# Comparison of RC Bridges using Pushover Analysis

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**Abstract -** Push over analysis is the nonlinear procedure for seismic assessment of structure. It is performance based analysis. It provides the engineers with a capacity to design structure which is reliable. The seismic response of RC bridge in terms of base shear and displacement on three span and six span bridges with the help of pushover analysis is carried out in this paper. In the present study the bridge is designed as per IS 456:2000, IS 1893:2016 and IRC 6 2016. The push over analysis is performed as per ATC 40 and FEMA 356. The main objective of this study is to compare the capacity of the two bridges of different spans with the help of Non-linear static pushover analysis. The pushover analysis of the bridge carried out using structural analysis and design software CSI Bridge (version 22).

***Key Words:*** Pushover analysis, Bridge structure, Pushover curves, Base shear, inelastic analysis

## 1. INTRODUCTION

Bridge is important structure in road networks for connecting two places. Initial cost of construction of bridges is high. Also it is not possible to construct the bridges in short period of time. Earthquakes makes impacts on the structures like bridges. Therefore, bridge should be designed by considering the earthquake. In India large number of earthquake occurred in last century. More than 50 % area of country is considered prone to damaging earthquake. If bridge gets damage indirectly effects on the growth of country. There is need of studying damage control of bridges.

Elastic analysis provides dynamic response of bridge. It does not provides failure mechanism or redistribution of forces which follows plastic hinges. Inelastic analysis such as nonlinear pushover analysis provides failure mechanism. Force distribution and target displacement are based on time- independent displacement shape. The use of non-linear pushover analysis came in to practice in 1970's but the potential recognized for last 10 to 15 years. Pushover analysis is mainly used to estimate strength and drift capacity of structure. This procedure can be used for new structure. The bridge design code in India does not made the seismic design demand. Therefore to evaluate capacity foreign codes such as FEMA, ATC 40 are taken into consideration.

## 2. BRIDGE CHARACTERISTICS AND MODELLING

For the analysis purpose six models with different characteristics have been prepared on the CSI Bridge software. The characteristics of these six models shown in Table 1, 2, 3,4,5,6.

**Table -1:** Characteristics of Model 1- Three Span RC Bridge

| | | |
|---|---|---|
| 1 | No of Spans | 3 N0 |
| 2 | Length of Each Span | 20 m |
| 3 | Total Length of Bridge | 60 m |
| 4 | Width of Bridge | 7.30 m |
| 5 | Column | 0.60 m x 0.45 m |
| 6 | Beam | 0.60 m x 0.45 m |
| 7 | Concrete | M 40 |
| 8 | Steel | Fe 500 |
| 9 | Foundation | Fixed |
| 10 | Bearing | Fixed |

The three span model of the Bridge is created with the help of CSI Bridge software (version 22) as shown in Fig.1

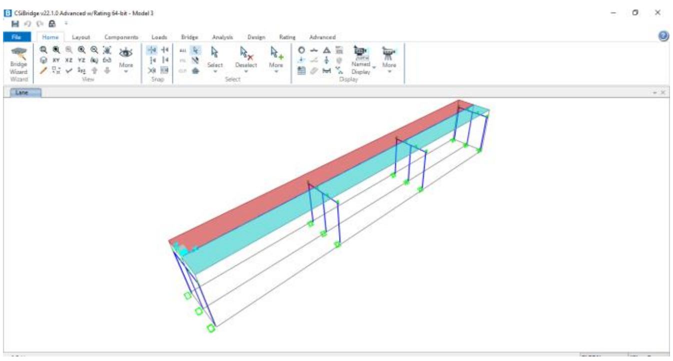

**Fig -1**: Model 1- Three Span RC Bridge in CSI Bridge Software

**Table -2:** Characteristics of Model 2- Six Span RC Bridge

| | | |
|---|---|---|
| 1 | No of Spans | 6 N0 |
| 2 | Length of Each Span | 10 m |
| 3 | Total Length of Bridge | 60 m |
| 4 | Width of Bridge | 7.30 m |

| | | |
|---|---|---|
| 5 | Column | 0.60 m x 0.45 m |
| 6 | Beam | 0.60 m x 0.45 m |
| 7 | Concrete | M 40 |
| 8 | Steel | Fe 500 |
| 9 | Foundation | Fixed |
| 10 | Bearing | Fixed |

The six span model of the Bridge is created with the help of CSI Bridge software (version 22) as shown in Fig 2.

