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"Constitution and facilities of Long Railway- Tunnel at Great Depth in JAPAN"

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0． Introduction (No.1 PW)

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1． Introductory

1） Problems or subjects on long tunnels in high speed railway (No.2 PW).

- At first, I would like to mention about the problem or subject on tunnels in high speed railway.

(1) (No.2 PW). As shown in **the figure**, the speed of train becomes higher, the radius of plane- curve larger and vertical gradient smaller in the line.

- Therefore, tunnels have been constructed longer and at deeper in the mountainous area.

(2) On such tunnel as long at great depth, problems or subjects in operation may be summarized followings.

1. Influence to running train due to high speed.
2. Operation and maintenance in long tunnel.
3. Prevention from disasters, for example train- fire.

And subject to preserve natural or social environment may occur, according circumstance.

- It may be constitution or cross- structure and facilities of tunnel to comprehend or synthesize such problems or subjects, with systems and methods of construction to be considered geography and geology along the route.

2） Outline of tunnel for example (No.3 PW)

- (No.3 PW：Table-A) I will introduce some examples of cross- structure. They are as shown in **Table- A.**
- **Gotthard Base** tunnel has 57.1 km length in Alp- transit line, in Swiss.
- **Seikan tunnel** has 53.9 km length in Tsugaru Straits line, in Japan.
- **EURO tunnel** has 50.5 km length in Channel line, between England and France.

＊ **Zimmerberg Basis** tunnel in Alp- transit line has 19.7 km length, in Swiss.

＊ A tunnel in **TGV** line, in France.

＊ And standard of tunnels in **Shinkansen** .

Shinkansen is Japanese name of new trunk line of high speed railway in Japan.

3）Cross- structure of tunnels（No.4～7 PW）

(1) (No.4 PW) : **Fig.P-1.** shows **Gotthard Base**, that consists of two tunnels of single track, being excavated by TBM or DB; drilling and blasting method.

・ The inner area of two tunnels is 108.2 m^2. And effective inner area, upper rail level, is 95.4 m^2.

(2) (No.5 PW) : **Fig.P-2.** shows **Seikan**, that consists of a main tunnel of double track, with pilot- and service- tunnel in the section under sea, excavated by DB or HC; header- cutting machine method.

・ The inner area of main tunnel is 69.6 m^2. And effective inner area is 66.4 m^2.

Pilot- and service tunnel has the inner area of 15.8 m^2, respectively.

Total inner area of cross- structure is 101 m^2, in the section under sea.

(3) (No.6 PW) : **Fig.P-3.** shows **EURO**, that consists of two tunnels of single track, and a service- tunnel, excavated by TBM.

・ The inner area of two tunnels is 90.8 m^2. And effective inner area, upper rail level, is 88.8 m^2. Service tunnel has the inner area of 18.1 m^2.

Total inner area of cross- structure is 108.9 m^2.

(4) (No.7 PW) : **Fig.P-4.** shows constitution of cross- structure of tunnels, for the compare.

These are, so called, super long tunnels.

(5) (No.8 PW) : **Fig.P-5.** shows two examples of cross- structure of tunnel in high speed railway line, in Europe.

＊ **The left** shows, **a tunnel in TGV** lines, is one horse- shoe typed tunnel of double track, excavated by conventional method; maybe NATM.

The inner area of the tunnel is 83.6 m^2. And effective inner area is 73.2 m^2.

＊ **The right** shows, **Zimmerberg Basis**, is one circular tunnel of double track, excavated by TBM.

The inner area of the tunnel is 92.3 m^2. And effective inner area is 74.0 m^2.

(6) (No.9 PW) : **Fig.P-6.** shows standard cross- section of tunnel in Shinkansen, horse - shoe type..

・ **The left** shows, **Dai- Shimizu**, was excavated by DB with steel rib and timbering in 1970s. The inner area of the tunnel is 67.2 m^2. And effective inner area is 64.4 m^2.

・ **The right** shows, **Iwate- Ichinohe**, was excavated by conventional method; NATM in 1990s. The inner area of the tunnel is 66.1 m^2. And effective inner area is 62.6 m^2.

- The inner area of the right is a little smaller than the left.

