Interpretive article

Space Creation Adopting the Results of Technical Development


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This article introduces efforts in economically creating new spaces over tracks and under elevation at stations. In those efforts, we first increased from 20 m to 31 m the height of structures where underground beams can be eliminated, then we adopted that structure to construction of over-track spaces. We are currently proceeding with construction work at Chiba and Higashi-Nakano stations that makes use of those results. At Shin-Aomori Station, we were also able to economically build under-elevation spaces by developing new column structures and column-beam joint structures. We evaluated safety regarding construction on artificial ground, and we established a manual for construction adjacent to tracks when trains are running. Through that manual, we clarified items by which we determine the situation is safe and the criteria for those so as to make it easier to expand daytime work. Here we will cover efforts in space creation up to now.

1 Introduction

Stations are lively spaces where passengers gather. By widening those, we could smoothen the congested flow of passengers and create new public, business and shop spaces. An issue in that is cost. Carrying out construction while securing passenger safety involved time constraints such as only being able to work at night when trains are not running. Such time constraints and narrow working spaces constrained by tracks, overhead contact lines, structures and the like led to cost increases. JR East is thus promoting a project that utilizes results of technical development to overcome those issues in terms of structure planning, design and construction.

2 Creation of Spaces Above Tracks

2.1 Revision of Structural Design Methods

Above-track buildings differ from ordinary buildings in that, due to construction constraints, they are frame-type structures without underground beams connecting the foundation piles, as shown in Fig. 1. At the same time, they need sufficient earthquake resistance to secure the safety of large numbers of passengers and operation of trains even in large earthquakes.

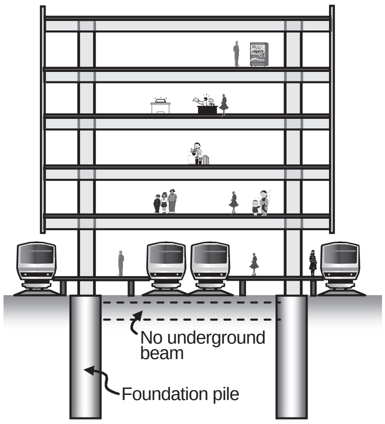

Fig. 1 Structure Using the Space Above Tracks

In terms of structural design of buildings that use the spaces above tracks, “Structural Design Standards for Structures (Low Level) above Tracks” (hereinafter, low level standards) were established in 1987 for low level structures such as elevated stations 20 m or less in height and having four or fewer floors. Low level standards were revised in 2002 to handle the revisions of related laws and regulations and the diversification of analysis methods and construction methods in line with technical advances. They include in their scope structural forms without underground beams bi-directionally. Those low level standards have been utilized in the design of many structures such as elevated stations. However, as expressed by Fig. 2, needs in terms of high-level use of above-track spaces in modern urban areas have increased, so there were calls to broaden the scope of low level standards. We thus conducted technical studies by means such as structural analysis on the effects of increasing the height of buildings. From that, we established design methods to sufficiently secure earthquake resistance even in large earthquakes. Study results and design methods were carefully deliberated by a committee that included academic experts and people involved in construction administration. The low level standards were thus revised in 2009 to cover structural design methods that handle structures of up to 31 m.

As a result of discussions with administrative officials, administrative handling of buildings designed under low level standards came to be shown in structure review guidelines for stationhouses and other railway facilities issued by the Japan Conference of Building Administration in May 2010. Those guidelines state that buildings designed within the scope for size etc. and within design conditions of the low level standards can be handled in ordinary confirmation application procedures. By revising the low level standards to handle heights of up to 31 m, structural design and administrative procedures thus became smoother.

