The Construction Technology that Executes a Large-scale Underground Station right under the Terminal Station (Minatomirai Line and Tokyu Toyoko Line Yokohama Underground Station)

Torajiro FUJIWARA, Takuya YAMADA, Toshihiko NIIBORI

Tokyo Construction Office, East Japan Railway Company

Construction Work Outline

"Minatomirai Line" is the newly established line based on city planning of the Yokohama-City "Minatomirai 21 Project". Yokohama Minatomirai Railway Co. Inc. of the 3rd sector method becomes an entrepreneur and connects Yokohama station ～ Motomachi-Chukagai station (about 4.1km) in underground. Also the Tokyu Toyoko Line that connects Shibuya～ Sakuragicho and Minatomirai Line run through each other. East Japan Railway Co. Inc. in this project, committed from the entrepreneur, and constructed the underground station right under the Yokohama station.

As the knot point where Tokyu Toyoko Line and Minatomirai Line run through each other, the large terminal station, Yokohama where about 2,300,000 people use everyday were selected. JR Keihin-Tohoku Line, Tokaido Line, Yokosuka line, Tokyu Toyoko Line, Keihin Electric Express Railway Line, Sagami Railway Line, and Yokohama Municipal Subway Line get into current Yokohama station by bank/elevated railroad/underground. Moreover, it has geographical condition that is enclosed north and south direction to the first class river, Aratama and Katabira, and also enclosed the east and west to the station buildings.

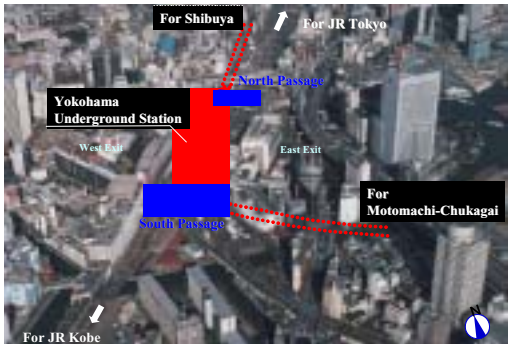

Photo 1: Around Yokohama Station

Therefore, the knot point where Minatomirai Line and Tokyu Toyoko Line run through each other, was selected about 25m right under JR Yokosuka Line and Tokyu Toyoko Line, and had been decided to construct the underground stations of 4～5 of layer box of the extension of 420m including crossing department 25m width .

We report mainly about the item that overcame it to the subjects by the numerous restriction conditions of the nature of soil condition, work space, work time etc., in building a large-scale underground station nearby the operation line, big city terminal station department in this manuscript.

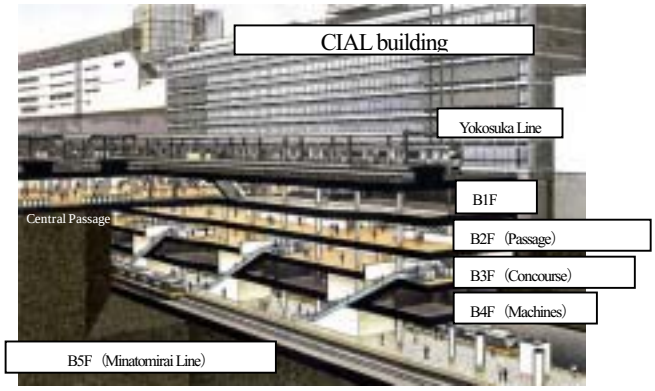

Fig.1: Completed image of Yokohama Stn.

General Condition around Yokohama Underground Station

ⅰ) The Nature Of Soil And Groundwater

The Yokohama station center as for the nature of soil situation of the present Yokohama station periphery, the depth, stratification situation etc. of the support foundation is changing largely as the boundary. The fine foundation that has 50 or more N value (Kazusa layer) exists at the northern part of Yokohama station, -15m under G.L. (Ground Level) .But the viscosity soil layer that has or less N value exists at the southern part of Yokohama station, from G.L. to

more than 40 m under. The Yokohama underground station became to be constructed in such a complicated foundation condition and needed many examinations on the design/execution.

Also, groundwater measure such as preventing the underground station structure body coming up, were a big subject. because the underground water level is high and also confined ground-water exists at the whole underground station construction place.

ⅱ) The Structure Outline of the Underground Station

Minatomirai Line Yokohama underground station is the extension of about 420 m, and in details 24 m of vertical shaft, 209 m of the main body of the station, and 185 m of the JR line crossing part. The main body of the station(*Fig.2*) is located right under the Yokosuka Line and Tokyu Toyoko Line of JR Yokohama station and are the structure of 5 layers (ground 1 layer, underground 4 layers)2 spans and become unit structure with JR elevated railroad. General part was constructed as S+RC structure due to time necessary for the construction shortening, and a part as SRC structure, from the adjustability with architecture specification, because of the idea that Tokyu Hotel Chain constructs a hotel in the underground station upper part in the future. The construction was executed with the inverted construction method. The JR line crossing part is the open cut tunnel where ties the shield tunnel at Motomachi side, and the main body of the station. Its structure is the RC rigid-frame box that changes among 3 layers 1 span from 4 layers 2 spans (*Fig.3*). We constructed the box under the elevated railroad that receives the JR Lines, because it is going across right under 8 JR Lines obliquely. Furthermore, the elevated railroad of the JR Lines direct top of the tunnel was made to be the structure that was separated with superstructure, without receiving by the tunnel from the consideration on earthquake resistance, but supported with the underground continuation wall constructed at the side of open cut tunnel. The construction was executed with the forwarded construction method.

