[論文]

SAMPOONG COLLAPSE
A Tragic Man－made Disaster

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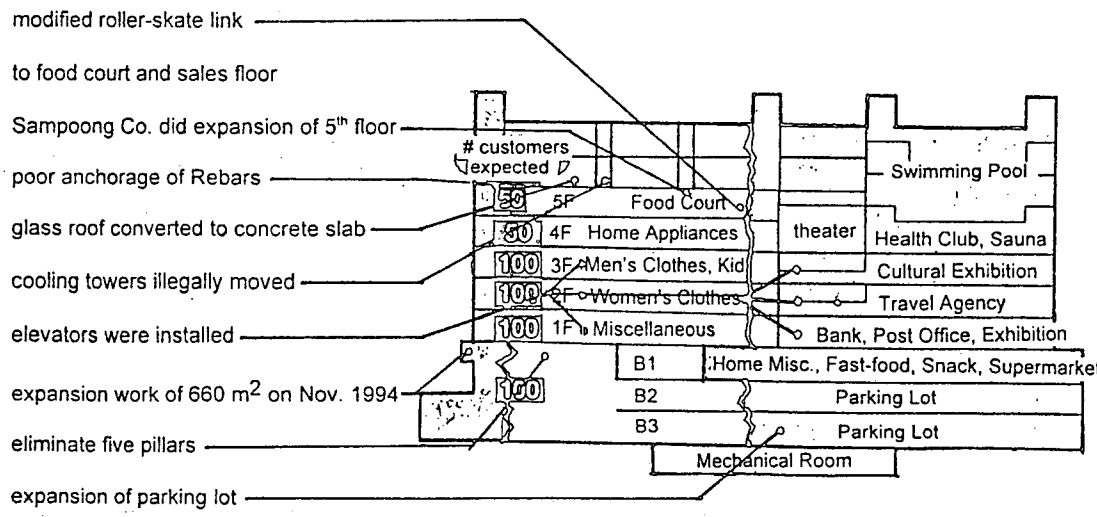
Contents

1. Outline of the Accident

(1) Name of the building : Northern wing of Sampoong department store.
(2) Location : Socho－Dong in southerm Seoul.
(3) Date and time of the collapse : 5:50 PM, June 29, 1995.
~Sudden fall－down from top floor to bottom of basement
(4) Casualties : 501 Killed, 937 injured.
~mostly store employees and evening shoppers.
(5) Bldg. Structure : Reinforced concrete structure, flat slab system w/ drop panels.
(6) Srories : Five stories above ground and four basement floors.
(7) Floor Area : Total 73,877㎡
(8) Construction Period : Sept. 1987~Dec. 1989.
~elapse of year : five and a half years.
(9) Section of Building



