

Grid structures in Wenchuan Earthquake

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Abstract

In 2008, an earthquake with magnitude 8.0 happened in Southwest China. Several grid structures damaged or collapsed in this earthquake. Through investigation in the earthquake hit area, documents and precious pictures of these damaged grid structures were collected. Some typical failure patterns were summarized and suggestions for designing of grid structures were also proposed.

Keywords: grid structure; Wenchuan earthquake; earthquake resistance

1. Introduction

In 2008, a tremendous earthquake with magnitude 8.0 happened in Wenchuan, a small county in southwest China. Lots of buildings and structures failed in the earthquake and some grid structures located in this area were also suffered heavy damages. My colleagues and me went into the earthquake hit area immediately after the earthquake and investigated these damaged grid structures. Through them, we collected lots of precious pictures and documents, and some typical failure patterns were summarized for convenience of structural design. All the failed grid structures can be sorted into two categories – light and heavy weighted grid structures.

The light weighted grid structures have small responses to earthquakes because of their weight. Since they belong to undetermined structures, they have high degree redundancy and safety reservation and show good anti-seismic performance and smaller damages in this earthquake (Figure. 1). The stadiums or gymnasiums used light weighted grid structures, such as Deyang Gymnasium, Jiuzhou Gymnasiums in Mianyang, were used as headquarters and salvage centers in this earthquake and played an important role. The main damages to light weighted grid structures are demonstrated in several types: members in the supporters were buckled and broke off by tension or compressing; the destruction of the connections between members and node-balls; damages to roof covers and etc. For heavy

weighted grid structures, many of them were found overall collapsed due to the use of concrete slabs as roofs, which led to bigger earthquake effects.

2. Light weighted grid structures

Because of their light weight, light weighted grid structures suffered only small damages. Through the investigation, we found only several of them were damaged but not collapsed. The typical damage patterns include strut buckling, connector failure, and roof plate falling.



Figure 1: Deyang Gym with a hyperbolic saddle roof; grid shell used here with welding connection; no damages to the main structure, only ceiling damaged and infilling walls cracked partially



Figure 2-a: A grid shell in Dujiangyan



Figure 2-b: internal space

Fig. 2-a~g show a damaged grid shell in Dujiangyan. We can find some members close to supporters are buckled under pressure or yielded under tension. The earthquake resistance intensity of Dujiangyan is 7 and so earthquake effects can be ignored in this city according to stipulations of Chinese code. But in Wenchuan earthquake, the earthquake intensity

reached 8 or 9, members close to supporter beard higher forces than designer had estimated, so many of them buckled under compression or yielded under tension forces (Figure 2-c, 2-d, 2-f). Failure can also be observed on connectors (Figure 2-e). Although some members failed, the whole structure survived in the earthquake because of its good integrity and redistribution of internal forces (undetermined structures).



Figure 2-c: (↑) member failed under tension forces

Figure 2-d: (→) member failed under tension forces



Figure 2-e: (↑) Failure between members and connectors

Figure 2-f: (→) members close to supporters buckled under compression

Figure 3-a~c show a grid shell in city Mianyang. This bolted grid shell was supported on cantilever columns. When earthquake happened, displacement on top of the columns exceeded design limit and caused some members connected to supporters failed or buckled.



Figure 3-a A grid shell in Mianyang



Figure 3-b struts close to supporters failed



Figure 3-c some members buckled under compression

3. Heavy weighted grid structures

Figure 4-a~c show the damages to a grid shell of a factory in Jiangyou city. The factory spans 28 meters, with 12 meters of column spacing, and has two stories. The first floor is constructed by reinforced concrete slabs; the roof is the combination of lattice shell and concrete slabs. The shell has a skylight shelf along the longitudinal direction. The shell and the lower concrete structures were divided, along the longitudinal direction, into two sectors by the seismic joint: one sector collapsed, the other was only with some small damages. The reason is there is a big hole by side of the constructional joint at the collapsed sector.



Figure 4-a the mechanical factory in Jiangyou, half collapsed



Figure 4-b the intact sector



Figure 4-c collapsed sector-Integral collapse

Figure 4-d~e shows collapse of concrete roof plate



Figure 43-d concrete plates as roof covering



Figure 4-e concrete plates fell

Figure 4-f~q show other pictures of this factory



Figure 4-f: (↑) Louver collapsed at the middle part
Figure 4-g: (→) Supporters and the connected members (1)



Figure 4-h: (↑) Supporters and the connected members (2)
Figure 4-j: (→) Supporters and the connected members (3)



Figure 4-k: (↑) members and nodes fell down on the ground (1)
Figure 4-m: (→) members and nodes fell down on the ground (2)

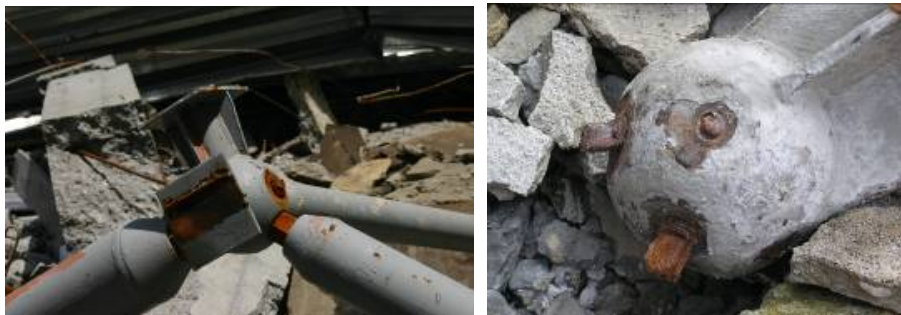


Figure 4-n: (↑) failed connectors, bolts on the nodes rusted and snapped (1)

Figure 4-o: (→) failed connectors, bolts at the nodes rusted and snapped (2)



Figure 4-p: (↑) neighbored grid roof intact

Figure 4-q: (→) neighbored grid shell; a few members buckled

4. Suggestions for grid design in earthquake area

Based on these damaged grid structures in Wenchuan earthquake, some suggestions should be mentioned especially for designing of grid structures in earthquake area with high intensity:

- a. In earthquake area, materials should not be use to the extreme yielding stress in order to maintain safety reservation. The members in key parts should be restricted to low stress level.
- b. Stress concentration always happens at supporters for spatial structures, so designers should set a reasonable arrangement of members connected to supporters to reduce the maximum stresses. In designing and construction, we should pay special attention to supporters and members connected to them.
- c. When analyzing spatial structures, an integral analysis considering co-work between roofs and bottom concrete structures should be carried.
- d. districts with Anti-seismic Intensity 7 are proposed to consider both the vertical and horizontal seismic motions, especially for heavy weighted grid structures.