Earthquakes and Structures

1. Earthquakes and structural effects of seismic vibrations

Every year several earthquakes occur on planet Earth with severe loss of human lives.

Earthquakes are natural events due to sudden movements on tectonic faults. The energy released during a strong earthquake could be equivalent to the energy of several atomic bombs.

Usually the engineers use a logarithmic scale to indicate the magnitude or energy released by an earthquake. The magnitude of the strongest earthquakes is about 9 (Richter magnitude scale) - such an earthquake could be strong enough to cause measurable variations on planet rotational motion!

During an earthquake most of us already experienced the vibrations at the Earth's surface due to the propagation of seismic waves along the crust surface. The intensity of the seismic vibrations decreases with the distance to the epicenter (see Figure 1 - home page of the presented program **EquakeStruct.exe**).

The main question we intend to answer with this project (**EquakeStruct.exe**) is*: **how do the seismic vibrations affect the civil engineering structures like bridges, dams or buildings?***

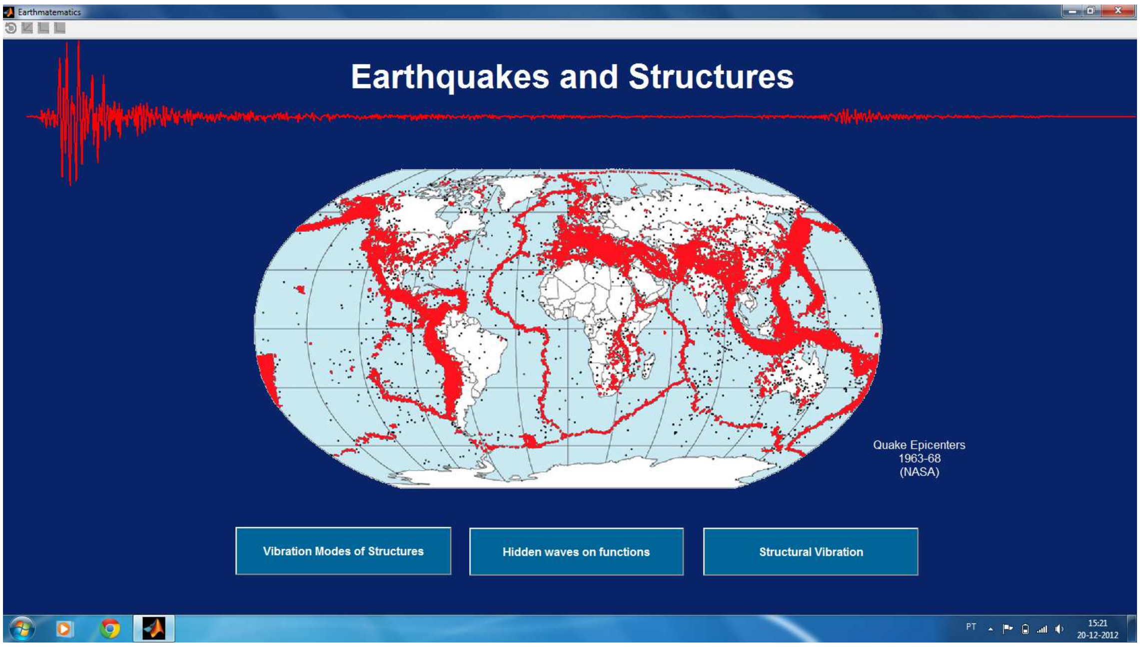

Figure 1 – Home page of the program **EquakeStruct.exe**.

2. Dynamic behavior of structures

To answer the above question structural engineers carried out several investigations in order to understand the dynamic behavior of civil engineering structures (the collapse of Tacoma Narrows bridge in 1940 due to a resonance effect induced by cyclic wind forces showed how important it is to study the dynamic behavior of structures).

Mathematics is the key to deeply understand the structural dynamic response of our structures to seismic base vibrations. The physics of the problem is described mathematically by a differential equation that can be solved for any structure using numerical methods. In the solution of these problems some fundamental numbers arise: they are named **natural frequencies** (measured in cycles/s or Hz) and they are intrinsic to each structure (like "finger prints"). The **natural frequencies** of a structure can be measured in situ and then compared with computed values.