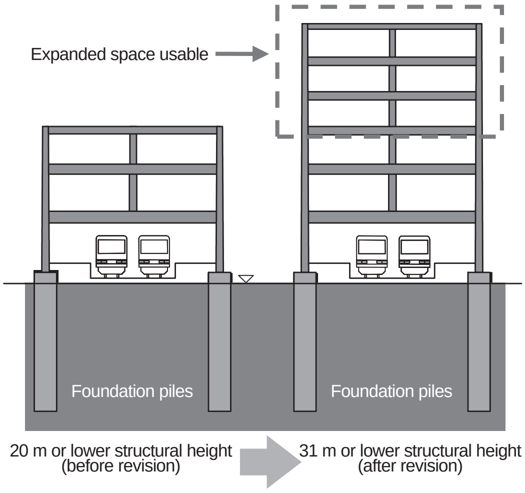

Fig. 2 Making Structures Using the Space Above Tracks to be Mid Sized

2.2 Application Project

(1) Chiba Station

The stationhouse and attached commercial building (station building) of Chiba Station, built in 1963, had degraded over time and were in need of seismic reinforcement. They also faced issues such as flow lines and visibility near the ticket gates. To overcome those issues, we came up with a plan to move the stationhouse to the third floor of the space over tracks to make it open and easy to navigate with wide passageways and a high ceiling. The station building was also rebuilt along with the stationhouse to create an attractive commercial facility linked with the station (Fig. 3).

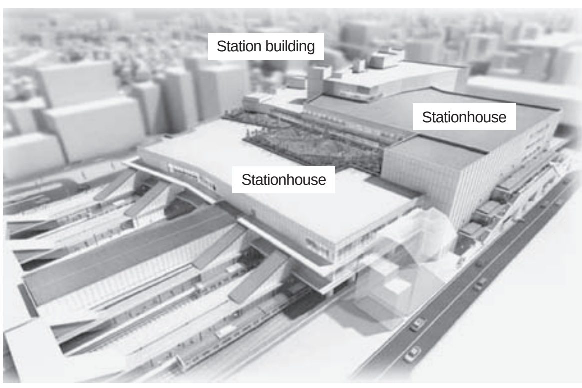

Fig. 3 Rendering of New Stationhouse and Station Building

Construction on the buildings for Chiba Station started in October 2011. The new stationhouse and station building are steel frame structures with seven floors aboveground and one floor underground (six floors aboveground for the new stationhouse), having a 70,000 m^2 floor area. That floor area is broken down into an approx. 16,000 m^2 station facility/concourse, approx. 6,000 m^2 commercial space within the ticket gates, and approx. 46,000 m^2 station building. The new station building is not above the tracks, so it was designed as a building incorporating underground beams. The new stationhouse is above the tracks, making it difficult to use underground beams. That stationhouse was thus designed as a pile-per-column structure with no underground beams in accordance with the low level standards expanded to apply to buildings of up to 31 m tall. The new stationhouse and new station building are separate structures joined with expansion joints (Fig. 4).

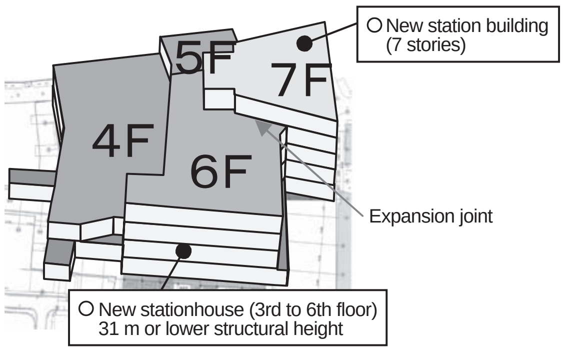

Fig. 4 Building Image Diagram

For the over-track part, 3 m diameter cast-in-place concrete piles are needed to satisfy conditions such as being an approx. 30 m tall six-level structure, having open spaces with few columns, having no underground beams and having long track-level (first floor) columns as those columns penetrate the viaduct. We thus introduced at Chiba Station a cast-in-place concrete piling method for locations with extremely small overhead clearance applicable even in narrow spaces due to use of compact and light machinery and a cast-in-place concrete piling method for locations where protective wall steel plates can be built simultaneously to prevent collapse of surrounding soil (Fig. 5). Technology was developed for those methods to allow large-bore piles to be mechanically constructed efficiently and allow day-and-night construction.

