Design of concrete structure test device on bridge using geophone

R A Priramadhi*, R R Rizaldy and M A Murti
Electrical Engineering, Telkom University, Bandung, Indonesia

*rizkia@telkomuniversity.ac.id

Abstract. The increase in population every year makes more and more owners of motorized vehicles and cars resulting in full access to the highway, not only the highway that experiences density while the bridge is one of the factors of density due to the number of motorized vehicles and cars that pass not only at a certain time the bridge will be congested and experience enough vibrations because the load carried by the bridge is different, the greater the load held by the bridge, the more the bridge vibrates, therefore the writer will make an instrument using a geophone sensor that can measure how much vibration on the bridge and analyze how strong concrete works on the bridge which often occurs density, with the elastomer or rubber pads used between abutments with the placement of the elastomer feeding road will reduce vibrations that occur due to the burden carried by the bridge. This tool will use the main components in the form of geophone sensors. Geophone converts ground motion into voltage, Geophone is a transducer of ground movement that is very sensitive. A geophone converts seismic energy, or vibration, into an electric voltage that can be measured accurately. In this study, it was found that geophone sensors can find out the amount of voltage and deflection that occurs when a vehicle crosses the bridge, to process data in this system using a microcontroller in the form of Arduino Uno and displayed in excel data to facilitate data collection. From this study it can be concluded with a maximum deflection of 0.3 cm or 0.003 meters at a time of 1045kg, meanwhile when a vehicle load of 2 tons to 10 tons will occur a maximum deflection of up to 2 cm on the Cilampeni Bridge and on the Kopo Toll Bridge.

1. Introduction
The structure of the bridge that is getting older will get older, uncertain environmental conditions and added vehicle loads through it are things that must be monitored on the health of the bridge. For this reason, bridge supervision is needed to avoid damage caused by environmental impacts such as heavy vehicle loads that pass [1-3]. In addition, overall structural supervision needs to be carried out after extreme conditions occur, such as earthquakes. So, in order to quantify structural performance measurements, it is necessary to carry out routine supervision and evaluation of the integrity of civil construction through the use of sensor network technology, whether using cables or wireless. This is what makes the structural health surveillance system the way it is currently used and as a research topic [4-6].

Structural health surveillance system is the utilization of destructive and non-destructive in-site sensing and analysis of structure characteristics, including structure responses, to detect changes that might have an impact on damage. the focus of the research is still on how to collect data, not yet developing an automatic monitoring system that operates for as long as possible. The main need that is
needed now is an effective and efficient method to collect data from a structure and process data for the purpose of measuring performance such as the level of correlated bridge health. 

And in 2018 there will be a shift in land resulting in deformation in one of the pillars of the Cisomang Bridge. Efforts to stop the movement carried out through two stages, namely the initial handling, including Grouting and Struting, as well as structural handling, which includes Bored Pile and Ground Anchor. After the bridge was repaired, the results of the survey and measurement survey indicated that there was no significant movement in the bridge pillars. Therefore, the existence of a bridge load monitoring system can prevent further damage because this tool can detect the magnitude of the deflection and the stress of the bridge [7-11].

2. Background

2.1. Structural health monitoring system of bridges

The main purpose of monitoring bridge health is to identify the symptoms of damage in the current condition based on vibrational signs when passed by vehicle loads through identification of deflections resulting from passing vehicles. The final output of this monitoring is the level of health of the bridge and the measurement of the bridge load which is defined as the value of the bridge that can still perform its services safely when receiving a load of vehicles that cross it.

2.2. Deflection

Deflection is a change in the shape of the beam in the y direction due to the vertical loading applied to the beam or rod. Deformation of the beam can very easily be explained based on the deflection of the beam from its position before experiencing loading. Deflection is measured from the initial neutral surface to the neutral position after deformation. The configuration assumed by neutral surface deformation is known as the elastic curve of the beam. Figure 1 (a) shows the beam in the initial position before deformation occurs and Figure 1 (b) is a beam in a deformed configuration which is assumed to be due to loading action.