Using the left button "Vibration Modes of Structures" we can see (figure 2) that each structure has its own natural vibration modes with the correspondent natural frequencies (this means that each structure "likes" to vibrate in some special modes with their own frequencies – **natural frequencies** of the structure). We will see that some problems (resonance effects) can arise when a structure is excited by base vibrations with a frequency that matches some of the **natural frequencies.**

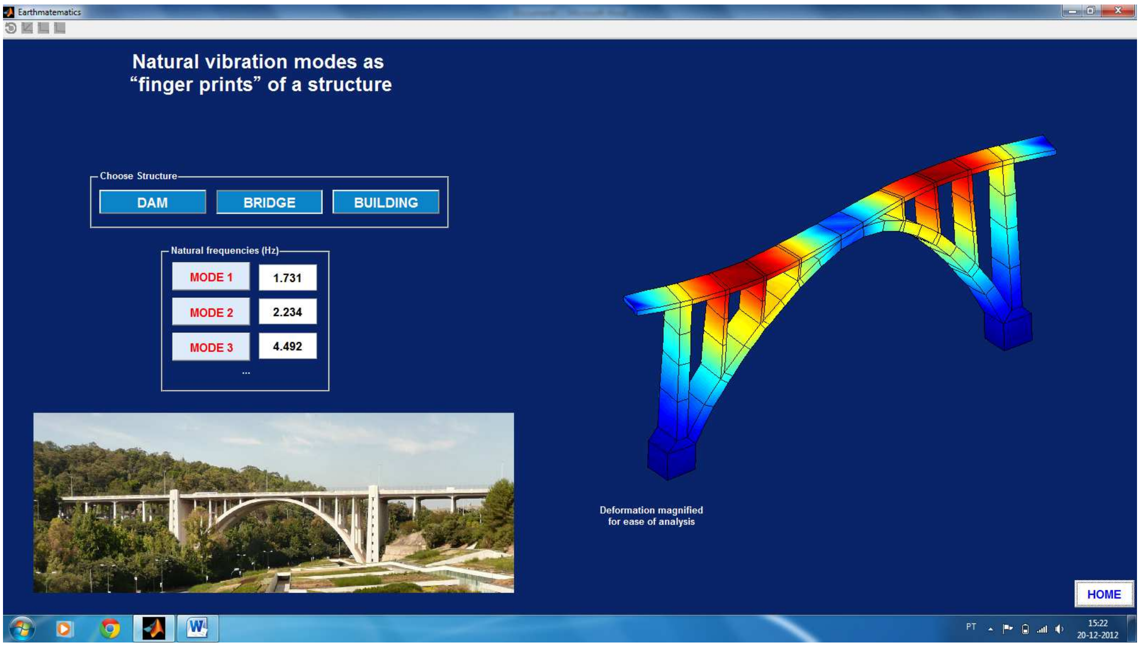

Figure 2 – Page for left button "Vibration Modes of Structures".

3. Decomposition of seismic accelerograms on harmonic waves using Fourier analysis

Seismic vibrations are usually measured by means of accelerograms. Like the usual functions an accelerogram can be seen as a time function that can be decomposed into a sum of waves by means of the Fourier series concept as it is showed on the page of the center button "Hidden waves on functions" (see figure 3). The amplitude of the waves "hidden" on a seismic accelerogram can be plotted as a spectrum of amplitudes. The peaks on this spectrum indicate the main waves contained on the accelerogram. If the frequencies of these main waves match some of the natural frequencies of a structure this means that such seismic accelerogram could be dangerous for the structure.