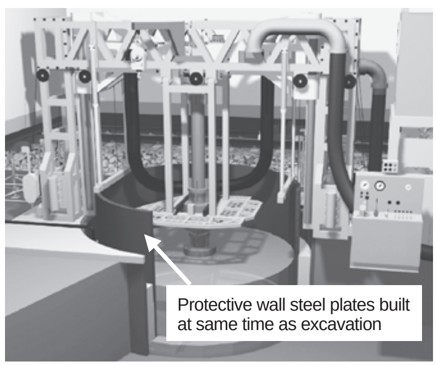

Fig. 5 Machine for Simultaneously Building Protective Wall Steel Plates

(2) Higashi-Nakano Station

Development of Higashi-Nakano Station is being done in conjunction with the conversion to a stationfront plaza of a construction yard that was used in expanding a nearby major roadway. In that project, Nakano Ward will build connecting facilities from the plaza to the west side stationhouse, and JR East will build artificial ground and a station building linked to the connecting facilities. Fig. 6 shows an image of what the west side will look like. Renovation to the existing stationhouse (west and east sides) will also be done, with the main stationhouse facilities moved from the east to west side.

The west side building is of a steel frame structure having five aboveground floors with a structural height of 30 m and floor area of 2,780 m^2 (usage: connecting facilities, child support facility, station facility, shops). Special design was initially assumed to be needed as it exceeds 20 m in height, requiring time for administrative procedures. However, it was deigned under the revised low level standards, so administrative procedures went smoothly. Fig. 7 shows a cross section view of the station building. The building has a single span in a direction perpendicular to the tracks (approx. 17 m), and the passageway part of the artificial ground extends more than 8 m. There are no underground beams in the direction perpendicular to the tracks, but the tops of piles are equipped with steel frame beams and braces to control the lateral displacement of pillars in the parallel direction. In consideration of effects on nearby walls and tracks, construction of RC underground beams involving excavation was avoided.

Construction of the station building started in March 2011, and it is scheduled to open in the summer of 2012.

Fig. 6 Image of the West Side of Higashi-Nakano Station

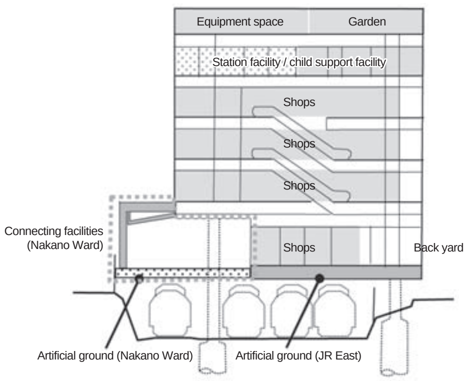

Fig. 7 Cross Section of the West Side Station Building (viewed perpendicular to the tracks)

3 Creation of Under-elevation Spaces

3.1 Structural Planning: Adoption of RC Columns Confined by Steel Plates and Socket Connection

Fig. 8 shows Shin-Aomori Station on the Tohoku Shinkansen Line that opened in December 2010. Height was restricted at the part of the station viaduct that crosses the conventional Ou Main Line. Beam height of the viaduct had to be 800 mm or less for mid-level longitudinal beams and 1,900 mm or less for high level longitudinal beams to enable a two-level viaduct and secure space for a concourse. We thus decided to use steel reinforced concrete (SRC) members for the beams.

On the other hand, columns had to be constructed in a narrow space in a short time due to proximity to the operating Ou Main Line. Concrete filled tube (CFT) columns would usually be used, but increased cost of steel tubes with a thickness of 76 mm was an issue. For that reason, we decided to use newly developed RC columns confined by steel plates and develop a method of joining those with SRC beams.

We studied whether we could adopt the socket connection developed for joining CFT columns and steel frames to join RC columns confined by steel plates with steel frame beams. Fig. 9 shows a rough sketch of the connection part. We conducted cyclic load tests with mockup specimens and confirmed that traditional evaluation formula for socket connection bearing force could be used.

3.2 Construction with Developed Structure

To start with, we reduced material expenses by approx. 20% by changing from CFT columns to the developed RC columns confined by steel plates. Then, by adopting socket connection of RC columns confined by steel plates with steel beams developed in line with construction of Shin-Aomori Station, beams of SRC members could be achieved. With that, we were able to secure space for a concourse.

