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Effect of restrainers on RC Bridge using Linear and Non linear analysis

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Abstract: *Damage to bridges has become quite common, which has led to new interest among engineers and researchers. Before the introduction of seismic codes, bridges were designed without any provision for ductility, thus being vulnerable to any seismic activity. In India, many bridges exist and since being constructed long time ago, they need to be made resistant to any disaster which can lead to their failure. Retrofitting is the process of making any structure seismically resistant. Instead of replacing any structure, a better solution is to retrofit. In this research, a RC bridge has been retrofitted using restrainers. A three span bridge has been selected which is supported on three circular piers. Restrainers have been used to connect pier cap to the deck slab. The linear and non-linear analysis has been carried out using SAP2000. The effect of restrainers has been later checked using the certain analysis. The evaluation results show that a certain difference occurs on using the restrainers when analysed especially in case of non linear analysis.*
Keywords: *linear analysis, non- linear analysis, Retrofitting, Restrainers, SAP2000.*

I. Introduction

Since many years, we have seen extensive damage of structures all over the world due to the earthquakes, India itself being very vulnerable to the seismic activities. In the past few decades, earthquakes have occurred in India time after time. After the major 2001 Gujarat earthquake and the 2005 Kashmir earthquake, it has become very important that a keen interest should be taken towards more safety and stability of structures. A lot of effort has been put up in making structural engineers and builders aware of the safety of the structures. The main steps taken include development of seismic design building code i.e. IS1893, part I, revised in 2002 which provides guidelines for the design of the safe structure. However the attention towards bridges is less. Since bridges form an important part in our day to day, they also need to be designed in such a way that they are resistant to seismic activities and at the times of disaster they are major mode of transport for rescue operations. Before 1970, bridges were not designed for adequate seismic resistance such as ductility thus making them more vulnerable to failure. Therefore since the revision of codes, the design & retrofitting is done accordingly. Bridges are analysed & designed according to seismic activities and the existing bridges have been or are to be retrofitted. Bridges have been a part of our world since the ancient times long before the seismic codes were introduced. During those times, bridges were constructed without any consideration or any guidelines for the seismic activity thus being vulnerable to earthquakes. However in today’s time, seismic codes are available and thus all the structures are designed accordingly.

Bridges in the absence of restraining devices, bearing are vulnerable to failure as these are unable to accommodate large seismic displacement and bearing seat is inadequate.

In this research, the effect of restrainers is seen on the RC bridge using the linear and non linear analysis.

II. Literature Review

1. Introduction

In the previous years as well, a lot of research has been done on the seismic behaviour of RC bridges. To save any structure from collapse or to rectify any damaged bridge, it is necessary to know about the seismic activity of an area such that when any bridge is retrofitting or any new structure is to be constructed, it is done according to the specifications in codes to prevent any damage in the future.

1.1. P.Rathish Kumar, T.Osshima, S.Mikami and T.Yamazaki(2007), Studies on RC and Ferrocement jacketed columns subjected to simulated seismic loading.

The work is carried out on RC and Ferro cement jacketed columns subjected to simulated seismic loading. The ferrocement jacketing has been proposed in many research works to be used as an alternative to strengthen RCC columns towards seismic loading, which has been examined under different axial load ratios. The effect of axial load on hysteric response and energy absorption capacity of RC and ferrocement confined columns is examined. A three scale model bridge pier specimen tested under different axial loads before and after retrofitting. The three RC columns were strengthened with six layers of ferrocement jackets. Woven mesh wire of 2.76mm opening and 0.44mm diameters was used as reinforcement jackets throughout the program. The width of the mesh was 985mm. the clear cover of 2.5mm on inner most & outer surface of wire mesh was provided. A small gap of 15mm was provided at bottom of piers between ferrocement jacket and bottom of footing, which prevents increase in flexural strength.

1.2. W.C.Yuan, S.B.Wang and L.C. Fan (1996), Response analysis of Suspension bridges.

In this paper, two domestic suspension bridges have been analysed by subjecting them to long period ground motion. The results for CQC method, SWAM method and time history method have been compared. A new modal combination method is developed and applied to response spectrum analyses of the two suspensions bridges. The comparison of the three methods shows that the result for the present new method is in agreement with that abstracted from time history method and the disperancy between them is less than 10%. It also shows that the CQC method underestimates the response by 25-35% while the SWAM method over estimates the responses by 10~20%. Thus it was concluded that the present new method gave better result which are satisfactory for suspension bridges.

1.3. Jianhua Li, Jie Li (2004), An efficient response spectrum analysis of structures under multi support seismic excitations.