(7) (No.10 PW) : **Fig.P-7.** shows cross- sections of tunnel of double track in Shinkansen, TGV and Alp- transit, for the compare.

(8) **Inner Cross- Section of Typical Tunnels(No.11 PW) : ＊＊**

＊ (No.11 PW) : **Table- B** shows the summery of inner cross- section of typical tunnels.

2. Tunnels in Shinkansen

- (No.12 PW) : **Fig.P-8.** shows standard of cross section of tunnels in Shinkansen. It is general rule of a tunnel of double track in Shinkansen, whether long or short, because of cheaper of the cost and easier of the work in construction and operation and maintenance.

(1) **Constructing system of long tunnel.**

- **The left and central** shows the cross- section constructed by conventional method.
- **The right** shows the cross- section constructed by system of mechanical shield. The inner area of the tunnel is 78.2 m^2**.** And effective inner area is 65.0 m^2.
- If the tunnel is constructed by TBM- system / RTM; Rock Tunnelling Machine, the cross- section will be similar as the mechanical shield.
- (No.13 PW) : Tunnels in Shinkansen have been almost constructed by conventional method, without mechanical shield in Quaternary formation. The reason is;
  (1) Geology is so alterative as TBM may be not adaptable to some parts in long tunneling.
  (2) The cross- section of excavation is too large in full face of TBM system.
  (3) Geography may be adequate to set access- shafts to constructing sections. It may be divided long tunnel into some constructing sections, not so long.
  (4) Access- shafts in long tunnel may be used for evacuation the tunnel in emergency, and for facilities in operation and maintenance.

(2) **Today- State operating Shinkansen**

- (No.14 PW) : **Fig. 1** shows equipments to operate train arranged in cross- section of tunnel.
  The red line in the left side is limitation of architecture and **the green line in the right side** is limitation of vehicle.
- (No.15 PW) : **Fig. 2** shows nationwide- net of Shinkansen.
  The line reciprocally white and black is in operation. That total length is approximate 2400 km.
- Trains can run with average speed of 240km/hour and with the maximum speed of 300 km/hour, between two stations at the distance more than approximate 80 km.

However, there are some very or common long and many short tunnels.

- That has been offered some by improvement or contrivance of vehicle, electricity, track and operation- system.

Provided what as mentioned before, I will explain constitution and facilities in longitude of long railway- tunnels in Japan.

3． Constitution and Facilities in Longitude of Long Railway-Tunnels in Shinkansen.

1） Long Railway Tunnels in Japan （No.15 PW：Table- 2）

- (No.16 PW)：**Table- 2.** shows 21 long railway tunnels more than 10 km.
  In them, 16 tunnels are in Shinkansen- line.
  And 4 tunnels of them have the length more than 20 km less than 30 km.
  Seikan Tunnel, longer than 30 km, will be dedicated for Hokkaido Shinkansen.
- **In long tunnels less than 30 km,** however the air is left in nature, there are no problems of aerial resistance and alteration of pressure and flow. In addition, artificial ventilation and cooling are not necessary in operation.
- Those long tunnels have subjects of maintenance and prevention from disaster, particularly train- fire.

2） Countermeasure and facilities of Fire- Accident in Tunnel

(1) Fire- accidents in Tunnel （No.17 PW：Table- 1）

- (No.17 PW)：**Table- 1** shows fire- accidents in traffic tunnels.
  In Japan, two serious fire- accidents were both in railway and road in 1970s.
  Since then prevention from fire- disaster in tunnel have been studied, respectively.
- (No.18 PW)：Railway- study has concluded a general rule as the most effective method for passengers to suffer the minimum disaster.
  If train is fired by any accident in tunnel,
  1. The train is running to the out of the tunnel,
  2. And to stop at an adequate position out of the tunnel,
  3. There passengers to evacuate or be rescued from the train, for refuge.
- The limit- length of train running from the fired point to the adequate space has been inquired approximate 30 km with train- speed and fire- progress.

(2) Link and Group of Tunnels (No.19 PW：Fig.-P8)

- (No.19PW)：**Fig.-P8** shows the conception of Link and Group of Tunnels.
- The portion between portal and portal of the next tunnel has not always the distance longer than a train. One train of Shinkansen is 400m long in maximum.

