Vulnerability Study of Derrick Supported Seismic Analysis Flare Using Incremental Dynamic

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ABSTRACT

The vulnerability of industrial plants to natural hazards has made world worries because of countries general disability about the prediction of the level of effects and preparedness for the consequences of these types of events. For this purpose, seismic assessment of plant equipment is a strategic issue. One of the most equipment that is used in most oil & gas plants is stack flares. Stack flares are a type of stacks that are used for burning additional flammable gases before causing any other problem for other plant facilities. Proper seismic assessment of this type of equipment has been missed in the past and its exact performance evaluation can be effective in determining probable damages in future earthquakes and distinguishing the weakness of components of this type of structure. In this study probabilistic seismic behavior of two designed and constructed stack flares are investigated and using incremental dynamic analysis their fragility curve and behavior factor are calculated. Results show that in ordinary intensities, the seismic demand of these structures is not considerable but in range of rare intensities, extreme damages are probable. Also, in the above case studies, the performance of 4-sided stack with respect to 3-sided stack was more proper, and seems more assessment is needed on the suggested behavior factor by codes.

KEYWORDS

Seismic assessment, Incremental dynamic analysis, Fragility curves, Behavior coefficient, Stack flare.

1. Introduction

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One of the equipment used in the majority of oil and gas industries is stack flare, which is used to secure industrial equipment against overpressure by releasing and burning gases [1]. Given the need for risk assessment to take precautionary measures in industrial facilities and the need for information on the collapse of structures in different PGAs, the development of fragility curves is essential for all structures in industrial plants [2], however, no comprehensive research Has not studied the seismic behavior of stack under real accelerograms, and no information is available on the behavior of these structures at high seismic intensities.

The focus of this research is on recognizing the seismic behavior of the stacks supporting structures and calculating their coefficient of behavior. For this purpose, two stack equipment were selected as a case study, and seismic assessment was performed using incremental dynamic analysis and extraction of fragility curves. Behavior coefficients under earthquake records are also calculated and presented for case studies.

2. Case studies details

The first sample located in Iran, Khuzestan province, is a 3-sided stack with height of 93 meters, which supports a chimney with height of 94.5 meters. This stack is located in an area with base design acceleration A = 0.25 g with SD soil type according UBC97 code, and the seismic load for the mentioned structure is also in accordance with this mentioned code. The 2nd sample is a 4-sided stack located in Iran, Bushehr-Assaluyeh province, with 86 meters height, which supports a chimney with 89 meters height. The base design acceleration A=0.5 g with soil type C according IBC 2009 code, and the earthquake load is also calculated according to the same code. Figure 1 shows the exact dimensions of the stacks and sections used in height.

The connections in both models are welded, and modeled continuously. Such approach has been used in Tian studies [3].

3. Details of Finite Element Model

Since the lateral stability of the stacks is provided by a braces structure, which consists mainly of pipe members, and due to the slender of these members, the failure mode is usually buckling mode, so the seismic performance is controlled by pipe members buckling. The basis for accurate prediction of structural response is the stress-strain relationship governing the behavior of materials.

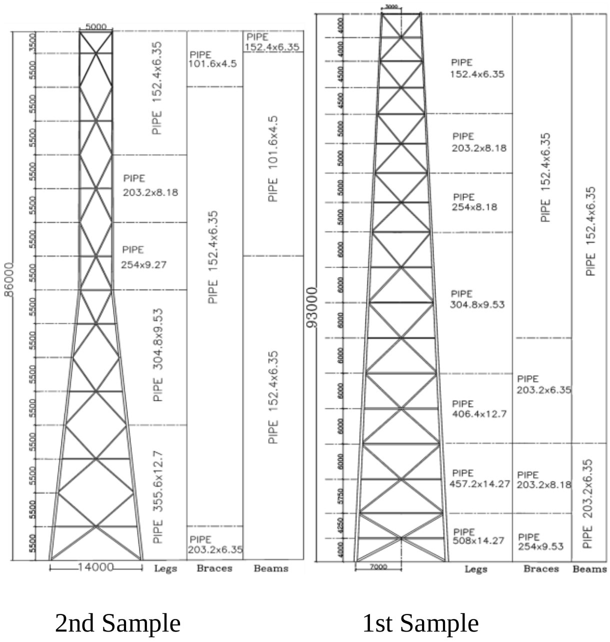

Figure 1. Geometric configuration and cross-sections of samples

Marshall push theory gives a seven-line model as shown in Figure 2 to predict the ultimate strength of braced steel structures, in which the member failure mechanism is based on a local buckling estimate [4].