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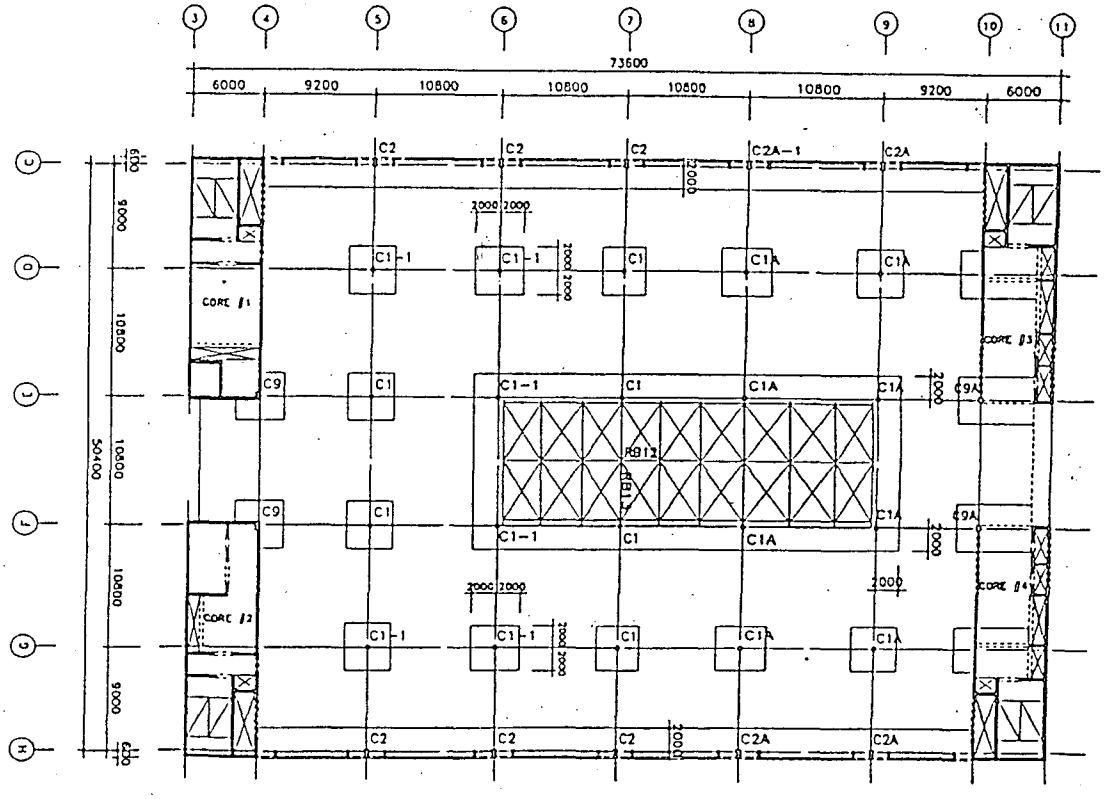
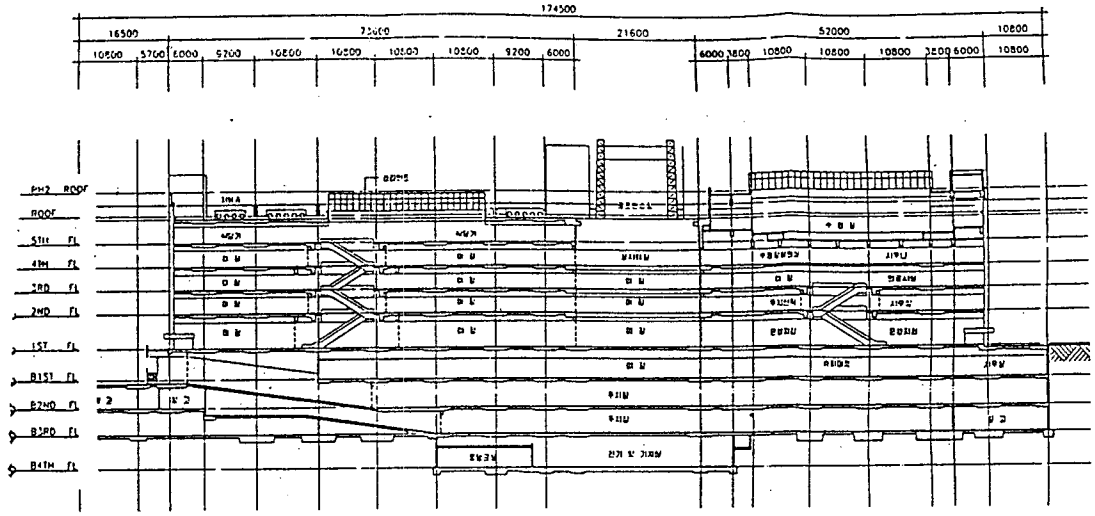
Chronology of Modification / Expansion of the Building