- In the case that the distance out of tunnels is less than length of a train, the portion is not adequate for passengers to evacuate smoothly and safely.
  Those two tunnels next to each other is considered as one tunnel with a link.
- Tunnels connected with link in a series get into a group.

(3) Countermeasure and Facilities of Fire- Accident in Tunnel (No.20—21 PW)

- (No.20 PW) : **As shown in the Figure,** when train- fire happens in long tunnel,
  the countermeasure is
  (1) For the train to run out of the tunnel,
  (2) For another train not to go into the tunnel,
  If the train not to run because of any accident,
  (3) For passengers to evacuate smoothly and safely from the tunnel
- (No.21 PW) : **Table- 3.** shows facilities or equipments of electric power, correspondence, information, illumination, evacuation and extinguishing fire in a group of tunnels, that has the length more than 20 km.
  They are for the countermeasure, as mentioned before.
- In addition, shafts for evacuation are set in the middle of the tunnel longer than approximate 10 km.

(4) Evacuation- shaft (No.22 PW : Fig. 5)

- (No.22 PW) : **Fig. 5.** shows a shaft for evacuation from a long tunnel in emergency.
- For the example, the shaft has the length of 1250 m, including 83 m horizontal part, and the gradient of 1/10.
- Ordinary area of cross- section of the shaft is approximate 25 m^2.
  Another shaft for evacuation is similar structure to this one, without length and gradient.
- In this example, also SSP is set.
  SSP is the acronym of Substation of Sectional Power- station, a kind of transformer of motive electricity for operation of train.
  The space set SSP needs approximately the length of 70m and the cross- area of 50 m^2.
  The accessing shaft (evacuation- shaft) is useful also for operation of train.

3) Arrangement of access- shafts in long tunnel (No.23—24 PW).

- I will explain the arrangement of inclined shafts of two tunnels longer than 20 km.

(1) (No.23 PW) : **Fig. 3.** shows Dai- Shimizu Tunnel in Jhoets Shinkansen.

- The tunnel was divided into 6 constructing section by arrangement of access- shafts, because of steep geography.

- 5 inclined shafts within 7 of access- shafts for construction have been used for evacuation in emergency. Thus, evacuation- points are arranged at intervals of distance less than 10 km, in the longitude of the tunnel.
- In addition, SSP has been set in the shaft at mid- portion of the tunnel (Mantaro). SSP is set at intervals of distance less than about 17 km in the longitude of the line.
- And a base to maintenance has been set on a shaft, having the gradient of 1/7 (Kandatsu). The evacuation- shaft is useful also for maintenance.

(2) (No.24 PW) : **Fig. 4.** shows about 100 km between Morioka and Hachinohe in Tohoku Shinkansen. There are many tunnels, short, long and very long.

- There are three groups of tunnels.
- **The left group and the right group**, respectively, is long of about 11 km and 21km, less than 30 km. The link has no tunnels longer than 10 km and paths for maintenance set on at each portal, those are useful for evacuation in emergency. Hence, the peculiar facility for evacuation is not necessary.
- **The central group** is long of 29 km nearly 30 km. So that, the peculiar countermeasure against fire- accident is necessary.
- And the link has a very long tunnel, that is Iwate- Ichinohe of 26 km length.
- 3 within 5 access- shafts to constructing section in Iwate- Ichinohe Tunnel have been used for evacuation- shafts. Thus, evacuation- points are arranged at intervals of distance less than 10 km in the longitude of the tunnel.

4. Tsugaru Straits Line and Seikan Tunnel.

1) Facilities to prevent disaster in Tsugaru Straits Line (No.25—28 PW).

(1) (No.25PW) : **Fig. 6.** shows location of Tsugaru Straits and Tsugaru Straits Line. I will explain facilities to prevent disaster in Tsugaru Straits Line.

- The line consists of **Seikan Tunnel**(middle in the figure), that's length is 54 km and **the access of Honsyu side to Seikan Tunnel** (left side in the figure) having length of 19 km, and **the access of Hokkaido side** (right side in the figure) having length of 15 km. Total length of the line is 88 km.
- The line has been operated as ordinary line since march in 1988.
  However, the line has structures and facilities for Shinkansen.
  Now, Hokkaido Shinkansen Line is under construction, without of this section.

