Innovations are made in terms of structures to create spaces near railway stations. For example, methods of seismic isolation construction with little displacement were employed in preservation and renovation of the historic Marunouchi stationhouse at Tokyo Station to allow the brick stationhouse to meet current aseismic standards and to avoid contact with adjacent viaducts. In construction of the Tohoku Through Line, we developed construction methods to improve aseismic performance of existing viaducts. In renovation of the stationhouse and attached commercial building of Chiba Station, we verified safety by tests and analysis and produced related standards to allow construction of piles and erection of steel frames even while trains are running. And in creating the Shinjuku Transportation Hub, we developed construction beams of prestressed concrete for excavation under the tracks that could be later used in the permanent structure.

1. Introduction

Creation of spaces near railway stations often involves construction above, below, and adjacent to tracks. Much of the work is done in the short time when there is no train or passenger traffic and in environments with height and width restrictions, making costs involved higher than those of ordinary architectural and civil engineering construction. We are therefore making efforts to innovate structural technologies, including those for design and construction, so as to reduce construction costs and time.

2. Preservation and Renovation of the Marunouchi Stationhouse at Tokyo Station

The Marunouchi stationhouse, known for its red brick structure, opened in 1914, but its roof and outer walls suffered damage in an air raid in 1945, resulting in the original three-story structure being changed to two stories. Work to preserve and renovate the building as shown in Fig. 1 was completed on October 1, 2012. Designated an important cultural property, the Marunouchi stationhouse was renovated to its original form while preserving the existing building as much as possible. Many matters worthy of special mention were involved in the preservation and renovation, such as it being the first time the exceptional floor area ratio districts system was created and applied and its design being re-created whenever possible based on past documents and the like. In terms of structure as well, revolutionary innovations were made in the preservation and renovation work. Items that proved to be particular issues in design and construction were…

1) Preserving and restoring the stationhouse in a way that meets current aseismic standards
2) Carrying out work while maintaining stationhouse functions such as passages and stairways used by approx. 180,000 people a day.

2.1 Seismic Isolators for Controlling Displacement

Aseismic performance was set for the stationhouse to be preserved and renovated where cracking would not occur in the brick walls in a mid-scale earthquake and where, in an anticipated large-scale earthquake, cracking would be allowed but the building could continue to be used without major repairs.

Fig. 1 View of the Marunouchi Stationhouse

Fig. 2 Seismic Isolation Cross-section and Seismic Isolators
Use of an aseismic structure was decided on to meet that required performance, but the viaduct of the Chuo Line is located adjacent to the east side of the Marunouchi stationhouse. Fig. 2 shows an outline of that structure. As the stationhouse is 335 m long, approx. 350 lead rubber bearings were set up and approx. 160 oil dampers used to keep deformation of the seismic isolation layer in a large-scale earthquake to 20 cm or less. Displacement in ordinary seismic isolated buildings is about 50 cm; but with the Marunouchi stationhouse, both seismic isolation and prevention of effects on adjacent structures were achieved.

2.2 Securing Passages for Passengers
Construction was carried out while securing passages for passengers. The stairways and escalators of the Sobu passage connecting to underground platforms of the Sobu Line and the central underground passageway were temporarily supported while excavation was done in the underground part to build a structure there. Fig. 3 shows a cross-sectional diagram and photograph of that.

3. Tohoku Through Line Construction
The Tohoku Through Line project involves linking the Tokaido Line at Tokyo Station with the Utsunomiya, Takasaki, and Joban lines at Ueno Station by double track to allow through service.

Construction of the Tohoku Through Line is expected to provide a number of effects. Those include alleviating congestion at locations such as between Ueno and Okachimachi (which are extremely crowded at commuting times), shortening travel time to Tokyo Station from the Utsunomiya, Takasaki, and Joban lines by eliminating the need for transfers, and enhancing the transport network connecting the north and south parts of the greater Tokyo area to contribute to revitalizing communities.

Fig. 4 shows installation of girders for the Tohoku Through Line. The existing Shinkansen viaduct near Kanda Station is a steel frame abutment and pier structure. With the new track, steel frame abutments and piers are built added on to the Shinkansen viaduct, and PC girders and steel girders are installed between individual piers or between piers and abutments. The existing Shinkansen viaduct built for the Tohoku Shinkansen, which opened in 1991, was designed to be earthquake resistant to an extent that would allow conversion to a multiple-level structure in the future. However, it would prove difficult to meet aseismic performance requirements after converting to a multiple-level structure under the new aseismic design standards for railway structures developed as a result of the 1995 Great Hanshin Earthquake. Thus, the issue to overcome was how to modify and reinforce the existing steel frame abutments and piers so as to be able to build structures for the Tohoku Through Line above the existing Shinkansen viaduct.

