Design and Construction of a Module for the Dynamic Excitation and Vibrational Analysis of Structures

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DESIGN AND CONSTRUCTION OF A MODULE FOR THE DYNAMIC EXCITATION AND ANALYSIS VIBRACIONAL OF STRUCTURES

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ABSTRACT

The present work this oriented to evaluate the vulnerability and seismic behavior of buildings, for which an exciter of eccentric mass has been developed, has designed a card of data acquisition, a software for the digital processing of the vibration signals has been designed and with the aid of an accelerometer and a variador of speed we will be able to obtain the dynamic characteristics of the building under test. Immediate goal is the one to design and to construct an electronic unit to produce and to measure vibration in the structures of civil construction on accommodation ladder, with the object of being able to know the dynamic characteristics this to make the corresponding decisions. The second objective is the approximation to the problematic one of the answer of a structure to a vibration. The third objective is from the point of view of the structural analysis, to offer to the specialist the parameters that allow him to make decisions and to evaluate the structure under test. The fourth objective is to propose the prototype to the specialists, like alternative methodology to evaluate the seismic risk of the constructions of experimental way and on accommodation ladder. They will determine if she can serve like so.

1. INTRODUCTION

It is necessary to evaluate the vulnerability and seismic behavior of buildings that are the factor on which it can be acted until the point to secure the diminution of risk in the homes during and after the occurrence of an earthquake and it does not exist, like now, the very great probability of their collapse. This work is pioneering in the city of Cusco, it constitutes a contribution to the knowledge of the dynamic behavior of structures and contains important methodology elements and of application that they will easily allow its application in areas of elevated seismicity in which the study of the dynamic behavior of the buildings is more important and urgent. The purpose of this work is to be able to design and to construct an exciter of eccentric mass able to force the vibration of a construction on accommodation ladder to realize the respective tests.

2. DEVELOPMENT OF THE WORK

Exciter of Eccentric Mass.- The vibrator of eccentric mass is developed to provide a source of appropriate excitation and to prove structures. This equipment develops harmonic forces through the rotation of united masses to the axis. The answer of the structure to the harmonic force, evaluates the dynamic properties of the structures (for example, natural frequencies, natural ways, etc.). The answer of a structure to the harmonic forces on a rank of frequencies, gives like result the curve us of frequency response, which shows the tips to us of resonance corresponding to each natural frequency of the structure. Knowing real the properties dynamic we can use them to validate and to improve the analytical models, to determine the causes of vibrations, to detect damages, etc.

The vibrators of eccentric mass use one or more eccentric masses turning to produce a force. A single eccentric mass turning produces a vector of omnidirectional force. This force has the proportional magnitude to the mass of the weight (m), eccentricity of the axis (e) and to the squared one of the circular frequency (w^2). The direction of the force changes with time so that the force of inertia of the rotating mass acts towards the origin. In other words, this force can be expressed like the sum of two perpendicular sinusoidal forces with the delay of phase of 90-degrees

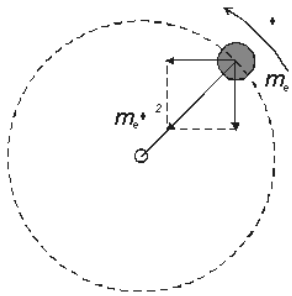


Fig. 1 Vibrator of omnidirectional eccentric mass

When the vibrator of eccentric mass has two mass rotating in direction opposed on the vertical axis. If the two masses have the same weight and with equal eccentricity with respect to the spin axis, the component of the force of inertia in one of the directions is cancelled and the components of the other direction are combined to produce a sinusoidal force. That is to say:

$$p(t) = (m_e e w^2) \sin wt \quad \text{(ec. 1)}$$

Where:

m_e = Total Mass

e = Eccentricity

ω = Circular Frequency of Rotation

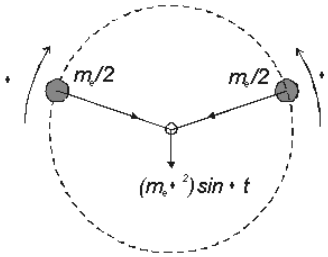


Fig. 2 Vibrator of Unidirectional Eccentric Mass

The amplitude of the excitation force is proportional to the squared one of circular frequency of turn of the mass. Therefore, it is difficult to generate the force to low frequencies and impractical to obtain the static answer of the structure.

