Concrete flaking in a Shinkansen tunnel of West Japan Railway Co.

[June 27th, 1999・October 9th, 1999, Fukuoka Prefecture]

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In June, 1999, concrete in the Fukuoka tunnel between Kokura and Hakata in JR Sanyo Shinkansen line flaked off. The flake hit a *Hikari* Shinkansen train running in the tunnel directly, and the roof of rolling stock was torn up within about 16m long and 1m wide, and part of the pantograph was damaged. The *Hikari* Shinkansen train stopped suddenly, since the power transmission stopped near the tunnel exit. Luckily, no one was injured, but suspension and delay of trains of this section arose one after another from the power cut in both up and down tracks.

Because of this accident, West Japan Railway Co. checked all tunnels of Sanyo Shinkansen line and made the safety announcement. But in October, the same year, it was found that about 226 kg concrete mass, which broke into 5 pieces, had fallen by the line of the Kitakyushu tunnel in the same section. West Japan Railway Co. stopped the Sanyo Shinkansen line, and about 10 hours were taken for all lines to restart.

By a series of these events, the safe image of the Shinkansen line was shaken.

1. Event

In June, 1999, concrete in the Fukuoka tunnel between Kokura and Hakata in JR Sanyo Shinkansen line flaked off and the flake hit a *Hikari* Shinkansen train running in the tunnel directly. And it was found that concrete mass had fallen in the Kitakyushu tunnel in the same section. (Photograph of the site is shown in Figure 1.) Since 1996, many cases of the concrete piece falling from viaduct had been reported, and it turned out that concrete structures of Sanyo Shinkansen line had problems with safety and durability.

Figure 1. Kitakyushu tunnel flaking site
(Source: Chugoku newspaper)

2. Course

At about 9:25 a.m., on June 27th, 1999, concrete in the Fukuoka tunnel between Kokura and Hakata in JR Sanyo Shinkansen line flaked off. The flake hit a *Hikari* Shinkansen train running in the tunnel directly, and the roof of coach 9 was torn up within about 16m long and 1m wide, and the pantograph of coach 12 and 10 was

damaged. Luckily, no one was injured, but the *Hikari* Shinkansen train stopped suddenly near the tunnel exit because of the power cut. Suspension and delay of trains of this section arose one after another from the power cut. By 1:30 p.m., both the up and down tracks restarted.

At about 4:10 p.m., on October 9th, the same year, it was found that the concrete mass (334cm wide, 40cm deep, 15cm high, and about 226kg in gross weight), which broke into 5 pieces, had fallen by the line of the Kitakyushu tunnel in the same section. West Japan Railway Co. canceled the operation of the Shin-Osaka-Hakata section, and restarted the operation of the Shin-Osaka-Hiroshima section by 9 a.m., and that of the Hiroshima- Hakata section by 4 p.m... This had an influence on about 62000 persons including vacationists on what was the first day of 3 straight holidays.

3. Cause

The cause of the Fukuoka tunnel accident was the inconsecutive plane of the concrete, which is called cold joint (CJ). (The figure which shows the outline of the accident is shown in Figure 2.) It is necessary to pour concrete into a form divided into divisions with the restrictions such as lateral pressure of mold, assembly of reinforced steel, temperature rise of mass concrete, technical constraint, and the quantity of the concrete which can be poured in one day, etc.. In this case, the condensation of the concrete poured in advance advances, and a plane of discontinuity occurs between old concrete and new concrete. Throughout construction, curing, and use, the crack was generated in the inside of the CJ, and it developed, and it seemed to cause the flaking.

In the Kitakyushu tunnel, the method called "flying arch method" was adopted. In this method, firstly the arch concrete was constructed, a protuberant pouring mouth was equipped between the mould of the side wall and the arch concrete, and the side wall concrete was poured later. This protuberant pouring mouth was not removed after completion of the tunnel. For some reasons such as subsidence of the side wall, the crack between the projection and the side wall was generated. Then, the crack developed further by water leak, temperature change, train vibrations, etc. over time, and it finally fell by the dead weight. The figure which shows the outline of the accident in the Kitakyushu tunnel is shown in Figure 3.

