10th International Congress on Civil Engineering, 5-7 May 2015
University of Tabriz, Tabriz, Iran

Studying the Effect of Length and Material Properties of Knee Element on Behavior Factor of Knee Bracing System using Nonlinear Static Analysis

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Abstract

In a knee brace system, at least one end of the diagonal member is connected to a small knee element instead of being connected to the beam-column intersection. The ductility in a knee bracing frame (KBF) is due to the knee element yielding in shear. On the other hand, the required lateral stiffness in such frames is provided by a diagonal member. Yielding of the knee element during a strong earthquake would ensure overall system stability without damaging the main structural components. Thus, reconstruction of the earthquake-resistant system would be easier and more economic. Considering the increased ductility and energy damping requirements set forth for building structures in seismic zones, the authors studied in the paper the effects of the length and properties of the materials used in knee bracing systems. To obtain reliable modeling and analysis results, first a suitable sample was selected from among the credible test models used in world renowned research centers and, subsequently, this sample was modeled by ANSYS software. Then, modeling accuracy was established by comparing corresponding load-deformation curves. Finally, by varying the knee member length and material properties, numerous models were generated in the ANSYS environment. Ultimately, such characteristics as ductility, behavior coefficient, ultimate strength, energy absorption, etc. were calculated and the relevant tables and curves produced.

Keywords: Knee brace, knee member/element, materials properties, ductility, behavior coefficient, nonlinear static analysis.

1. Introduction

Structures designed for areas with high seismicity must satisfy two criteria. First, they must have sufficient stiffness to control the lateral displacements to prevent any structural and non-structural damage during the moderate but frequent earthquakes. Second, the structures must have sufficient strength and ductility to prevent collapse under severe earthquakes. The structures with steel frames are widely used in the commercial and industrial buildings.
According to the lateral load resisting system, the steel frames are divided into four types including moment resisting frame (MRF), centric bracing frame (CBF), eccentric bracing frame (EBF) and knee bracing frame (KBF) as shown in Fig. 1. The experiments conducted on the four systems showed that CBF system has a very higher stiffness compared to MRF system and thus is incapable of providing sufficient ductility. The results of this experiment are shown in Fig. 2. To overcome the shortcomings and deficiencies of MRF and CBF systems, a new structure called EBF was proposed [1]. This system is able to bear large deformations through eccentrically adjusting the diagonal member relative to the lower beam. Therefore, it acts like a ductile fuse and provides a good ductility for the entire structural system. According to the results presented in Fig. 2, EBF system provides a higher ductility and stiffness as compared to the CBF and MRF systems.
On the other hand, KBF system has a higher stiffness in comparison with the EBF system. It is not so simple to repair the beams in the EBF system which are damaged after the earthquake as a major part of the main frame. For the ease of restoration, the link beam is used in the KBF system to dissipate the energy of the lateral force. This system was first proposed in 1986 [2].
Thereafter, it was reviewed by other researchers [3-6]. This system uses the secondary structural part (the knee) as a ductile fuse to ensure adequate ductility. On the other hand, it provides a good lateral stiffness by adjusting the diagonal