Parametric Study of Solid Circular RCC Pier with Emphasis on Seismic Design

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Abstract— This work describes the parametric study for the analysis and design of Reinforced Concrete (RC) bridge piers with solid circular cross sections which are typically used in deep valley bridge viaducts. The adequacy of the cross sections of piers has been studied for 2 lane road bridges for 5m to 20m in height for 16m span bridge. "MIDAS CIVIL" software is used as a platform for the analysis and design. The aim of this study is to generate database for preliminary design of pier R.C. bridges under seismic loading. Using the database, the user would be able to establish design of the bridges, given the structural scheme and other design parameters, understanding the behaviour of pier of RCC bridges under seismic condition and also Design of Pier as per IRC: 112-2011 (Ultimate Limit State).The study report contains charts that represent utilization ratio and percentage of steel for initial estimates for different types of pier forms for RCC bridges. And finally, Parametric study is done to obtain economic diameter of the pier for which we get optimize design of the pier.

Key words: RCC Bridge Piers, Solid Circular RCC Pier

I. Objective of Work

- To study the behavior of reinforced concrete pier under seismic forces.
- To study the change in seismic behavior of pier by the changes in diameter of pier.
- To study the change in seismic behavior of pier by the changes in span of bridge.
- Variation of utilization ratio, % of steel, dynamic period and displacement of pier in different conditions.
- Finally to design a RCC circular pier for higher utilization ratio & better seismic performance.

II. Scope of Work

- To carry out analysis and to optimize design of pier of 16 m span bridge deck with different height and critical loadings as per IRC using MIDAS CIVIL.
- Parameters for which comparison is done are
  1) Utilization Ratio
  2) Dynamic period
  3) Displacements in along and across span
  4) Percentage of steel

III. Introduction

A. General Overview

In recent time, bridge engineering is extending their limits and accepting new challenges for designing the better bridges and strengthening of existing ones. The span and the height of the bridges increase day by day, many records are sets and broken in very quick succession.

The past two decade have been unprecedented growth of the knowledge in the field of concrete bridges, development of new structural forms, and new methods of computer based analysis and design and development of high strength materials. The need of new rationalized methods for bridge structure in general, based on limit state approach, in line with international practices, has been felt for long time. Keeping view of this, the task of this study for concrete bridges is to establish a common procedure for design of bridges with consideration of earthquake effects in India, based on the limit state method.

Mountain Bridges is generally consists of variable pier heights, so not only the geometry of the bridge will affect its earthquake response, the height and type of pier major factors affecting earthquake response. Under the earthquake, the combination of high pier and short pier made the force of bridge even more complicated. An earthquake is a sudden, violent shaking of the ground .Earthquake is the worst among the natural disasters. It is very important to design the structure after the understanding the behavior of the earthquake. The structural designer has many alternatives to select form when defining a structural system that fit the architectural layout.

B. Bridge Loading

- Dead and Superimposed Dead Load For general and building structures, dead or permanent loading is the gravity loading due to the structure and other items permanently attached to it. It is simply calculated as the product of volume and material density. Superimposed dead load is the gravity load of non-structural parts of the bridge. Such items are long term but might be changed during the lifetime of the structure. An example of superimposed dead load is the weight of the parapet. There is clearly always going to be a parapet so it is a permanent source of loading. However, it is probable in many cases that the parapet will need to be replaced during the life of the bridge and the new parapet could easily be heavier than the original one. Because of such uncertainty, superimposed dead load tends to be assigned higher factors of safety than dead load. The most notable item of superimposed dead load is the road pavement or surfacing. It is not unusual for road pavements to get progressively thicker over a number of years as each new surfacing is simply laid on top of the one before it. Thus, such superimposed dead loading is particularly prone to increases during the bridge lifetime. For this reason, a particularly high load factor is applied to road pavement. Bridges are unusual among structures in that a high proportion of the total loading is attributable to dead and superimposed dead load. This is particularly true of long-span bridges.

