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Parametric study of RC Bridge piers with State-of-The-Art ductility provisions

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Abstract*— Bridges form a key component of a country's infrastructure.as these are very important structures it is very essential that they should be structurally sound. In case of an earthquake event, bridges are very essential for transportation and post-earthquake relief measures. The earthquake resistance of a structure is dependent largely on its ductility rather than strength, and hence the ductility of bridges is an important aspect. Since in bridges only the piers are allowed to undergo inelastic deformations, the ductile performance of piers plays a critical role. Considering this, IRC 112-2011 has given ductile detailing provisions to be mandatorily followed for bridges in seismic zones III, IV and V. In this study, a highway bridge in seismic zone IV has been considered. A comparison has been made for transverse confinement reinforcement as per IRC 112-2011, RDSO Seismic Design Guidelines - 2015 and AASHTO LRFD Bridge Design Specifications. Besides the effect of various parameters which include different shapes, heights, cross section sizes, spans and concrete grades on the displacement ductility of piers has been worked out by carrying out moment curvature analysis. Also the effect of change in form (i.e cantilever vs portal pier) on displacement ductility has been studied.

***Keywords*— Bridge pier, confinement, displacement ductility, ductile detailing, moment curvature.**

I. Introduction

Bridges are the structures that link any two points by crossing any obstruction. Because of their functional utility, these structures should remain usable even after an event of earthquake so as to allow transportation of relief materials from one place to another and for maintaining accessibility of affected people to other parts for availing medical facilities, etc.

The superstructure generally does not enter the inelastic stage during an earthquake. Therefore, ductility of superstructure under seismic shaking has not been a major concern in bridge superstructures during past earthquakes.

Earthquakes do not apply direct force on the structure, rather the force is generated due to inertia of the moving body. In a seismic event, ductility of a structure is of much more importance as compared to strength. However, in bridges, the only structural component that can undergo inelastic deformations to dissipate energy imparted by earthquake shocks are the piers. Thus the ductility of piers is of utmost importance.

In lieu of globally changing design procedures, Indian Road Congress (IRC) has also incorporated ductility provisions in the unified code for concrete and prestressed concrete structures i.e. IRC 112-2011 : Code of practice for concrete road bridges. The inelastic behavior of the concrete structures largely depends on the detailing adopted. Keeping this in mind, an entire chapter has been dedicated to ductile detailing of structural elements for seismic resistance. These provisions were however missing in the predecessors of IRC 112 i.e. IRC 18 and IRC 21. The RDSO guidelines have also given due importance to ductile detailing.

II. Objectives

The emphasis of this study is to analyze the bridge piers designed as per IRC 112-2011 LSM method for displacement ductility and its dependence on various parameters. This study has been carried out for a 3 lane highway bridge on a river in seismic zone IV. The forces acting on pier have been calculated as per IRC 6-2017.

Following variations have been carried out to study variation in displacement ductility:

a) Code for confinement reinforcement: IRC 112, RDSO Seismic Design Guidelines, AASHTO LRFD Bridge design specifications

b) Grade of concrete: M40, M45, M50

c) Shape of cross section: Solid circle, Solid Square, Solid Diamond, Hollow Circle, Hollow Square

