

R&D on Space Creation Technology — Present State and Future Outlook

Deputy General Manager, Frontier Service Development Laboratory,
Research and development Center of JR East Group

Mitsuru Shimizu



The Frontier Service Development Laboratory has set research themes and is conducting R&D based on each of the four cornerstones of JR East's Group Vision 2020: "Pursuit of Maximum Safety Levels", "Expansion and Creation of New Markets", "Enhanced Operation Stability and Reliability", and "Lessening Environmental Impact". This issue of JR Technical Review will introduce typical themes for which work is underway under the key phrases of countermeasures against earthquakes, construction near tracks, next-generation construction and fabrication systems, increasing Shinkansen speeds, reducing construction costs and countermeasures against noise.

The issue will further introduce themes we need to take on in the future using the key phrases of safety measures for situations such as earthquakes, increasing quality of structures, increasing safety during construction, construction methods for over- and under-track spaces and protection of the environment along tracks.

1 Introduction

The Frontier Service Development Laboratory was established in December 2001. In a two-team structure covering service design and structural system design, we conduct R&D from a customer point of view and with the newest technologies to bring about innovative solutions for station and onboard services, as well as solid structures to support them.

The structural team has set research themes related to space creation technology and is conducting R&D based on each of the four cornerstones of JR East's Group Vision 2020: "Pursuit of Maximum Safety Levels", "Enhanced Operation Stability and Reliability", "Expansion and Creation of New Markets" and "Lessening Environmental Impact".

This issue of JR Technical Review will introduce as themes in "Pursuit of Maximum Safety Levels" countermeasures against earthquakes for architectural and civil engineering structures and development of methods of predicting the impact that construction near tracks has on existing structures. In themes related to "Enhanced Operation Stability and Reliability", we will introduce research on next-generation construction and fabrication systems. As "Expansion and Creation of New Markets" themes, we will introduce efforts in increasing Shinkansen speeds and in reducing costs of construction involving open-cut excavation under tracks. And as a theme related to "Lessening Environmental Impact", we will introduce countermeasures against noise for steel railway bridges.

2 R&D on Space Creation Technology

2.1 R&D on Countermeasures Against Earthquakes

2.1.1 Countermeasures Against Earthquakes for Over-track Buildings

Unlike with ordinary buildings, over-track buildings face

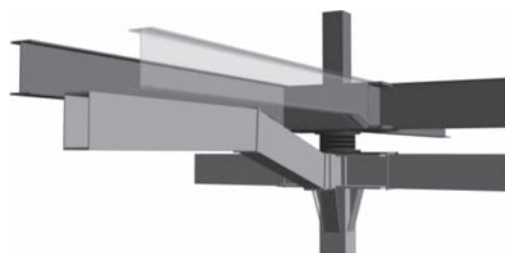


Fig. 1 Frame Form Around Seismic Isolation Layer

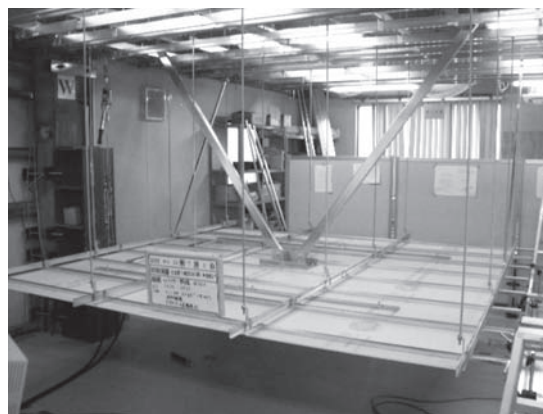


Fig. 2 Developed Aseismic Ceiling

severe constraints in terms of design and construction such as difficulty in installing underground beams. For that reason, we are aiming to reduce seismic response by applying seismic isolation technologies to over-track buildings, thus shortening construction time and costs. Development for that application is reported in "Development of Low-rise Over-track Buildings Using Thick Laminated Rubber Seismic Isolation Materials".