In this paper, response spectrum method is proposed for the seismic analysis of a multi-support structure subjected to spatially varying ground motions. Based on theoretical framework by Heredia-Zavoni and Vanmarcke, an approximate and efficient analysis of the frequency integral of spectral parameters and cross-correlation coefficients is presented. The proposed procedure is demonstrated for a two-span beam-like structure under multi-support excitations. Computed results based on this simplified method are shown to be in close agreement with results obtained from Monte Carlo simulation and the MSRS. Furthermore, a dramatic reduction of the computational time is achieved. The proposed computational algorithm provides an efficient method for the analysis of multi-support structural system.

1.4. N.K.Dowell (2012), Non-Linear time history seismic analysis for bridge frame structures.

In the paper the incremental form of the closed-form approach is presented and nonlinear time-history results for a typical bridge frame subjected to earthquake loading are compared to results from the stiffness method. The new closed-form approach is based on modified classical analysis techniques and is so fast and stable that bridge designers may now consider using nonlinear time-history analysis for the seismic design of typical highway bridge structures. The new method is extremely fast compared to all other methods that depend on matrix manipulation at each increment for the 1000s of load increments used in nonlinear time-history seismic analysis.

2. Restrainers

These belong to the family of longitudinal retrofit. When the bride span is inadequate relative movement in the span can result in the unseating thus leading to collapse. Restrainers limit the movement of the span thus preventing any failure. These are attached to the deck of the slab to limit movement or to adjacent slabs. We can either use a bar or a cable. Cable restrainers have been used extensively in California and have been identified as a relatively simple and inexpensive retrofit strategy to minimize the risk of unseating (Priestley et al. 1996). Restrainer cables are usually galvanized steel cables with a diameter of 0.75 in (19mm) and lengths may vary between 5ft to 10ft. the slack may be provided from 0-19mmi.e. up to 0.75in. The goal of the restrainer design is for the restraining component to remain in the elastic region, so the added ductility of bars is not considered a major advantage [Federal Highway Administration (FHWA) 2006]. The reduced flexibility also requires that the bars are much longer than cables in order to allow for the same range of motion of the structure [Federal Highway Administration (FHWA) 2006]. For these two reasons, restrainer bars have historically been used much less frequently than restrainer cables.

III. Linear Analysis

The entire procedure is known as the response spectrum method of analysis and is developed using the following steps.

1. A modal analysis of the structure is carried out to obtain the mode shapes, frequencies, and mode participation factors for the structure.
2. An equivalent static load is derived to get the same response as the maximum response obtained in each mode vibration, using the acceleration response spectrum of the earthquake.
3. The maximum modal responses are combined to find the total maximum response of the structure.
4. The maximum responses obtained in each mode of vibration are generally combined using three different types of modal combination rules, namely: (i) ABSSUM, (ii) SRSS, and (iii) CQC.

IV. Non-Linear Analysis

Time history analysis techniques involve the stepwise solution in the time domain of the multi degree-of-freedom equations of motion which represent the actual response of a structure. Time history analysis requires time history records of any past earthquakes. Here we have used time history records of Delhi region and the Indian standard codes namely: IS 1893-2002. Time history analysis has been carried out for a spectral acceleration of 0.24g on hard soil, with a damping of 5%. Each record is divided into 4000 steps with acceleration spaced at 0.02s.

V. Structural Model

The RC bridge including the piers and girders are modeled by 3D frame elements. The girder- pier joints are modeled by giving end offsets to frame elements, to obtain the bending moments and forces at beam and column faces. The piers of the bridge are circular and the bridge deck is trapezoidal. The pier cap is rectangular and at the both ends are the abutments. The bridge model has three spans. The pier ends at foundations are fixed. The total span of the bridge is 250m. For this research, three spans of length 12.5m, 12.4m and 12.69m have been taken up. The piers of the bridge are circular in shape with a diameter of 1m, which are located at a distance of 1.35m, 3.7m and 6.05m from one end of the pier cap, with height of 8m each. The length of the pier cap is 7.5m.