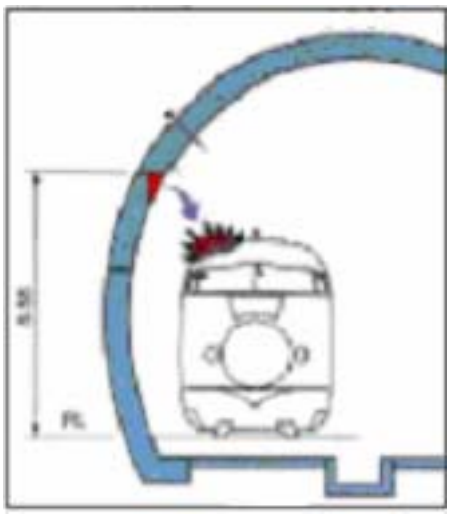

Figure 2. The outline of Fukuoka tunnel accident

(Source: Nikkei construction)

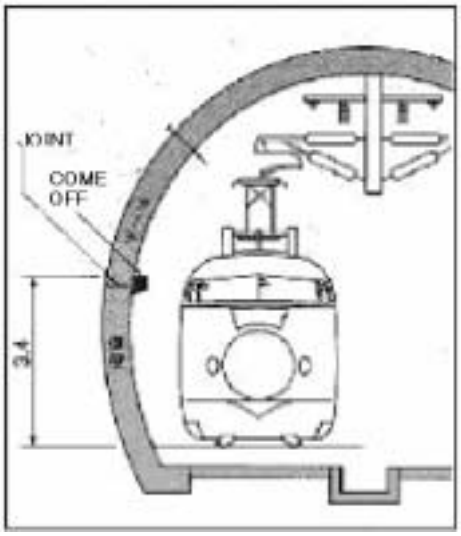

Figure 3. The outline of Kitakyushu tunnel accident

(Source: Nikkei construction)

4. Immediate Action

The accident on June 27th resulted from a cold joint (CJ), which West Japan Railway Co. did not make to be one of check items then. West Japan Railway Co. checked CJ of all 142 tunnels of Sanyo Shinkansen line (they extended for about 280km.) by carrying out a hammering test. CJ was found at no less than 2049 places in 93 tunnels. It carried out temporary measures such as removal of the bad part by hitting, and the safety announcement was made in August after the check.

Figure 4. Hammering test

(Source: Chugoku newspaper)

On October 9th, after about 3 months, as if mocked the inspection on CJ, the protuberance in tunnel side wall, called placing mouth collapsed. West Japan Railway Co., which considered the situation serious by these 2 accidents "assumed all situations" for prevention of recurrence of the accident, and from October 25th, carried out the bigger inspection than ever with its deadline on December 15th to all 142 tunnels. From November 8th, a total of 9 trains in both up and down tracks of the Hiroshima- Hakata section were canceled or partly canceled, the last train was run at an earlier time, and the work time of the same section was extended by about one hour. Since the whole line opening (March, 1975), there was a complete inspection involving a suspension of operations for the first time. The photograph of Figure 4. shows the aspect

of the hammering test which was opened on November 13th to public by West Japan Railway Co. which did the whole inspection because of the accident of the Kitakyushu tunnel.

５．Countermeasure

Since West Japan Railway Co. had successive concrete piece flaking accidents, while it carried out a review of inspection periods, inspection methods, criteria, and repair method of tunnel, viaduct and the like, it promoted the introduction of the accreditation system in the repair work and positive introductions of the results of the new technology development, etc., and it tackled the improvement of the maintenance system.