![Figure 1. Deflection.](image)

The distance of displacement y is defined as beam deflection. In application, sometimes we have to determine the deflection of each x value along the block. This relationship can be written in the form of an equation which is often called the curve deflection equation (or elastic curve) of the beam. The structural system is placed horizontally and which is mainly intended to carry lateral loads, that is, loads that work. Perpendicular to the axial axis of the rod. Such loads typically appear as gravity loads, such as self-weight, vertical live load, crane load and others other beam systems can be pointed out, for example, building floor beams, bridge girders, tap beam supports, and so on. The axis of a rod will be detected from its original position if the object is under the influence of the force used. In other words, a bar will experience a transversal load, whether the load is centered or evenly distributed, it will experience deflection. The elements of the machine must be tough enough to prevent disharmony and maintain accuracy of the influence of loads in buildings, floor beams cannot be flexed excessively to negate unwanted psychological effects of occupants and to minimize or prevent with fragile materials. Likewise, the strength regarding the deformation characteristics of structural buildings is most important for studying machine vibrations as well as stationary and flight buildings. even if action arises normally,
it is mainly caused by relatively small external loads, for example due to the vehicle's friction on the bridge girder, or for example due to sloping placement.

2.3. Geophone
Geophone is a sensor that can measure vibrations that propagate. A geophone is generally a coil which is hung by a spring around a permanent magnet, all of which are contained in a protective casing. When the coil moves relative to the magnet, voltage is induced in the coil which depends on the relative speed between the coil and the magnet.

The working principle of Vibration caused by the burden of bridge bearing on the geophone causes the spring in it to oscillate. The movement of the spring oscillation causes a flux due to the turns of the position changing to the magnet. Because of the flux, induced GGL appears.

Induced GGL is the potential difference that occurs at the ends of the coil due to the influence of electromagnetic induction. Induced voltage detected in the coil of wire is proportional to the amount of vibration that is captured by the sensor. The output of the geophone sensor is a voltage that can be described as a sinusoidal signal.

Geophone works based on Faraday's Law, where an electric current will occur when a coil changes in magnetic flux. The voltage will be directly proportional to the flux change. What is stated in the equation:

\[ \varepsilon = -N \frac{\Delta \Phi}{\Delta t} \]  

\( \varepsilon \) = induced GGL (volts)  
\( N \) = Number of coil windings  
\( \Delta \Phi \) = Change in magnetic flux (weber)  
\( \Delta t \) = time lapse (s)  
A negative sign indicates the direction of the induced electromotive force (emf).

3. Methods
General description of the system design that will be realized in this final project is the design and realization of the vibration test system on the bridge as shown in the block diagram below: Initially there is a vehicle that passes and causes vibrations to propagate so that vibrations can be received by the geophone sensor, the geophone sensor will produce an analog signal derived from the movement of the oscillation of the coil and the magnet inside the geophone itself, after which the analog signal generated The geophone will be forwarded to the microcontroller to be processed into a voltage value and an adc value.
Then the value of the voltage and the value of the ADC will be displayed on the monitor to be analyzed how much the stress that arises due to the load passing over the bridge and will also see the amount of deflection using a laser distance meter that serves to display changes in the elasticity of concrete on the bridge. The data that has been obtained will be compared to see the difference between the two different bridges during its construction.

4. Result and discussion

4.1. Small vehicle

In testing figure 6 it can be concluded that on private vehicles crossing the Cilampeni Bridge the average amplitude read by the geophone is 0.019088667 V and the average deflection produced is 0.001466667 m.

\[ y = 0.5264x - 0.0086 \]
\[ R^2 = 0.7821 \]

![Figure 3. General system design.](image)

In testing figure 7 it can be concluded that on private vehicles crossing the Kopo Toll Bridge the average amplitude read by the geophone is 0.0178426 V and the average deflection produced is 0.0014 m. The bridge is still suitable for pedestrians and vehicles because the deflection does not reach 0.020 m in 100 kg.

![Figure 4. Small vehicle chart on cilampeni bridge.](image)
In figure 6 and figure 7 it can be concluded that deflection has a relationship where the greater the amplitude, the greater the deflection, this occurs because a passing private vehicle will produce a voltage that depends on the vehicle load, the deflection that occurs is due to the force given the vehicle on a concrete bridge. The bridge is still very convenient for pedestrians and vehicles because the deflection does not exceed the specified limit.

