Collapse accident under New Haengju Bridge construction work [Seoul City, Korea. July 31st, 1992]

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When New Haengju Bridge over the Han-gang River which connects the Jiangxi Ward in capital Seoul City with the Goyang city, Gyeonggi-do in Korea was under construction, its 10 bridge piers and the bridge girder of 1020m length collapsed. The fault originated in the cable-stayed bridge part in the center just before the completion.

Fortunately, no one was killed.

Photograph 1 the situation right after the collapse accident of New Haengju Bridge.
(Donation: Prof.Yozo Fujino, University of Tokyo)

1. Event

At around 6:55 p.m, July 31st, 1992, New Haengju Bridge over the Han-gang River which connects the Jiangxi Ward in capital Seoul City with the Goyang city, Gyeonggi-do in Korea collapsed suddenly (see photograph 1, figure 1).

Since the accident occurred after the work was finished and the workers had left the site at 6:30 pm, no one was killed. It is said that the bridge under construction had no specific abnormality right before the collapse accident. It brought about the damage of the various equipments of several billion won which had been temporarily put on the completed girder, and the extension for 2 years and 3 months of the construction which had started in 1987 and planned to be finished in December, 1992, at the construction expense of 17 billion won.

The New Haengju Bridge is a prestressed concrete(PC) box girder highway bridge of 1460m length and 14.5m of width which consists of 3 spans connected cable-stayed bridge (100m+120m+100m) in the central part and multispan connected digits of the 60m span of both sides, as shown in figure 2. The substructure is composed of caisson

foundations or pallet pile foundations, bridge piers of reinforced concrete and the main tower in the cable-stayed bridge part and abutments.

The features of the collapse situation was that the whole parts collapsed all at once since the entire part of 800m was a PC connected box girder structure and it was a unified structure, and that a form of destruction which is the breakage of the whole cross section occurred at various parts of the girders.

