EFFECTS OF BI-DIRECTIONL LOADING ON DUCTILITY CAPACITY OF HIGH STRENGTH RC PIERS

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It has been observed that considerable simultaneous bi-directional moment and torsion demand is inevitable in the RC piers of curved or skewed bridges. This has resulted in reduction of ductility of the single piers within the nonlinear response in earthquakes. However sufficient data is not available yet on the response of High Strength RC (HSRC) piers in such condition. In this research, numerical models of HSRC piers have been developed in ABAQUS finite element software to study different parameters affecting the ductility of the element during several loading protocols. Variation in section and element aspect ratio, concrete characteristic strength, longitudinal reinforcement ratio and transverse reinforcement ratio are considered in the defined samples. Cyclic axial and cyclic biaxial lateral loading protocols (diamond & butterfly) simultaneously with torsion were applied in the model.

The behavior of reinforcing bar was modeled by elastic-perfectly plastic and ductile damage in the software with a uniaxial material over the element section with a material model. Concrete was model is the modification of Drucker-Prager strength model (Kmiecik & Kamiński, 2011). The model is well-stablished and is being successfully used to simulate the behavior of steel-reinforcement concrete (Jankowiak et al., 2005). As for a verification of the numerical model, Figure 1 shows the hysteretic behavior of the element acceptablly follows the experimantal results presented in Rodrigues et al. (2012).

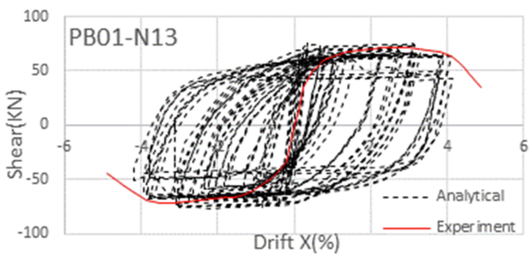

Figure 1. Comparion of numerical results with the experimental results in Rodrigues et al. (2012).

Four parameters of (a) shape and form of the section (b) material properties (c) longitudinal and transversal reinforcement ratio and (d) aspect ratio of the section (H/D) are employed to define the model. For each section, two levels of longitudinal and transversal reinforcement ratio are considered ($\rho_l = 1\,.\,2$), ($\rho_h = 0.75\,.\,1.25$). The characteristic compression strength of concrete is taken as (f_c=75, 100 Mpa). Aspect ratio equal to $\frac{H}{D} = 3$ & 5 are studied. The section properties are shown in Figure 2-a.

The level of combined bending and torsion identified by non-dimensional parameter is described as rotation-drift ratio r, defined as $\mathrm{r} = \frac{\theta}{\delta}$ in which θ and δ are the applied rotation and lateral displacement, respectively. Ratio of r has four levels including 0.5, 1, 2, 4 are applied in the model as presented in Figure 2-b. Displacement and moment values are calculated using Equations 1 and 2.

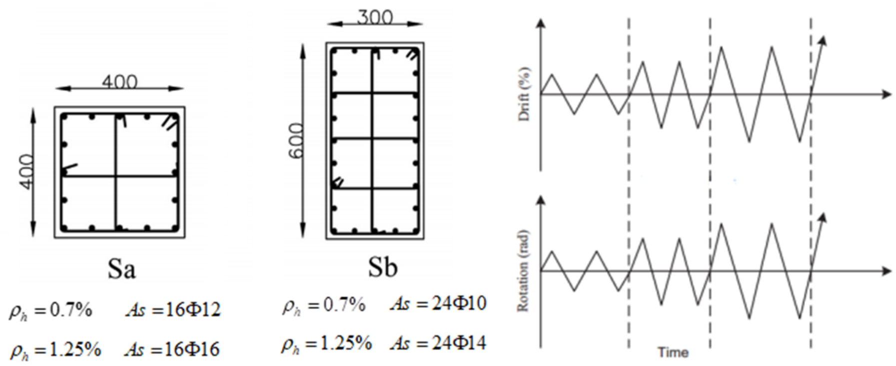

Figure 2. a) Element section properties in the study, b) Loading protocols applied in the model.

$$\Delta_{u-r_i} = \sqrt{\Delta_{x-r_i}{}^2 + \Delta_{z-r_i}{}^2} \quad (1)$$

$$M_{u-r_i} = \sqrt{m_{x-r_i}{}^2 + m_{z-r_i}{}^2} \quad (2)$$

Figure 3 demonstrates the result of reduction of capacity in percent as a function of a) effect of loading protocol and b) effect of transversal reinforcement ratio.

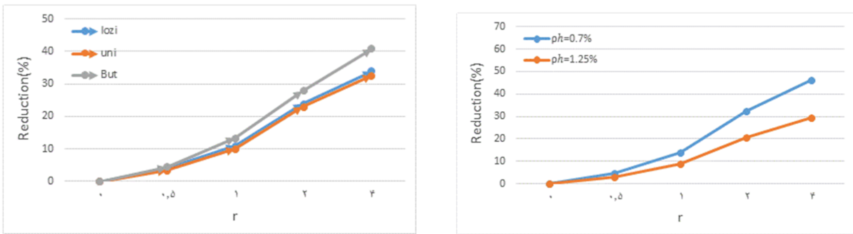

Figure 3. Ductility reduction a) effect of loading protocol, b) effect of transversal reinforcement ratio.

CONCLUSION

- The drift capacity and maximum strength under biaxial lateral displacement are heavily depended on loading path. Drift capacity reduction (R_Δ) and maximum strength reduction (R_M) is significantly different for butterfly and diamond loading path. The studied sections were faced considerable reduction under butterfly loading path in comparison with diamond loading path.
- Drift capacity reduction (R_Δ) and maximum strength reduction (R_M) was affected by "rotation-drift ratio". Increasing in "rotation-drift ratio" cause more damage in columns.
- As the transversal reinforcement ratio increases aforementioned reductions decrease. The mean ductility capacity reduction is 15% and 24% for $\rho_h = 1.25$ and $\rho_h = 0.75$ respectively.
- Although the flexural behavior was dominant in the column, drift capacity reduction (R_Δ) and maximum strength reduction (R_M) decrease while aspect ratio increases. The mean ductility capacity reduction is 14% and 26% for two aspect ratios equal to 5 and 3 respectively.

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