- Live loads Road bridge decks have to be designed to withstand the live loads specified by Indian Roads Congress (I.R.C: 6-2014). Highway bridges: In India, highway bridges are designed in accordance with IRC bridge code. IRC: 6 -2014 gives the specifications for the various loads and stresses to be considered in bridge design. There are three types of standard loadings for which the bridges are designed namely, IRC class AA loading, IRC class a loading and IRC class B loading.

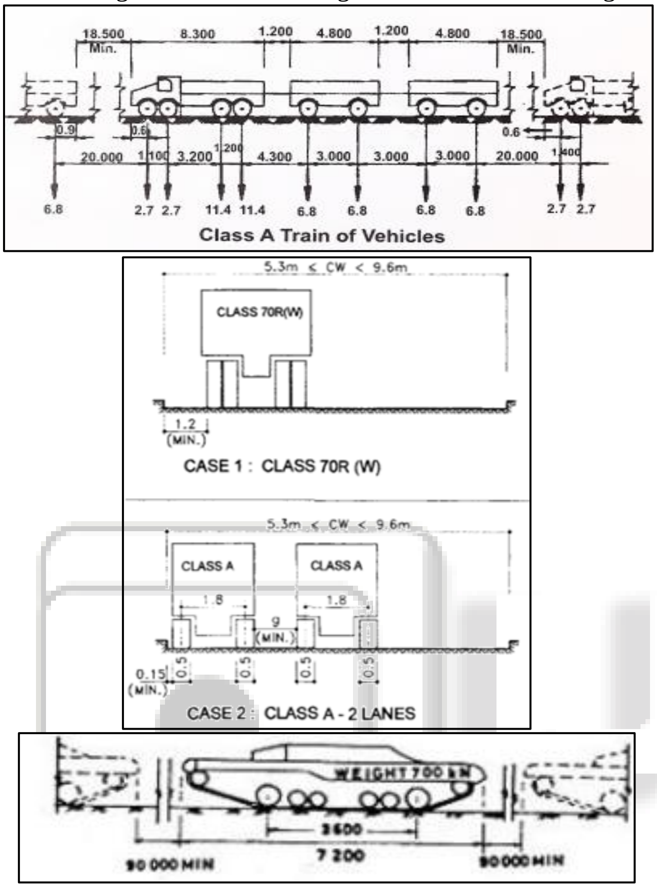


Fig. 1: Bridge Loading

IV. SEISMIC EFFECT ON BRIDGE

For the severe damage of bridges in the past earthquakes, most designers have pay attention to the seismic design of high piers for mountain bridges. It is difficult to repair after the bridge damaged by the earthquake, because designers of domestic and foreign lack the design experience about high piers under high intensity earthquake.

The damage of the major earthquake in the world, the damage of high piers bridge in mountain mainly focuses on the following. First, the damage of abutment, such as position of abutment changed, abutment settlement, wing-wall damaged and cracking, dislocation of construction joints as well as collision and damage of the main beam. Second, the damage of piers and piles, such as piers and piles inclined, breaking and cracking, the steel yielded of lower part of concrete bridge pier, etc. The damage of main beams, falling of the beam is the most common, the reasons are the collapse of piers, damage of supports, collision of beams and large relative displacement between adjacent piers resulted in lacking of adequate beam device. Third, the damage of supports, such as supports inclined, cut, anchor bolt pullout, roller supports rolling off, supports its own destruction, etc.

Fig. 2: Displacement and Rotation of Bridge

Fig. 3: Damages in Pier

Fig. 4: Damages in Bearings

V. DESIGN EXAMPLE

- Clear width of roadway= 7.5m
- Span centre to centre of bearings =16m
- Average thickness of wearing coat = 80mm

A. *Cross section of Deck*

Three main girders are provided at 3.0m centre to centre

- Thickness of deck slab = 200mm
- Wearing coat = 80mm
- Width of main girders = 300mm
- Cross girders are provided at every 4m interval
- Breadth of cross girder = 300mm
- Depth of main girder = 160cm at the rate of 10cm per meter of span

The depth of cross girder is taken as equal to the depth of main girder to simplify the computation

The bridge is first analysed using I.R.C. specifications.

