*i*Journals: International Journal of Software & Hardware Research in Engineering
ISSN-2347-4890
Volume 8 Issue 3 March 2020

Dynamic Analysis of Lumped Parameter Bridge Model Subjected to Earthquake Considering Soil Deformation

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DOI< 10.26821/IJSHRE.8.3.2020.8303>

Abstract

Earthquake is a natural phenomenon that cannot be avoided. Nowadays, the frequency of earthquakes increases dramatically, the damage caused by earthquakes is great, serious consequences to human and economics. With the expectation that the original look of the effect of interactions between soil structures during the earthquake behavior of bridges, especially bridges equipped with viscous damper. This the study dynamic analysis of bridges with viscous dampers subjected to earthquake considering soil deformation. The results of the analysis compared with the case without considering the deformation of the soil so that we can note that when we analyzed the effect of the bridge under earthquake loads.

Keywords: Dynamic Analysis, Lumped Parameter, Model Subjected to Earthquake, Soil Deformation, Bridge Deformation

1. INTRODUCTION

Earthquakes or earthquakes are the vibrations on the Earth's surface as a result of the sudden release of energy in the Earth's crust and generating earthquake waves. It also occurs on planets with a solid crust like the Earth (Donald Hyndman, David Hyndman. 2009). Tectonic earthquakes occur anywhere in the earth where there is sufficient stored elastic strain energy to drive fracture propagation along a fault plane. The sides of a fault move past each other smoothly and aseismically only if there are no irregularities or asperities along the fault surface that increase the frictional resistance. Most fault surfaces do have such asperities, which leads to a form of stick-slip behavior. Once the fault has locked, continued relative motion between the plates leads to increasing stress and therefore, stored strain energy in the volume around the fault surface. This continues until the stress has risen sufficiently to break through the asperity, suddenly allowing sliding over the locked portion of the fault, releasing the stored energy (Ohnaka, M. 2013).

The magnitude of damage caused by earthquakes depends on many factors such as the depth of the earthquake center, the strength of seismic tremors recorded and measured by Richter scale; the intensity of the seismic waves impacting the strata of the earthquake-prone area was assessed according to 10 degrees of the Modified Mercalli (2008) scale. At the same time, they also depend on the distance from the central point to the places, the structure of strata of the earthquake-stricken area, the structures built on the earthquake-prone land such as houses, buildings, bridges, roads, dams, electric poles, airports, stadiums, ports, etc (Ohnaka, M. 2013). In addition, the extent of damage caused by earthquakes also depends on geographic factors such as hilly areas, plains, areas with large rivers and lakes coastal, urban, city, density of residents; preparedness of community of people in earthquake disaster prevention.

Earthquakes damaged many constructions such as houses, roads, bridges, etc. and caused huge economic losses. Therefore, the design of buildings, bridge construction, etc. capable of withstanding earthquakes to reduce the loss of life and property is essential. Under the effect of earthquakes, the bridge structure generates energy, causing the breakage of the supporting structures, destroying the works. To release this energy, one of the solutions is to use viscous damper devices. At the same time, under the effect of earthquakes, there is an interaction between the earth and the structure of the building. The reason is that the soil and foundation are not always tight, in weak areas it will directly affect the structure of the building and bridge construction. Therefore, the analysis of earthquake-resistant bridges with viscous equipment considering soil deformation is close to the actual working of the system: Soil-bridge structure.

2. GENERAL INTRODUCTION ABOUT THE DEVICE BUMPERS VISCOUS

Viscosity is an important factor that not only affects human health directly like blood viscosity. In the food, industry, petrochemical or transportation industries, determining the exact viscosity index or viscosity parameters will determine the success of the product (D. Lee and D. P. Taylor. 2010). All liquids such as oil, gasoline, ice cream, chocolate or alcohol have a specific viscosity jam. Viscosity will affect the liquid movement. If this viscosity index is too high or too low, it is not good.