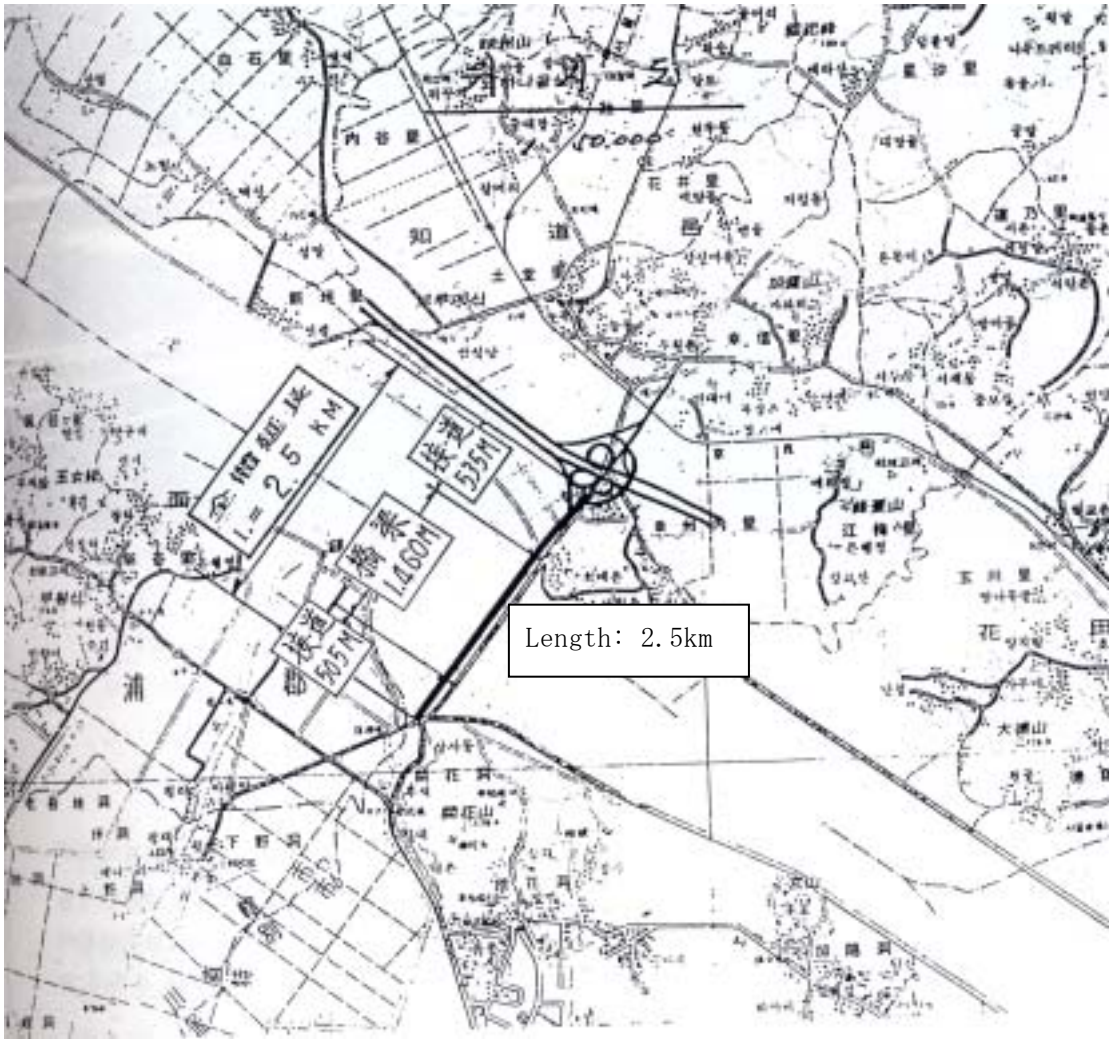

Figure 1: Position of New Haengju Bridge.

2. Course

The PC connected box girders were installed by the extrusion method (Incremental Launching Method). Each block was constructed in 20m lengths in the production yards installed near the abutment of both sides, and were pushed out while being connected one after another. It was planned to complete the section of 800m south from the northern abutment and the section of 660m north from the southern abutment by the extrusion method.

Since the span of the superstructure (the bridge girder part) was 60m, 2 temporary

pillars (temporary piers) were installed in each of the 2 rather long spans at the cable-stayed bridge section which were 100m and 120m long, and, in the each primary spans near the production yards on both sides and in the span where the bridge girders from both sides meet, temporary pillars were installed.

One of the features of the wire of the PC cable-stayed bridge over the 3 spans was that it was not typical flexible steel cable, and that rigid PC members were used in it.

It was planned to install plain concrete at appropriate timing into the central part (20m long) of the central span within the 3 ones under the cable-stayed bridge for the counterweight to suppress the negative cross sectional power, which is caused owing to the length (120m) of the central span which is longer than the side ones of 100m length. It is said that this plain concrete for the counterweight installed just before the accident acted as an unexpected load on the temporary pillars which were placed at the center span.

By the day of the collapse accident, the caisson foundations, the pallet pile foundations, the abutments, the bridge piers, 2 main towers of the cable-stayed bridge and the PC connected box girder part had been all completed except for the facilities for military purposes. The installation of the cable for the main tower of one side was finished and the cable for the other was temporarily put on the surface of the bridge girder. The concrete installation work of the joint with the bridge girder was carried out while the required tensile force (prestress) was not supplied to the cable.

Then the collapse accident occurred, and the PC connected box girder part of about 800m length which was pushed out for the south from the northern abutment was completely destroyed, and the main tower of one side broke. The temporary pillars and 10 piers were damaged heavily or destroyed (see Figure 2).