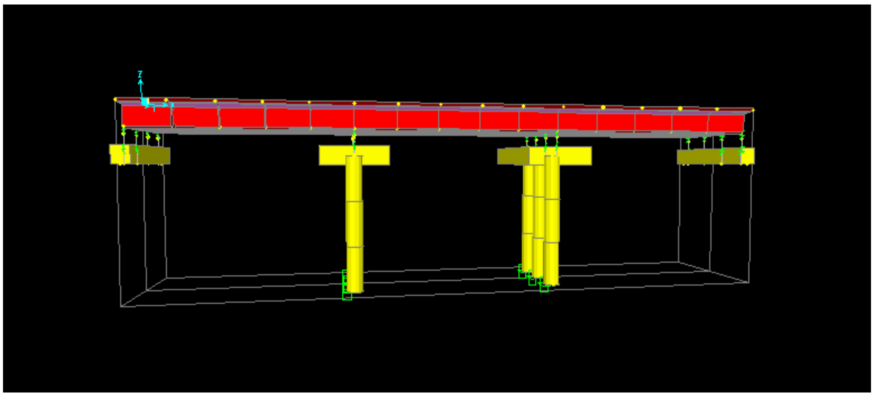

Fig 1 Model of a bridge

VI. Model of RC Bridge With Restrainers

The retrofitted fitted model is same as the model without retrofitting except it consists of additional elements called as restrainers. As discussed earlier, restrainers are connected from the deck slabs to the pier cap or columns or at the abutments. The restrainers used have a length of 0.696m. The area of the restrainers is 6.452 E-04, and the slack length provided is 0.19m.

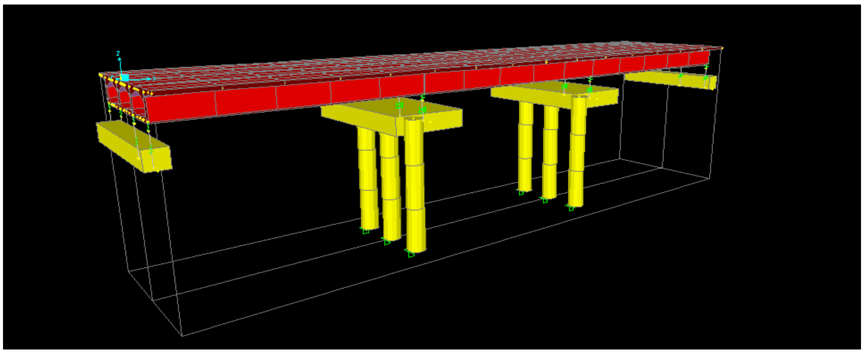

Fig 2 RC bridge model with restrainers

VII. Results And Discussion

1. Introduction: The analysis has been carried out on SAP 2000. The model of the RC bridges has been checked for base reactions, moments and displacement on the bridge piers. The analysis was performed in both longitudinal and transverse directions. Linear analysis was first carried out for the scale factor which was used for the response spectrum analysis as SPECX and SPECY. The time history analysis was carried out for the time history records of Delhi region using Indian Standard code IS1893 (2002) as THX and THY starting from the gravity load as GRAVITY. The time history records consist of 4000 steps with acceleration spaced at 0.02s.

2. Linear Analysis This analysis has been carried out using the Indian standard code IS 1893 (2002) specifications. The soil conditions used in this case is soil type II i.e. medium soil conditions for a zone factor of IV i.e. PGA of 0.24g. The damping ratio used is 0.05%. The scale factor used in this analysis is 1.5 for both the cases. The maximum displacement at the pier top i.e. at joint 1144 for RC bridge without retrofitting is 0.000231m and for the RC bridge with restrainer, the maximum displacement at joint 1144 is 0.00022m.The maximum base reaction obtained is 610.093 KN for the first case and 610.824 KN for the latter case.