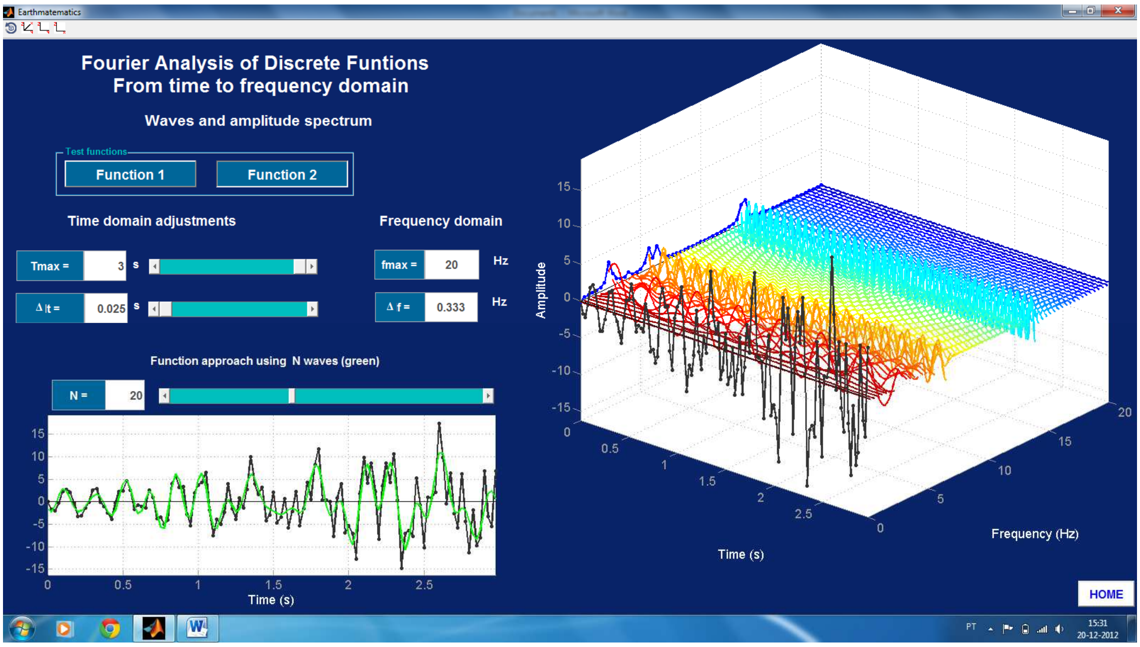

Figure 3 – Page for center button "Hidden waves on functions".

4. Resonance effects. How earthquakes can affect our structures

Using the right button "Structural vibrations" (figure 4) the user can see how two different buildings with its own natural frequencies and correspondent vibration modes behave under harmonic base vibrations of different frequencies and under two different earthquakes with clearly different spectral contents.

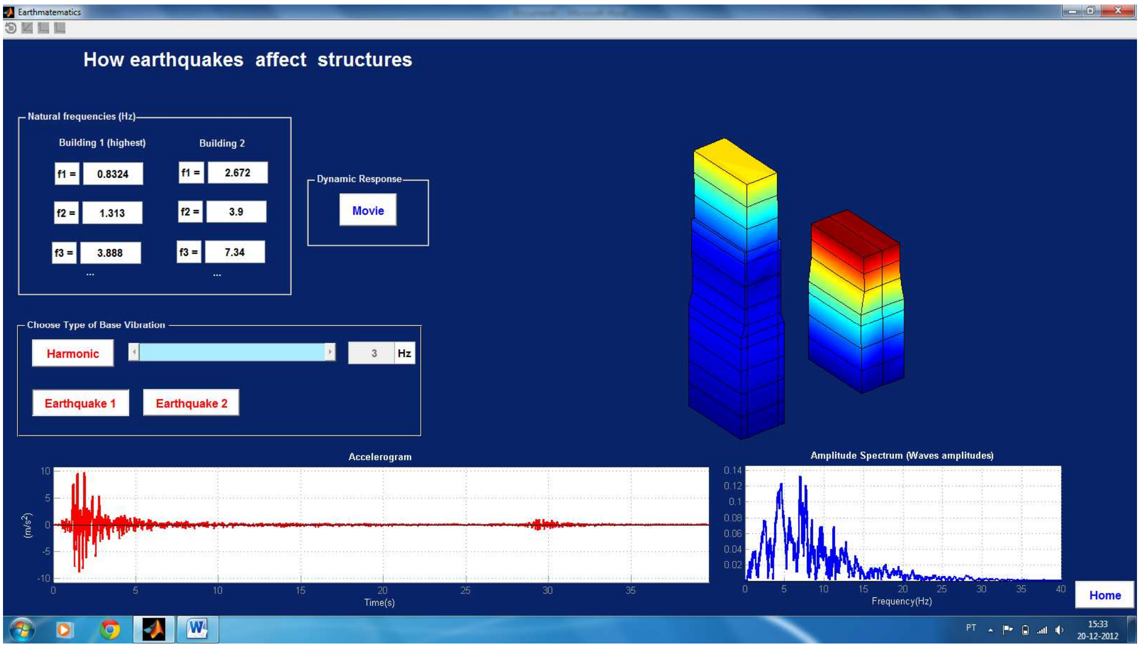

Figure 4 – Page for right button "Structural vibrations".