4.2. Truck

In testing the figure 8 it can be concluded that the large trucks passing the Cilampeni Bridge - the average amplitude read by the geophone is 0.056976267 V and the average deflection generated is 0.018266667 m. The bridge is still suitable for pedestrians and vehicles because the deflection does not reach 0.020 m in 100kg.

In testing figure 9 it can be concluded that on large trucks passing the Kopo Toll Bridge the average amplitude read by the geophone is 0.043019667 V and the average deflection generated is 0.017666667 m. The bridge can still be used for pedestrians and vehicles because the deflection does not reach 0.020 m in the weight of 100kg.
Figure 7. Truck chart on tol kopo bridge.

Figure 8 and Figure 9 show a very large increase that can occur because the burden on large truck vehicles can be twice as large as small trucks causing maximum vibration and deflection on the bridge but still within the concrete loading limits on the bridge so that the bridge can still be used well in the future.

4.3. Ratio amplitude to mass
In this final project, the deflection relationship between mass and amplitude is of high concern because it is interconnected if the mass of the load is large, the deflection that occurs is large and if a high vibration will indicate a high amplitude.

Figure 8. Graph of voltage to mass.
In figure 10 and figure 11 it can be concluded that the mass of a vehicle on the bridge will affect the vibration magnitude of the bridge, the greater the deflection that results when a very heavy vehicle mass crosses the bridge because the greater the weight of the vehicle the greater the force will be borne by concrete bridges.

5. Conclusion

From the results of testing and analysis that have been obtained, the authors get the conclusions of this Final Project are as follows: The design of the geophone sensor system was successfully realized using Arduino Uno, Geophone Sensor, and ADS1115 module. The system has been calibrated using power supply with accurate results. Small vehicles provide small deflection when crossing bridges and bridges are still very feasible to use. Small trucking vehicles provide significant deflection but are still below the bridge loading standard. Large truck vehicles provide maximum deflection of the bridge loading limit but the bridge can still be used because it does not exceed the bridge loading provisions. The bridge is healthy because all data analysis and retrieval does not exceed the limits specified in the bridge loading.

References

[1] Putra S A, Sani G A A, Nurwijaya A T, Anandadiga A, Wijayanto P B, Trilaksono B R and Riyansyah M 2018 Sistem Penilaian Kondisi Jembatan Menggunakan Respons Dinamik dengan Wireless Sensor Network Jurnal Nasional Teknik Elektro dan Teknologi Informasi (JNTETI) 7 3 338-343
[2] Tschope C and Wolff M 2009 Statistical classifiers for structural health monitoring IEEE Sensors Journal 9 11 1567-1576
[3] Sazonov E, Li H, Curry D and Pillay P 2009 Self-powered sensors for monitoring of highway bridges IEEE Sensors Journal 9 11 1422-1429
[4] Lydon M, Taylor S E, Robinson D, Callender P, Doherty C, Grattan S K and O’Brien E J 2014 Development of a bridge weigh-in-motion sensor: performance comparison using fiber optic and electric resistance strain sensor systems IEEE Sensors Journal 14 12 4284-4296
[5] Araujo A, Garcia-Palacios J, Blesa J, Tirado F, Romero E, Samartín A and Nieto-Taladriz O 2011 Wireless measurement system for structural health monitoring with high time-synchronization
accuracy IEEE Transactions on instrumentation and measurement 61 3 801-810

[6] Islam A K M, Li F, Hamid H and Jaroo A 2014 Bridge condition assessment and load rating using dynamic response (No. FHWA/OH-2014/7) (Ohio: Dept. of Transportation. Office of Statewide Planning and Research)

[7] Mohamad K 2009 Perancangan Sistem Akuisisi Data Gelombang Seismik Berbasis Mikrokontroller H8/3069F (Universitas Indonesia)

[8] Faiz N 2018 Pemantauan Lendutan dan Frekuensi Alami Struktur Jembatan Menggunakan Algoritma Fast Fourier Transform (Universitas Telkom)

[9] Nababan P H 2008 Structural Health Monitoring System Alat Bantu Mempertahankan Usia Teknis Jembatan Constr. Maint. main span Suramadu Bridg 1-2

[10] RSNI T-02-2005 2005 Standar Pembebanan untuk Jembatan, Badan Standardisasi Nasional

[11] RSNI T-12-2004 2004 Perencanaan Struktur Beton Untuk Jembatan, Badan Standardisasi Nasional