d) Height: 11.2m, 8.7m, 6.4m

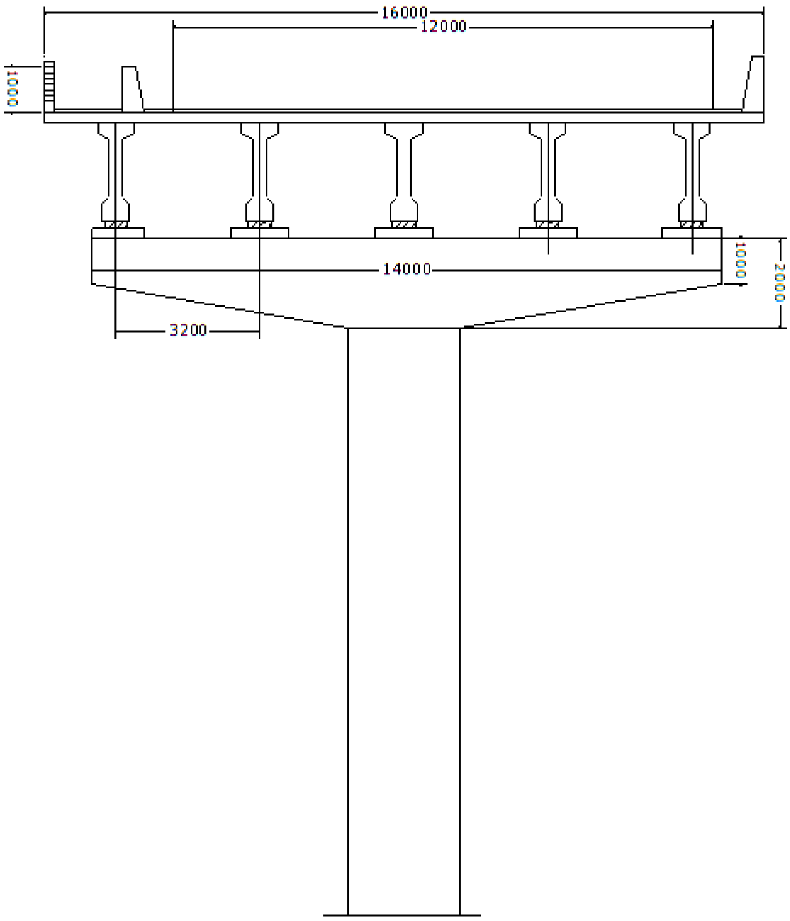
e) Span: 20m simply supported PSC span, 40m simply supported PSC span

f) Form: Cantilever solid circle, Portal solid circle

III. METHODOLOGY

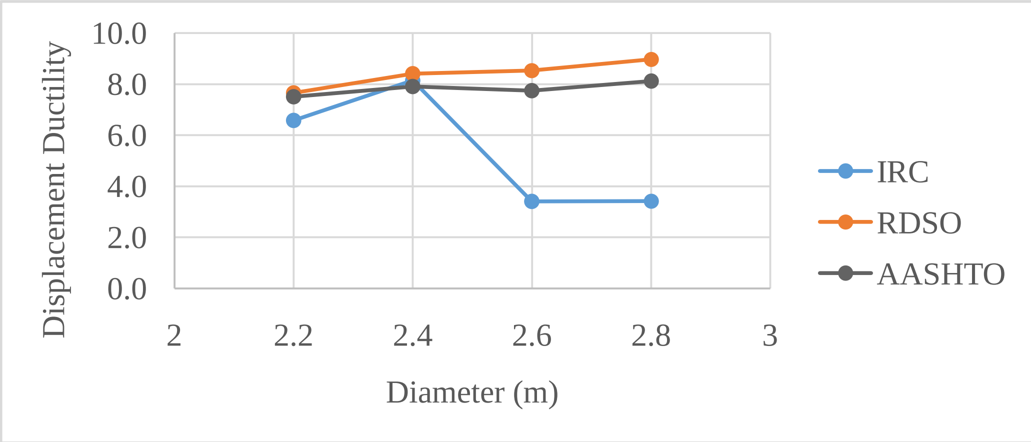
The piers have been designed as per IRC 112-2011 equivalent rectangular stress block for strength combinations. Stresses in pier sections were also checked for rare combination as per IRC 6-2017. The reinforcement grade has been adopted as Fe500D for longitudinal as well as confinement reinforcement, as it satisfies the minimum percentage elongation criteria for seismic zone IV. The base of piers is considered to be fixed.