Further benefits of the developed construction method using socket connection are that the complex structure of beam and column member connection could be omitted and that error in steel frame assembly can be absorbed. With the latter benefit, socket tube position can be adjusted during construction. As socket tube eccentricity can be up to 30 mm, SRC beams with socket steel tubes hoisted by crane after installation of RC columns confined by steel plates can be coupled by their erection hardware and that hardware was loosened when erecting steel frame beam members. Fig. 10 shows that construction being performed. While there was some variation, the maximum eccentricity of the 52 joints of columns and socket steel tubes was 28 mm, and steel frame construction could be completed within the specified control values. That contributed greatly to reduction of the construction period. Thanks to those innovations, the under-elevation space shown in Fig. 11 could be built economically by the December 2010 opening of the station.

Fig. 8 Tohoku Shinkansen Shin-Aomori Station

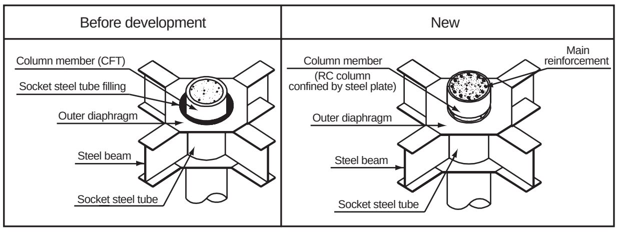

Fig. 9 Rough Sketch of Socket Connection Part

(a) Overall view of construction (b) Socket connection part

Fig. 10 Construction Using the Socket Connection Method

Fig. 11 Under-elevation Space at Shin-Aomori Station on the Tohoku Shinkansen

4 Expansion of Daytime Construction Times

4.1 Construction Above Track

When building an artificial ground and the like in the space above tracks, construction has to be planned carefully to secure passenger safety and operation of trains. When doing hoisting work on artificial ground like in Fig. 12, for example, work was often done with the tracks closed at night due to risks such as the load falling. That meant work could only be done in a limited time slot at night, a major element in creating longer work periods.

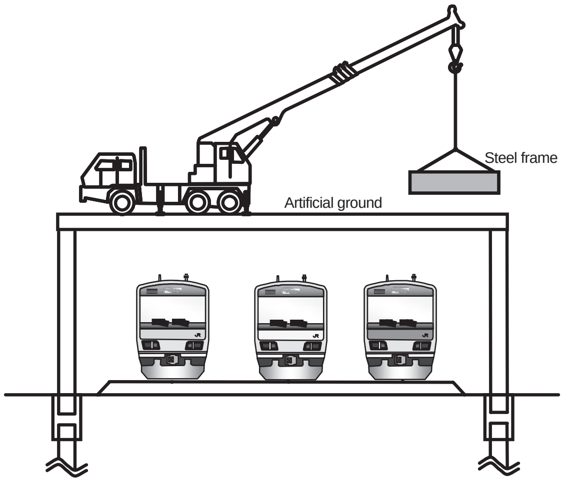

Fig. 12 Hoisting Work on Artificial Ground

We thus put together a manual as items to study to expand daytime work from a standpoint of reducing the work period and costs. Through that manual, we clarified items by which we determine the situation is safe and the criteria for those so as to make it easier to expand daytime work.

4.2 Manual for Construction Adjacent to Tracks when Trains Are Running

Here we will introduce drop impact test results when covering plates are installed on top of floor slabs. This is used as an example in the safety measures for work on artificial ground covered by a manual for construction adjacent to tracks when trains are running that we put together this time.

(1) Overview of drop impact test

A test specimen was prepared in a 1 span x 1 span (16 x 13 m) range assuming the structure actually built, and free-fall drop tests of hoisted loads were performed. The hoisted load was 1 segment of two levels (5th and 6th floor) column members, assuming steel frame construction. The weight of the column members was 6.5 tons. Fig. 13 shows a diagram of the test specimen, Fig. 14 the drop test and Fig. 15 a detailed diagram of the floor slab. Test specimen A was for a drop height of 11 m, and test specimen B was for 1 m.