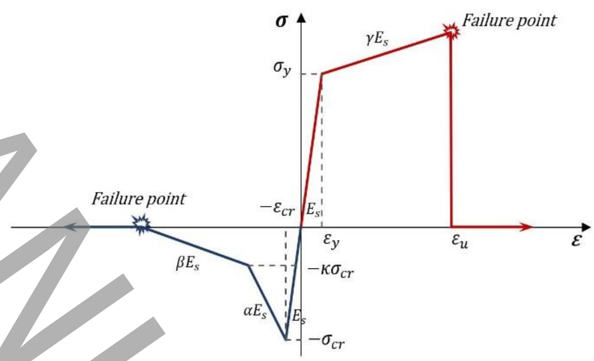

Figure 2. Marshall Defined behavior of axial elements with pipe cross-section

4. Methodology

Using Visual Basic coding language for Excel (VBA) and its interaction with SAP2000, an IDA was performed for both models under 20 accelerograms, and IDA curves as shown in Figure 3 were obtained for both models. In the existing codes and articles, there is no specific value or method to determine the limit state values of flare equipment. The pushover analysis is conducted to acquire the corresponding thresholds for different limit states. The first limit state (serviceability) requires the tower remain in the elastic stage during the earthquake. The third limit state (collapse prevention) in the pushover curve, corresponds to the point that a small increment of lateral force results in a significant increase of drift value and finally by considering the damage control level, equal to 0.75 of collapse prevention level, the limit states are determined. This approach has been used in some other studies [5].

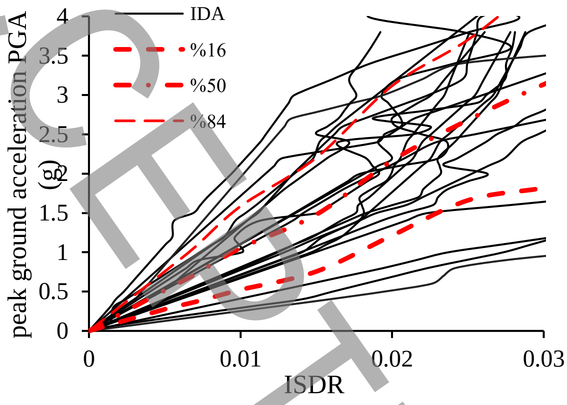

Figure 3. IDA curves with summarized diagrams for the first sample

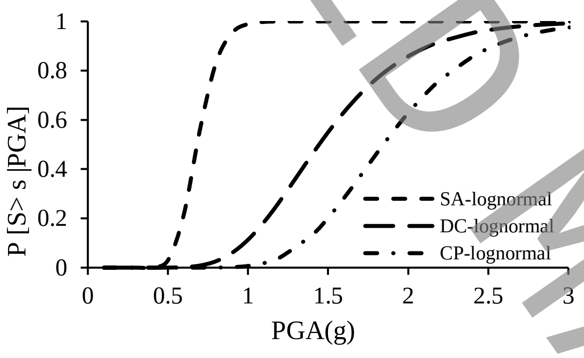

Figure 4. Fragility curves for the first sample

5. Results

By reviewing the results, it was observed that the resulting fragility values for both samples are close to each other. Also, the structures have a tiny probability of failure within the code's earthquake intensities, but for strong ground motions (high-intensity earthquakes), failure of these Structures are likely.

Regarding the of the studied structures, assuming a normal distribution for the obtained data, close median and dispersion for both structures were observed in the results of ductility and over-strength coefficients. This similarity indicates the possibility of considering a single behavior coefficient value regardless of the number of sides.

6. Conclusions

The produced fragility curves show the seismic safety of this type of structures (concerning probability values close to zero) for all limit states in the range of earthquakes up to 0.5 g, while the earthquake in the region is 0.35 g and the probability of exceeding the state is very low. The main reason for this result is the low mass of the structure and consequently, low seismic effects compared to the effects of wind load in the design of these structures. The result is acceptable due to the prevailing wind load for the design of these structures and is compatible with reports [5].

The obtained values of extra strength coefficient, ductility coefficient, and behavior coefficient for the first sample were 2.35, 1.16, and 2.75, respectively, and for the second sample were equal to 2.44, 1.27, and 3.12, and it was observed that the difference in the number of stack sides do not have much effect on the value of the behavior coefficient and equal behavior coefficient can be adopted for this type of structures. The calculated behavior coefficient for the 3-sided stack is 4% higher and for the 4-sided stack is 8% less than the code regulation value and it seems that the code regulation value is appropriate.

It is worth mentioning that the results are based on a case study on two samples of stack, and to express these results with more certainty, it is necessary to study a wider range of various types of these structures at different heights.

7. References

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