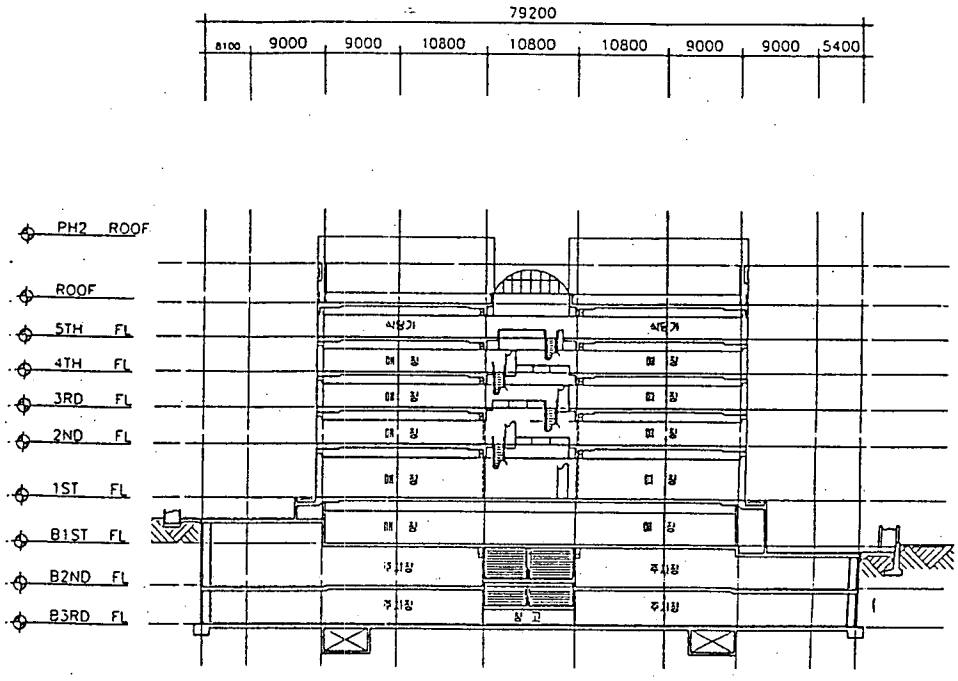
Date	Description
Sept. 15, '87	Construction initiated by Woosung Co.
Jan. 31, '89	Skeleton completed by Woosung Co.
Feb. 01, '89	Expansion of 5th floor by Sampoong Construction Co.
Nov. 27, '89	Temporary permit of usage
Dec. 01, '89	Ward Office's permit of whole building
Oct. 21, '94	Expansion of basement sales floor by 660m²
Jun. 15, '95	Expansion of basement for parking lot
Jun. 29, '95	Collapse of northern wing whole building



Framing Plan at Roof Slab



Longitudinal Section at the Building



Cross Section of the Building

2. Causes of the Accident

The causes of the accident can be summarized as following

(1) Design and Engineering
- neglected thorough analtsis of structure caleulations.
- did not follow the design code and procedures.

(2) Construction and Supervusuon
- irregular practice by the construction company.
- loose supervision of the construntion.

(3) Maintenance
- frequent modification.
- illegal expansion of sales floor.

Detailed Analysis of the causes

(1) Less span than design

Design : three span or more	Actual : two span only

(2) Longer span than design

Adequate : 7.5m 0r less	Actual : 10.8m × 10.8m

(for a better space view, less number of columns were used)

(3) Overloads of roof

Design : 100 kg / m²	Actual : 210 kg / m²

(4) Relocated cooling tower (400 tons)

Design : rear	Actual : front

(5) Column reinforcement

Design : ϕ =800㎜ w/bars	Actual : ϕ =600㎜ w/bars
D22−16EA	D22−8EA

(6) Management by shoddy sub−contrantor

(7) Failure of quality control : poor qualities in concrete slabs, walls, and pillars.

(8) Absence of proper management and supervision of the project

(9) frequent modification and illegal expansion of the floors

(10) Impact of crumbling top floor

(11) Failure of punching shear at periphery of columns

☞ In summary,
- aii engineers were lacking professionalism, and
- work haphaxardly and carelessly out of bab habit, which is so called, "it's all−right syndrome."

☞ With the painful lessons form the "Sampoong" accident still vivid in our minds, each one of us makes···

Building Code For Flat Slab Design

Design Procedures

Methods of analysis—All flat slab structures shall be designed un accordance with a recognized elatic analysis subject to the limitations of Sections 2102 and 2103, except that the empirical method of design given in 2104 may be used for the design of flat slabs conforming with un limitations given therein. Flat slabs within the limitations of Section 2104, when designed by elastic analysis, may have resulting analytical moments reduced in such proportion that the numerical sum of the positive and average negative bending moments used in design procedure need not exceed the sum of the corresponding values as determined from Table 2104(f)

Empirical Method

General limitations—Flat slab construction may be designed by the empirical provisions of this section when they confirm to all of the limitations on continuity and dimensions given herein.

LIMITATIONS FOR USE OF FLAT SLAB

1. L/B = Not more than 1.33.
   Slab continuous over 3 or more panels in each direction.
3. The successive span lengths in each direction differ by not more than 20% of the longer span. Columns may be offset a maximum of 10% of the span in the direction of the offset from either axis between center line of successive columns.