3. DESIGN AND CONSTRUCTION

We know that the maximum force, the tip of force produced by the exciter of eccentric mass this dice by:

$$F := Mt \cdot e \cdot w^2$$

Where:

F	:	Force
Mt	:	Total Mass
e	:	Eccentricity
w	:	Frequency of Rotation

A approximate maximum force of 1200 N is desired, if we considered a mass of 20 kg, then would need an eccentricity 10 cm, thus has:

$$e := 0.1 \qquad Mt := 20 \qquad f := 4 \qquad \omega := 2 \cdot \pi \cdot f$$

$$F := Mt \cdot e \cdot \omega^2$$

$$F = 1263 \text{ N}$$

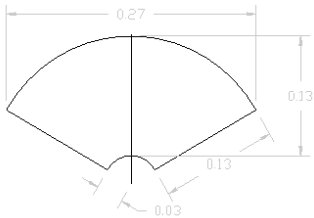
Therefore the following design became:

Photography of the Designed Exciter of Eccentric Mass

Fig. 3 Pphotography of the Eccentric Mass

Fig. 4 Photography of the Complete Exciter

In order To calculate the eccentricity of the mass, we only must find the center of mass, thus we have:



$$R := 0.16$$

$$XcR := \frac{\int_{-\frac{\pi}{3}}^{\frac{\pi}{3}} \frac{R^3 \cdot \cos(\theta)}{3} \, d\theta}{\int_{-\frac{\pi}{3}}^{\frac{\pi}{3}} \frac{R^2}{2} \, d\theta}$$

$$XcR = 0.088 \text{ m}$$

$$r := 0.03$$

$$Xcr := \frac{\int_{-\frac{\pi}{3}}^{\frac{\pi}{3}} \frac{r^3 \cdot \cos(\theta)}{3} \, d\theta}{\int_{-\frac{\pi}{3}}^{\frac{\pi}{3}} \frac{r^2}{2} \, d\theta}$$

$$Xcr = 0.017 \text{ m}$$

Then the eccentricity will be:

$$e := \frac{\pi \cdot R^2 \cdot XcR - \pi \cdot r^2 \cdot Xcr}{\pi \cdot R^2 - \pi \cdot r^2}$$

$$e = 0.091 \text{ m}$$

For our mass that is of 20 kg and one frequency of 4Hz we have:

$$e = 0.091 \qquad Mt := 20 \qquad f := 4 \qquad w := 2 \cdot \pi \cdot f$$

$$F := Mt \cdot e \cdot w^2$$

$$F = 1147 \text{ N}$$

Equipment of Data Acquisition.- For the design of the Card of Data Acquisition, i am used the integrated AD1674, that is a digital analogous converter of 12 bits of resolution and with a rank of + 5V in the entrance, able to first give to 8 bits and soon 4 bits, following the controls with which counts like: A0, CS, R/C, etc

In the entrance a filter has been implemented happens low with a gain of 200. This work and to be able to determine of better way the natural frequency of the structures under test is desired to eliminate the signals whose frequency is over

10 Hertz, since the natural frequencies of the structures are below 10 Hertz, is so when designing the filter for this intention is counted with C = 220 nF, therefore the approximated resistance to achieve our objective would be 68K.
The cut-off frequency would be:

$$R := 68000 \qquad C := 220 \cdot 10^{-9}$$

$$Fc := \frac{1}{2\pi R \cdot C}$$

$$Fc = 10.639 \text{ Hz}$$

Algorithms of Characterization and Control.- The program for the acquisition and analysis of results has been developed with the compiler Borland C++ Builder 6, who allows a visual programming us for Windows, with forms, buttons, labels, etc., as it is possible to be observed in the following diagram, in such a way that the interface with the user is but friendly and of easy use.

