

Seismic Performance for Steel Frames with Different Layouts of Knee Brace

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Abstract—The different layouts of knee braces will affect the mechanical performance of the structure to some extent. Nevertheless, an extensive review of related literature indicates that the effect of different layouts of knee brace in steel frame structure is not considered. Typical models of multi-storey building (six-storey) were set up, whose seismic properties were analyzed (including modal analysis and time-history analysis) by finite element software ABAQUS. The effect of layout of braces to internal force, displacement, energy-dissipating capability was observed through comparison. According to the calculation analysis, it was found that lateral displacement and inner forces of the knee braced frame structure were all changed with different degrees, especially for the layer shear force, the effect was the strongest. The layer shear force decreased greatly when the bracing location was in the midspan compared with the bracing location which was in the sidespan. Thus, it was suggested that the bracing location was preferentially considered to arrange in the midspan of the structure under the precondition of meeting the usable function on the structure.

Keywords—steel frame structure; knee brace; brace layout; time history analysis

I. INTRODUCTION

Different with the traditional steel frame structure, new kind of node—beam-column-connected nodes on the underhorn of the frame has been presented in recent years. It is regarded as the dissipative member with the low yield strength and deformation performance. Under the effect of frequent earthquake, the knee brace can improve the resistance to lateral stiffness of structure, and to reduce lateral deformation of the steel structure system; Under the rare earthquake action, the knee brace members yield firstly, consuming the earthquake energy by the plastic deformation of knee brace, protecting the beam-column joints, reducing plastic deformation of the structure, to make it satisfy the seismic requirements which is “The strong node, The weak component”. At the same time, this kind of knee brace can be easily replaced when it is disabled before accomplishing the predetermined function, which can realize the quick fix of structure. This study has compared and analysed the

earthquake response of four typical kinds of knee brace in six-storeyed steel frame through the finite element software.

II. COMPUTATION MODULE

A. Multistory Frame Module

Welder font H 350x175x7x11 and H 250x250x9x14 (mm), respectively, are used to fabricate the steel frame equipped with knee brace (Fig. 1). The length for beam and column is respectively 1200, 1600 (mm). The size of knee brace geometry is 80x6, b and h for 720 and 480 (mm). According to the seismic structural requirements of the braced frame system in the Code for Design of Steel Structures (GBJ50017—2003)[1], while referring the relevant conclusions conducted by Modid[2-4] who optimize the knee brace frame system, namely to achieve the optimal performance of nodes, the arrangement of knee brace should be parallel to the diagonal of frame. Model of knee brace with low yield point of Q235B steel, steel beams and columns using Q345B steel. The section of beam and column are H section, beams and columns with rigid connection.

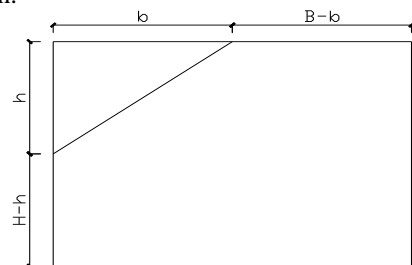


Figure 1. Knee brace system simplifies the calculation.

B. Layouts of Knee Brace

According to the research of Zhou[5], this study proposes four different layouts of knee brace in the steel frame: program 1(sidespan arrangement), program 2(side and middle span arrangement), program 3(midspan arrangement) and program 4(uniform arrangement in every span). Each layout program has been shown in the Fig. 2. All of these programs have the same steel quantity.

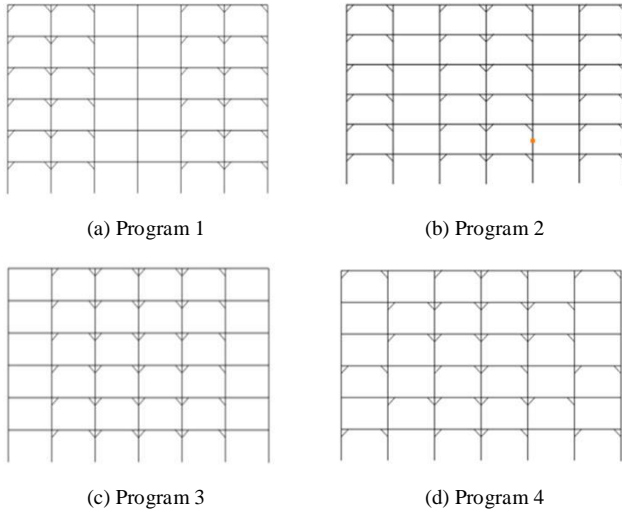


Figure 2. Layouts of knee brace in steel frame.

