**Lightweight Structures Collapsed by Heavy Snow in January 1998 in Japan**

Ken'ichi Kawaguchi
Associate Professor, Dr._Eng. Institute of Industrial Science, University of Tokyo

Institute of Industrial Science, University of Tokyo,
Roppongi 7-22-1, Minato-ku, Tokyo 106-8558, JAPAN
Tel. +81-3-3402-6231 (ext.2557)
Fax. +81-3-3479-0247

**ABSTRACT**

In January 1998, heavy snow have struck the Kanto and Koshin'etsu area in Japan. Three school gymnasiums in Yamanashi prefecture were collapsed under the snow load. The paper reports the damage overview of this snow disaster. Two of gymnasiums were collapsed by the snow fall and the third one was collapsed during rain, which was falling on three days after the snow fall and penetrating into thick snow on the roof.

## 1. INTRODUCTION

Last winter in Japan, from January 14th night through 15th evening, heavy snowfall have struck Kanto and Koshin'etsu area. By this snow three school gymnasiums, rather conventional steel frame structures, in Yamanashi prefecture were collapsed (Table 1). This paper overviews the damage to these gymnasiums and to a small net structure, a bird cage in a zoo in Tama area in Tokyo.


Fig.1 Yamanashi prefecture

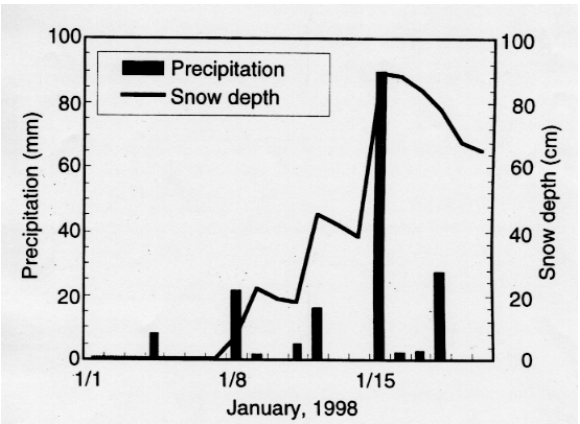


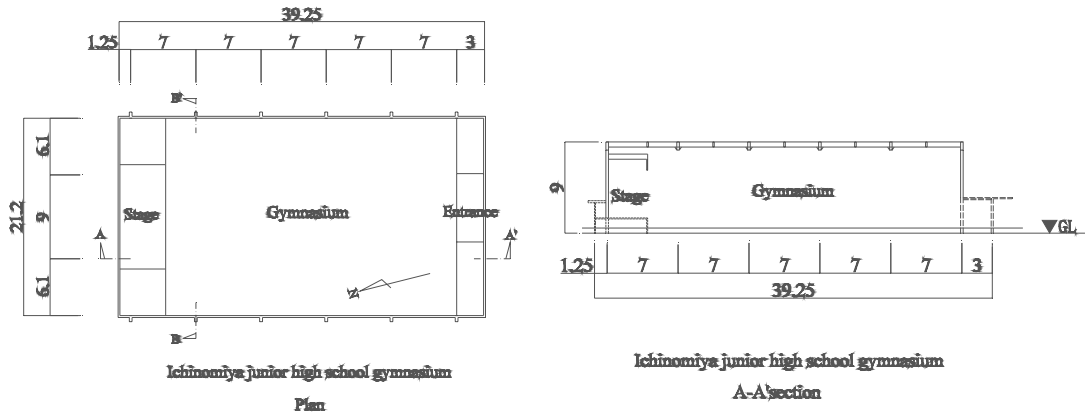

Fig.2 Rainfall and snow depth recorded at Kawaguchiko meteorological station ( by courtesy of prof. T.Takahashi at Chiba univ.)

