Evaluation of Dynamic Parameters of the Vierendeel System under Cyclic Loading

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Abstract

Vierendeel systems are widely used because of not using diagonal members, providing free space for passage of pipes and ducts, ability to cover the more height of the structure, creation a unique view for the structure and, so on. In engineering design, due to lack of the theory on the vierendeel system's stiffness, design depends on experience. In this paper, for evaluation of nonlinear behavior of the structure a numerical analysis on one-story, three-story and five-story vierendeel systems under cyclic loading is presented. OpenSees software is used in order to evaluate the behavior of the system considering both the material and geometric non-linearity. So, the seismic parameters of the system, such as yield load, deformation, ductility, energy dissipation, and strength and rigidity degradation are obtained. Then, the influences of the vierendeel system height and its height over width ratio are studied.

Keywords: Vierendeel Systems, Cyclic Loading, Numerical Analysis, Seismic Performance

1. Introduction

A vierendeel system is an open web girder consisted of top and bottom beams named chords, and vertical internal and external members named posts that are connected by moment resisting connections. Hence, these members are subject to bending, shear and axial load effects. The stiffness of the system depends crucially on the bending stiffness of vertical and horizontal members and on the joints connecting the members. The analogy between a vierendeel system and a beam is similar to that for a parallel chord truss except that the shear mode component is due to bending of the chords and the posts, rather than to axial deformation of the diagonals and posts [1]. This system is named vierendeel after Arthur Vierendeel (1852-1940), a famous Belgian civil engineer born in Leuven whose experimental work still forms the basis of designing such systems.

The vierendeel systems have various applications in the infrastructures, such as bridges, skyscrapers, and the airports walkways since, the height over span ratio reduces the boom forces and moments and so, eases the problem of forming the joints [2]. They provide useful solutions in certain cases; for example, when removal of the diagonal members from a conventional truss is desirable for access reasons, or practical and technical purposes. The vierendeel systems can resist against lateral loads. Also, a special vierendeel system has been engineered in order to deal with the slenderness of the building that provides totally column-free space on alternate floors in spite of the building's slenderness and height (e. g. cantilevered towers), [3].

However, in some cases, vierendeel systems may be more expensive to be produced than conventional trusses with diagonal members; furthermore, they may have less stiffness than triangulated trusses.

A few theoretical and experimental studies have been done for investigation on the performance of concrete or steel vierendeel systems. Varghese et al. [4] have studied the strength and performance of reinforced concrete vierendeel systems in their elastic as well as ultimate load conditions, under vertical loading on the joints. They have presented the influence of depth over span ratio of the systems on their behavior and, the importance of selecting a proper depth over span ratio so as to provide desirable cracking characteristics and effective stiffness. Cuixia Wei et al. [5] have proposed a formula to find the most reasonable height for any flat vierendeel system using analytical method or FEM. They have shown that the most reasonable height can provide the most stiffness and the least deformation. Furthermore, the influences of the chord's properties on the most reasonable height have been discussed. Chen et al. [6] have carried out an experimental study with LYP steel shear panels to investigate the performance of the vierendeel systems. By proper design, the LYP steel shear panel is able to dissipate a large amount of seismic energy, and its shear deformation angle can be more than 6% without degradation of its strength. Del Savio et al. [7] have investigated the influences of semi-rigid joints on the structural forces and displacements in the vierendeel