0.6)

3.1.2 Types of soil samples used

The below are the soil samples which were collected from the local area.

1. Sandy soil
2. Red soil
3. Black soil
4. Laterite soil
5. Loamy soil

Compaction tests were conducted as per IS 2720 PART 5-1985 and determined the dry density and optimum moisture content.

3.2 Circuit Assembling

The SW420 Vibration sensor is placed in the breadboard in the columns, and interface at pin number 9 in Arduino board which is the input pin mentioned in the code. The respective ground pins and 5V pin are interfaced with ground and 5V pin in Arduino UNO board. From the Arduino board, 5V power supply is given to the adapter and adapter will take 230V input and provide as a 5V output constant regulator power supply. Arduino connections and circuit assembling is shown below in Table 1 and Figure 1 respectively.

Table 1. Arduino Connections

S NO.	Arduino UNO	SW420 Vibration Sensor
1.	5V	VCC
2.	GND	GND
3.	9	DO

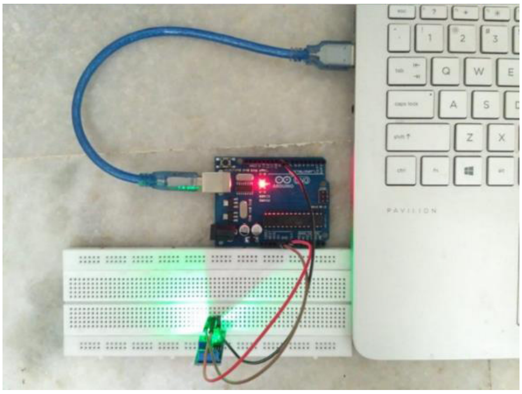

Fig 1. Circuit Assembling

3.3 Working Principle

The working procedure of this study is to determine the density of all the soil samples collected initially by using standard compaction test as per IS code through which dry density and optimum moisture content are obtained. Vibration propagation is measured by using SW

420 vibration sensor. Later the vibration propagation with and without fly ash barrier is measured by using SW420 vibration sensor.

3.3.1 Testing Parameters calculated during vibration testing

Amplitude reduction factor

The amplitude of vibration is the distance of movement of the wave from its original or equilibrium position or the maximum displacement of a wave on either side of its mean position is called Amplitude and magnitude required to reduce the amplitude from a safe vibration propagation which can be resisted by the building is known as the amplitude reduction factor. Sample Arduino code is shown in Figure 2.

$$ARF = V\ without\ fly\ ash\ barrier / V\ with\ fly\ ash\ barrier \quad (1)$$

Where,
V without barrier = Velocity measured when there is no fly ash barrier.
V with barrier = Velocity measured when there is a fly ash barrier present in between the vibration source and the sensor.

Frequency Reduction Factor

The number of cycles that a vibrating object completes in one second is called frequency. The unit of frequency is hertz (Hz). The ratio in both the cases with barrier and without barrier gives two different frequency values whose ratio gives the frequency reduction ratio.

$$FRR = f\ without\ barrier / f\ with\ barrier \quad (2)$$

Where,
f without barrier = The frequency measured when there is no fly ash barrier
f with barrier = The frequency measured when there if fly ash barrier presents in between the vibration source and the sensor.

$$FREQUENCY = 1/\ Time\ period \quad (3)$$

Where,
Time period is the time taken by the wave to complete one complete vibration and it is measured in seconds.

$$VELOCITY = Distance / Time \quad (4)$$

Where,
Velocity is used when calculating the amplitude reduction factor.

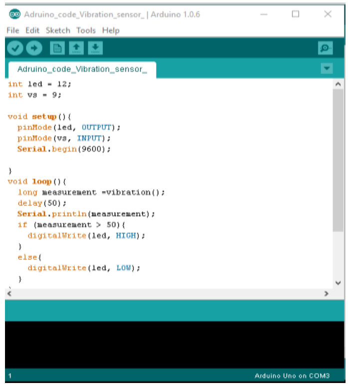

Fig 2. Arduino code

3.4 Testing Environment

In the present study, testing of vibration propagation in soil due to various sources and calculating the reduction or any changes are observed in the frequency of the vibration when a fly ash infilled barrier is introduced and the respective changes are calculated by analyzing the frequency and amplitude of vibration waves while passing in the soil. In laboratory, the soil sample taken and placed in the metal tray and the assembled circuit is placed in the apparatus prepared and at 10cm and 20cm length between the vibration sensor and the vibration source. The vibration source produces the vibrations and then the values detected by the sensor is displayed on the Arduino software. In the field, testing was conducted in the open area by placing of the vibration source is in the intervals of 5cm and taken up to 25cm. And the results are displayed in the Arduino IDE software are noted. Figure 3 shows vibration testing by using fly ash barrier and without using fly ash barrier.

Fig 3. Vibration testing by using fly ash barrier and without using fly ash barrier

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4 Experimental Investigation and Results

4.1 Standard compaction test results

Table 2 and Figure 4 shows the maximum dry density and optimum moisture content of all the soil samples.