COMPRESSION DUE TO BENDING

¼ of the width of the strip or drop panel shall be taken as the width of the section in computing compression due to bending. (For positive and negative moments, tension reinforcement to be distributed over entire strip.) Account shall be taken of any recesses which reduce the compressive area.

THICKNESS OF SLABS

1. L/36 Without drop panel, but not less than 5" nor t_1.
   L/40 With drop panel, but not less than 4" nor t_2.

*2. $t_1 = 0.028L\left(1-\frac{2c}{3L}\right)\sqrt{\frac{w'}{f'_c/2000}} + 1\frac{1}{2}"$

*3. $t_2 = 0.024L\left(1-\frac{2c}{3L}\right)\sqrt{\frac{w'}{f'_c/2000}} + 1"$

4. Where the exterior supports provide only negligible restraint to the slab, the values of t_1 and t_2 for the exterior panel shall be increased by at least 15%.
5. The maximum total thickness at the drop panel used in computing negative steel area shall be $1.5t_2$. The side or diameter of the drop panel shall be at least 0.33 times the span in the parallel direction.
6. The minimum thickness of slabs where drop panels at wall columns are omitted shall equal $(t_1 + t_2)/2$ provided the value of c used in the computations complies with General Notes No.3.

* t_1 and t_2 in inches, L and c in feet.
w' = uniformly distributed unit dead and live load.

SHEAR

Shearing unit stress V on a vertical section which follows a periphery b at distance d beyond the edge of the column or column capitel and parallel or concentric with it, shall not exceed the following values when computing $v = \frac{V}{bjd}$.

(a) $0.03f'_c$ but not more than 100 p.s.i. when at least 50% of the total negative reinforcement in the column strip passes through the periphery.

(b) $0.025f'_c$ but not more than 85 p.s.i. when 25%, which is the least value permitted, of the total negative reinforcement in the column strip passes through the periphery.

(c) Proportionate values of the shearing unit stress for intermediate percentages of reinforcement.

(d) Where drop panels are used, the shearing unit streys on vertical sections, which lie at distance d beyond the edges of the drop panel and parallel with them, shall not exceed $0.03f'_c$ nor 100 p.s.i. At least 50% of the total negative reinforcement in the column strip shall be within the width of the strip directly above the drop panel.

REINFORCEMENT

The ratio of reinforcement in any strip shall not be less than 0.0025bd. Spacing of bars shall not exceed 2 times the slab thickness. Length of splice – 36 diameter.

GENERAL NOTES

1. The coefficients of the table may be varied by no more than 10% provided the numerical sum of the + and − moments remains unchanged.
2. For columns without a capitol the distance c shall be taken as the dimension of the column in the direction considered.
3. For columns with brackets take c equal to twice the distance from center line of column to the point where the thickness of the bracket is 1½".
4. Panels supported by marginal beams on opposite sides shall be designed as one or two-way slabs.

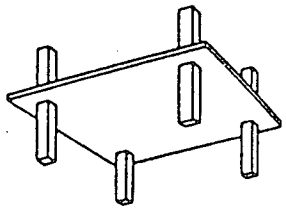
OPENINGS IN FLAT SLAB

1. Openings of any size may be provided in a flat slab in the area common to two intersecting middle strips provided the total positive and negative steel areas are maintained.
2. In the area common to two column strips, not more than ¼ of the width of strip in any span shall be interrupted by openings. The equivalent of all bars interrupted shall be provided by extra steel on all sides of the openings.
3. In any area common to one column strip and one middle strip openings may interrupt ¼ of the bars in either strip. The equivalent of the interrupted bars shall be provided on all sides of the openings.
4. Any opening larger than described above shall be analyzed by accepted engineering principles and shall be completely framed as required to carry the loads to the columns.