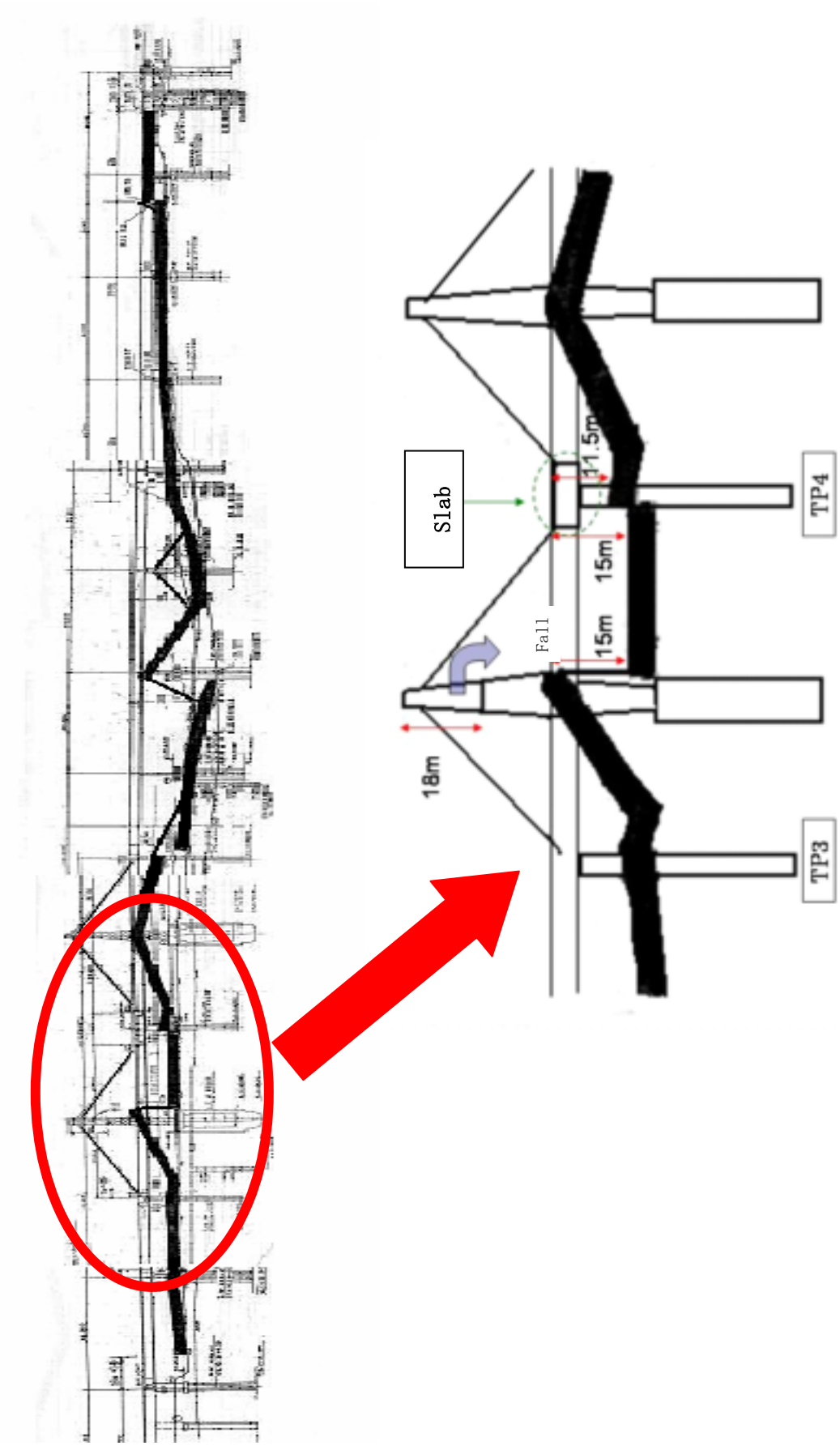

Figure 2: Outline of the structure of New Haengju Bridge and the collapsed part

(Source: Author made from several materials)

3. Cause

The collapse originated in the center span between 2 main towers of the cable-stayed bridge, and the collapse of the temporary pillars which were set there was supposed to be the direct cause (see Figure 3).

The connection performance of the PC connected box girders which were constructed by the extrusion method was considerably lowered (shear slip) by the installation work of the cable and the plain concrete. Therefore, the vertical load that acted on the temporary pillars increased considerably. As the result, the load supporting capability of the temporary pillars was markedly weakened, and the unexpected force and deformation acted on the PC connected box girders near the main towers and the cable, and it led to the collapse of the main towers and the bridge girder. Since the whole PC box girder section of 800m length was a connected digit structure, it is supposed that the big change of the load action condition by a collapse of one place triggered the collapse of one after another place where the cross sectional power surpassed the yield capability of the member.