Once the piers are designed, moment curvature analysis is carried out in MIDAS GSD (general section designer). For hollow piers the stress strain curve for confined concrete as specified in IRC 112-2011 has been used. The displacement ductility capacity is then calculated as per CALTRANS SDC.

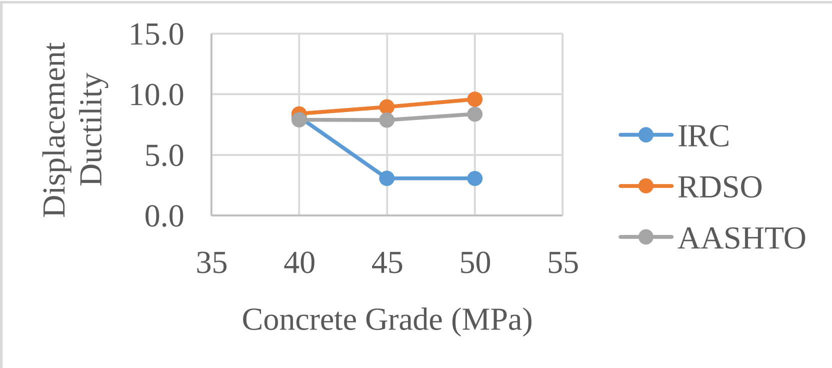


Pier and superstructure configuration-Dimensions in mm (pier heights are variable)

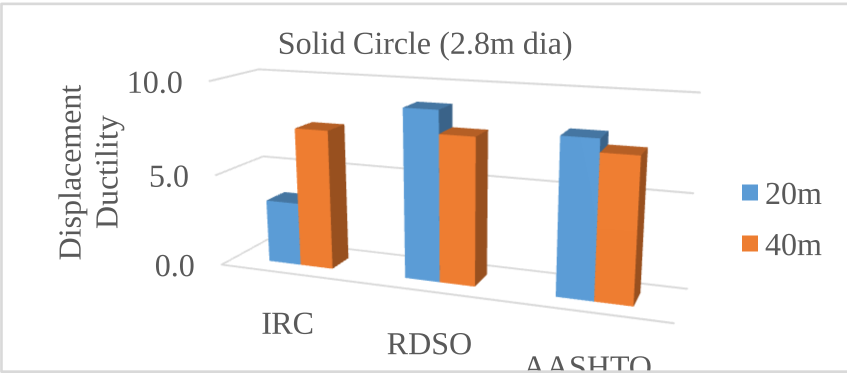
IV. RESULTS



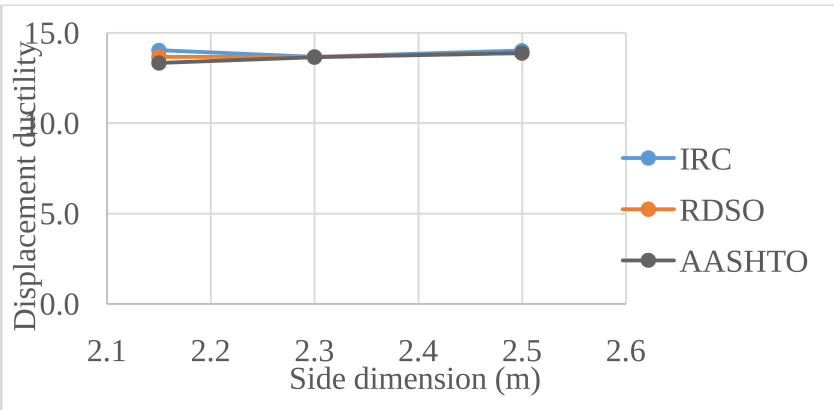
Displacement ductility - Solid circle - size variation



