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Seismic Behaviour of Reinforced Concrete Bridge under Significance of Fluctuating Frequency

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Abstract: ***Earthquake is the result of sudden release of energy in the earth's crust that generates seismic waves. Ground shaking and rupture are the major effects generated by earthquakes. It has social as well as economic consequences such as causing death and injury of living things especially human beings and damages the built and natural environment. In order to take precaution for the loss of life and damage of structures due to the ground motion, it is important to understand the characteristics of the ground motion. The most important dynamic characteristics of earthquake are peak ground acceleration (PGA), frequency content, and duration. These characteristics play predominant role in studying the behavior of structures under seismic loads. The strength of ground motion is measured based on the PGA, frequency content and how long the shaking continues. Ground motion has different frequency contents such as low, intermediate, and high. Present work deals with study of frequency content of ground motion on reinforced concrete bridges. Linear time history analysis is performed in structural analysis and design (ANSYSIS) software. The proposed method is to study the response of small, medium, and long span reinforced concrete bridges under low, intermediate, and high-frequency contents ground motions having equal duration and peak ground acceleration. The response of the bridges due to the ground motions in terms of displacement , velocity , acceleration and base shear can also be find out. The results got from the three types of bridges are compared and find out the most suitable span for bridges built in seismic prone area.***

Keywords: Seismic Behaviour of RC Bridge

1. Introduction

1.1 General

An earthquake is the result of a rapid release of strain energy stored in the earth's crust that generates seismic waves.
Structures are vulnerable to earthquake ground motion and damage the structures. In order to take precaution for the damage of structures due to the ground motion, it is important to know the characteristics of the ground motion. The most important dynamic characteristics of earthquake are peak ground acceleration (PGA), frequency content, and duration. These characteristics play predominant role in studying the behaviour of structures under the earthquake ground motion. Severe earthquakes happen rarely. Even though it is technically conceivable to design a belt structure for these earthquake events, it is for the most part considered uneconomical and redundant to do so. The seismic design is performed with the expectation that the severe earthquake would result in some destruction, and a seismic design philosophy on this premise has been created through the years. The objective of the seismic design is to constraint the damage in structure to a worthy sum. The structure designed in such a way that should have the capacity to resist minor levels of earthquake without damage, withstand moderate levels of earth quake without structural damage, yet probability of some none structural damage, and withstand significant levels of ground motion without breakdown, yet with some structural and in addition non structural damage.

An Integral bridge is a bridge, which is built monolithically as one structure. These bridges are also known as integral abutment bridges, joistless bridges are rigid frame bridges. Different with a conventional bridge, which is constructed with the incorporation of movement joints, integral bridges are built without movement joints and connections. As a result, compared to conventional bridges, integral bridges will be stiffer as this provides greater redundancy. There are two types of integral bridges, namely fully integral bridges and semi integral bridges. Fully integral bridges are constructed rigidly without any expansion joints or bearings, whereas semi – integral bridges typically have sliding bearings but no expansion joints. The first advantage of this kind of this bridge is an improved cost regarding construction and maintenance .The reason behind this is the fact that integral bridges do not have expansion joints and bearings so that the process of the construction can be relatively simple compared to traditional bridges. Joints and bearings can account for a significant portion of the cost when compared to traditional bridges because they need to be maintained properly, regarding their vulnerability in fatigue and corrosion. Therefore by eliminating joints and bearings the cost can be significantly reduced. Secondly, integral bridges are simple in their design because the designers do not need to design the bearings and joints. Thirdly, these bridges can be constructed rapidly due to the absence of bearings and joints. The obvious structural advantage is the increased degree of redundancy and this leads to improved structure. When compared to other types of structures, integral bridges are considered to posses good dynamic load (earthquake) resistance. The reason for this is that integral bridges, as rigid and monolithic structures, have a high redundancy, smaller displacements, can eliminate the possibility of unseating, and have a larger damping due to soil structure interaction. Therefore, it is interesting and useful to explore the seismic behavior of integral bridges under the significance of fluctuating frequency.

In present work, 10m , 20m , 40m, 60m span integral bridges are subjected to 3 ground motions of low, intermediate , and high frequency content .The bridges are modeled as two dimension and linear time history analysis is performed using structural analysis and design (ANSYS) software.

1.2 Research Significance

The earth shakes with the passing of earthquake waves, which discharge energy that had been confined in stressed rocks and were radiated when a slip broke and the rocks slid to release the repressed stress. The strength of ground shaking is determined in the acceleration, duration, and frequency content of ground motion. The responses of RC bridges are strongly dependent on the frequency content of the ground motions. Ground motions have different frequency content such as low, intermediate, and high. Small medium and large span bridges show different response under low, intermediate and high frequency content ground motions. The present work shows that small, medium and large span RC bridges behave under low, intermediate and high frequency content ground motions.