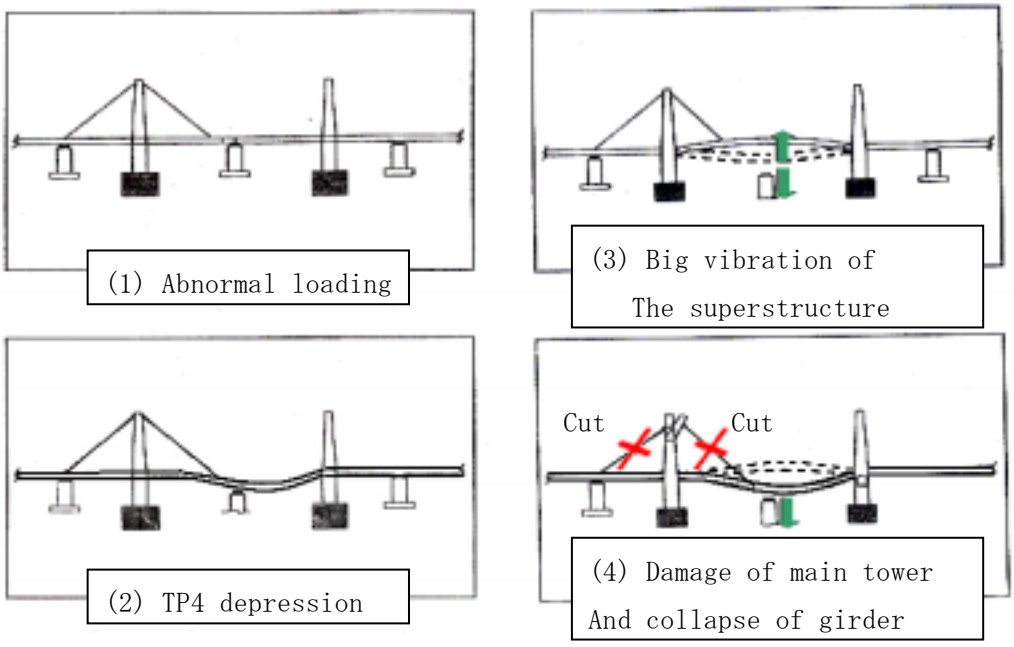

Figure 3: Collapse mechanism of the cable-stayed bridge part

(Source: Author made from several materials)

There might have been a failure in design and construction concerning the load supporting performance of the temporary pillars. However, since the construction was carried out without any prior examination about the effect of the load which arises during erection on the temporary pillars, the cable, superstructure, and substructure, it is evident that an excessive load acted and destroyed the members.

According to the accident report by Korea Soc. of Civil Engineering, the possible accident causes were, improper span design, improper selection of the cable construction method, impossible connection with an adjacent serial digit, improper

selection of the pier foundation construction method, improper design of the position and the structure of the temporary pillars, shortage of the safety of the temporary pillars in between the 2 main towers, shortage of cooperation between the design staffs of the super/substructure and the cable-stayed bridge since they were separated, incapability as a whole of the participants such as constructors, designers, and supervisors, and frequent and complicated staff changes.

The quality of the ready-mixed concrete which was the main material of the PC connected box girder bridge had been suspected to be bad, but it was proved not to have any defect as concrete material by the test of the material extracted from the site.

4. Immediate Action

The destroyed part of the bridge was removed and newly constructed.

The whole part of the PC connected box girders of 102m length, 1 damaged main tower, and 12 piers were removed. In the demolition, breakers (large rock drill), the dropping steel sphere strike method, nonvibratile high temperature and the pressure jet method, and wires-saw method, etc. were applied. The removal of the main tower was determined by horizontal load safety test.

The remedial work was carried out by the joint enterprise of DS Co. from Germany in the substructure and DRS Co. from USA in the superstructure under thorough design checking and construction management, and New Haengju Bridge opened on May 19th, 1995.

5. Countermeasure

As a result of the technological study during the remedial construction, many design changes were carried out.

(1) The cable of PC member whose rigidity was big was changed into flexible steel one in order to improve the workability and reduce the dead load.

(2) They reduced the load on the main towers by changing the cable-stayed bridge part (300m) to steel and concrete synthetic girder from PC connected box girder, and the length constructed by the continuous extrusion method was changed to 420m.

(3) The foundations of the removed 12 piers were changed to the circular concrete piles and their number and length was increased. The piers were strengthened by adding partitions to inside the hollow sections. Two of the three temporary pillars of the cable-stayed bridge part were changed to permanent structures, and the other was changed to steel from concrete.