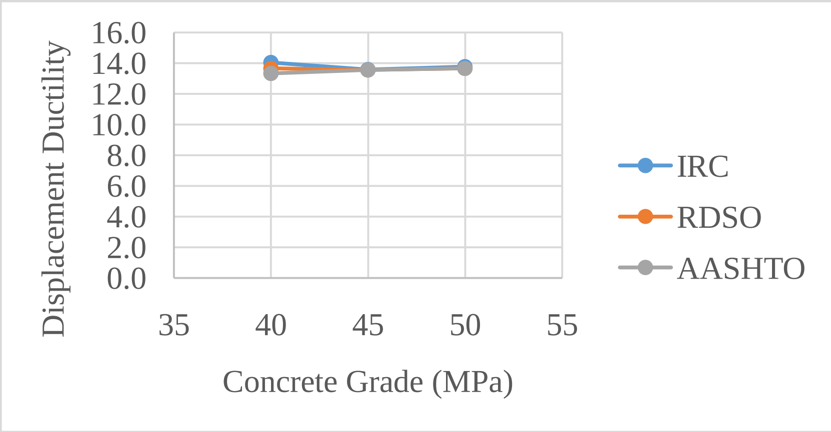
Displacement ductility - Solid circle - concrete grade variation



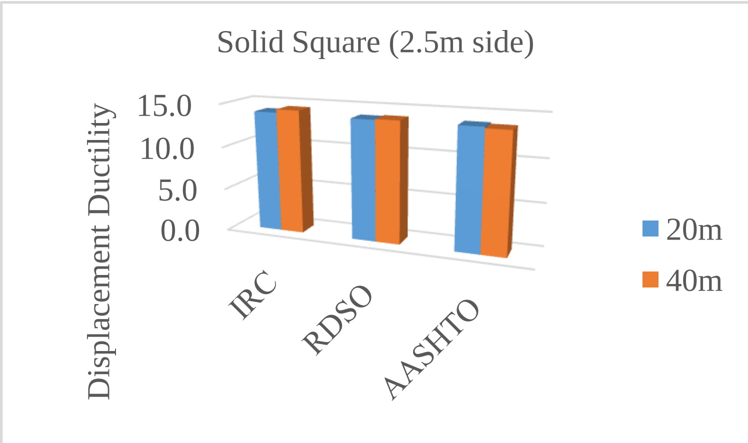
Displacement ductility - Solid circle - span variation



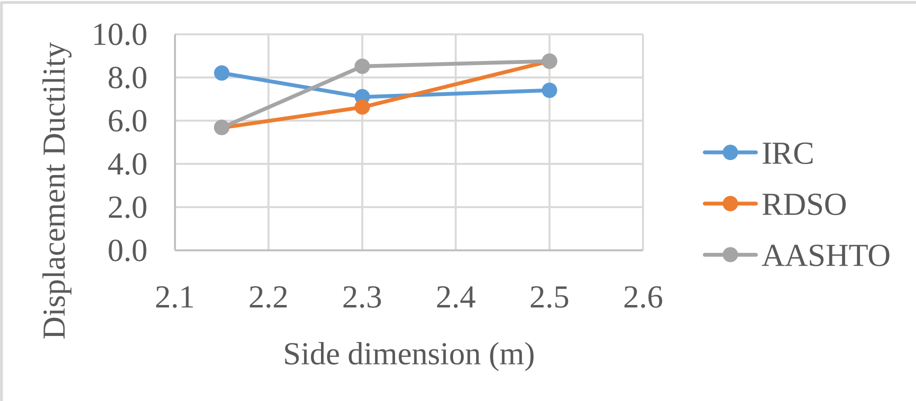
Displacement ductility - Solid Square - size variation