(2) (No.26 PW) : **As shown in Fig. 7.**, each access to Seikan Tunnel has many tunnels, each of them is not long, but they are arranged successively.

- Therefore, the measure to prevent disaster is need the consideration on the line whole.

- Emergency- stations, those are the basic facility to prevent disaster, are synthetically arranged at interval less than 25 km.

  2 emergency- stations are arranged out of tunnel in accesses, and 2 emergency- stations are arranged in Seikan Tunnel.

(3) (No.27 PW) : **Fig.8.** shows arrangement of facilities and equipments to prevent disaster due to train- fire.

- Apparatuses to monitor train- fire are arranged on the railway between emergency- stations or ordinary station. In addition to them, sensors to detect smokes are arranged on lining of Seikan Tunnel.
- If the train is judged fired by those equipments or available information, the train stop at next emergency- station, besides another train does not enter or runs out the section between the emergency- station and next.
- Emergency- station has the faculty for passengers smoothly to evacuate from the train stopping at the station, and for party concerned to the railway or brigade to extinguish the fire.

(4)(No.28 PW) : **Fig.9.** shows arrangement of equipments to prevent disaster due to earthquake.

- Generally in Japan, seismographs to measure seismic acceleration are arranged on important point of the line.

  It is general rule to correspond soon after earthquake causing greater acceleration than some grades of rule. The correspondence is distinguished to phases in accordance with degree of acceleration.
- Besides acceleration- seismographs, seismographs to measure seismic velocity are arranged on important points in Tsugaru Straits Line.

  Velocity- seismographs detect more urgently the earthquake than acceleration- seismographs and avail to guess damage in the structure of of the railway due to earthquake.
- Ｂy those systems, it is not sufficient to guess urgently and exactly the damage due to earthquake in Seikan Tunnel.

  Therefore, in addition to those systems, flow- meters to measure inflow- water are set at many sections and highly sensitive strain- meters are set on lining concrete at sections of geological or geotechnical problem in the part under sea.

２）Constitution and Facilities of Seikan Tunnel(No.29—40 PW).

(１) Alignment of Seikan Tunnel (No.29—31 PW)

- (No.29 PW) : **The figure** shows the route in plane of Seikan Tunnel. The minimum radius of carve is 6,500m, for both of Shinkansen and ordinary line.

- (No.30 PW) : **The figure** shows the constitution of the tunnel in vertical longitude. The constitution in land- parts is same as the common tunnel of Shinkansen.
- The constitution in the part under sea is peculiar of deference from the common, because of the construction- system under deep sea and the operation- system of the super long tunnel.

  There are a long inclined shaft and deep vertical shaft on each shore. and pilot tunnel and service tunnel in the part under sea.

  Pilot- tunnel is whole between bottoms of each inclined shaft.

  Service- tunnel is branched off the middle of inclined shaft and along Main tunnel.

  The section of approximately 5km of middle of the part under sea has not service- tunnel. There, pilot- and service- tunnel are coincident.

＊ (No.31 PW) : **The figure** shows the cross- sectional constitution in the part under sea.

（2） Ventilation and Cooling (No.32 PW : Fig. -11.)

- (No.32 PW) : In a tunnel longer than about 30 km, some problems on air- flow and alteration occur left in nature. Problem on heat accumulated due to operation, mainly train, occurs left in nature. **Fig. -11.** Shows- air flow in Seikan Tunnel.
- Left side of the figure shows ordinary state.

  Air intaken by blower at portal of inclined shaft flows through pilot- tunnel to the center, through main tunnel to portal of land- part and is exhausted there.

  In Seikan Tunnel, the ventilation is artificialized to keep temperature constant.
- Right side of the figure shows the air- flow for the train fired to stop at the emergency- station.

  Fresh air inflows to Service- Tunnel branched off at the middle of inclined shaft, and flows through the evacuation gallery to main tunnel in the section of the emergency- station.