In the 2011 Tohoku Earthquake, Sendai Station on the Tohoku Shinkansen as well as conventional line stations suffered damage such as falling ceiling panels. Such damage in gymnasiums and other buildings with large spaces had also occurred at

past earthquakes such as the Geiyo Earthquake, Tokachioki Earthquake and Miyagioki Earthquake, prompting calls for aseismic ceilings that can withstand large earthquakes. We report on the results of development for those aseismic ceilings that can withstand large earthquakes in “Development of Aseismic Ceilings for Large Spaces in Upper Floors of Buildings”.

2.1.2 Research Taking into Account RC Pier Reinforcement After Earthquakes

If the base of an RC pier is damaged in an earthquake, excavation up to the damaged part and repair of that involving temporary coffering, temporary piers and the like is required for piers in rivers. That could lead to longer work time and increased restoration costs. We thus researched controlling where damage occurs when RC piers are damaged in a large earthquake so the damaged part will be in a location that can be easily repaired. This is reported in “Basic Research on Flexural Damage of RC Piers Having Cut-off Rebars”.

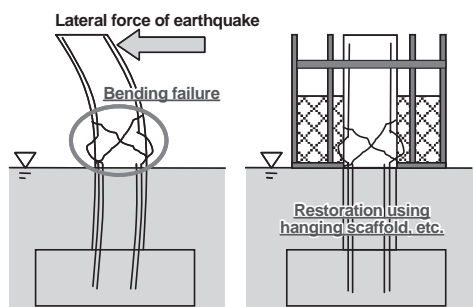


Fig. 3 Damage at Easily Restorable Locations

2.2 Development of Methods of Predicting Effects on Structures with Construction Near Tracks

Piles often need to be constructed near tracks and existing buildings when erecting over-track buildings. Those piles must be constructed in a way that the work does not affect safety of running trains or nearby buildings. An auxiliary method of pile construction such as ground improvement is implemented first to secure safety. However, proper assessment of the effects of pile construction near tracks must be done to define the necessity of supplementary construction and the appropriate scope of that.

We have developed as a simple method of analyzing effects of construction in the planning stage finite element method (FEM) analysis software that incorporates the shear strength reduction method. That is reported in “Development of a Method of Analyzing Behavior of Cast-in-place Bore Walls Using the Shear Strength Reduction FEM”.

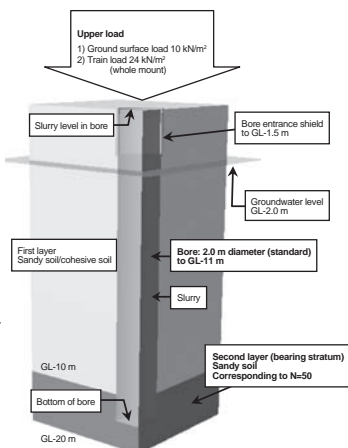


Fig. 4 Analysis Model Used in Parameter Study

2.3 Research on Construction and Fabrication Systems for the Next Generation

People from many organizations are involved in construction and improvement projects at JR East from the formulation/planning stage through survey/design, construction and maintenance phases. Handoff between organizations at individual work process stages as the project progresses is done mainly by paper diagrams, and data is kept by the individual department. We thus believe that it is important to reform the mechanism where individual departments at each stage information hold separately, forming a new construction and fabrication system appropriate for achieving high quality in structures and efficient management.

As the first step in defining this new construction and fabrication system and achieving the system, we studied 3D modeling in the survey/design stage. We report on that in “Basic Research on Next-generation Construction and Fabrication Systems”.