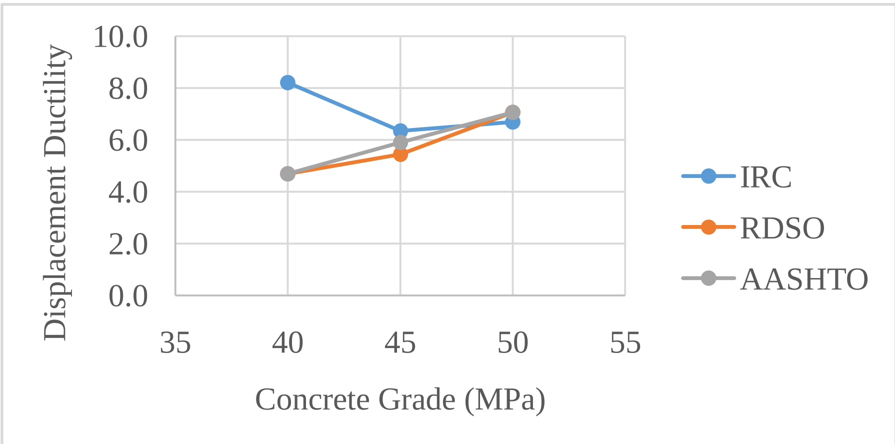
Displacement ductility - Solid Square - concrete grade variation



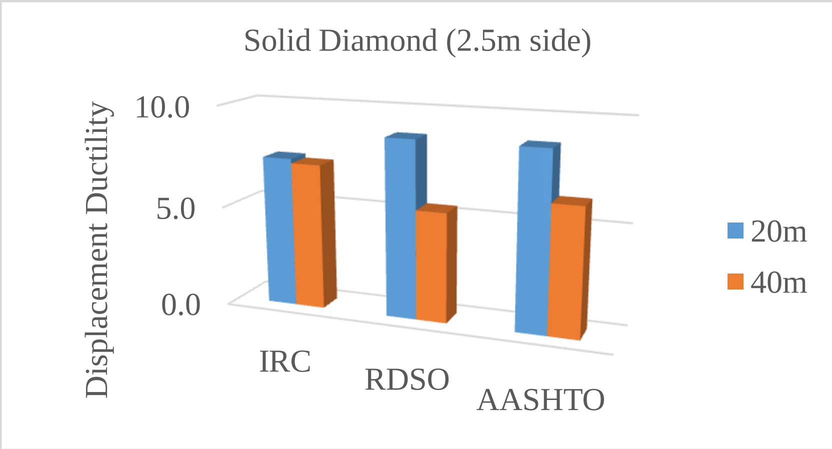
Displacement ductility - Solid Square - span variation



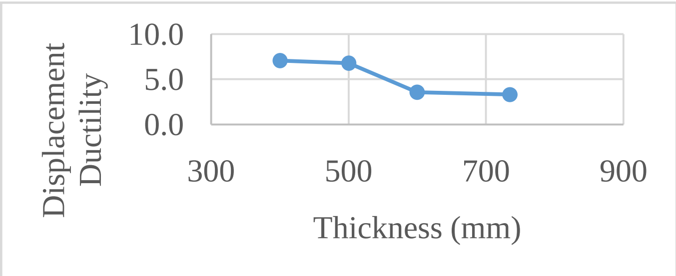
Displacement ductility - solid diamond - size variation



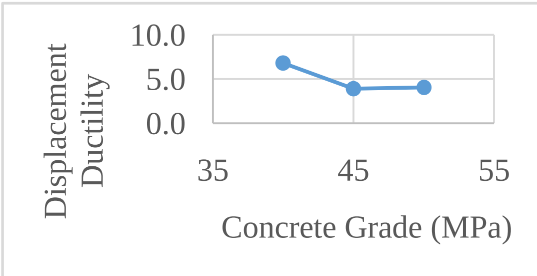
Displacement ductility - solid diamond - concrete grade variation



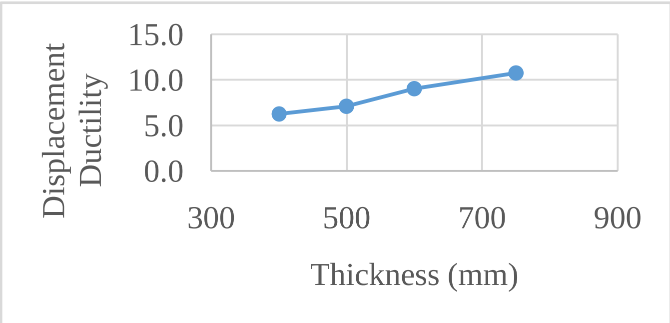
Displacement ductility - solid diamond - span variation