Fig. 3 Construction with Stairways and Escalators Temporarily Supported

Fig. 4 Installing Girders in Construction of the Tohoku Through Line

Fig. 5 Seismic Reinforcement of Columns
(Spiral Reinforcements in Hollow Steel Columns)
3.1 Increasing Aseismic Performance of Existing Shinkansen Viaduct Columns

Columns of the existing steel frame viaduct have a square cross-section, and they were designed to have a hollow cross-section within steel plates. The area around the columns has shops using the space underneath the viaduct, so it would be difficult to install braces and dampers to reinforce from the outer surface of the columns. We thus studied how to reinforce from the interior of the columns and decided to fill with concrete and place spiral reinforcements as shown in Fig. 5. By using spiral reinforcements, the internal core concrete surrounded by those spiral reinforcements remains undamaged even in regions of major deformation, preventing abrupt drop in load bearing ability and increasing deformability. We are currently conducting experiments to confirm aseismic performance with this method of reinforcement.

3.2 Improving Earthquake Resistance for Existing Viaduct Piles

We have also developed and applied a construction method for improving aseismic performance without reinforcing underground columns and pile material. This involves laying foundation slabs that suppress displacement of viaducts on the ground surface. This method, shown in Fig. 6, was applied to RC viaducts at the approach to Tokyo Station. It also achieved major reduction in construction time and costs.

Construction is underway at Chiba Station to make it a terminal station functioning as a gateway to Chiba that is easy to navigate and has a feel of openness (Fig. 7). Work involved relocating and rearranging station facilities and providing an attached commercial building and in-station commercial space. The concept involves relocating the concourse to the third level above the tracks and having the station be above the tracks so as to raise safety, amenity, and ease of moving about, allowing the station to act as the face of Chiba.

4.1 Large-diameter Piles Adjacent to Tracks

A large-scale building will be constructed in the space above tracks, so the positions of columns must not interfere with tracks and stairways. This creates many restrictive conditions on the positions of columns and piles, and their intervals also become wider in places. For construction of piles in particular, the construction period became longer and expenses became higher for reasons such as...

1) Foundation piles have large diameters, and there is no machinery that can construct them.
2) Construction could only be done in the late-night hours at locations close to the tracks or with limited space (platforms, etc.).

We thus developed with a construction company two new
methods of constructing cast-in-place piles as shown in Fig. 8. The method shown on the left is the “pile-driving method for locations using both core walls and protective walls” where protective steel sheets are installed at the same time as excavating for piles so as to prevent the surrounding earth from collapsing. On the right is the “pile-driving method for locations with ultra-low clearance” where compact and lightweight machinery allows work in confined spaces. Using these pile construction methods, construction can be done even when trains are running, reducing construction time for piles to approx. 1/5 what it would have taken using conventional methods.

4.2 Constructing Steel Frames while Trains Are Running
We have also clarified the safety margin and prepared standards to allow construction of steel frames 24 hours a day, even in times when trains are running. In that, we tested by dropping a steel frame on specimens simulating floors under construction with actual construction in mind. Using steel frame weight and drop height as parameters, we clarified the safety threshold. Fig. 9 shows a drop test.

Shinjuku Station boasts the largest passengers usage of any station in Japan, and we are working to make it into a transportation hub with convenient transfers to busses, taxis, and ordinary passenger cars in addition to trains. In creating the Shinjuku Transportation Hub, we are using the space above the tracks south of the Route 20 (Koshu Kaido Avenue) overpass to create 1.47 ha of artificial ground, making transportation facilities expand three-dimensionally.

The building for transportation facilities will encompass four levels. It is planned to have track on the first level, station facilities, a pedestrian plaza, and other facilities on the second level, a taxi and other ordinary vehicle loading area on the third level, and expressway bus related facilities on the fourth level (Fig. 10).

We are also building an underground structure under the Yamanote Freight Line (tracks 1 to 5). This will house machinery rooms and the like for the entire facility in an area about a third that of the artificial ground.

5.1 PC Construction Girders
When building structures under tracks, construction girders and temporary structures temporarily support the track and platform during construction. The track at the worksite is temporarily supported by PC construction girders for use in the permanent structure, which do not need to be removed in the future, and by temporary piers. Fig. 11 shows installation of PC construction girders. PC construction girders have fewer assembly members on the left and right main girders with cross beams at three locations. Work using this construction method involves laying a girder span all at once or in sections in the short work time at night with preinstalled stoppers and the like as rulers.

Conclusion
This article has introduced some examples of innovating structure technologies for creating new spaces. Spaces with value are usually near stations and railway lines. Construction for creating those spaces still has many restrictions in terms of time and space, so we will work to make further improvements into the future.