The bridge is analysed as follows:

VI. MODELLING OF TEE BEAM BRIDGE GIRDER IN MIDAS

Modelling of the bridge is done in MIDAS CIVIL the rendered view is shown below.

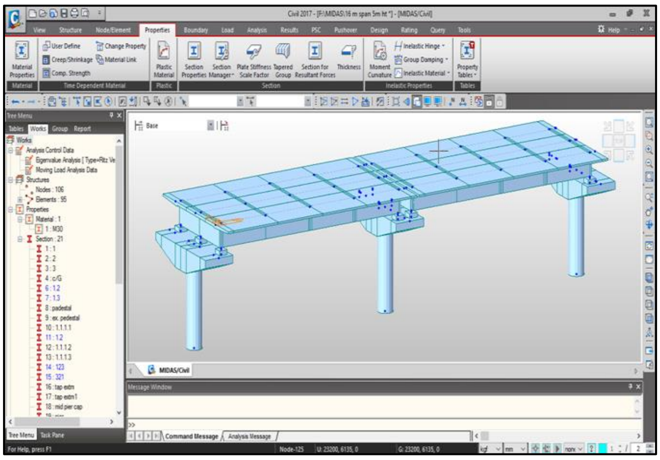
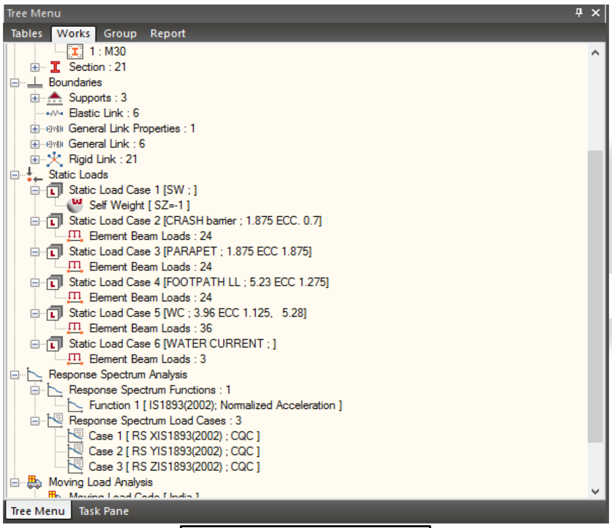


Fig. 5: Modelling

A. *Loading*

All types of loads are applied in Midas such as self weight, earthquake foeces, vehicular load, superimposed load and water current forces.



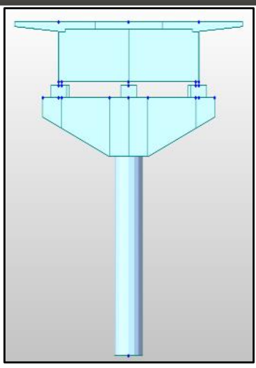


Fig. 6: Loading

VII. PARAMETRIC STUDY

A. *Parametric Study*

- Diameter of pier ranging from 0.9 m to 2.5 m.
- Height of pier 5m,10m, 15m and 20m
- Thus 27 models with diameter from varying from 0.9 m to 2.5 m and height varying from 5m to 20m are taken for parametric study.
- Following parameters are compared
  - Utilization Ratio
  - Percentage of steel
  - Displacement in along/across span direction
  - Dynamic period

16 M span	Utilisation Ratio							
Dia (m)	0.9	1	1.25	1.5	1.75	2	2.25	2.5
5m Ht	0.958	0.97	0.9602			0.235	0.168	0.128
10m Ht	0.973	0.968	0.958	0.973	0.726	0.461	0.234	0.175
15 m Ht	NA	NA	0.97	0.965	0.959	0.701	0.51	0.241
20 m ht	NA	NA	NA	0.978	0.977	0.974	0.806	0.556