ⅲ) The Conditions on Construction

Yokohama station is large terminal station whose passengers are 2.3 million a day. And it is managed by the tight schedule for railway transportation and even the freight train travels. Although this underground station was constructed with the open cut construction method, the slow down of the train was not permitted in this case. Also, usually the underground station crosses to a right angle in the existing railroad track to fix the influence range to the existing line minimum, but the Yokohama underground station has existing station building with underground structure in both sides of the existing railroad track, needed to construct the underground station in parallel in the existing railroad track. Therefore, the construction extension of the temporary construction beam, that receives the train load temporary became to (total of 283 leagues) about 2.4km in

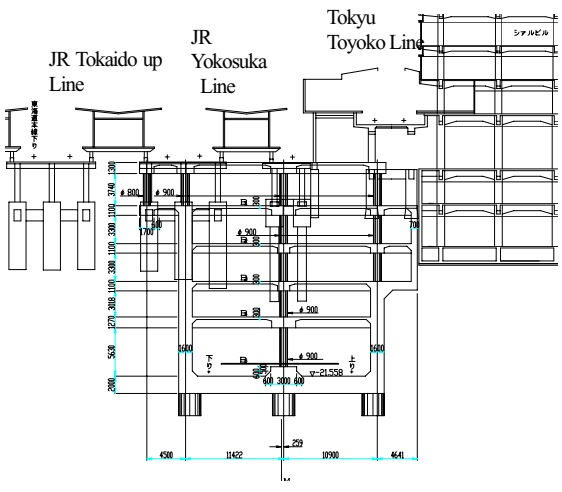

Fig.2: Cross Section of Station

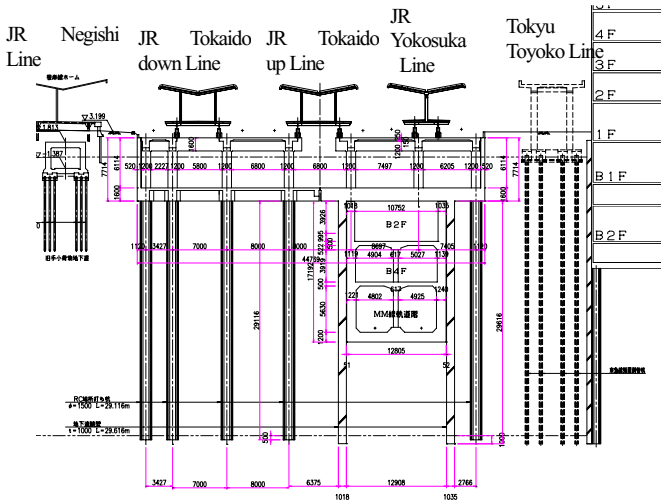

Fig.3: Cross Section of Station(crossing part)

all. Besides, we needed to execute in the short work time, between time to stop feeder line(about 2 hours and 20 minutes in shortest) and time to interrupt on the track(about 3 hours in shortest) , about. 4 hours average.

Overcoming of Each Condition by Technical Development and Construction Method Examination

Among the general condition and the conditions on construction expressed with the preceding clause, piling up examination to accomplish this project into the process, we carried out the improvement and development of the technology for subject overcoming.

Development of the Steel Pipe Pile Pressing by Screw Turn

The temporary pile of the construction beam is as long as 30m because the support layer is deep with a fragile foundation. However, the pile became a jointed pile with 17 connection places because clearance of the place to construct is restricted to 2.5m by the electric wire. We adopted the steel pipe joint by screw that shows it in *Fig.4* to execute this pile in about a few hour limited work time. The shortening in the execution quantity increase, execution time in a night were enabled by this development. About 3 years and about 50% of process shortening ,connection time needs it 20 minutes when we adopt the case of the steel pipe joint by screw, while connection time needs it 90 minutes in the case of the welding joint of to every 1 place and about 5～6 years of process.