Table 1: School gymnasiums collapsed by snow

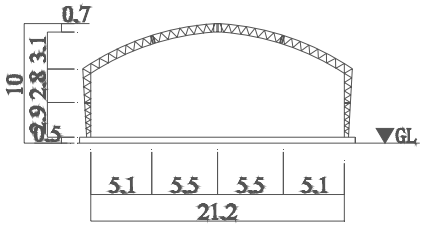
| School Name | Year of Completion | Floor Dimension | Frame type | Date and time of the Collapse |
|---|---|---|---|---|
| Ichinomiya junior high school | March 1963 | 21.2m x 39.25m | Steel trussed arch | 14:00, 15th Jan. |
| Kawaguchikonan junior high school | August 1970 | 25.38m x 46.2m | Low V hinged arch | 16:30, 15th Jan. |
| Kitafuji technical high school | February 1967 | 27.0m x 39.5m | Low V hinged arch | 8:00 18th Jan. |

## 2. ICHINOMIYA JUNIOR HIGH SCHOOL ( Completion : March 1963)

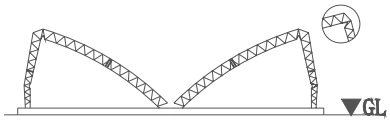
Neighbors who heard the large crash became aware of the collapse and informed to the school. The structure of the gymnasium was steel trussed arch assembled with light channel steels. Four spans in the middle part were collapsed while two spans near to both end walls stood still. Bolts connecting bottom chords at the center of the arch girders were broken off by shear (photo 3). Bottom chords of the girder ends or inner chords of the column tops were buckled (photo 4 (a), (b)). With these failures, whole of a single frame collapsed in mostly M shape (fig. 3(d)) . Since snow on the roof moved to lower place, the inner two spans in the middle part, which were further from the end walls, were most heavily damaged. For these two frames buckling of inner chords of columns were observed (photo 4 (c)). Some of the bases were rotated as the frame deformed.




(a) Plan view (b)A-A’section




Ichinomiya junior high school gymnasium
B-B'section




Ichinomiya junior high school gymnasium
Mechanism of collapse

(c) B-B'section (d) Mechanism for collapse

Fig.3 Ichinomiya junior high school

(a) Before collapse (b) After collpase

Photo 1: Ichinomiya junior high school gymnasium

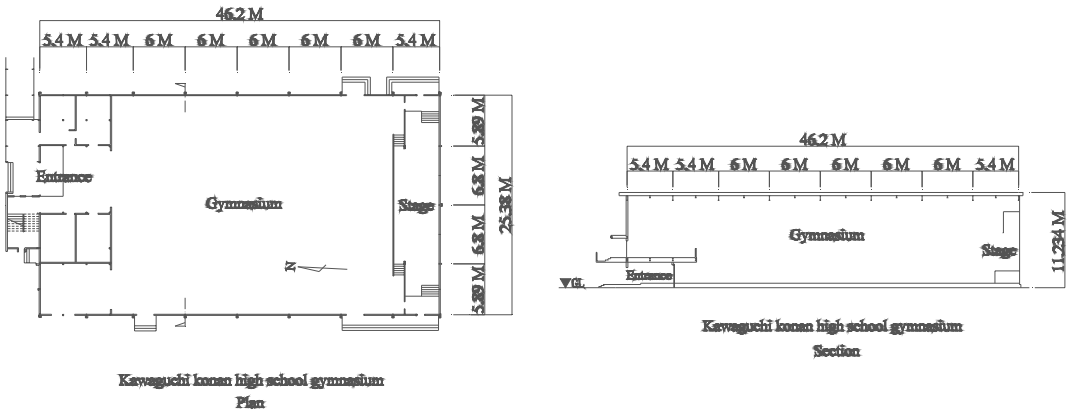
Photo 2: Interior view Photo 3: Shear cut of the center connection