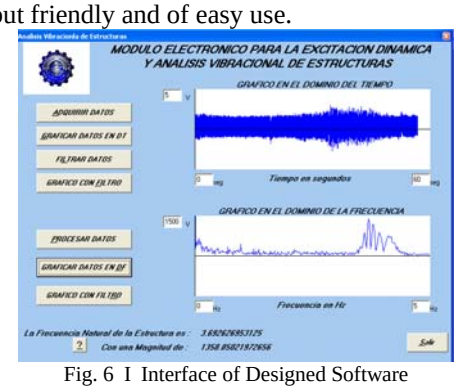


Fig. 6 I Interface of Designed Software

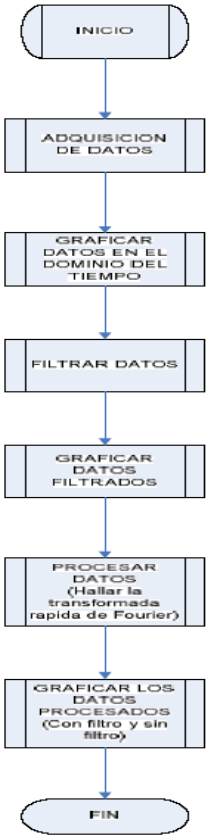


Fig. 7 General flow chart

4. TEST PROTOCOL

Fixed and I nail the Exciter of Eccentric Mass in the floor of the construction under test.

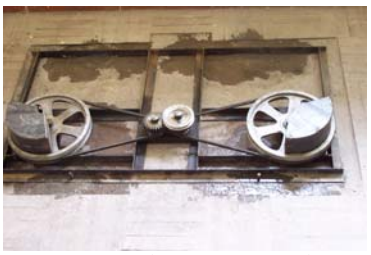


Fig. 8 Photography of the Installation of the Exciter

In order to carry out the test, the motor of the Exciter of Eccentric Mass to a varied of speed is connected to manage a sweeping in the rotation frequency. In this case we used the varied Siemens Micromaster.

Programming the Variador of Speed:

What it is wanted to obtain is to secure a frequency variation that behaves like an ascent incline during 30 second and soon an incline of slope of other 30 seconds to complete the minute of test for which we have designed the card.

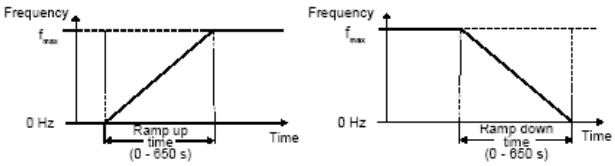


Fig. 9 Meaning of the parameters of frequency of the variador Micromaster

First that must do is to determine the maximum frequency of the incline, for which we resorted to the P005 parameters of the variador of speed and we determined the maximum frequency.

- P005: SetPoint (Hz).

We determined the time that goes has to delay the variador in arriving at the maximum frequency, for which we resorted to the P002 parameter of the variador we fixed and it to 30 seconds.

- P002: Time of the Incline of ascent (seg).

Soon we determined the slope that will have our incline, for which we resorted to the P013 parameter of the variador we fixed and it to the same value of the maximum frequency to have an incline which in the time of 30 seconds arrives at the maximum frequency.

- P013: Maxima frequency of the motor (Hz).

Finally we determined the time of the slope incline, for which we resorted to the P003 parameter of the variador and we fixed also it to 30 seconds.

- P003: Time of the Incline of slope (seg).

I settle 1 accelerometer Bruel&Kjaer in the wall of the laboratory:

Parameters of the Data Acquisition

- Frequency of sampling fs=500Hz
- Resolution of the conversion: 12 bits
- Rank of voltage of the converter A/D: +-a 5V
- Configuration of the charge amplifier:
  - Sensitivity: 1 pC/ms-2
  - Gain: 0.316 Voltios/ ms-2
  - Cut-off frequency filter high pass: 0.2 Hz
  - Cut-off frequency filter low pass: 100 Hz

5. RESULTS

In order to be able to realize a good analysis of the obtained results rms in m/s2 is due to calculate for each registry the acceleration and the frequency to which the highest tip appears.