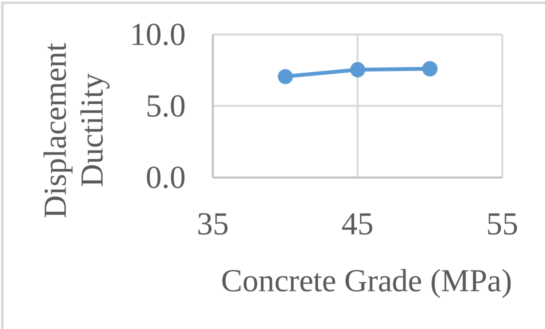
Displacement ductility - hollow circle - size variation



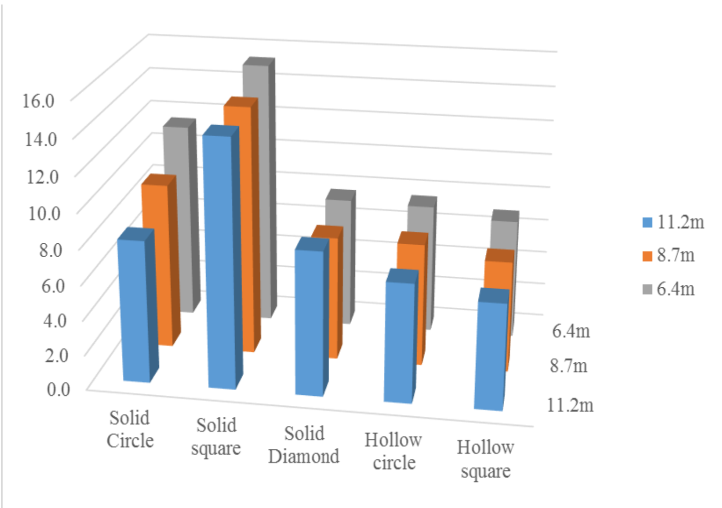
Displacement ductility - hollow circle - grade variation



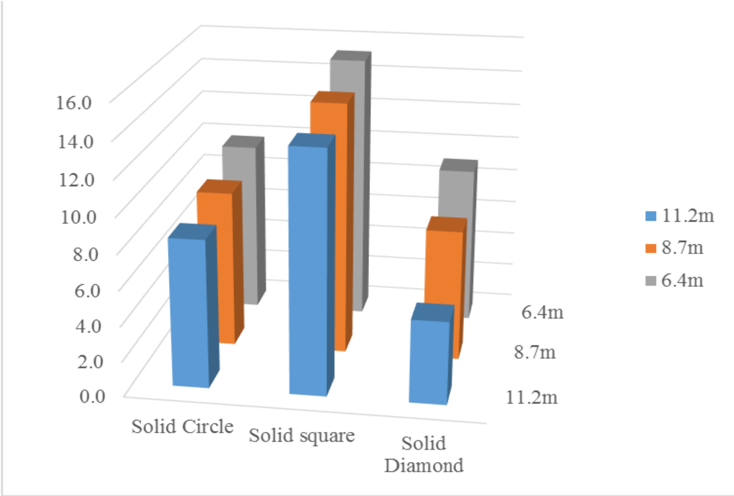
Displacement ductility - Hollow Square - size variation