The construction bureau of Korean government carried out safety checks on public works and public facilities, and special inspections on bridges of the national roads.

The necessity of instituting law, regulation and technical standards on the construction management technology was shared in order to strengthen responsibility

and authority of the design and construction company, and in order to improve the construction supervision system.

A prior qualification check system (P.Q.) for judging the construction ability of the builders was introduced.

Remedies such as prior announcement of schedule price and basic research expenses, a multiple schedule price system, installation and extension of tender and a contract monitoring committee were introduced and the penal regulation on prior leakage of tender information was strengthened in order to prevent foul play in the tendering and contract of public works.

6. Knowledge

Loose application of new technologies is an origin of disaster.

Immature imported technologies can cause fatal accidents.

Supervising engineers who can understand and manage the whole of the process of material selection, designing and construction are necessary. However, there are many difficulties in training them.

It is necessary to design considering the changes of loading conditions and structural deformation caused by moving the construction equipment and the structure during construction work.

Poor preparation and lack of risk management from greed are origins of major accidents.

7. Background

In the atmosphere by the rapid economic growth in 1970's in Korea, the bridges constructed in the capital city Seoul were criticized for lacking aesthetic sense in 1980's. The government officials who reacted to this criticism too sensitively applied the PC cable-stayed bridge easily which was the latest method and the appearance was graceful and airy, without grasping the safety and structural characteristics. Since this was the first case of this method in Korea, the design and construction specifications and technical standards of concrete cable-stayed bridge were unimproved. But the government officials authorized the application of the unaccustomed method in order to improve the domestic technology without effectively requiring the preparation of specifications for the new construction method. In addition, the central design review committee installed in the Diet had showed only general precaution and had not mentioned technical instructions under construction. As a result, it was pointed out that the accident was caused by leaving the technological study on design and construction and evaluations of the safety to the foreign engineers. It is said the fatal factor that no one cared about the outrageous behavior of leaving the cable of 120t weight made by PC member on the floor of the

connected box girder bridge since the Australian engineers didn't see it as a problem.

Byuck San Construction Co., Ltd. which was the builder ordered the construction completely from the subcontractors, since it did not own any required designing and erection planning technology. It used the drawing and specification and construction plan which were required in tendering and contract as it had been made by the subcontractors. The engineers of the Construction Promotion Public Corporation and the Courtesy Technology Group who were the design and construction supervisors did not have sufficient technological ability to manage the innovative PC cable-stayed bridge.

The Korean construction industry at that time suffered supply difficulty of construction material (inflow of bad material, shortage of such as cement, aggregate) and labor shortage (inflow of inexperienced worker). And it is also said the cause of the accident that they were rushing the construction of New Haengju Bridge since the completion was drastically delayed from the end of 1990 to the end of 1992, became of the government budget shortage in addition to the above factors.

Since it was designed without considering the construction procedure, the design and the construction procedure were frequently changed after the construction started. The possibility of the excessive loading on the temporary pillars might have been overlooked because of that.

In many cases of Korean public construction at that time, the orderers such as the government, local governments, and public corporations customarily presented the aimed completion year to the constructors by deciding it without sufficient examination about construction characteristics. Since the orderers set short design period in order to move up the completion, the investigations of geology and ground density and measurements of land shape and rivers in the fields were rough. Therefore, there were many cases in which there was no getting away from changing the design after the construction had started.

In addition, it is said that the supervision and inspection by the orderer was only to view the appearance roughly.

8. Sequel

In Korea in the economic development which originated from the big success of the Seoul Olympics 1988, the serial collapse accidents by the beginning of 1990 represented by New Haengju Bridge highlighted the order looseness of the government mechanism during the change period of the administration. The necessity of a big reform to prevent foul play and corner-cutting in construction projects by the government bureau was pointed out. However, this criticism has unfortunately been proved right by the collapse accident of Seongsu Bridge 2 years later, and the floor collapse accident of Sampoong department store in business.

9. On the Side

2 years after the New Haengju Bridge accident, a lot of articles were issued in Japanese newspapers and magazines and so on about the collapse accident of Seongsu bridge which occurred during operation and killed many people. In the case of New Haengju Bridge, news about it in Japan was very little because there were no casualties. Descriptions in this paper were all translated from the Korean materials.

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