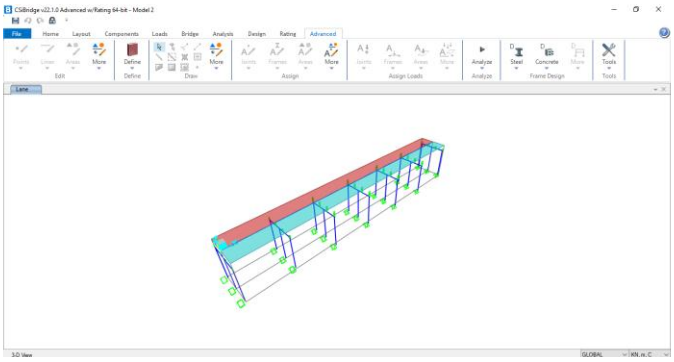

**Fig -2**: Model 2- Six Span RC Bridge in CSI Bridge Software

**Table -3:** Characteristics of Model 3- Three Span RC Bridge

| | | |
|---|---|---|
| 1 | No of Spans | 3 N0 |
| 2 | Length of Each Span | 20 m |
| 3 | Total Length of Bridge | 60 m |
| 4 | Width of Bridge | 7.30 m |
| 5 | Column | 0.60 m x 0.45 m |
| 6 | Beam | 0.60 m x 0.45 m |
| 7 | Concrete | M 30 |
| 8 | Steel | Fe 500 |
| 9 | Foundation | Fixed |
| 10 | Bearing | Fixed |

**Table -4:** Characteristics of Model 4- Six Span RC Bridge

| | | |
|---|---|---|
| 1 | No of Spans | 6 N0 |
| 2 | Length of Each Span | 10 m |
| 3 | Total Length of Bridge | 60 m |
| 4 | Width of Bridge | 7.30 m |
| 5 | Column | 0.60 m x 0.45 m |
| 6 | Beam | 0.60 m x 0.45 m |
| 7 | Concrete | M 30 |
| 8 | Steel | Fe 500 |
| 9 | Foundation | Fixed |
| 10 | Bearing | Fixed |

**Table -5:** Characteristics of Model 5- Three Span RC Bridge

| | | |
|---|---|---|
| 1 | No of Spans | 3 N0 |
| 2 | Length of Each Span | 20 m |
| 3 | Total Length of Bridge | 60 m |
| 4 | Width of Bridge | 7.30 m |
| 5 | Column | 0.60 m x 0.45 m |
| 6 | Beam | 0.60 m x 0.45 m |
| 7 | Concrete | M 30 |
| 8 | Steel | Fe 415 |
| 9 | Foundation | Fixed |
| 10 | Bearing | Fixed |

**Table -6:** Characteristics of Model 5- Six Span RC Bridge

| | | |
|---|---|---|
| 1 | No of Spans | 6 N0 |
| 2 | Length of Each Span | 10 m |
| 3 | Total Length of Bridge | 60 m |
| 4 | Width of Bridge | 7.30 m |
| 5 | Column | 0.60 m x 0.45 m |
| 6 | Beam | 0.60 m x 0.45 m |
| 7 | Concrete | M 30 |
| 8 | Steel | Fe 415 |
| 9 | Foundation | Fixed |
| 10 | Bearing | Fixed |

## 3. LOADING

Loads are considered as per IRC 6: 2016.