Viscosity is often referred to as fluid resistance. You can think of water (low viscosity) and honey (high viscosity). However, this definition can be confusing when we look at liquids with different molecular densities. Therefore viscosity cannot be compared with the naked eye (Rakesh K. Goel, San Luis Obispo. 2004). At the molecular level, viscosity is the result of the interaction between many different molecules in the liquid. This can also be interpreted as friction between molecules in a liquid. Just like in the case of friction between moving solids, the viscosity will determine the energy needed to create the fluid flow, the more fluid the higher the molecular density, the higher the viscosity index.

Each fluid has its own viscosity and can be measured to determine the so-called viscosity index or viscosity index, expressed in Greek letters. The coefficient is proportional to the performance required to cut a fluid. A viscous liquid requires a source of pressure to move. The difference in fluid velocity between the contact edge (where it is zero) and the center is another measure of viscosity. This velocity slope is small for viscous liquids, which means that the velocity is not much larger in the center than its direction.

The force in the device bumpers viscous is determined by the formula:

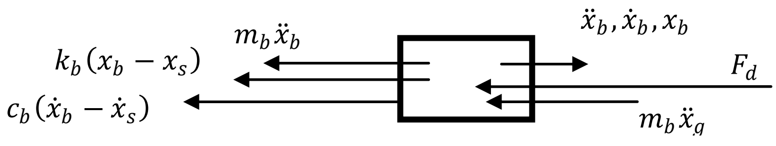
$$f_D = C_\alpha sgn(\dot{u})|\dot{u}|^\alpha (1)$$

InsideC_α is viscous drag coefficient, $\dot{u}$is the speed of the viscous device, *sgn*$(.)$is the notation function, *sgn*$(\dot{u})$ =1 when i $\dot{u}$>0 và *sgn*$(\dot{u})$ = -1 when$\dot{u}$< 0, và $\alpha$is the viscous drag coefficient limitedfrom 0.2 to 1.

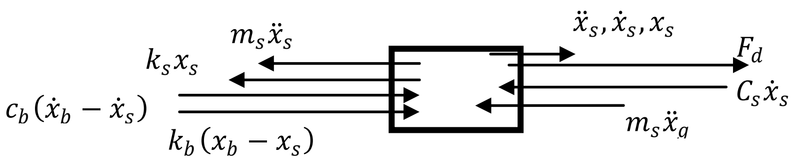
When α=1,equation (1)become$f_D = C_1\dot{u}$is linear viscosity resistance. Therefore, the exponent α epresents the nonlinearity of the viscous device.

3.ANALYSIS OF EARTHQUAKE-RESISTANT BRIDGES CONSIDERING SOIL DEFORMATION

3.1 The Motion Equation of the LPMs Model has Viscous Bumpers



(a) Upper texture



(b) caps of cylinders

Figure 1. The simple-spherical model has viscous bumpers and characteristic elements

Using the Dalambe principle (Figures 1a and 1b), we formulated the differential equation of motion of the system. The result we have a system of motion equations of two degrees of freedom system has the form:

$$m_b\ddot{x}_b + c_b(\dot{x}_b - \dot{x}_s) + c_d|(\dot{x}_b - \dot{x}_s)|^\alpha sgn(\dot{x}_b - \dot{x}_s) + k_b(x_b - x_s) = -m_b\ddot{x}_g$$

$$m_s\ddot{x}_s - c_b(\dot{x}_b - \dot{x}_s) - c_d|(\dot{x}_b - \dot{x}_s)|^\alpha sgn(\dot{x}_b - \dot{x}_s) + C_s\dot{x}_s - k_b(x_b - x_s) + k_s x_s = -m_s\ddot{x}_g$$

(Equations 2)

Figure 2 : System of differential equations

Inside: x_b,$\dot{x}_b$, $\ddot{x}_b$respectively, relative displacement, relative velocity, relative acceleration according to the time history of the upper structure compared to the land: x_s, $\dot{x}_s$, $\ddot{x}_s$respectively, the relative displacement, velocity and acceleration of the cylinder's relative to the ground, $\ddot{x}_g$is the acceleration of land according to time history, m_b is the weight of the upper structure, $k_b$is lateral stiffness of a rubber pillow, $c_b$is the coefficient of drag of high bearing, $m_s$is concentrated mass at the cylinder cap, $k_s$is the horizontal stiffness of the structure under the bridge, $c_s$is drag coefficient of the structure under the bridge, $c_d$is the drag coefficient of viscous device,$\alpha$is the shield number of a nonlinear viscous device.