(a) End of the girder (b) Top of the column (c) Buckling of the column

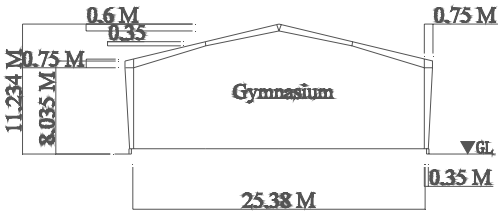
Photo 4: Failure at some positions

**3. KAWAGUCHIKONAN JUNIOR HIGH SCHOOL ( Completion : Aug. 1970)**

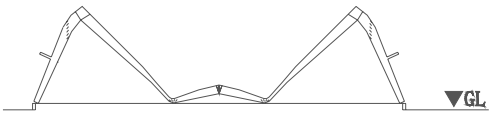
During the snow strong wind was blowing at this area. As same as the previous case, neighbors who heard the large crash became aware of the collapse and informed to the school. The structure of the gymnasium was low V shaped steel hinged arch assembled with thin prefabricated steel I-beam. The depth of the beam varies along the span and takes the smallest depth at the quarter of the span. The beam-column connection is a bolt connection using a special cross shaped steel element. Among nine span frames four spans in the middle part were completely collapsed while remaining five spans covering a stage and storage adjacent to end walls survived without any damage. Plastic hinges were observed just next to the beam-girder connections located at one third of the span from either side. By large torsional buckling columns were deformed from their tops to where the gallery floors were attached. Such failure formed mechanisms for collapse. Bolts at the bases were badly corroded, so that some of the bases were rotated and pulled off from the anchor bolts.