## 3. ANALYSIS

Pushover is a static nonlinear analysis method where a structure is subjected to gravity loading and a monotonic displacement controlled lateral; load pattern which continuously increases through elastic and inelastic behavior until an ultimate condition is reached. Lateral load may represent the range of base shear induced by Earthquake loading and its configuration may be proportional to the distribution of mass along structure height, mode shape.

Output generates static pushover curve which plots a strength-based parameter against deflection. For example, performance may relate the strength level achieved in certain members to the lateral displacement at the top of the structure, or bending moment may be plotted against plastic rotation. Results provide insight into the ductile capacity of the structural system, and indicate the mechanism, load level and deflection at which failure occurs. When analyzing frame objects material non linearity is assigned to discrete hinge locations where plastic rotation occurs according to FEMA 356 criteria. During the static pushover analysis strength drops, displacement controlled and all other nonlinear software features including link assessment P delta effect and staged constructions are considered. The different models with changing span, Grade of concrete and grade of steel are analyzed.

In this case pushover analysis is performed for the bridge on CSI Bridge software by considering gravity, push x and push y load cases. Pushover curves were obtained from the pushover analysis.

## 4. RESULTS

The Pushover analysis is carried out for six models. The pushover curves for model 1 in 'X' Direction (longitudinal) and in 'Y' Direction are shown in figure 3 and 4. A brief comparison of results were tabulated in the table no 8. Base shear for different models is shown in table 7.