Table 1: Parametric Study

16 M span	% of steel							
Dia (m)	0.9	1	1.25	1.5	1.75	2	2.25	2.5
5m Ht	2.7	1.68	0.47	0.2	0.2	0.2	0.2	0.2
10 m Ht	3.9	2.81	0.97	0.25	0.2	0.2	0.2	0.2
15 m Ht	NA	NA	2.27	0.823	0.293	0.2	0.2	0.2
20 m ht	NA	NA	NA	1.74	0.76	0.333	0.2	0.2

Table 2: Parametric Study

16 M span	Displacement along span Direction Dx (mm)							
Dia (m)	0.9	1	1.25	1.5	1.75	2	2.25	2.5
5m Ht	7	5.18	2.57	1.31	0.735	0.476	0.33	0.237
10 m Ht	13.87	11.19	7.87	6.21	3.92	2.41	1.51	1
15 m Ht			9.3	9.93	7.78	6.22	5.55	3.95
20 m ht				14.51	11.6	9.51	7.97	6.78

Table 3: Parametric Study

16 M span	Displacement in across span Direction Dy (mm)							
Dia (m)	0.9	1	1.25	1.5	1.75	2	2.25	2.5
5m Ht	13.7	9.8	4.715	2.5168	1.448	0.88	0.565	0.379
10 m Ht	36.28	25.52	12.27	6.67	3.21	2.44	1.6	1.08
15 m Ht			21.98	11.89	7.01	4.41	3.16	2.01
20 m ht				18.04	10.58	6.65	4.41	3.1

Table 4: Parametric Study

16 M span	Dynamic Period (sec)

Dia (m)	0.9	1	1.25	1.5	1.75	2	2.25	2.5
5m Ht	1.275	1.052	0.7137	0.5358	0.436	0.38	0.35	0.335
10 m Ht	2.5	2.045	1.35	0.97	0.74	0.59	0.497	0.431
15 m Ht			2.17	1.55	1.18	0.93	0.796	0.65
20 m ht				2.27	1.72	1.37	1.12	0.95

Table 5: Parametric Study

VIII. Comparison of Results

Results from MIDAS CIVIL obtained are compared

The following graph shows the variation of Utilization Ratio with respect to height and diameter of Pier.

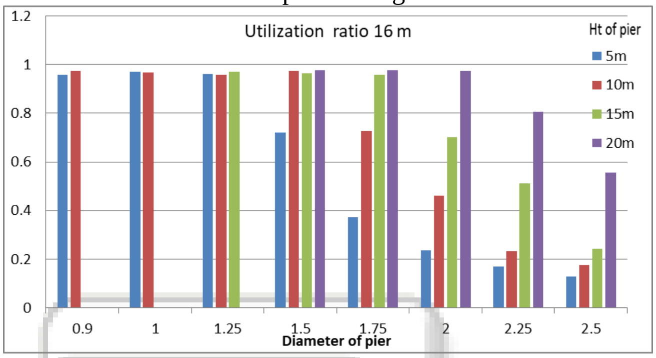


Fig. 7: Variation of Utilization Ratio with respect to height and diameter of Pier

The following graph shows the variation of % of steel with respect to height and diameter of Pier.

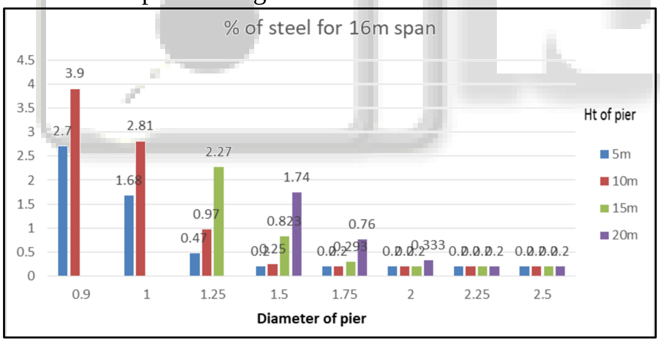


Fig. 8: Variation of % of steel with respect to height and diameter of Pier

The following graph shows the variation of Displacement along span direction with respect to height and diameter of Pier.