C. Finite Element Module

The research adopted ABAQUS finite element software which had excellent calculation on seismic performance of steel structure. 3D beam element was used in the model (Fig. 3). The mixed hardening constitutive model was regarded as the material constitutive model of the module, which satisfying the Von-Mises yield criterion[6].



Figure 3. The model of knee brace on steel frame in ABAQUS

III. CALCULATION RESULTS

A. Results of Modal Analysis

Modal analysis had conducted on four different layouts of knee brace in steel frame[7-9]. The five lowest order on natural vibration period of each scheme (T) was presented in Tab.1, and five lowest order on natural vibration period of each scheme was shown in Tab. 2.

TABLE I. NATURAL VIBRATION PERIOD OF EACH SCHEME (S)

Number	Program 1	Program 2	Program 3	Program 4
Modal 1	0.742	0.692	0.665	0.652
Modal 2	0.254	0.231	0.219	0.131
Modal 3	0.144	0.132	0.130	0.122
Modal 4	0.127	0.110	0.108	0.103
Modal 5	0.105	0.098	0.094	0.098

TABLE II. THE FIRST TWO ORDER MODEL VIBRATION OF EACH SCHEME

Number	Program 1	Program 2	Program 3	Program 4
Modal 1				
Modal 2				

The results of calculation showed that: the structure of the natural vibration period decreased with the increase of lateral stiffness. In order of natural vibration period, it goes from largest to smallest: program 1, program 2, program 3, program 4. The maximum period for four arrangement schemes of knee brace differs by 12% from the minimum. The layout of knee brace can not influence primary vibration mode, as the first two order modes are basically the same.

B. Bottom Shearing Force Method

The structure of the facade rules could be simplified calculated by the bottom shear method, according to the Code for Seismic Design of Buildings (GB 50011 2010)

[10]. In general, the natural vibration period of multi-story light steel structure above six storeys ranged 0.5s to 2s. The seismic influence coefficient (α) could be presented by the following equations:

$$\alpha = \left[\frac{T_g}{T} \right]^\gamma \eta_2 \alpha_{\max} \quad (1)$$

The relationship between α and T could be conducted, it showed:

$$\delta\alpha = -\frac{T_1 + T_2}{T_1 - T_2} \cdot \frac{\left[\frac{1}{T_2}\right]^\gamma - \left[\frac{1}{T_1}\right]^\gamma}{\left[\frac{1}{T_2}\right]^\gamma + \left[\frac{1}{T_1}\right]^\gamma} \delta T \quad (2)$$

However, the $\delta\alpha$ equaled to δT when the value of γ was 1. The two equations was proposed as follows:

$$\delta T = \frac{T_1 - T_2}{0.5(T_1 + T_2)} \quad (3)$$

$$\delta T = \frac{\alpha_1 - \alpha_2}{0.5(\alpha_1 + \alpha_2)} \quad (4)$$

Calculating the layer shear force (V) of each scheme on the basis of first order natural vibration period (Tab. 3) and the obvious equations.

TABLE III. THE LAYER SHEAR FORCE OF EACH SCHEME (KN)

Floor	Program 1	Program 2	Program 3	Program 4
6	116.86	124.82	128.04	134.53
5	157.49	201.68	209.51	214.09
4	244.52	254.93	274.39	278.71
3	299.16	307.45	324.65	332.75
2	323.54	342.51	361.08	364.54
1	351.27	363.77	382.57	387.21

C. Time History Analysis

According to the revelant requirements, the module should be set as seismic fortification intensity of seven degrees, class III, the first group. The Trial of seismic simulation carried out by EI-Centro wave, maximum of frequent earthquake acceleration time history curve evaluated 35cm/s^2 , rare earthquake took 220cm/s^2 . It is observed that the calculation results of storey drift for four different layouts of knee brace in steel frame under the effect of EL-Centro wave for frequent earthquake (Fig. 4).