(a) Plan view (b) Section 1




Kawaguchi konan high school gymnasium
A-A'section




Kawaguchi konan high school gymnasium
Mechanism of collapse

(c) Section 2 (d) Mechanism for collapse

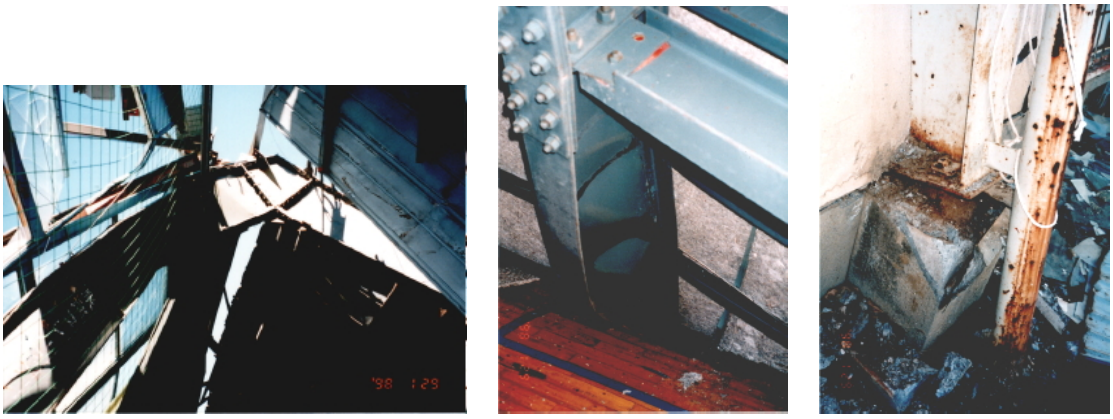
Fig.4 Kawaguchikonan junior high school

(a) Before collapse (b) After collpase

Photo 5: Kawaguchikonan junior high school gymnasium

(a) Interior view 1 (b) Interior view 2

Photo 6: Interior view



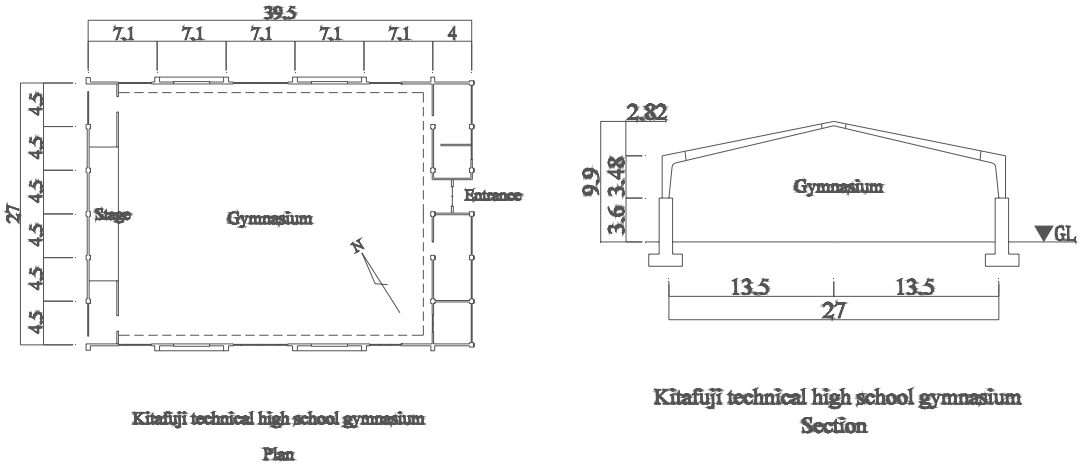
(a) Column torsional deformation (b) Plastic hinge (c)Base and anchors

Photo 7: Failure at some positions

**4. KITAFUJI TECHNIAL HIGH SCHOOL ( Completion : Feb. 1967)**

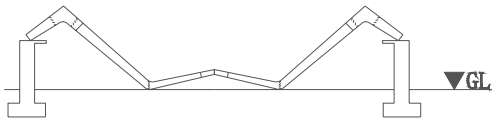
This structure did not collapse during snow on 15th. It rained from 17th through 18th and the structure collapsed in the morning of 18th. Again Neighbors found the collapse and informed to the school. From the foundation to the gallery level the structure was made of reinforced concrete. The upper structure was low V shaped hinged steel arch. The beam-column connection was prefabricated as one unit. Four spans in the middle part were collapsed while two spans of both end walls were not collapsed and leaned inside being pulled by beams connecting end wall frames to the inner collapsed frames. For collapsed frames plastic hinges were observed at the connection with beams located at one-third of the span. Other plastic hinges were observed at the ends of girders or at the tops of columns. Bases on the R.C. galleries were forced large rotation and all anchor bolts were broken off.

Thick snow on the roof absorbed rain. The rainfall on 18th was of 30mm, which is equal to the distributed load of 30kgw/$m^2$.




(a) Plan view (b) Section

Fig.4 Kawaguchikonan junior high school




Kitafuji technical high school gymnasium
Mechanism of collapse

(c) Mechanism for collapse

Fig.5 Kitafuji technical high school

(a) Before collapse (b) After collpase

Photo 8: Kitafuji technical high school gymnasium

(a) Interior view 1 (b) Interior view 2

Photo 9: Interior view

(a) Girder torsional deformation (b) Plastic hinge (c)Rotated columns and bases

Photo 10: Failure at some positions

## 5. BIRD CAGE ( Completion : Aug. 1996)

During snow on 8th through 9th a cable net roof for a flamingo birdcage in a zoo at Tama area of Tokyo was broken. The dimension of the roof was 36mx13.3m. Main cables were 9mm diameter and spanned 28m between two main poles of 12m high. The net was fish net with 40mmx40mm square grids. Such grid of the net is fine enough for snow to lie on. One of the main poles was buckled under the snow load.

(a) General view (b) Broken nets and a main pole

Photo 11: The flamingo birdcage after the collapse

## 6. CONCLUSIVE REMARKS

Last winter we experienced unusual snowfall distribution in Japan. It snowed very little where people usually have much snow and more snow has fallen where people usually have very little snow. The collapsed gymnasiums were designed based on the old local design code. The recent local code requires more snow load. However our design codes are based on the just recent decades' observation records. Slight change of climate condition can cause severe natural disasters.

It was just the beginning of winter terms in schools and all of three gymnasiums were used for opening ceremonies or gymnastic club activities on the day before the collapse. Nothing symptomatic was reported and each collapse occurred suddenly in a very short

time. Although 15th was a national holiday and 18th was Sunday it was miraculously lucky that no one was using the gymnasiums when they collapsed.