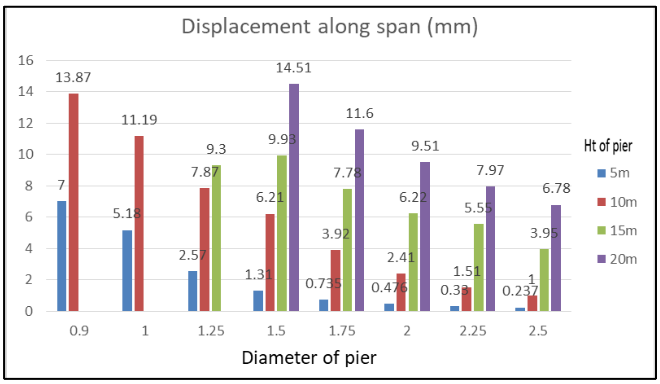


Fig. 9: variation of Displacement along span direction with respect to height and diameter of Pier

The following graph shows the variation of Displacement across span direction with respect to height and diameter of Pier.

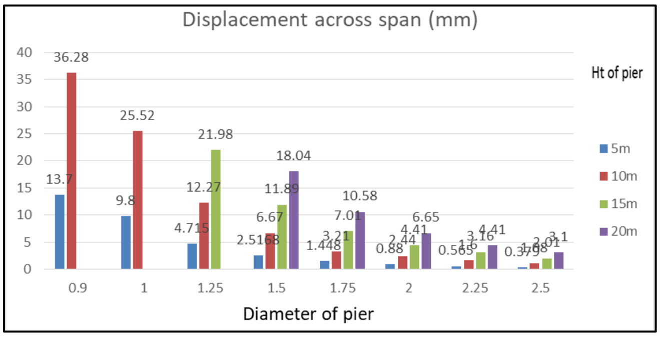


Fig. 10: Variation of Displacement across span direction with respect to height and diameter of Pier

The following graph shows the variation of Dynamic period with respect to height and diameter of Pier

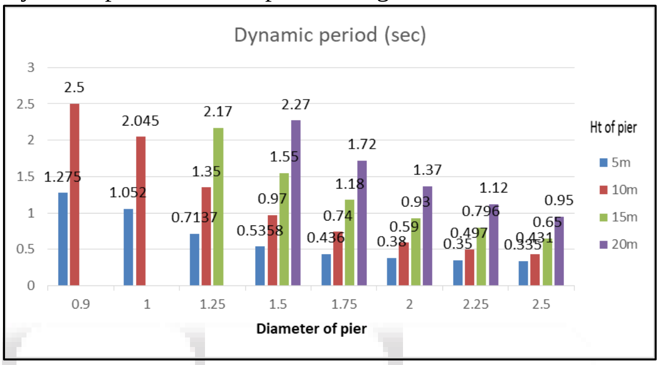


Fig. 11: Variation of Dynamic period with respect to height and diameter of Pier

IX. Conclusion

- It is found that pier having diameter from 0.9 to 1.25m gives optimized design for pier height from 5 to 10 m.
- It is found that pier having diameter from 1.5 to 1.75 m gives optimized design for pier height from 15 to 20 m.
- It is found that pier having diameter from 2.0 to 2.5m give maximum utilization ratio only in case of 20 m height of pier.
- As increasing the height of pier displacement going on increase rapidly in either or direction and simultaneously dynamic period goes on decreasing.

References

[1] IRC 6 -2014 Code Of Practice For Standard Specifications And Code Of Practice For Road Bridges
[2] IRC: 112-2011 Code Of Practice For Concrete Road Bridges
[3] Indian Standard Code Of Practice For Plain And Reinforced Concrete, Is 456-2000, Indian Standard Institution ,New Delhi
[4] Ye Zheng-wei, Xiang Yi-qiang1, Ye Zheng-wei* Analysis and Comparison on Wind Load of Long Span Girder Bridges with High Pier,2011
[5] Francisco J. Martínez , Fernando González-Vidosa Design of tall bridge piers by ant colony optimization.2011
[6] A.Rahai and M.Arezoumandi "Effect of Vertical Motion Of Earthquake on RC Bridge PIR" 14th World Conference on Earthquake Engineering