Table 2. MDD and OMC of Soil

Type of soil	Maximum Dry Density (g/cc)	Optimum Moisture Content (%)
Red soil	2.50	13.0
Black soil	2.44	13.5
Laterite soil	2.20	14.0
Loamy soil	2.28	14.0

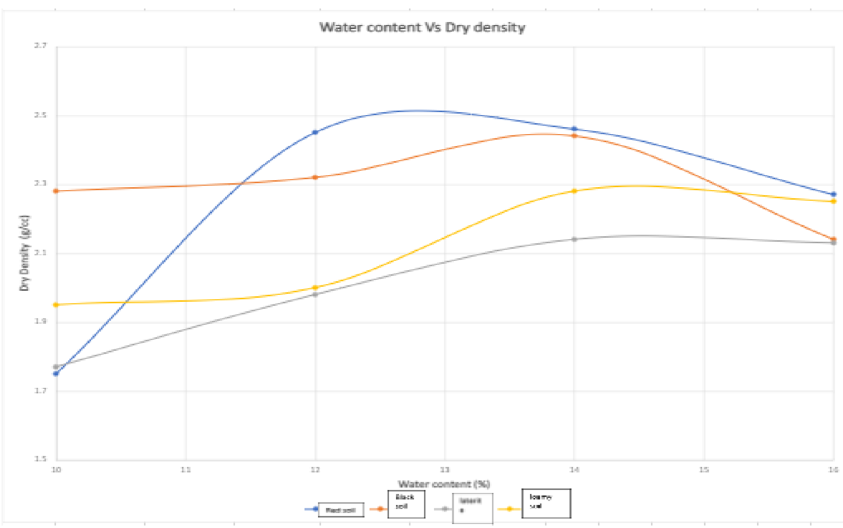

Fig 4. Graph depicting MDD and OMC of four soil samples

4.2 Vibration sensor results

Fly ash barrier used is of 28cm in length, 5cm width and 4cm in height.

4.2.1 Sample calculations

Table 3 shows the Amplitude reduction factor (ARF) and Frequency reduction ratio (FRR) results for 10cm and 20cm.

A = 0cm, B = 20cm = 0.20m,

Obtained Arduino results while testing for AB (20cm) = 4473 milliseconds = 4.473seconds.

Frequency = 1/ 4.473 = 0.223 Hz

Velocity(V1) = AB/t (in seconds) = 0.20/4.473 = 0.0447 m/sec

Table 3. ARF and FRR comparison at 10cm and 20cm

	Amplitude Reduction Factor		Frequency Reduction Ratio	
	10cm	20cm	10cm	20cm
Sandy soil	0.8	1.41	0.92	1.38
Red soil	0.91	1.329	0.919	1.33
Black soil	0.97	1.6	0.98	1.58
Laterite soil	0.970	13.89	0.98	0.02
Loamy soil	0.96	1.5	0.98	1.275

4.3 Field Testing Arduino Results

Figure 5 shows the Arduino results at from 25cm to 5cm.

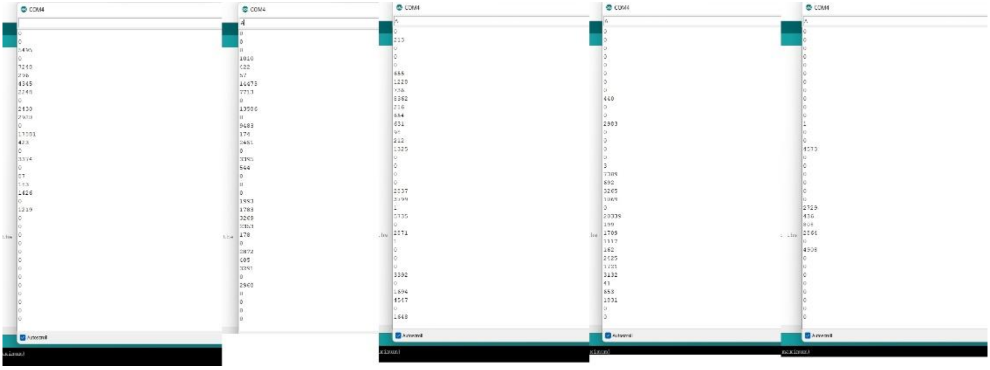

Fig 5. Arduino results at 25cm, 20cm, 15cm, 10cm and 5cm

5 Conclusion

From this study, it is observed that fly ash barrier can reduce the propagation of vibration waves from the buildings. Fly ash barrier can be used effectively for isolating the vibrations from various sources like earthquakes, heavy vehicle movement near railway tracks, etc. Fly ash barrier helps in decreasing the impact of vibration on the buildings when analyzed by various parameters like amplitude reduction factor and frequency reduction ratio. The parameters are analyzed by using IoT with the help of SW420 vibration sensors. The results were analyzed fast and efficient with the help of the vibration sensors. With the calculation of these parameters, adverse effects can be reduced which are caused by vibrations on buildings.

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