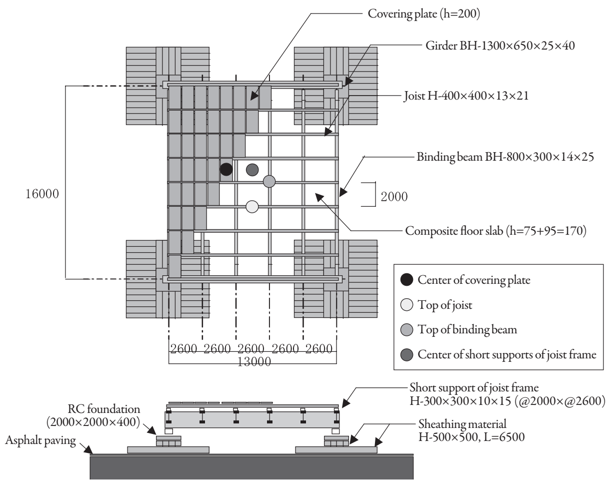

Fig. 13 Schematic Diagram of Specimen

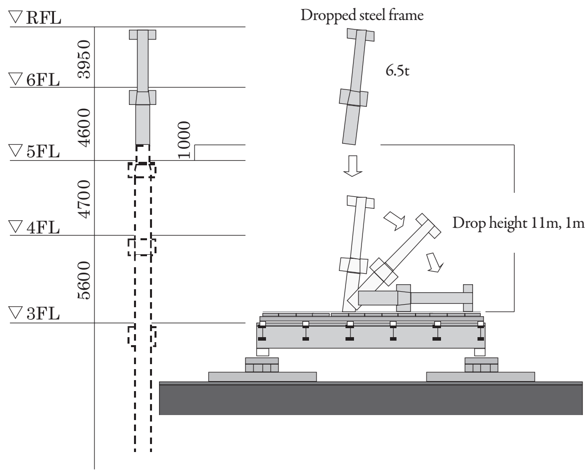

Fig. 14 Schematic Diagram of Drop Test

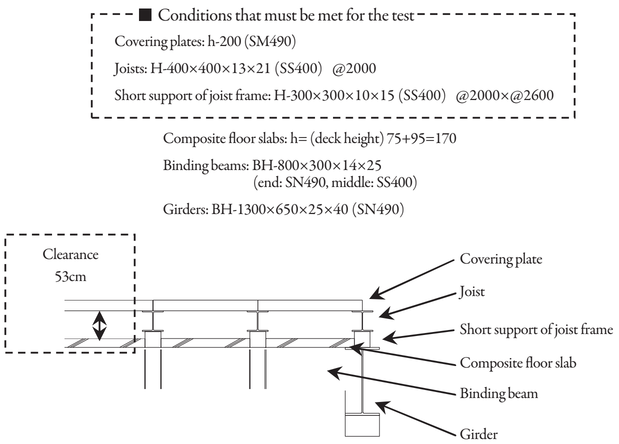

Fig. 15 Detailed Diagram of Floor Slab

(2) Test results

Drop tests were performed as shown in Fig. 16

In the drop location of test specimen A (slab + covering plate), the covering plate and joist were damaged as shown in Fig. 17. However, the slab, beam, column and other locations suffered almost no damage, demonstrating that there was no effect on the bottom of the slab. For test specimen B without a covering plate (slab only), the column steel frame member penetrated the slab at a drop height of just 1 m. Under these test conditions, curing the floor slab with a covering plate proved to be effective against impact from drop of hoisted loads.

Based on those results, we studied items such as a floor slab structure that is safe even if a hoisted load should be dropped and the hoisted load weight. From those, we defined the scopes in which construction can be done while trains are running.

Fig. 16 Testing

Fig. 17 Damage to Covering Plate

(3) Future efforts

We plan to go forward with technical development in areas such methods to secure safety are simpler than using covering plates.

5 Conclusion

In the future, we would like to conduct technical development according the needs of individual stations and worksites to create new spaces. If the results of technical development can lead to improvement of administrative procedures and formulation of manuals, they could be adopted for future projects. We thus intend to actively conduct work for those.

Reference:

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