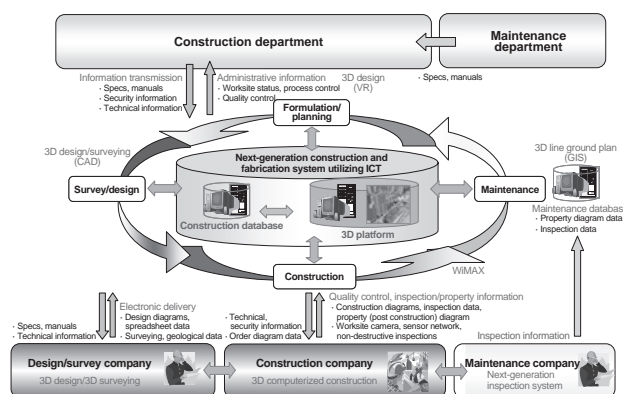


Fig. 5 Image of Next-generation Construction and Fabrication System

2.4 Efforts for Increasing Shinkansen Speeds

2.4.1 Research on Reducing Deflection of Viaducts

Civil engineering structures for Shinkansen lines are, for the most part, designed for a maximum design speed of 260 km/h. In studying safety of concrete girders as Shinkansen speed increases, we found that some girders did not meet standard values for deflection defined in terms of ride comfort set down in design standards for maximum speeds in excess of 300 km/h. As a countermeasure to reduce such girder deflection, we developed a construction method whereby existing noise barriers that were originally not structural members can be utilized as part of the structure. We report on that research in “Development of a Construction Method for Reducing Deflection of PC Girders Utilizing Binding of Existing Sound Insulating Walls”.

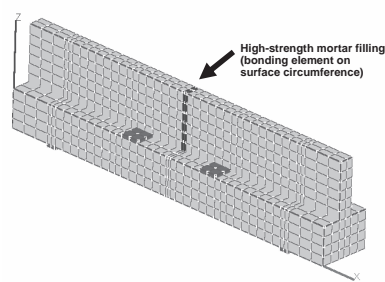


Fig. 6 Analysis Model for Effects of Sound Insulating Wall Binding

2.4.2 Research on Ground Vibration with Increased Speeds

There is concern about ground vibration along Shinkansen routes with increased Shinkansen speeds. Concern is especially high on the Tohoku Shinkansen regarding the effects of ground vibration for sections with firm ground. We thus studied application of past prediction methods to firm ground. The results of that and plans for the future are reported in “Development of a Method of Analytically Considering Ground Vibration”.

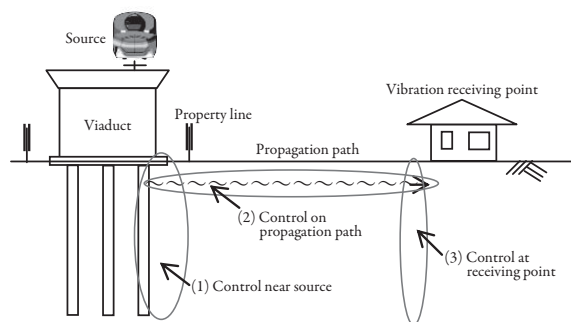


Fig. 7 Vibration Control on the Ground

2.5 Research on Technologies for Building Spaces Under Tracks

The temporary girder method of construction where track is temporarily supported on temporary girders while open-cut excavating has been widely adopted for building structures under tracks. JR East generally uses sleeper hug type temporary girders as the temporary girders. Those temporary girders are produced in the same way as other structural girders by being built up, so cutting and drilling of holes in the steel material is involved. Thus, a long production period including raw material procurement and high production expenses are involved. For that reason, production of temporary girders has become an issue in carrying out the project.

We thus developed temporary girders with leased material used as general steel retaining wall braces as a component material. Using those girders allowed for easy procurement and reduced fabrication, so the construction period could be shortened and costs greatly reduced.

We report the development in “Development of Temporary Girders Using Steel Retaining Walls Braces”.

