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EVALUATION OF THE METHODS ESTIMATING STRUCTURAL STRENGTH REDUCTION FACTOR UNDER FAR FIELD RECORDS

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The structural strength reduction factor is defined as the minimum ratio of lateral resistance of structure with a completely elastic behavior to that of the same structure with nonlinear behavior, for a given displacement ductility ratio. It is influenced by the imposed demand of earthquake on the structure and has a decisive impact on achieving performance objectives. The more precise estimation of mentioned demand, the more economical the design would be.

It is worth mentioning that, in different performance-based methods, such as energy-based and equivalent linearization design, the strength reduction factor directly or indirectly plays a key role. Over the past four decades, extensive research has been conducted to estimate the strength reduction factor, which indicates the importance of this estimation in structural design. Newmark and Hull (1973, 1982), Riddle and Newmark (1979), Lai and Biggs (1980), Riddle Hidalgo and Cruz (1991), Hidalgo and Arias (1990), Osteraas and Krawinkler (1990), Nassar and Krawinkler (1990), Vidic et al. (1994), Miranda (1993), Miranda and Bertero (1994, 1991), Ordaz and Perez-Rocha (1998), Lee et al. (1999), Espinosa and Gilmore (2002), Ruiz-Garcia Miranda (2003), Chopra (2004), Zhai (2006), Hatzigeorgiou (2010), ASCE41 (2017).
In previous studies, various methods have been proposed for predicting the quantity of Rμ. In this paper, a statistical study is conducted to assess the accuracy of 17 methods based on 2 quantitative criteria. For this purpose, 1230 single degree of freedom (SDOF) systems are modeled with nonlinear elastic-perfectly plastic behavior with 5% equivalent viscos damping and a fixed initial stiffness. SDOF systems are categorized in 41 ductility groups in the range from 2 to 6 (with 0.1 interval) each comprised of 30 different period values from 0.1 to 3 seconds (with 0.1 interval) by use of varying seismic mass in OpenSEES. Also, with the use of 44 far-field ground motion proposed by FEMA P-695 in two groups of soil types, C and D, 54120 nonlinear analyses are performed and average values of strength reduction factor are calculated. As a result, a comparison between various methods is drawn and the most appropriate method for estimation of Rμ has been reported

In Figure 1, as an instance, actual values of the strength reduction factor, resulting from nonlinear analysis versus the estimated amounts derived from three methods corresponding to soil type D are shown.

Also, in order to evaluate the mentioned methods quantitatively, the following two criteria have been used. Root Mean Square Logarithm Error and Root Mean Square Error are presented by Equation 1 and Equation 2, respectively.

$$RMSE = \sqrt{\frac{\sum\left(R_{\mu,est} - R_{\mu,com}\right)^2}{n}} \quad (1)$$

$$RMSLE = \sqrt{\frac{\sum Log\left(\frac{R_{\mu,est}}{R_{\mu,com}}\right)^2}{n}} \quad (2)$$

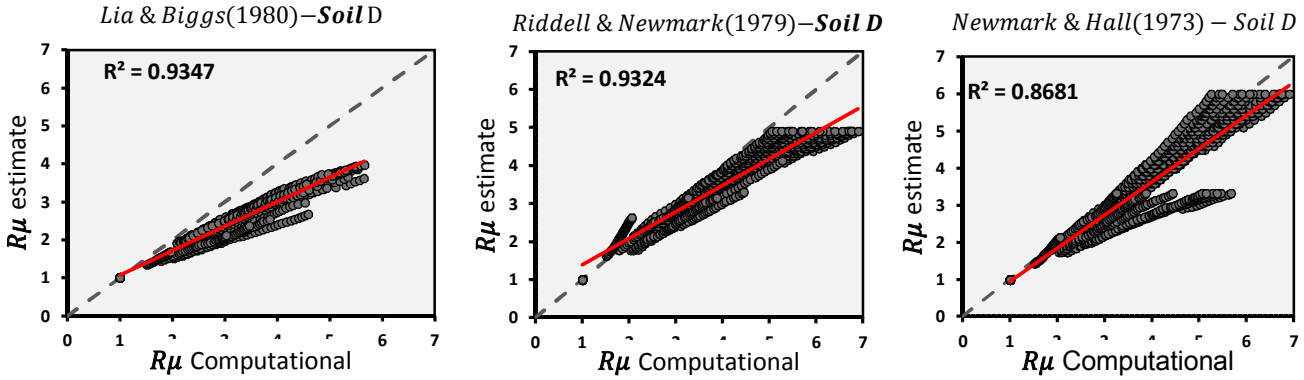

Figure 1. The actual values curve versus the estimated amount obtained from three methods for type D soil.

The result of this study showed that the method provided by the Ruiz-Garcia and Miranda (2003) yields the most accurate estimations of strength reduction factors one for soil type D and the methods proposed by the Nassar and Krawinkler (1991), Zhai (2005) and the ASCE41-17 hold following ranks with low difference and For soil type C, Osteraas and Krawinkler (1990), Nassar and Krawinkler (1990), Ruiz-Garcia and Miranda (2003) method have similar applicability.

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