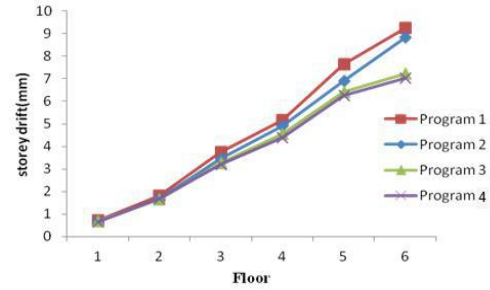


Figure 4. The storey drift of models under the frequent earthquake.

The same procedure may be easily adapted to obtain the the storey drift of the steel structure with the effect of EL-Centro wave for rare earthquake (Fig. 5).

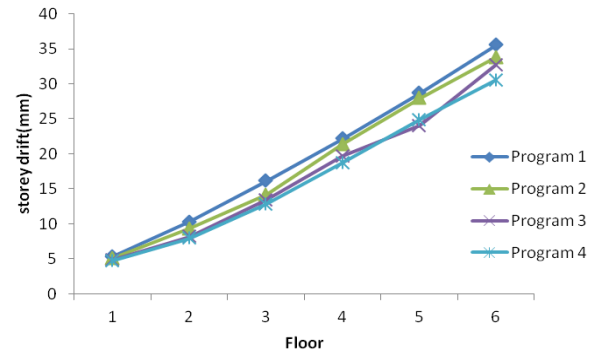


Figure 5. The storey drift of models under the rare earthquake.

The storey displacement of four layouts of the knee brace in steel frame structure increased range from top to bottom under the effect of EI-Centro earthquake wave, the maximum of improvement reaching 20%, and the storey drift of program 4 was the smallest among the four schemes from the beginning to the end.

D. Comprision and Summary

Above all, this paper have obtained these parameters of four arrangements for knee brace in steel structure, such as, natural vibration period, layer shear force and storey drift. Thus, it is important to make this form (Tab. 4) and these conclusions as follows through comparing the previous parameters.

TABLE IV. THE COMPRISION OF PARAMETERS AMONG LAYOUTS OF KNEE BRACE

Parameter	Program 1	Program 2	Program 3	Program 4
Natural vibration period	Maximum	Larger	Smaller	Minimum
Bottom shearing force	Minimum	Smaller	Larger	Maximum
Storey drift	Maximum	Smaller	Larger	Minimum
Lateral stiffness	Minimum	Larger	Smaller	Maximum
Summary	Not recommend, worst performance	Not recommend	Recommend	Recommend, best effect

IV. CONCLUSION

In this study, knee brace was installed in steel structures with different arrangement to improve seismic performance. This research attempted to evaluate the natural vibration period, bottom shearing force and storey drift of the steel frame structure with four layouts of knee brace. It was observed that the layout of knee brace in program 4 had the best performance, and the program 1 worst. Each order modal vibration of the steel frame did not appear obvious changes after shifting the knee brace position from sidespan to the midspan on the steel frame. The layouts of Knee brace almostly has no effect on the main vibration mode. As the knee brace knee transferred from the sidespan to the midspan, natural vibration period of structure was reduced, and each layer of the shear force gradually increased. When Knee brace was arranged in the midspan, the lateral stiffness was superior to those installed in sidespan; The more continuous did knee brace arrange on the direction of length, the more the integral stiffness of structure can increase effectively, while the buckling constraint brace in the structure can give full play to its functions under the horizontal seismic action. According to the previous decorative principles, it can make full use of the energy dissipation performance of knee brace under the effect of earthquake, but also should consider the layout of architecture comprehensively and the economic factors.

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