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ENERGY-BASED DESIGN OF KNEE-ELEMENT CONNECTION FRAMES (KCFS) IN PIPE RACKS

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This paper studies the application of Knee-element Connection Frames (KCFs) as a seismic load resisting systems for petrochemical structures. This structural system only uses simple connections and provides a zonlular rigid connection compared to the concentrated rigid connections used in moment-resisting frames (MRFs). KCFs are of particular advantage over other load-resisting systems in petrochemical structures, such as piper racks, due to their ample access for maintenance and enhanced structural performance (Hsu & Jean, 2003). In conventional engineering practice, pipe racks are typically designed with MRFs in the transverse direction to allow flow of equipment, and with braced frames in the longitudinal direction to provide the required stiffness (Drake & Walter, 2010). However, KCFs entail both the aforementioned advantages to a sufficient extent (Asghari & Saharkhizan, 2019). This system benefits from improved stiffness, strength and ductility simultaneously and facilitates accessibility and reparability after a major earthquake. Furthermore, unlike building structures with confining architectural limitations, KCFs can be deployed throughout pipe rack structures and in any direction.

In the past two decades, extensive research has been conducted to evaluate KCFs seismic performance and to determine the most efficient configurations (Leelataviwat et al., 2011, 2017). This study utilizes an energy-based approach (energy balance concept) to design pipe racks. This concept implies that the energy required to push the structure up to a target displacement monotonically is equal to the maxim earthquake input energy computed from the pseudo-velocity response spectrum (Choi and Kim, 2006). In this approach, firstly, a general favourable yield mechanism (Figure 1) and a level of expected performance is determined by selecting an expected plastic rotation for the structure. Then, the amount of input energy is assumed to be dissipated only through plastic hinges throughout the structure. As mentioned above, input seismic E_i per unit mass in this study is calculated by the means of the pseudo-velocity spectrum as follows:

$$E_i = \frac{1}{2}MS_{pv}^2 = \frac{1}{2}M\left(\frac{S_{pa}}{\omega}\right)^2 = \frac{1}{2}M\left(\frac{TS_{pa}}{2\pi}\right)^2 \tag{1}$$

This design approach is eventually implemented with modelling a pipe rack structure in Sap2000 and non-linear static analysis is performed to corroborate the design concept and assumptions. The results demonstrates an acceptable correlation in assumed general yield mechanism and the real structure behavior. Plastic hinges are spread throughout the structure height which implies a desirable input energy consumption.

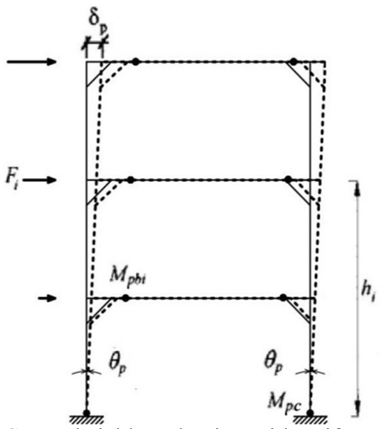

Figure 1. General yield mechanism with uniform story drift.

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