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# Applying Genetic Algorithm to estimate the behavior factor of EBF steel frames under pulse-type near-fault earthquakes, performance level approach

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**ABSTRACT:** The most important feature of the behavior factor is that it allows the structural designer to be able to evaluate the structural seismic demand, using an elastic analysis based on force-based principles quickly. In seismic codes such as the 2800 Standard, this coefficient is merely dependent on the type of lateral resistance system and is introduced with a fixed number. However, there is a relationship between the behavior factor, ductility (performance level), structural geometric properties, and type of earthquake (near and far). The main purpose of this paper is to establish an accurate correlation between the geometrical characteristics of the structure, performance level and the behavior factor in eccentrically steel frames under earthquakes near-fault. For this purpose, a genetic algorithm is used. Initially, a wide database consisting of 12960 data with 3-, 6-, 9-, 12-, 15- and 20- stories, 3 column stiffness types, and 3 brace slenderness types were designed and analyzed under 20 pulse-type near-fault earthquakes for 4 different performance levels. To generate the proposed relation, 7533 training data in the form of genetic optimization algorithm were used. To validate the proposed relationship, 2515 test data were used to calculate the mean squared error of the relationship in the fitness function. The results of the correlation show accuracy of the proposed coefficients. Also, the comparison of the response of maximum inelastic displacement of 5stories EBF from the proposed correlation and the mean inelastic time history analysis confirms the accuracy of the estimated relationship.

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## 1- Introduction

One of the prevalent methods for building seismic design is the force-based design (FBD) method which is used in common codes such as Eurocode 8 [1]. In this method, seismic forces are used to design structures under the Life-Safety performance level, using a fixed behavior factor (R or q). In the FBD method, the maximum displacement and nonlinear inter-story drift ratio can be obtained by multiplying the elastic values by the behavior factor R. Krawinkler et al. (1996) showed that the structural response is very sensitive to the acceleration pulse continuity by evaluating the steel moment frame due to the near-fault record [2]. Other observations showed that the main response of structures due to near-fault earthquake with fling-step effects (permanent displacement at the strike-parallel direction of a strike-slip fault) was obtained at the first mode and wavelike vibrations without the fling-effect cause main response of structure were obtained at higher modes of the structures [3].

This article proposes a simple expression for estimating of behavior factor of the EBFs. These formulae are expressed based on geometrical characteristics of EBFs and are obtained based on the parametric study, including numerous nonlinear time history analyses of 162 EBFs with 4 performance levels under 20 near-fault ground motions. The considered geometrical characteristics include the number of stories, the brace slenderness, the stiffness of the columns and the ratio of the link beam length to the total length of the beam. The genetic optimization algorithm is used to estimate the correlation of behavior factors. It can be perceived that the outcomes of the proposed patterns are in good agreement with the exact results of nonlinear time history analyses.

## 2- Material and Method

### 2- 1- Description of Frames

This study is based on 2-D regular frames with a constant height of 3 meters and 5 meters' bays. The columns are pinned connected to the base and capable of conveying the moment forces along with their height. The beams are also pinned connected to the columns. Dead and live uniform loads on beams are 2500 and 1000 kg/m, respectively. Moreover, the yield stress of steels is considered equal to 2400 kg/cm2. The number of stories, ns, is considered to 3, 6, 9, 12, 15 and 20. The fundamental period of the frames is calculated by using the relation T=0.08H0.75 and considering H as the total height of the frames [4]. Links have been classified into short, intermediate and long length, which are the same as indicated in previous studies [5-7]. For values less than 1.6Mp/Vp (where Mp and Vp are the plastic moment and

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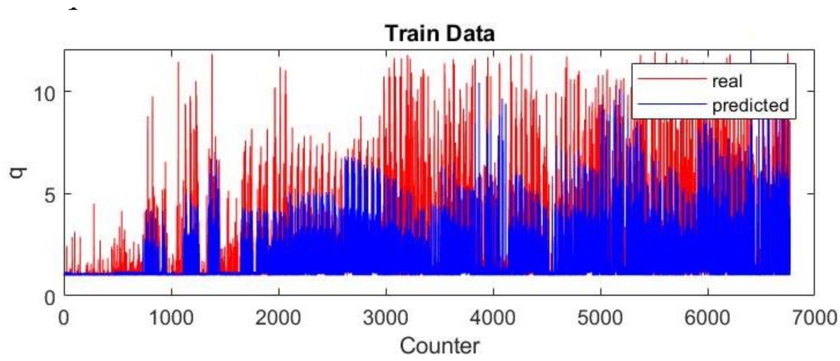