3.2.Simulation System of Differential Equations of Motion

With the system of differential equations of motion of the model was prepared (2) we conducted simulation by Mathlab-Simulink. But here we only consider the linear problem, which is a special case of the nonlinear problem when$\alpha = 1.0$ (Figure3).

Table 1: Data collected

mb(kNs2/m)	100	ms(kNs2/m)	10
cb(kNs/m)	99.0454	cs(kNs/m)	328.5
cd(kNs/m)	246	ks(kN/m)	98100
kb(kN/m)	9810		

The input data and the result so that Simulink can be run are taken from M-File as follows, their units are as data tables. 1:

% value of the parameter:

ms=10;

mb=100;


```
Kb=9810;
Ks=98100;
cxib=0.05;
cxis=0.05;
Cb=2*mb*cxib*sqrt(Kb/mb)
Cs=2*(ms+mb)*cxis*sqrt(Ks/(mb+ms))
Cd=246;
o2b=Kb/mb
o2s=Ks/(mb+ms)
gama=ms/(ms+mb)
rs=Kb/Ks
o1=(1-gama)*o2b*[1+rs/(1-gama)-[((1+rs/(1-gama))^2)-(4*gama*rs/(1-gama))]^0.5]/(rs*2*gama)
co1=sqrt(o1)
T1=2*3.14/co1
Tb=2*3.14/sqrt(Kb/mb)
```

