Research on elastic-plastic failure behavior of steel double-layer grids structure system (36X 48m) used in the badminton practice gymnasium under strong earthquake wave

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Abstract. In this paper presents a calculation investigation on the Elastic-plastic incremental dynamic response elastic-plastic analysis of gymnasium practice hall under the loads of EL-Centro earthquake. the appraisal results on their anti-failure performances are presented under strong earthquake action based on the plastic-hinge theory. In the analyses, the geometric and material nonlinear effects are considered simultaneously based on the plastic-hinge theory. The plastic development level of the rod, the deformed shape and the failure type and the ductility are estimated by plastic hinge principle. The results show that the failure model of the structure under the earthquake wave action is the complicated combination of strength failure and elasto-plastic dynamic local buckling in deferent areas of the structure; When the structure reached its failure critical limit, the development of the plastic hinges is not sufficient and only 14.7% of the rods enter into their plastic stage; the maximum displacement of structural failure is 549cm. Its critical failure peak acceleration of EL earthquake wave when applied in the combination of three directions is 733gal, which is 1.8 times more than the official seismic fortification level of 8 degree (major earthquake, 0.2g) and can be served as earthquake victims shelter in the area of 8 degree seismic fortification; Its displacement ductility coefficient is 5.034,which shows the structure owns good energy dissipation capacity.

Introduction

Many disastrous earthquakes show that the large span public buildings were used as earthquake shelters and disaster relief headquarter sites[1]. However, we only carry out earthquake design checking on these structural systems in order to work safely during disastrous earthquakes, the structures of these buildings are required to be designed under strong earthquake action larger than the official seismic major fortification So the appraisal method on their anti-collapse performances under strong earthquake action is needed to be studied. in this paper, the elasto-plastic dynamic analysis on dynamic failure behaviors of steel double-layer grids supported by The H-shaped columns used in a gymnasium with the function of earthquake victims shelter under disaster earthquake is carried out and appraisal results on their anti-failure performances are presented under strong earthquake action based on the plastic-hinge theory[2].Therefore these results can provide a theoretical basis for the large span public buildings design in future..

Analysis Model

The sports practice gymnasium with plane size of 36X48m and cornice elevation level of 10 m is shown in Fig.1. Its roof structure is a double-layer grid with square on square pyramids supported by H-shaped columns. Its grid size is 3mX3m, its grid height is 3.5 m. gymnasium is designed firstly according to the current national standards with official seismic fortification level of 8 degree (0.2g) and site classification of type Ⅲ, design reference period of 50 years, design characteristic period of ground motion of 0.45 s. Its peak ground acceleration for the small and the major earthquake is respectively 70 gal and 400gal[3].The damp is taken as Rayleigh with the damping ratio 0f 0.02 or 0.05 for elasticity or elasto-plasticity. The material adopts bilinear elastic-plastic material model with the density 7850Kg/m3, elasticity modulus 2.06Gpa, tangent modulus 6.18GPa, the Poisson ratio 0.3, and the yield strength 235MPa. The top chord cross section sizes are among φ76X4 and φ127X4, the lower chord cross section sizes are among φ89X4 and φ76X4, the web member cross section sizes are 95 φX4, φ102X4, and the cross section sizes used The nonlinear analysis on the spatial truss under EL-Centro wave is carried out with plastic hinge method by SAP2000. The generalized force-displacement relation for the plastic hinge defined in the members of the structure is defined according to **FEMA356**[4]**.**

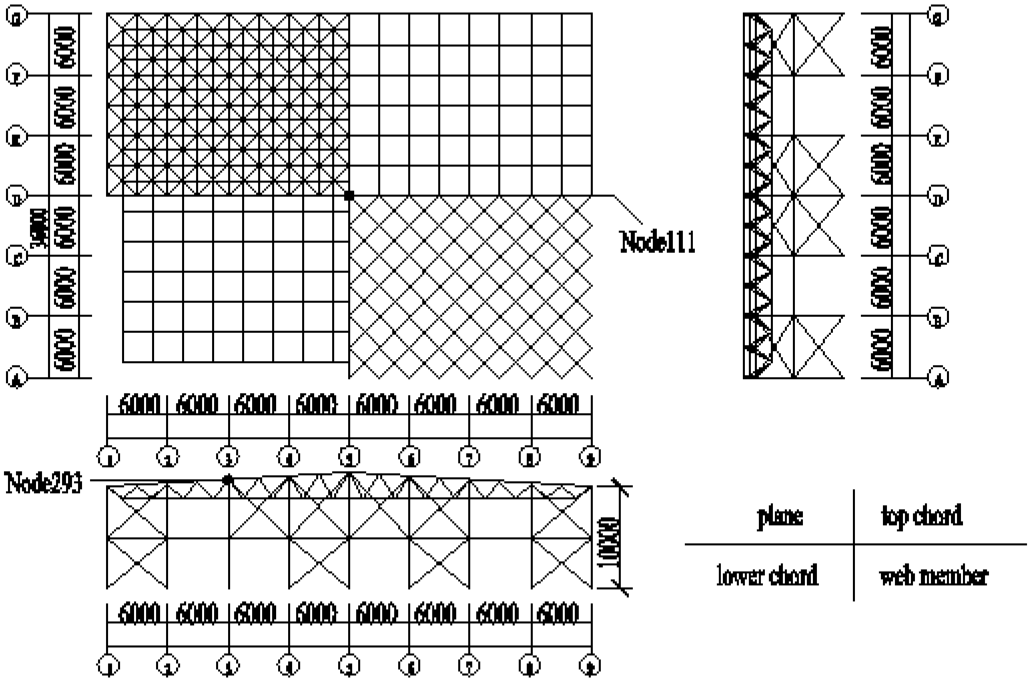

Fig. 1 Structure layout
(The node number shown in this figure are feature nodes)