Train 1 0 - 70 Hz	
Acceleratión rms (m/s2)	**Frequency with the found high tip but (Hz)**
0.865 m/s^2	3.72 Hz

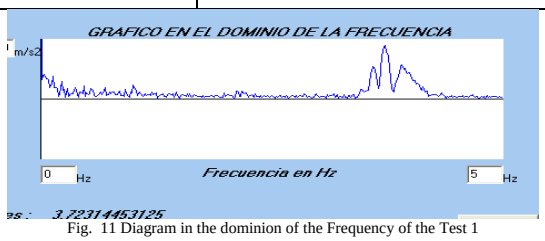


Fig. 11 Diagram in the dominion of the Frequency of the Test 1

Train 2 0 - 74 Hz	
Acceleratión rms (m/s2)	**Frequency with the found high tip but (Hz)**
0.869 m/s^2	3.69 Hz

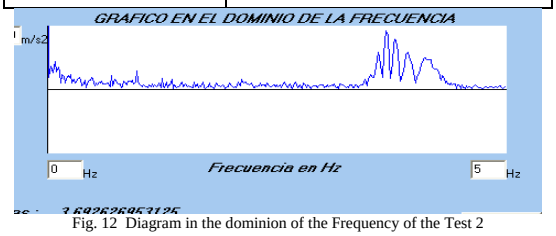


Fig. 12 Diagram in the dominion of the Frequency of the Test 2

Train 3 0 - 80 Hz	
Acceleratión rms (m/s2)	**Frequency with the found high tip but (Hz)**
0.871 m/s^2	3.72 Hz

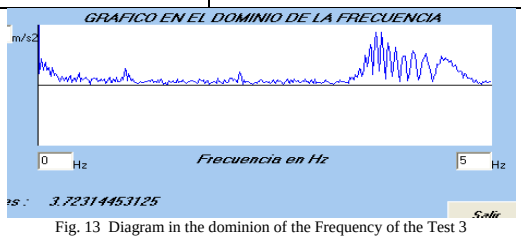


Fig. 13 Diagram in the dominion of the Frequency of the Test 3

In the spectrum of Fourier of the measured acceleration usually one identifies the fundamental period of the building, like the one of maximum spectrum amplitude of smaller frequency than one is within the interval of inherent frequencies of the building.

Results of the tests			
Nº	**Sweeping of Frequency (Hz)**	**Acceleratión RMS (m/s^2)**	**Frequency with the found high tip but (Hz)**
1	0 - 70 Hz	0.865 m/s^2	3.72 Hz
2	0 - 74 Hz	0.869 m/s^2	3.69 Hz
3	0 - 80 Hz	0.871 m/s^2	3.72 Hz
4	0 - 60 Hz	0.757 m/s^2	3.34 Hz
5	0 - 70 Hz	0.776 m/s^2	3.45 Hz
6	0 - 75 Hz	0.805 m/s^2	3.39 HZ
7	0 - 80 Hz	0.845 m/s^2	3.46 Hz
AVERAGE		**0.827 m/s^2**	**3.54 Hz**

Table 1 Obtained result of All the Tests

The found natural frequency would be:

3.54 Hz

6. CONCLUSIONS AND RECOMMENDATIONS:

- Profit to be constructed an electronic unit to produce and to measure vibrations in the structures of civil construction on accommodation ladder.
- The Exciter of Eccentric Mass produces the force necessary to be able to excite to the structure with an entrance signal, therefore the construction of Exciters of Vibration is viable.
- The answer of the structure to the excitation produced by the Exciter of Eccentric Mass has a tip in the frequency of 3,6 Hertz, which agrees in all the realized tests.
- In spite of having a filter it happens under implemented in the Card of Data Acquisition, the signal of 60Hz is introduced within the data.
- The obtained results must be verified by other tests with impulsive excitation, which were not realized not to be within the reaches and not counting on resources.
- The sweeping of frequency produced by the variator can be controlled by means of developed software and from that way the frequency rank is obtained from automatic way.
- The natural frequencies of the structures always are to low frequency.
- For to obtain better results, the accelerometer must be fixed to the wall of the best way possible and thus to avoid false data that they take to us to commit error in the calculation.

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