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Effect of Concrete Strength on the Seismic Behaviour of Pier

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Abstract— **This paper is presents the analytical investigation on the behaviour of high strength, slender, rectangular, reinforced-concrete bridge pier in earthquake conditions. The behaviour of the pier as a whole is investigated. The pier with rigid foundation is modelled using STAAD Pro for seismic analysis. The effects of pier slenderness, characteristic compressive strength, axial-load, bi-axial bending, and their combinations of existence with seismic excitations were investigated. The results of this analysis were used to predict the behaviour and the response of piers subjected to seismic excitation.**

Keywords— High strength, Dynamic Analysis, Seismic Excitation, Frequency, Modal Actions.

I. INTRODUCTION

In recent years, the concrete structures throughout the globe have been subjected to Strong Earthquake motions which lead to huge damage to the structures leading to its unrepairable conditions along with the significant loss of human lives. Concrete Bridges in particular of such situations will produce considerable physical deterioration due to its heavy mass and inadequate stability for horizontal loads in its lateral direction and several uncertainities like material and geometrical characteristics, non reliable prediction of gravity loading and such load combinations which collectively converts the nature of assessing the behavior of such structures under strong seismic vibrations to a more complex process. The fundamental period of vibration of a majority of bridges is in the range of 0.2 to 1.2 second. In this range, the structural response is high because it is close to the predominant periods of earthquake-induced ground motions (Kunde & Jangid). With the huge land transport infrastructural developments taking place in India which started about a couple of decades ago in the sectors of both highways as well as railways projects are being executed adopting simply supported span system, continuous span system, integral bridge deck systems and many more to serve its intended purpose. A very few or less information is available on the bridge pier response when it is subjected to seismic excitation along its minor axis especially for a single cantilever pier. In order to improve and understand the seismic behavior of high strength reinforced concrete bridge pier. In this analytical study two types of pier configuration P1 (short pier) and P2 (slender pier) having the same cross sectional properties for both pier types is been considered. The seismic analysis is performed considering the grade of concrete as variable as per Indian standard codal provisions adopting dynamic analysis by response spectrum method.

The three dimensional pier models consists of Rectangular cross section with isolated footing as its foundation which is loaded over its top by pre stressed concrete unicellular box girder deck system to facilitate the movement of traffic as an elevated transport system in urban area. The concrete for the pier is considered as M45 grade to M100 and the slenderness ratio is lesser as well as greater than 12. The grade of concrete for the foundation is also considered as M90. The structure is considered as discontinuous simply supported deck system supported over two numbers of piers for each span. The pier type P1 is of 10m height where as pier type P2 is of 18m high above rigid concrete foundation.

II. LOADINGS

The total weight of the superstructure is imposed as dead load on the top of the pier which is 3750 Kn and the corresponding bending moments on the respective major and minor axis of the pier is applied as it is arrived based on the geometrical irregularities, alignment of viaduct and due to different consecutive span dimension of the pier considered. The superimposed dead load for the pier constitutes approximately around 60% of the dead load and the same is also applied along with its corresponding biaxial moments over the pier top. The analysis is performed for no live load conditions i.e., for not considering the vehicular traffic over the superstructure.

III. DYNAMIC ANALYSIS

The dynamic analysis is performed for dead load and superimposed dead load combinations without considering the live loads or moving loads. As per Indian standard codal provisions the dynamic analysis is performed by response spectrum method. The IS1893 design spectrum used in this analytical investigation is presented in table 2. The damping value is considered as 5% and the peak response quantities for member forces, displacements and base reactions has been combined as per complete quadratic combination method.

TABLE 2 :IS 1893 DESIGN SPECTRUM

PERIOD (sec)	ACCELERATION (m/sec^2)
0.03	1
0.05	1.35
0.1	1.95
0.2	2.8
0.5	2.8
1	1.6

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IV. RESULTS AND DISCUSSIONS

Table 3 shows the response modal base actions for pier type P1 at first mode and for various grade of concrete ranging from M45 to M100. The variation of fundamental time period of vibration for the considered two types of pier is represented graphically in figure 1. The fundamental time period of vibration of pier type P1 is in the range of 0.137 to 0.166 seconds. From figure 2 it is observed that for increase in the strength of concrete the base shear value is being decreased in case of short pier. Upto M60 grade the base action decrement is around 1.32% for every 5Mpa increment of concrete strength. Beyond M60 grade of concrete the decrement value is observed to be around 1%. The modal base actions for pier type P2 is presented in table 5 for its first mode. From figure 2 the fundamental time period of vibration of pier type P2 is in the range of 0.435 to 0.531 seconds. The variation of base shear value with the grade of concrete is plotted for both the type of pier as shown in figure 2, where as figure 3 displays the variation of base moment about minor axis of pier with various grades of concrete. In case of slender pier from figure 3 it can be seen that the base shear value is increasing against the increasing value of concrete strength upto M60 grade of concrete further the base shear is constant till M100 grade of concrete. Similar trend is observed in case of base moment variation with respect to different grades of concrete. Upto M60 grade concrete the base action increment is around 1.14% for every 5Mpa increment of concrete strength. Further beyond 60mpa compressive strength of concrete there is no variation of base actions.