On the other hand, one opinion is that the investigation and analysis and countermeasure from the impartial standpoint should be made possible by establishing an accident investigation organization independent of the project-implementing body, and another opinion is that the Shinkansen is an infrastructure important to the country, the maintenance of it should not be entrusted only to JR, and it is necessary for the country to tackle the maintenance as a national project which has priority over the other public works. And, there is an opinion that a series of inspection and repair are superficial, and it may not become a drastic solution to the problem including the degradation of the concrete inside.

The new technology introduced into the tunnel maintenance

① Tunnel Maintenance System (TuMaS)

The Results of the whole safety inspection of the tunnels in 1999 have been stored into a data base, and this has become the system with mobile function that makes quick and easy update, retrieval and editing of repair history and transformation, etc...

② Tunnel lining surface inspection system (SATUZO)

By irradiating lining surface with laser and detecting intensity of the reflected light, the system can measure the crack. This is a system which is a remarkable improvement of speed and precision of measurement over those currently in use, and it aims at automated inspection in the future, and possesses the function of automatic detection of the crack (Figure 5.).

Figure 5. Inspection by SATUZO
(Source: West Japan Railway Co)

③ Others

In addition, there are inspection techniques under improvement directed towards the

practical use and new technology about the viaduct maintenance, etc.

6. Generalization

Though these 2 accidents did not lead to the human injuries, because they were the accidents involving the Shinkansen, which transports large passengers at a high speed, there was the sufficient possibility in which the great damage could happen, and the interest of the nation was focused on the way of safety management of West Japan Railway Co... In addition to the technical problem of construction technology and maintenance technology, a makeshift or ex post facto monitoring management attitude came to light. The effort which prevents generation and recurrence of accident by reexamining these problems has been made.

7. Knowledge

・It is necessary that the research institute sufficiently recognizes the mechanism (neutralization and alkali-aggregate reaction, etc.) in which concrete structure deteriorates and copes technically with it.

・It is necessary to examine the solution to problems of concrete construction, such as design of appropriate pouring methods and management of the site process.

・From the viewpoint of proposal and evaluation of new maintenance techniques, in addition to technical aspects such as the mechanization of inspection process, an approach from the political side that management systems and management ideas are reexamined is also necessary.

・In order to obtain the trust of the user, the attitude of "attaching greater importance to safety than to management" is important and the effort, which the user doesn't notice, for previously preventing accidents is necessary.

・About infrastructure which is scheduled to be constructed, considering utilizing the infrastructure for a long time into the future, it is necessary to make designs which consider a balance of maintenance costs and initial costs.

8. Background

The background factors which caused the developing early deterioration of concrete to become the social problem from 1980's, were rush work, execution defect with it, and the use of sea sand because of material shortage, etc..

In March, 1975, Sanyo Shinkansen was all opened for use, but the opening was 3 months behind schedule, and the situation was that the construction period could not be extended any longer. In addition, the oil crisis came, and the rushed work was done

when the material shortage happened, in addition to a manpower shortage because of the construction rush. It was not strange even if the work accuracy was made little of. This brought about execution defect like CJ, which became a cause of the Fukuoka tunnel accident.

At the end of the high-growth period, the sea sand, which was cheap and considered to be inexhaustible attracted attention in the Chugoku district, which was not blessed with good river sand, and much sea sand was also used for Sanyo Shinkansen. Sea sand promotes corrosion of steel and alkali-aggregate reaction, if it has not been desalinized beforehand. Some ready mixed concrete traders said that it was unusual to use correctly washed sea sand in those days, when rush work was forced. The year when the Ministry of Construction in those days gave an official notice to request the completeness of desalinization was 1977, 2 years after the whole opening of Sanyo Shinkansen.

9. On the Side

In the television image after the accident-generation, the work situation in which the inspector who looked up and opened his mouth during the hammering test of the concrete wall in the tunnel by hammer was broadcasted many times, and the society's trust for the civil engineering technology lowered. As a result, this case can be said to be one of the motives for the implementation of automatic measurement by the mechanization.

＜Reference＞

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