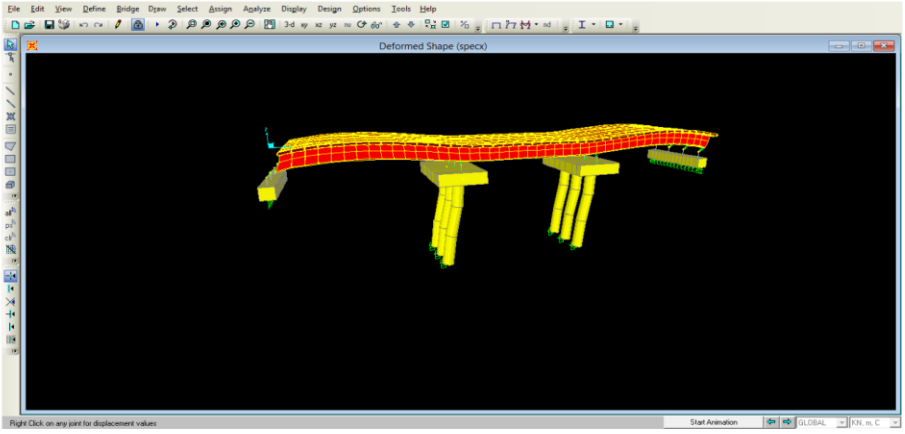

Fig 3 Linear analysis for RC bridge

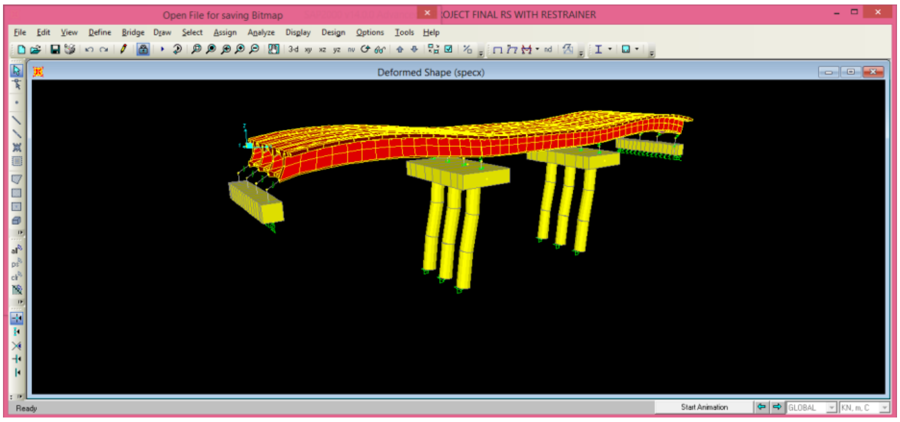

Fig 4 Linear analysis for RC bridge with restrainers

3. Non-Linear Analysis

This non- linear analysis is carried out by using the time history records of Delhi region for hard soil. The specifications from the Indian standard code IS 1893 (2002) have been used. For this analysis, gravity loads have been used. The total numbers of steps are 4000 with acceleration spaced at0.02s. The maximum displacement is checked at top of the pier i.e. at joint 1144 which is 0.035m in x direction and 0.000126 m in y direction for RC bridge without restrainers. For the second case i.e. bridge with restrainers has the maximum displacement at the top of pier as 0.00078m in x direction and 0.000124 m in y direction. The maximum base reaction for RC bridge is 2158.033KN and 2008.527 KN for RC bridge with restrainers.

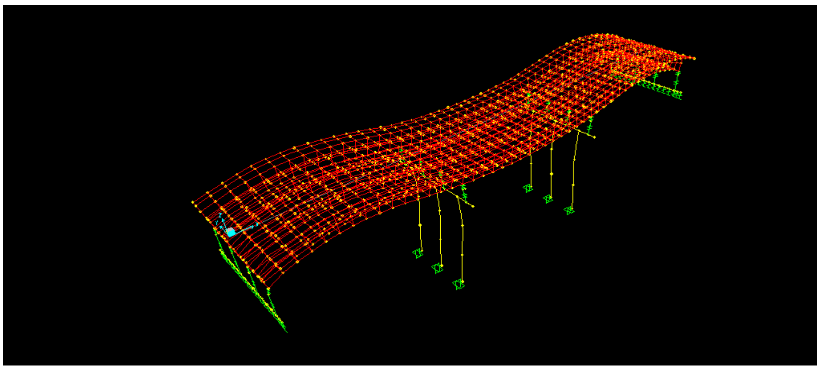

Fig 5 Non-Linear analysis for RC bridge

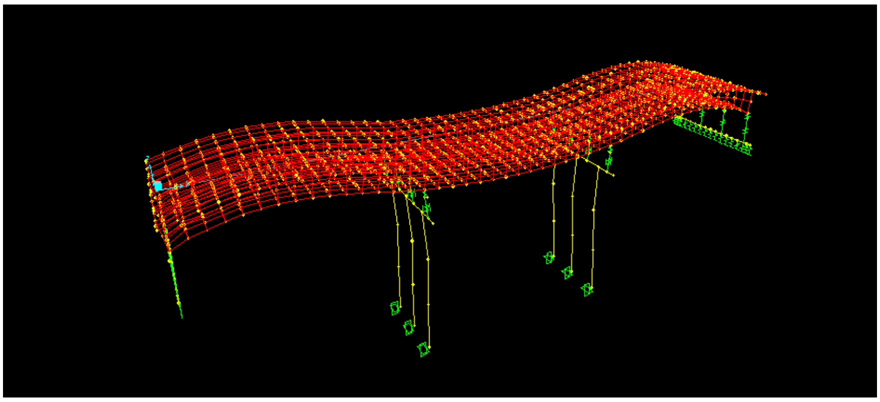

Fig 6 Non-Linear analysis for RC bridge with restrainers

After performing the above mentioned analysis, the displacement and base reactions for both cases are compared for both cases. As it can be seen the restrainers have a huge effect when analysed using non linear analysis for displacement and base reaction.

VIII. Conclusion

Bridge is a structure that extends horizontally and is restrained at both ends. This is what makes it different from the buildings. In this report, the two cases of RC bridge with and without retrofitting have been analysed using SAP 2000. After carrying out the analysis, we conclude that the use of restrainer does affect the seismic stability of the bridge. They limit the span movement in both the directions thus making it seismically more stable.

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