2. Modelling

2.1 Modeling the structure

For the present work, a three-span pre-stressed concrete bridge located in India (Tandon, 2005) was used as the basis for a parametric study to determine the influence of dynamic characteristics of earthquake ground motions. India is a high-risk earthquake region, and it is suitable to adopt one of its existing integral bridges to be analyzed in this study. The bridge is an existing pre-cast concrete integral bridge. A side view of the bridge superstructure can be seen in Figure 1.

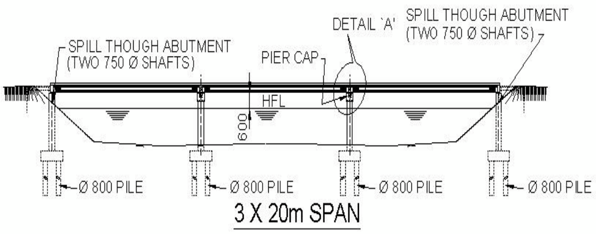

Figure 1: Side view (Tandon,2005)

The bridge consists of three 20-metre spans which are supported by reinforced concrete piers. The piers are constructed on a pile cap which has a thickness of 1.2 m. The size of the piers is 7 m high and 750 mm in diameter. There are six cylindrical concrete piles with an 800 mm diameter. The concrete material density is 2400 kg/m3.The superstructure consists of eleven concrete I girders and a concrete slab. The bridge depth deck and width are 150 mm and 8400 mm respectively. A 2D study of the bridge was chosen for a number of reasons. First, this would provide a simple approach capturing the 'in-plane' longitudinal response.

2.2 Modeling of Regular RC Bridges

10m, 20m, 40m & 60m span integral reinforced concrete bridges , which are considered as small , medium and large spans bridges.

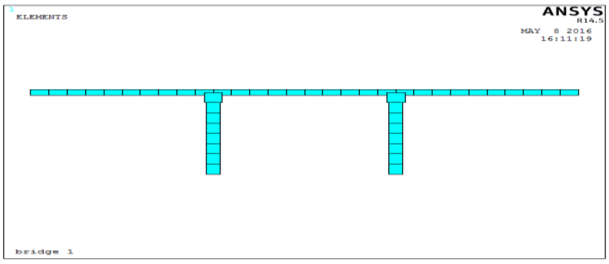

Figure 2: 10m Span Bridge

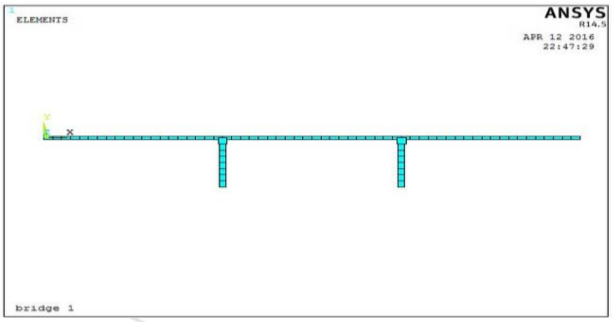

Figure 3: 20m Span Bridge

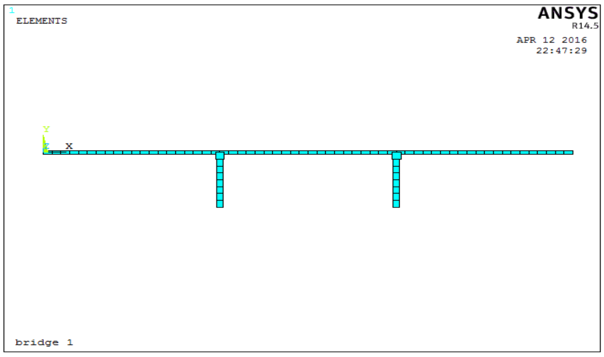

Figure 4: 40m Span Bridge

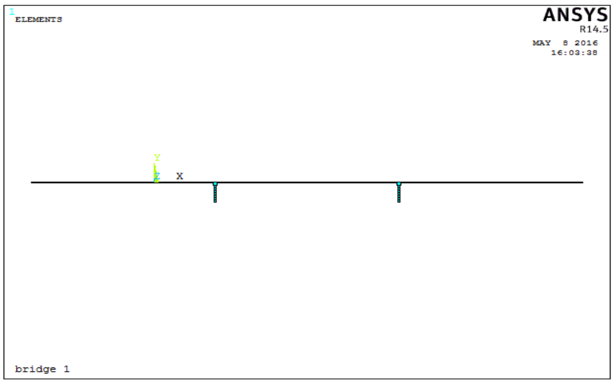

Figure 5: 60m Span Bridge

2.3 Material Property

Table 1shows concrete and steel bar properties, which are used for modeling the reinforced concrete bridges in ANSYS software.