  The air smoked and heated by the fire is exhausted through vertical shaft by the vacuum- blower.

  The shorten rout can flows sufficient air for passengers to flee from the fire.

（3） Main Facilities (No.33PW : Fig. -10.)

- (No.33PW) : **Fig. -10.** shows constitution and arrangement of main facilities to operate the railway set in the tunnel.

  They are SSP, emergency- station,

  I will mention about emergency- station and base to maintain railway.

(1) Position of Emergency- station

- Because of the tunnel longer than 30 km, adequate point in the tunnel is necessary for the train to stop and passengers to evacuate and refuge. The point is called emergency- station.
- The emergency- station is situated at the most adequate distance less than 30 km from any point in the tunnel of 54 km length. Therefore, two emergency- stations have been set under each shore.

(2) Facilities and Faculties of Emergency- station (No.34－38 PW)

- (No.34PW)：**Table- 4.** shows facilities and faculties in the emergency- station.
- In the space under ground, it is most necessary of ventilation and extinguishing fire in addition to conduction and information, for passengers to evacuation and refuge safely and smoothly.
- Facilities in the emergency- station function synthetically. It may be illustrated for comprehension.
- (No.35PW)：**The figure** shows the vicinity of the emergency- station , in panorama- view from Honshu- side to Hokkaido- side.
  Main tunnel, Emergency- station, Evacuation- galleries, Conductive tunnels
- (No.36PW)：**The figure** shows the ventilation and the route of evacuation in a fire- accident. The fresh air, intaken by the fan at the portal of the inclined shaft, flows sequentially through the inclined shaft, the service- tunnel, conductive tunnel, evacuation- galleries and into the main tunnel. Passengers take the route in the reverse way of the air- flow, for evacuation and refuge.
  The air contaminated or smoked by fire is vacuumed by the fan at the portal of the vertical shaft.
- (No.37PW)：**The figure** shows facilities or equipments set in the emergency- station.
  Television- camera, Sprinklers; upper, lower side and center of track.
  Hydrant in evacuation- gallery.
- (No.38PW)：**The figure** shows the train stops at the emergency- station in the main tunnel. Platform, Evacuation- gallery, Sprinklers; upper and center of track.

4） Base to maintain Railway (No.39,40 PW)

- The base to maintain Shinkansen line is set at intervals from 20 to 30 km.
- **The base** is situated at the most adequate distance less than 30 km from each other and base out of Seikan tunnel.
  The base out of Seikan tunnel is set at emergency- station out of tunnel.
  Two base in Seikan Tunnel have been set near points under both each shore.
- (No.39PW)：**The figure** shows the arrangement and constitution of the base of one

side, in panorama view.

- **It** is ordinary to maintain facilities both of electricity and track with motor- cars.

  Motor- car called in Japan is to run or hauling trolleys with inner combustion- engine.

  A maintenance- tunnel is to keep motor- cars and trolleys for both series.
- **Of course,** a facility to set on and off motor- cars belongs each track. Therefore, the main tunnel has been widened about 160 m^2 in cross-section at the point.
- (No.40PW) : **The figure** shows a maintenance tunnel by the main tunnel, in the section widened for motor- cars set on and off.

  The left is main tunnel. The right is maintenance- tunnel.

  The machine to set on and off motorcars is not yet installed. The machine will be installed on the concrete- base in front of portal of maintenance- tunnel.

5. Conclusion

- Thus as mentioned, the constitution and facilities of long tunnels in Shinkansen are concluded followings.

1. Tunnel longer than 10km has almost same inner cross- section for double track of the standard of main tunnel. It's not involvement in length of tunnel.
2. Tunnel longer than 10km has shafts for passengers to refuge from train not able to run in the medium in the tunnel.
3. Tunnel longer than 20km is possible to have shafts for patrol or maintenance on facilities of railway in the medium of the tunnel.
4. Ordinary ventilation is sufficient left in nature in the tunnel not longer than 30km. Tunnel longer than 30 km needs artificial ventilation controlled.
5. Tunnel longer than 30 km has emergency- stations in the medium of the tunnel. The tunnel is possible to need base to maintain railway in the medium of the tunnel.

Thank you for your kind attention.