**Fig. 1. Real and predicted q from predicted correlation (training data)**

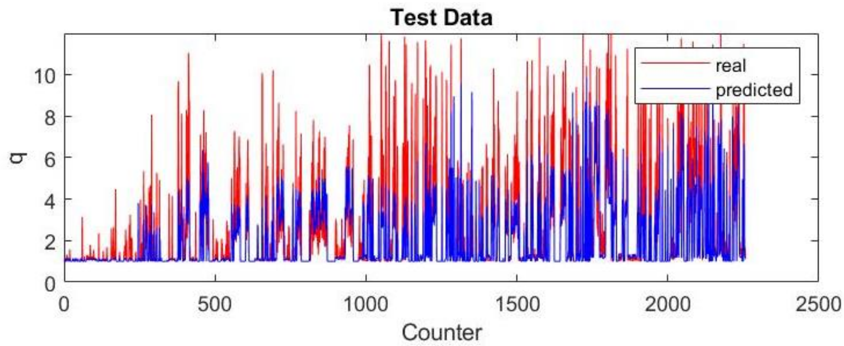


**Fig. 2. Real and predicted q from predicted correlation (test data)**

the plastic shear strengths, respectively), the link behavior is controlled by shear, while for values greater than 2.6Mp/Vp it is controlled by flexure. For link lengths between 1.6Mp/Vp and 2.6Mp/Vp, a combination of both shear and flexural yielding occurs [8].

### 2- 2- Research Methodology

Based on capacity design principles, diagonal braces, columns and beam segments outside of the links are designed to remain essentially elastic [9, 10]. Therefore, these members must have adequate strength to resist forces corresponding to the expected strength of the link, including strain hardening [11]. The braces are designed to have sufficient resistance due to seismic loading equal to forces generated by adjusted link shear strength. The design of the beam outside of the link is similar to the brace. The columns are designed to resist the forces due to the adjusted shear strength of all links above the level of the column.

The EBFs have been designed in accordance with AISC 360-10 [8] by means of ETABS 2016 [12] software. Thus, a database family of models is generated at 6 (ns) * 3 (α) * 3 (λ) * 3 (ξ) = 162 members. In the following, all EBFs has extended with 4 different rotation angle of link beams values, in accordance with the 4 performance levels. The first performance level is related to forming the first plastic hinge in the link beam and the rest of the performance levels are taken from ASCE41-13 [13], corresponding to the angle of rotation of the link beam.

### Results and Discussion

Several cases were examined by previous researchers [14, 15] to find an appropriate correlation between these parameters for q prediction. After several regressive examinations, they found that there is a powerful relationship between the independent parameters, the number of stories (ns), braces slenderness (λ), stiffness of columns (α), fundamental period of structure (Tp) and roof ductility (μR) and (q) for CBF steel frames under regular earthquakes. To account the effect of link beam length, ξ, is considered as an extra parameter to the function. Moreover, due to the properties of near-fault earthquakes, parameter T/Tp, change to Tp. The roof ductility, , is obtained by dividing the in-elastic roof displacement, Δi, on the yielding displacement, Δy, obtained by nonlinear time history and pushover analysis, respectively.

Figure 1 shows the real and predicted q from predicted correlation in the training data. For the verification of the proposed correlation, test data including 2515 data sets were used. Figure 2 shows the real and predicted q from the proposed correlation in the test data. According to the results presented in Figure 2, it seems that there is an acceptable agreement between predicted q values from the proposed correlation and the real q values.

## 3- Conclusions

As a result, after studying a considerable number of EBF frames, nonlinear dynamic analysis of a large database was prepared. The genetic algorithm (GA), which is one of the most powerful techniques of artificial intelligence in optimization, has been used to develop the correlation. As suggested by simple relationships, it is possible to obtain an acceptable estimate of seismic demand parameters without the need for complex analysis. The main emphasis is on introducing the capability of the proposed relationship in adapting them to the framework of design methods based on elastic analysis. The new empirical relation is proposed to predict the behavior factor q for EBF steel frames under the near-fault earthquakes. The proposed correlation is a nonlinear function of the number of stories, braces slenderness, stiffness of columns, fundamental period of the structure, link beam to beam length ratio and roof ductility. To evaluate its accuracy, the Mean Squared Error (MSE) and correlation coefficient (R) between predicted values from the proposed correlation and real values in the test data were calculated. The correlation coefficient in the test data was 0.8307. Finally, a 5-storey steel frame with force factor 7 (2800 standard, Rev 4 for EBF frames) was designed and analyzed using nonlinear time history against the acceleration of the present paper to evaluate the robustness of the proposed relationship in estimating the nonlinear displacement of the structure.

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