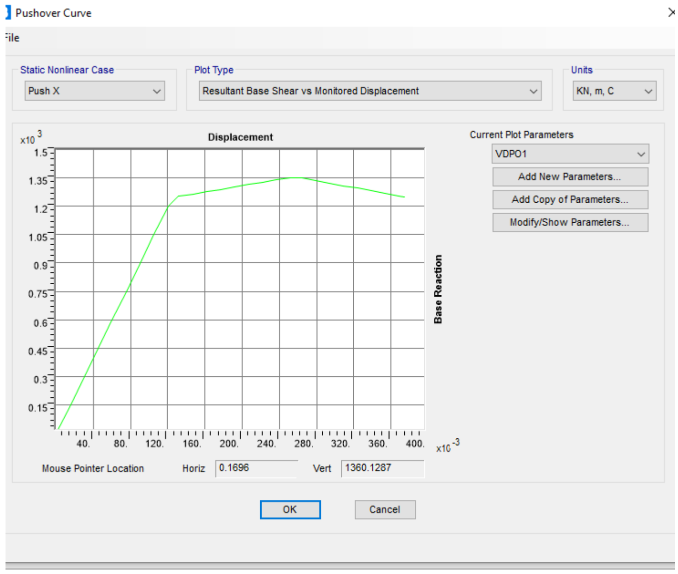


**Fig -3**: Model1- Pushover Curve in Longitudinal Direction

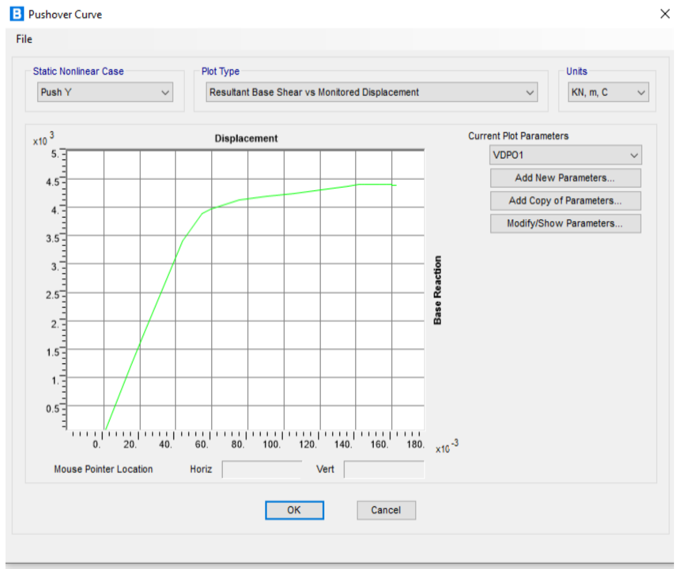


**Fig -4**: Model1- Pushover Curve in Lateral Direction

**Table -7:** Model Base Shear

| Model | Description | Base shear in x direction KN | Base shear in Y direction KN |
|---|---|---|---|
| 1 | M 40 and Fe 500 (3 Span) | 1351.30 | 4407.50 |
| 2 | M 40 and Fe 500 (6 Span) | 2282.07 | 7664.39 |
| 3 | M 30 and Fe 500 (3 Span) | 1294.03 | 4167.61 |
| 4 | M 30 and Fe 500 (6 Span) | 2184.54 | 7296.66 |
| 5 | M 30 and Fe 415 (3 Span) | 1148.16 | 3736.13 |
| 6 | M 30 and Fe 415 (6 Span) | 1928.95 | 6485.37 |

**Table -8: Bridge Model comparison on base shear**

| Model | Comparison between | Base shear % increase | Base shear % increase |
|---|---|---|---|
| 1 | Model 1 and Model 3 | 4.23 | 5.44 |
| 2 | Model 1 and Model 5 | 15.03 | 15.23 |
| 3 | Model 2 and Model 4 | 4.27 | 4.89 |
| 4 | Model 2 and Model 6 | 15.47 | 15.38 |
| 5 | Model 1 and Model 2 | 40.78 | 42.49 |
| 6 | Model 3 and Model 4 | 40.76 | 42.88 |
| 7 | Model 5 and Model 6 | 40.47 | 42.39 |

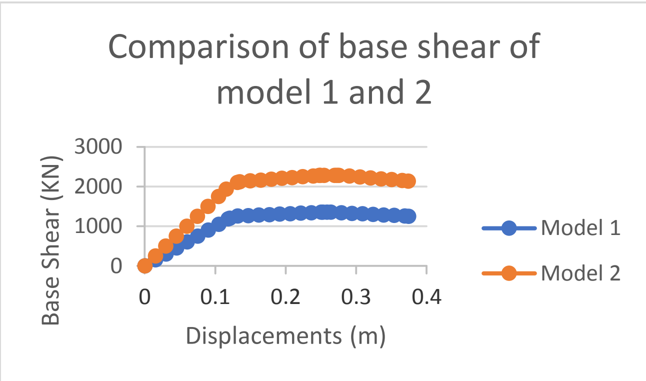


**Chart -1**: Comparison of base shear of model 1 and 2 in x direction

The comparison of the Model 1 and Model 2 has been made on the basis of displacement vs base share as shown in Chart 1 due to its drastic change of base shear.

## 5. CONCLUSIONS

From the results obtained,
1) For the same length and width of bridge, by changing the span width, Grade of Concrete and Grade of Steel, the base force taken by short span bridge in X direction is 40.78% more than bridge with long span. Similarly the base force taken by short span bridge in Y direction is 42.49% more than bridge with long span.

2) When the span and Grade of steel is remains constant and only change in Grade of Concrete, the base force taken by short span bridge in X direction is 4.23% more than bridge with long span. Similarly the base force taken by short span bridge in Y direction is 5.44% more than bridge with long span.

3) When the span remains constant and change in Grade of Concrete and Grade of Steel, the base force taken by short span bridge in X direction is 15.03% more than bridge with long span. Similarly the base force taken by short span bridge in Y direction is 15.23% more than bridge with long span.

4) As the base shear values in ' Y' direction are more than in 'X' direction, bridge is stronger in 'Y' direction.

From the above conclusions change in span length, Grade of Concrete and Grade of Steel directly affects the base shear capacity of the bridge structure.

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