Kết quả

Cb = 99.0454; Cs = 328.4966;o2b = 98.1000; gama = 0.0909; rs = 0.1000

o1 = 89.1076; co1 = 9.4397; T1 = 0.6653; Tb = 0.6341

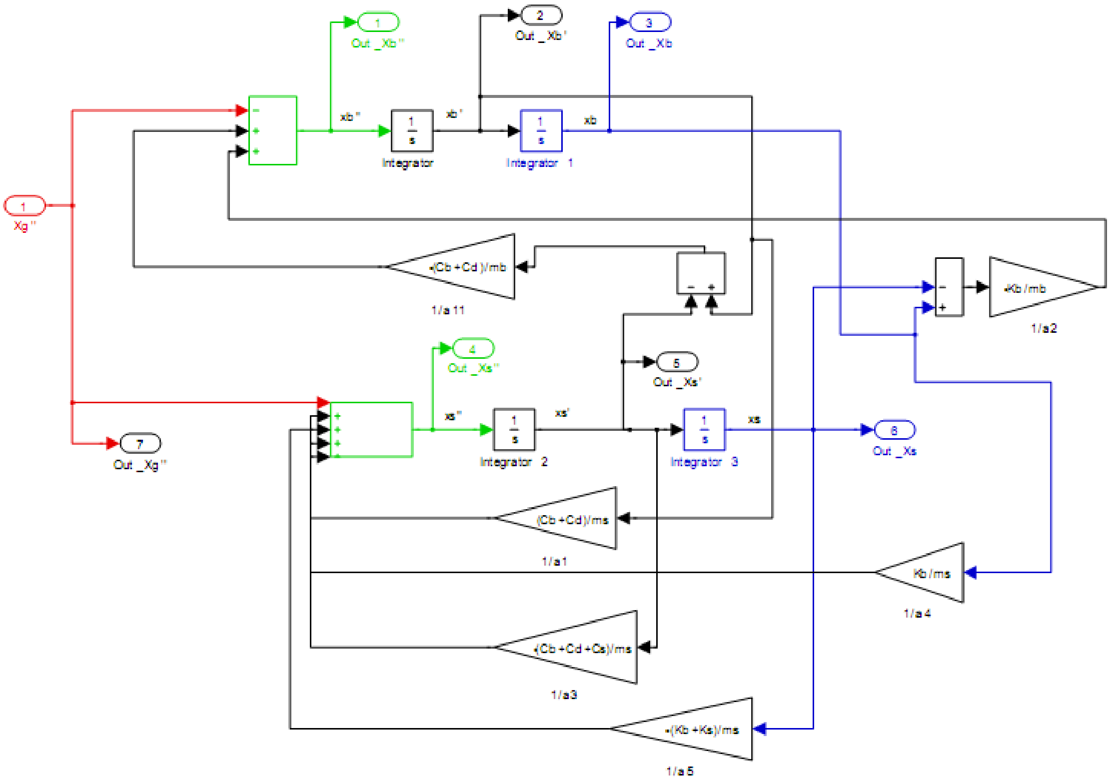


Figure3. The Subsystem block simulates the system of equations 2

3.3. Reaction of upper Structure according to Drag Ratio of Viscous Drag Device

Structural data: Conducting analysis of the bridge model, with the following structural parameters:

$$m_b = 100\ kNs^2/m;\ m_s = 10\ kNs^2/m;\ k_b = 9810\ kN/m;$$

$$k_s = 98100\ kN/m;\ c_d = 0\ kNs/m;\ (cxis)\xi_s = 5\%.$$

M-file cho kết quả $C_b = 99.0454\ kNs/m;\ C_s = 29.8633\ kNs/m.$

Acceleration spectroscopy data: Considering the pier attached to the foundation (schematic diagram) and affected by earthquake load is the acceleration chart of the El-Centro earthquake (1940).

From the results we see, as the drag ratio of the viscous drag device increases, the displacement and acceleration of the upper structure decrease.

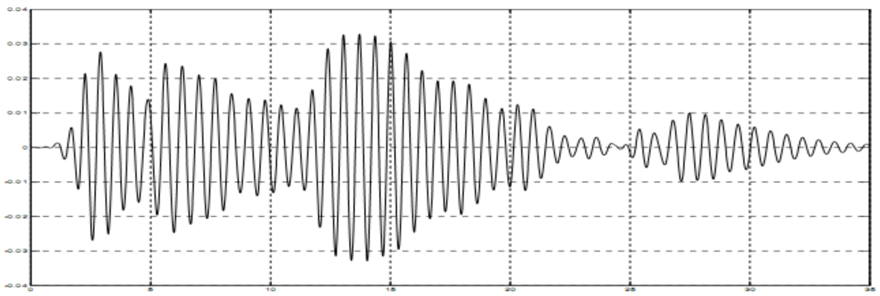


Figure4. Difference in displacement of structure of the upper part $V_{\xi_d=0\%} - V_{\xi_d=10\%}$

3.4.Reaction of upper Structure when Spherical Rigidity Changes

Investigate the bridge with bearing hardness Kb, proceed to change the knee hardness by 10%, 20% to investigate the reaction of the upper KC.

From the results for the displacement chart in Figure 5 shows that, as the stiffness of spherical bearings increases, the displacement of the upper structure decreases.

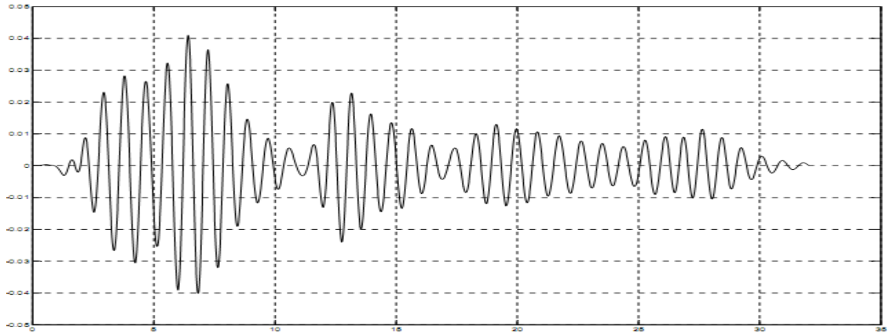


Figure5. Difference in displacement of structure of the upper part $V_{Kb} - V_{1.2Kb}$

3.5.Reaction of upper Structure when Foundation width Changes

The geological data is a medium loose sand layer, 15m thick, taking into account the soil liquefaction. We changed the width of the foundation corresponding to the width: 3m, 6m, the top of the foundation is on the natural ground, the foundation is buried at a depth of 2m.