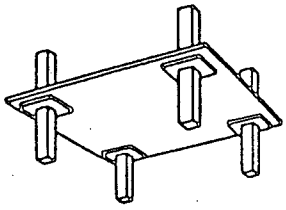
3. Characteristics of the Building Structure

Reinforced concrete structure with drop panels

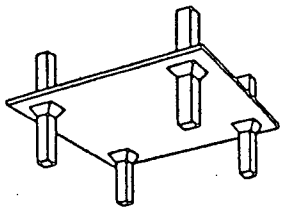
flat plate slab



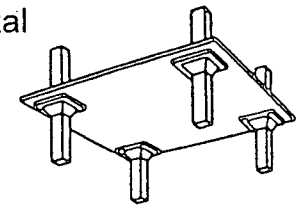
flat plate slab w/drop panel



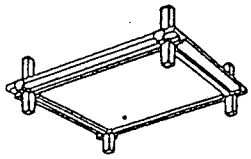
flat plate slab w/capital



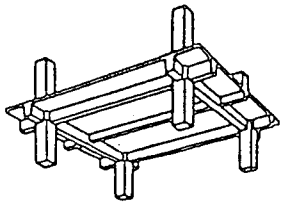
flat slab w/drop panel and capital

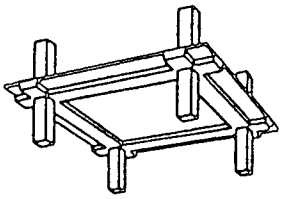


one-way slab

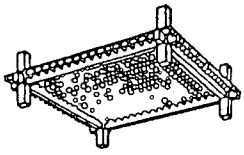


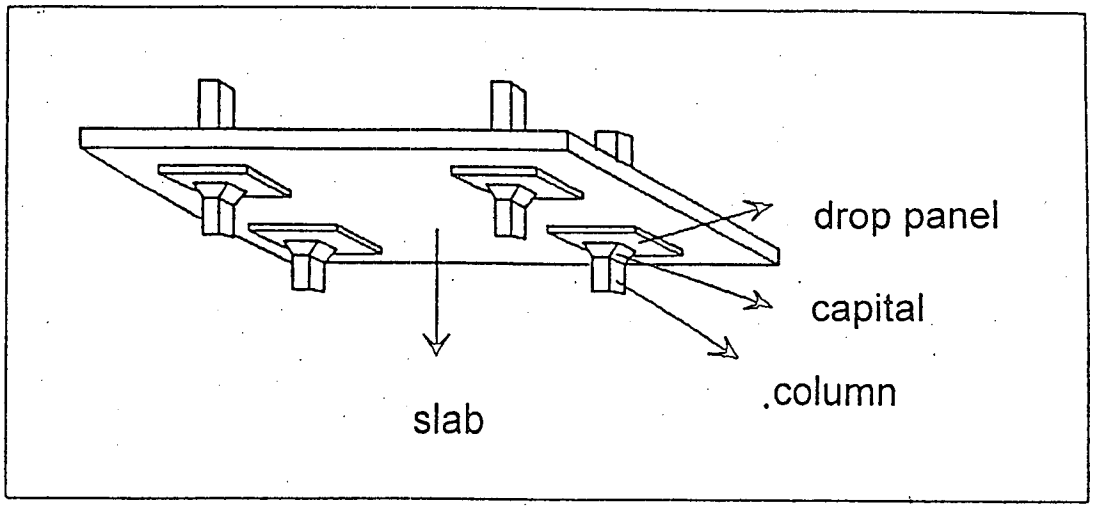
two-way slab



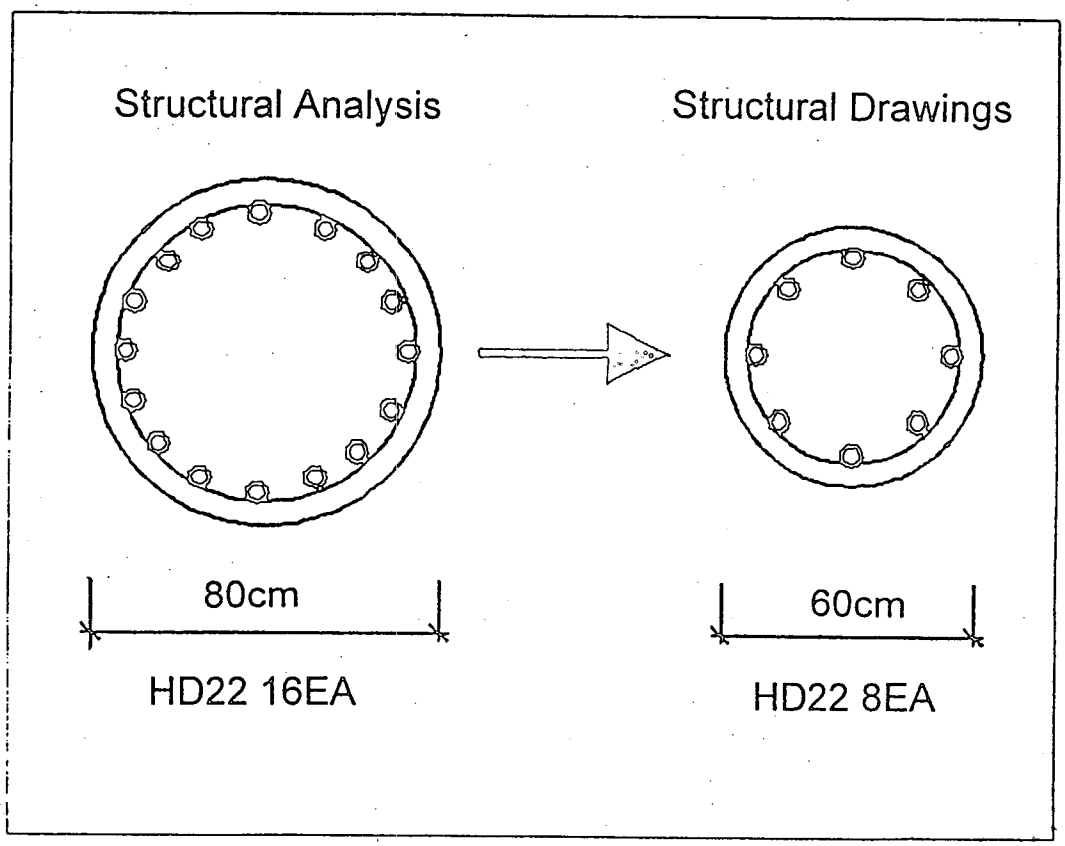


waffle slab





Flat Slab Composition



The difference between drawings and calculations

4. Remedial Measures after the Accident

The govetnment enforced safety measures affecting every stage of construction from designing and building to supervision and management. The accident brougt positive changes in our loose attitude and unconsciousness for safety.

The actions are,

(1) Establishment and enforcement of a special law for major facilities of public use:
- all facilities of public use shall be safety-checked regularly, and report shall be made to relvant government office.
- management and supervision of construction shall be enforced at every construction stage.
- introduce relevant laws in favor of harsher punishments to those responsible for shoddy construction and negligence in precentive safety measures.

(2) The government will establish safety officials who will,
- make safery measures of construction related disasters.
- make code and regulations to ensure and maintain cinstruction safety.
- select and apptove qialified Safery investigation firms.

(3) Opening ghe supervision and management market to foreign firms or third parties.