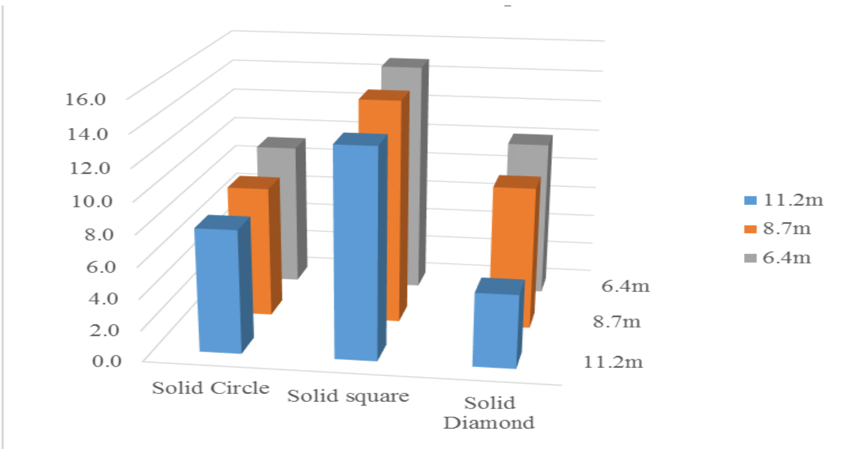
Displacement ductility - Hollow Square - grade variation



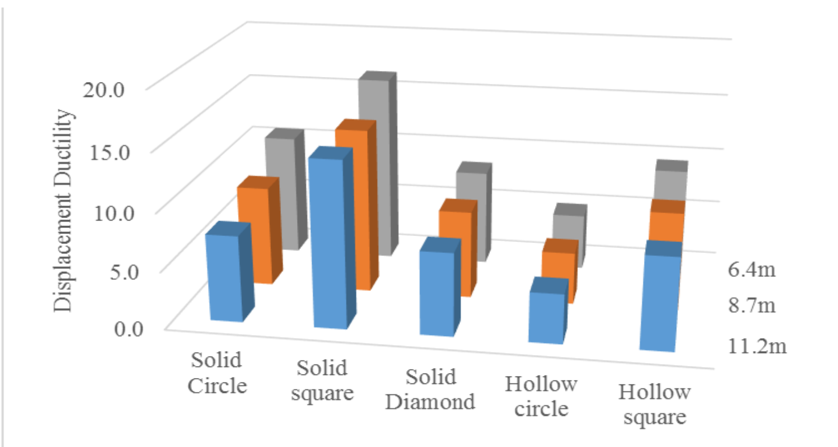
Variation in displacement ductility with height - 20m span – IRC



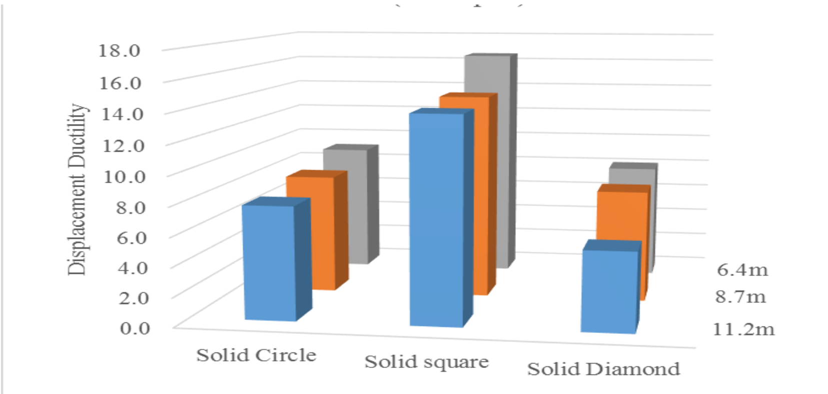
Variation in displacement ductility with height - 20m span – RDSO