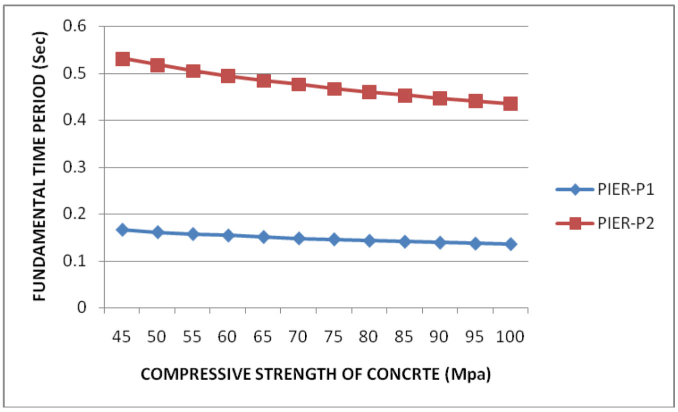

Figure 1. Effect of Concrete strength on Fundamental time period.

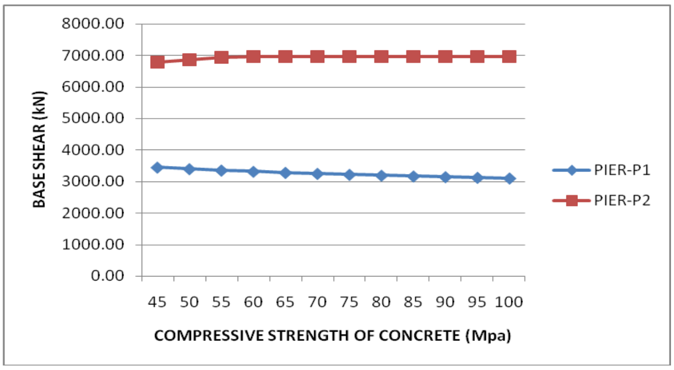

Figure 2. Effect of Concrete strength on Base Shear value.

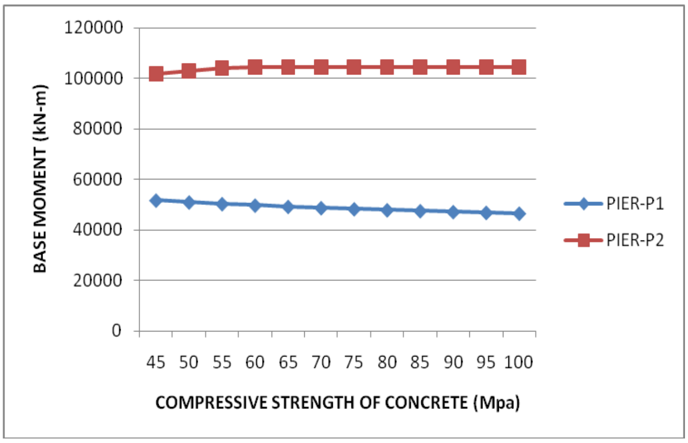

Figure 3. Effect of Concrete strength on Base Moment value.

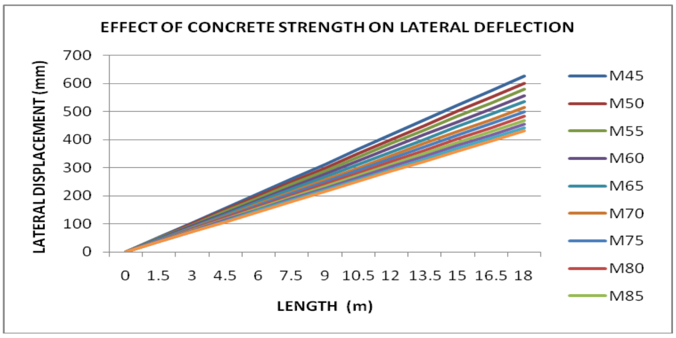

Figure 4. Effect of Concrete strength on pier top displacement for pier type P2.

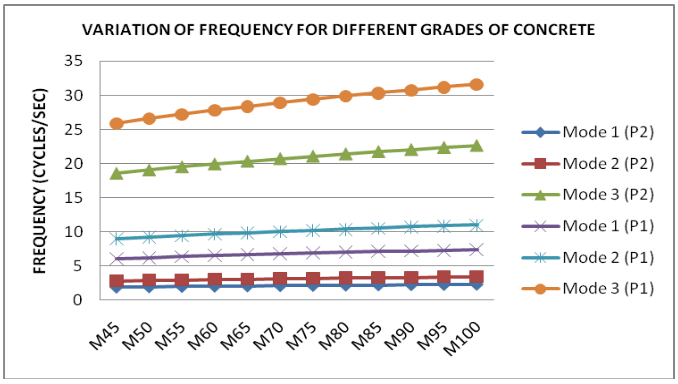

Figure 5. Effect of Concrete strength on Frequency.

CONCLUSIONS:

In order to understand the earthquake resistant behavior of reinforced concrete bridge pier, an analytical three dimensional pier modal analyses subjected to seismic excitation were performed and the following results is concluded.

1. The fundamental period of vibration of high strength reinforced concrete bridge pier analysed is in the range of 0.136 to 0.531 seconds.
2. Seismic resistance of bridge pier is inversely proportional to its slenderness ratio. Higher the slenderness ratio of pier leads to lesser resistance to earthquake forces.
3. The maximum displacement of pier top in case of seismic excitation along longitudinal direction is

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approximately half of its value compared to that of pier top displacement for seismic excitation along transverse direction.

4. The concrete strength of pier has direct influence in performance against seismic excitation. Lesser the characteristic strength of concrete higher is the pier top displacement.
5. Since the pier top displacement for lateral seismic excitation is higher, the lateral stability of pier has to be given much importance when the pier is subjected to biaxial bending base actions.
6. When the pier is not on rigid foundation, the behavior of pier has to be studied based on the actual site soil investigation data which further also depends on the type of deep foundation.

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