Results and Analysis

Nonlinear time history calculations on the model are carried out by SAP2000 with El-Centro wave chosen as earthquake wave applied in the combine direction of Y+0.85X+0.65Z. The initial condition for each time-history calculation is the deformed state of the structure under the whole dead load and the half live load. Many calculations with different peak value of the input earthquake wave applied to the structure designed according to the official Seismic fortification level(shorted as SFL) are carried out to find two limit conditions for the structure. The first is the elastic limitation; the second is critical failure state. The number and the distribution of the plastic hinge are provided in Tab.1. the relationship curves between the maximum displacement of nodes and peak ground acceleration (shorted as PGA) are respectively shown in Fig.2. the time history displacement response of the characteristic node are respectively shown in Fig.3.Displacement ductility coefficients of the structure are listed in Tab.2.The failure model is shown in Fig.4.

Tab.1 The plasticity development level in 733gal.

PGA/ gal	Region	Number of plastic hinges					Region percentage (%)	Total number of plastic hinges	Total percentage (%)
		B-IO	IO-LS	LS-CP	CP-C	C-E			
360	Top chord	1	—	—	—	—	0.21	1	0.06
	Lower	—	—	—	—	—	0.00		

	chord								
	Web member	—	—	—	—	—	0.00		
	Lower structure	—	—	—	—	—	0.00		
733	Top chord	9	10	—	3	98	25.6	266	14.7
	Lower chord	32	55	—	4	17	22.1		
	Web member	3	9	—	9	11	4.9		
	Lower structure	—	1	—	8	—	6.8		

Note: "—" indicates that no plastic hinge

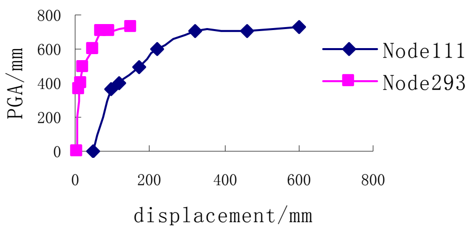

Fig.2 The horizontal displacement of the feature node of the support structure - the PGA curve

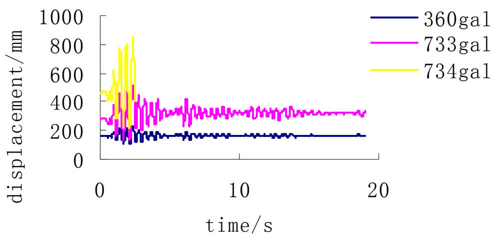

Fig.3 Disp. time history curves of Node 111

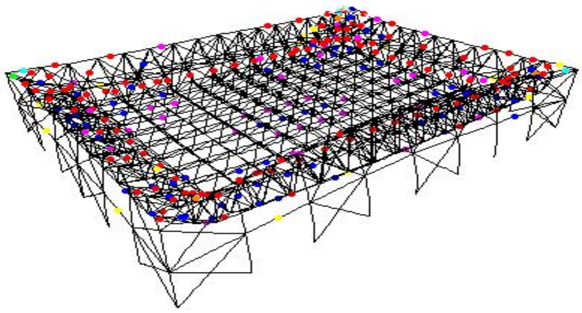

Fig.4The failure mode and the plastic hinge distribution

Tab. 2 Displacement ductility coefficien

Critical PGA (gal)	Node number	Absolute displacement	yield Displacement ratio
360	111	109	1.00
733	111	549	5.034

According to Tab.1~2 and Fig.1~4, the results can be concluded as follows:

The elastic limitation PGA for three direction input is 360. It is much larger than the PGA of the official SEL for small earthquake (70gal).

According to the B-R criterion [6,7], the failure model of the structure under the earthquake wave action is the complicated combination of strength failure and elasto-plastic dynamic local buckling in deferent areas of the structure. The critical PGA for this direction input is 733gal. It is much larger than the PGA of the official SEL for major earthquake (400gal).

The displacement ductility coefficient is 5.034 for the structure, and the ratio of its bars with plastic hinge appearing for ultimate critical state is 14.7% when EL earthquake waves applied on the structure, the development of the plastic hinges is not sufficient.

When its critical failure peak acceleration of EL earthquake wave when applied in the combination of three directions, all the members in the E stage are compression failure.

All results about show the structure have some deformed capacity and energy-dissipation capacity before collapse under earthquake.

Summary

When the structure reached its failure critical limit, the development of the plastic hinges is not sufficient and only 14.7% of the rods enter into their plastic stage. the maximum displacement can reach 549mm. there are many plastic hinges generated in the top chord and the lower chord. The displacement ductility coefficient is 5.034 for the structure, which shows the structure owns some energy dissipation capacity.

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