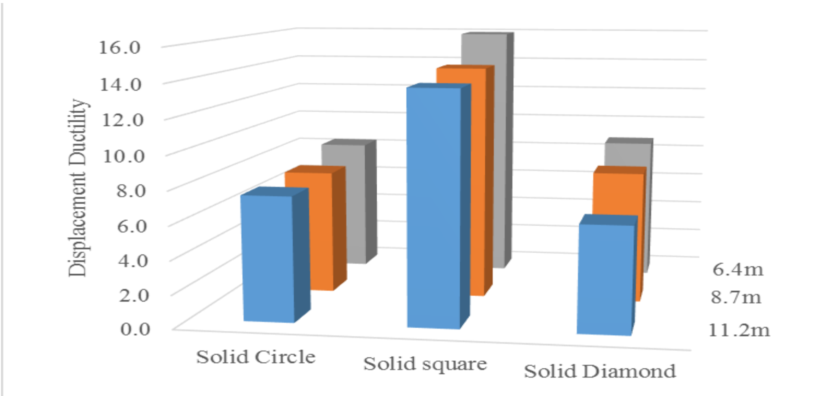
Variation in displacement ductility with height - 20m span – AASHTO



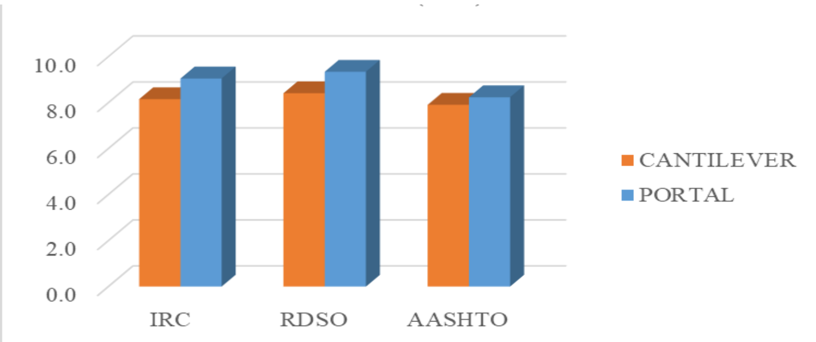
Variation in displacement ductility with height - 40m span – IRC



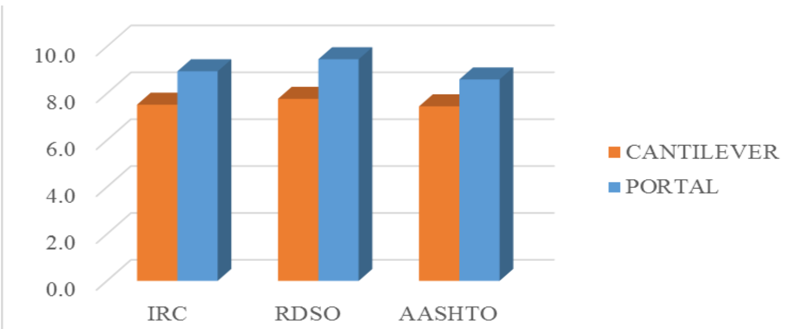
Variation in displacement ductility with height - 40m span – RDSO



Variation in displacement ductility with height - 40m span – AASHTO



Displacement ductility variation - cantilever vs portal - 20m span



Displacement ductility variation - cantilever vs portal - 40m span

V. CONCLUSION

- The displacement ductility capacity was seen to be increasing with higher grades of concrete for piers with confinement reinforcement.
- Also, an increase in size was causing increase in displacement ductility capacity for piers detailed as per RDSO and AASHTO while reducing for solid circular and hollow circular piers detailed as per IRC.
- As the height was increasing, the displacement ductility capacity was decreasing irrespective of span and code of detailing.
- An increase in axial load due to increase in span was causing a reduction in displacement ductility capacity for all shapes of cross section.
- Among the cross sections considered, maximum ductility is shown by solid square section pier.
- It was also seen that portal piers were more ductile than cantilever piers irrespective of span and code of detailing.
- The lightly loaded (normalised axial force less than 0.064 i.e. those that do not require confinement reinforcement) circular piers detailed as per IRC 112 were showing drastic reduction in ductility as compared to those detailed as per RDSO and AASHTO.

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