From the results, as shown in Figure 6, in the first 5 seconds, the displacement and accelerometer do not change with the width of the foundation. Then their charts split but their values are not much different.

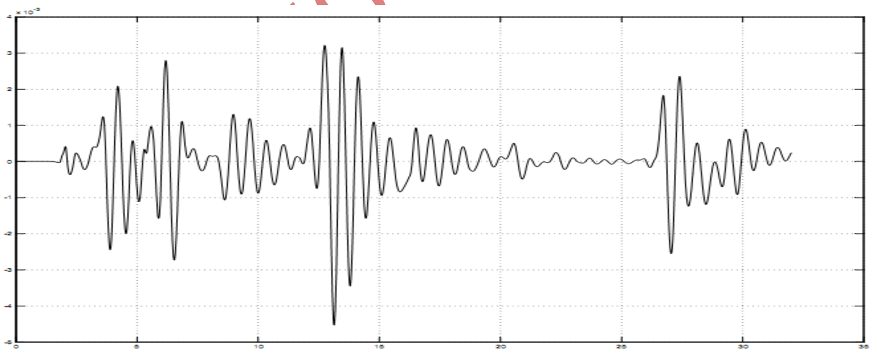


Figure 6. Difference in displacement of structure of the upper part $V_6 - V_3$

3.6.The Reaction of the upper Structure when the Depth of Buried Foundation Changes

The input data of the bridge structure is as in item 3.5, but here we consider the foundation with width 5, height 2m, buried at different depths: 1.5m and 2m.

Looking at the results, we see that when the depth of buried foundation changes, the displacement and acceleration of the upper structure do not change much. If you look at Figure 7, although the depth of foundation depth is 0.5m, the maximum displacement is only 4mm.

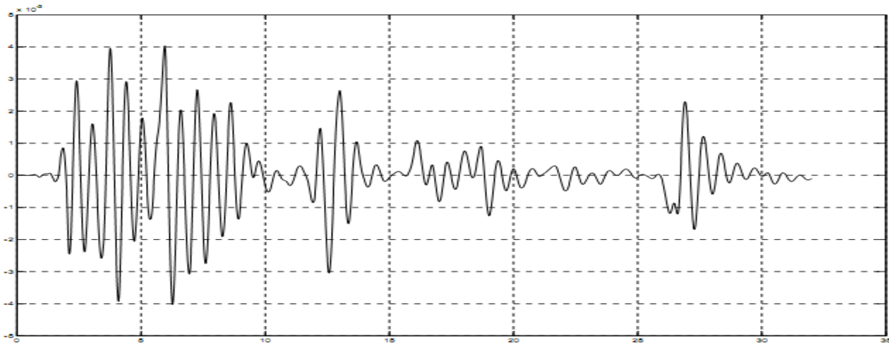


Figure 7. Difference in displacement of structure of the upper part $V_{1.5} - V_{2.0}$

4. CONCLUSIONS AND RECOMMENDATIONS

With the above analysis results give us some conclusions as follows:

When analyzing the effect of the vicious device, it shows: Viscous device helps to reduce the displacement and acceleration of the superstructure.

From the results of SSI analysis on the Deformed mesh of CyclicTP, we see: The points in the foundation area have different displacements and accelerations, the locations with large accelerations are at the top of the nail heart.

Foundation width and depth of foundation do not affect the acceleration chart at the top of the foundation when analyzing SSI.

Through this petition, please:

Conduct research in the author's direction but consider the case of a vicious device that works non-linearly and corresponding to the case of the pile foundation.

When analyzing the response of bridges with and without considering SSI, the displacement and acceleration of the upper structure are always much bigger than the caps. This suggests that: It is necessary to take measures to protect the superstructure against the effects of earthquakes. These solutions may be: Expanding the size of the caps of abutments; using anchors and chains to keep the span structure; agitated isolation measures; dissipate energy by viscous drag device; etc.

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