5. Example or Remedial Measures Abroad

	JAPAN	USA	France
Name of Accident	◦ Gas explosion in subway construction site, Osaka, Japan	◦ Collapse of swinging bridge at Hyatt Regency Hotel, Kansas City, Missouri, USA.	◦ Collapse of casino roof slab in supermarket, Nice, France
Date	Apr. 8, 1970	July 17, 1981	Jan. 26, 1994
Casualties	79 killed	114 killed, 200 injured	3 killed, 97 injured
Summary of Accident	◦ explosion of gas leaking from cracks in gas main ◦ iron girders and plate coverings blown away ◦ tilted steel beams ◦ cars tumbled into construction pits	◦ Collapse of a swinging bridge of 40 meter span down to dance party of several hundreds ◦ Controversy on causes, 1. safety problem in design 2. mismanagement of hotel allowing several hundred persons over the bridge	◦ collapse of casino roof over sales floor of 800m^2. ◦ About 1700 tons of earth and concrete debris over the sales floor.
Fact-finding and Administrative Actions	◦ resumption of construction first -> compensation -> investigation afterwards. ◦ investigation mainly focused on whether there was violation of the safety laws. ◦ Cooperative investigation with Osaka University ◦ Max. 3 years, min. 6 month imprisonment to the accused. ◦ Strict safety procedures enforced afterwards.	◦ Investigation for 4 years and 5 months concluded GCE International guilty -> license cancellation. ◦ More than 400 lawsuits to the hotel (total compensation ~ 113 Million $) ◦ 1000$ to 1300 attendant for their emotional damage ◦ mandatory safety bond afterwards	◦ investigation for the cause of accident over 1 year blamed careless and under-qualified workmanship. ◦ Construction foreman lacking knowledge of structural engineering ◦ under-qualified construction supervisor.