Table 1: Properties of concrete and steel bar

Concrete Properties		Steel Bar Properties	
Unit weight (γ_c)	25 (kN/m³)	Unit weight (γ_s)	76.9729 (kN/m³)
Modulus of elasticity (E_c)	22360.68 (MPa)	Modulus of elasticity (E_s)	2x10^5 (MPa)
Poisson ratio (ν_c)	0.2	Poisson ratio (ν_s)	0.3
Thermal coefficient (α_c)	5.5x10^{-6}	Thermal coefficient (α_s)	1.170x10^{-6}
Shear modulus (G_c)	9316.95 (MPa)	Shear modulus (G_s)	76923.08 (MPa)
Damping ratio (ζ_c)	5 (%)	Yield strength (F_y)	415 (MPa)
Compressive strength (F_c)	30 (MPa)	Tensile strength (F_u)	485 (MPa)

2.4 Ground Motion Records

Bridges are subjected to ground motions. The ground motion has dynamic characteristics, which are peak ground acceleration (PGA), peak ground velocity (PGV), peak ground displacement (PGD), frequency content, and duration. These dynamic characteristics play predominant rule in studying the behaviour of RC bridges under seismic loads. The structure stability depends on the structure slenderness, as well as the ground motion amplitude, frequency and duration. Based on the frequency content, which is the ratio of PGA/PGV the ground motion records are classified into three categories:

- High-frequency content PGA/PGV > 1.2
- Intermediate-frequency content 0.8< PGA/PGV< 1.2
- Low-frequency content PGA/PGV < 0.8

The ratio of peak ground acceleration in terms of acceleration of gravity (g) to peak ground velocity in unit of (m/s) is defined as the frequency content of the ground motion. The ground motions are scaled to 0.2 g PGA and 40 second duration in order to see the effects of the frequency content on 10m , 20m, 40m and 60m span RC bridges. Three ground motion records with their characteristics and classified as low, intermediate and high-frequency content.

Table 2: Ground motion characteristics and classification of its frequency-content

Records (Station)	1940 Imperial Valley (El Centro)	1995 Japan (kobe)	2013 Australia (Solomon Island)
Magnitude	7.1	6.9	6.2
Epicentral Distance (km)	-	17.6	28.4
Duration (s)	53.46	37.7	39.9
Time step for response computation (s)	0.02	0.01	0.01
PGA (g)	.2141	.5169	.1447
PGV (m/s)	.4879	.56	.0816
PGA/PGV	.44	.92	1.8
Frequency Content Classification	Low	Intermediate	High

Table 3: Ground motion characteristics and classification of its frequency-content for 40s duration.

Records (Station)	1940 Imperial Valley (El Centro)	1995 Japan (kobe)	2013 Australia (Solomon Island)
Magnitude	7.1	6.9	6.2
Epicentral Distance (km)	-	17.6	28.4
Duration (s)	53.46	37.7	39.9
Time step for response computation (s)	0.02	0.01	0.01
PGA (g)	.2141	.5169	.1447
PGV (m/s)	.4879	.56	.0816
PGA/PGV	.44	.92	1.8
Frequency Content Classification	Low	Intermediate	High

3. Result and Discussion

3.1 Overview

In this chapter, the results of 10m, 20m , 40m and 60m reinforced concrete bridges in terms of displacement, velocity, acceleration are presented in (x) transverse direction. The responses of the structures due to the ground motions are found. In section 6.2,10m RC bridge responses due to 1940 Imperial Valley (El Centro) El Centro EW component, 1995 Japan (Kobe) and 2013. Australia (Solomon Island) component ground motions are shown. In section 6.3 and 6.4, the 20m and 40m regular RC bridge responses due to the above three ground motions are displayed respectively. Finally, in section 6.5, the results of the 60m regular RC bridge due to the mentioned ground motions are presented.

Table 4: Interpretation of results

Lengthing span	Displacement		Velocity		Acceleration	
	Max	Min	Max	Min	Max	Min
10m	GM1	GM3	GM3	GM1	GM3	GM1
20m	GM1	GM3	GM2	GM3	GM2	GM3
40m	GM3	GM1	GM2	GM3	GM2	GM3
60m	GM2	GM3	GM1	GM3	GM2	GM3

GM1-El Centro Earthquake - Low Frequency
GM2-Kobe Earthquake - Intermediate Frequency
GM3-Solomon Earthquake - High Frequency

4. Conclusion

It can be summarized that low-frequency content ground motion has significant effect on responses of regular RC bridges. However, high-frequency content ground motion has very less effect on responses of RC bridges. It is found that the intermediate-frequency content ground motion has less effect than low-frequency content ground motion and more effect than high-frequency content ground motion on the RC buildings.

5. Future Scope

The present work is carried out to study the behavior of 10m, 20m, 40m and 60m span regular reinforced concrete bridges under low, intermediate, and high-frequency content ground motions. The structure responses such as displacement, velocity, and acceleration are found and the results are compared. The study of frequency content of ground motion has wide range; one can study the behavior of structures such as steel building, steel bridges, reservoir etc. under low, intermediate, and high-frequency content ground motion.

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