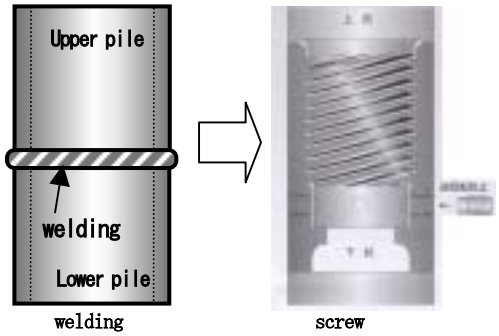

Fig.4: Steel Pipe Joint by Screw

Development of the Steel Pipe and RC Beam Joining Method

The short period and advanced execution accuracy were demanded to the connection part of the steel pipe pile head, when we needed to execute the side beam of the temporary elevated railroad. A chain of joining by conventional welding in 3 hours of the nighttime are impossible and there was a problem in the execution accuracy of the joining by screw in connection direction. We developed the construction method that we put connection part over the steel pipe pile like cap, filled up by acrylic resin system glue and join with the steel pipe pile, and filled up concrete inside that intends the unification. It reduced the work quantity and digging quantity at the time of execution, shortened the work time that usually need 2 nights to 1 night, and materialized a substantial cost-down.

Development of the Machinery Caisson

We needed to construct the underground station core column (φ2.6m, L=about30.0m) under narrow work condition that was right under the existing operation line and the clearance was restricted as long as about 5m. So we have come to construct the caisson but there are problems of bad working condition and decrease of skilled workers and there was the possibility that the construction will not be executed smoothly and safety. Thereupon, we developed the execution machine to dig and install linear plate automatically and were materialized smooth mechanization execution of caisson type pile works under a narrow condition.

Development of the Joining Method of Steel Pipe and RC Pile

The steel pipe column was adopted as core column, the main column of the underground station, to shorten the time necessary for the construction. RC beam was adopted as the beam to tie the column from a viewpoint of economic efficiency. Because the place where the steel

pipe and RC join exist about 400, so the simple joining and execution method was requested. It made the unit structure that concludes the diaphragm, connection part plate of the steel pipe column, and the plate that welded the reinforcing rod for the machinery joint, with the bolt. Executed by precast, reduced work site, contributed to time necessary for the construction shortening. We executed the small model experiment to this joining method, checked and confirmed the efficacy by the three dimensions FEM analysis constituted as adhesion deterioration style model.

Development of the Constituted Element Continuation Wall

It was scheduled not able to construct widening part by open cut construction method by the viewpoint of the structure stable if the construction of the station under B2F hasn't done, digging outside part of the continuation wall (we call widening part) west side of station and executing box construction. However, it was requested as it makes the time to open of early for 2 months from the entrepreneur. The time necessary for the construction became needed to be shortened due to this. Therefore, we executed the square steel pipe called JES (Jointed Element Structure) vertically, concomitantly using with human power digging. Concrete was filled up within JES. Without waiting for the construction of under B2F of the station part from this case, the execution of the main wall, also be the temporary sheathing, is possible (*Photo 2*).

The application range reaches the wide area of about 500m^2 where it shows in *Fig.5*. Usually, we used JES toward length this time, although it uses it to the railroad track under crossing construction work toward the side, and shortened for 3 months from the process at the beginning.

To the End

The Tokyu Toyoko Line turns underground on January 31, 2004 and the Yokohama underground station becomes a use start and on February 1, 2004 Minatomirai Line in practice. Because of the large-scale terminal station there were the severe restriction on train operation and passenger flow. Also, it was special nature of soil condition right under the station. Piled up various examination and time necessary for the construction was shortened for 2 months than the first plan (March, 2004). Second terms of the underground stations associated with the removal construction work of a Tokyu Toyoko Line elevated railroad began after the opening of the Minatomirai Line. We hope that this manuscript becomes the reference of the future construction works and same kind of underground station construction works. We thank for all the people who were concerned, in this project last.

Photo 2: Constructing JES toward Length

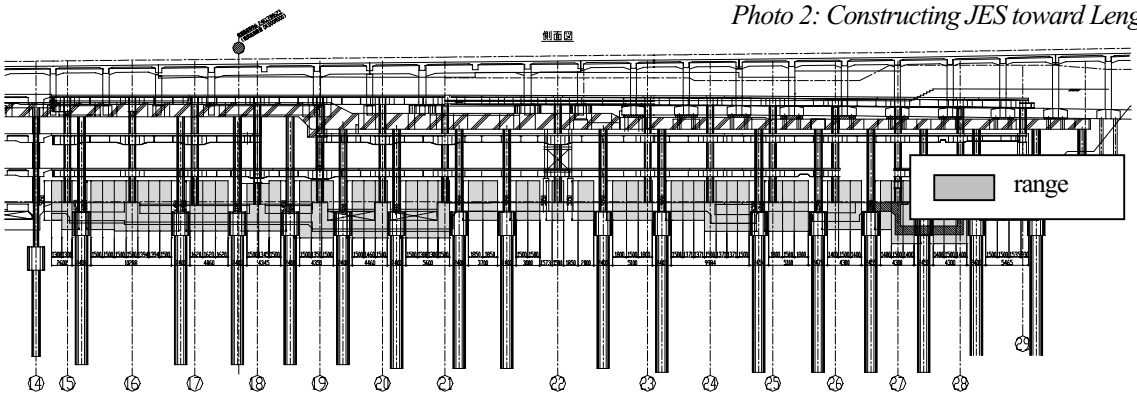

Fig.5: Place to Apply JES toward Length