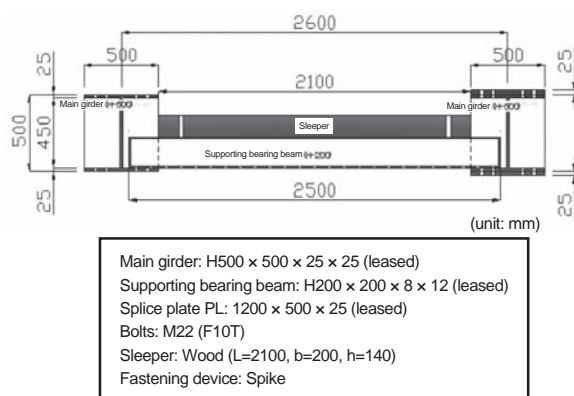


Fig. 8 Full-scale Load Test Sample (Cross Section)

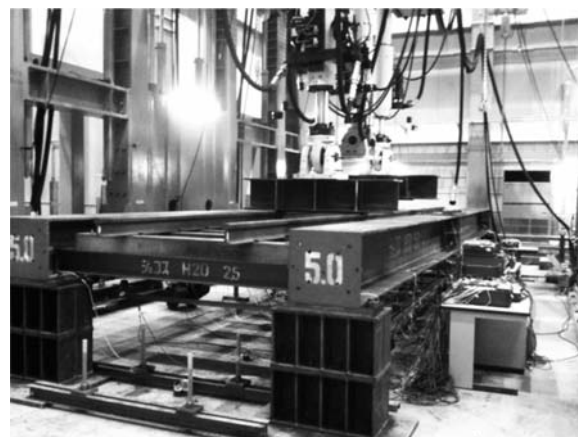


Fig. 9 Full-scale Load Test

2.6 Countermeasures Against Noise for Steel Railway Bridges

Taking countermeasures against sound for steel railway bridges along conventional lines where structure noise (noise generated from vibration of structures such as steel beams when a train passes) stands out is an important issue in terms of protecting the environment along the track. However, a method of quantitatively predicting noise along the track including structure noise generated from steel railway bridges has not yet been put in place. We thus measured structure noise and vibration on conventional line railway bridges in the Kanto area, surveyed vibration on main vibrating locations on steel railway bridges and relation to structure noise radiating with that, and put together a method for predicting noise. As a result, we were able to predict at accuracy of around 3 dB or less. We report that prediction method in “Prediction by Numerical Simulation of Conventional Railway Noise Including Structure Noise”.

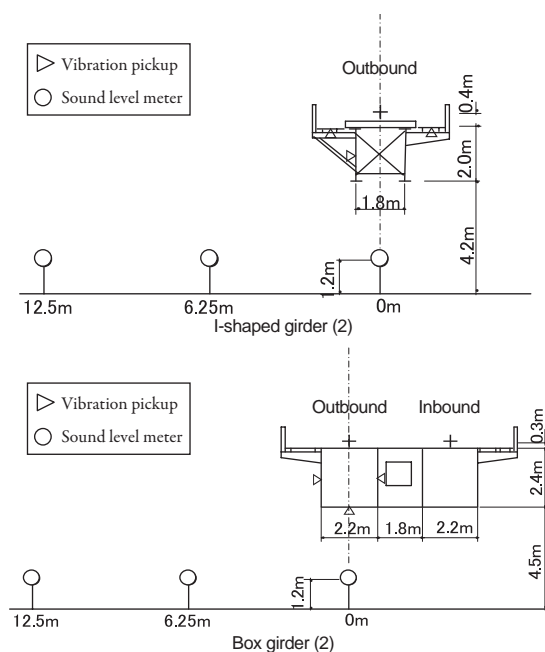


Fig. 10 Vibration and Noise Measurement at Steel Railway Bridge

3 Future Efforts in Space Creation Technology

3.1 R&D Concerning Safety Measures Such as in Earthquakes

In earthquake protection measures for civil engineering structures, we have hitherto worked on aseismic reinforcement of structures such as viaducts that will have general shear failures first. That was done for the Shinkansen and in areas such as south Kanto and Sendai. We are currently proceeding with reinforcement of structures such as viaducts for those that will have borderline bending and shear failures or bending failure first. Consideration is being made for proceeding with R&D to make work on such measures progress more efficient.

We also need to go forward with reinforcement of older non-reinforced concrete structures and embankment structures. And as we need to study methods of conducting measures upon establishment of methods of assessing safety against earthquakes for those structures, we are considering building and utilizing in a prompt manner experimental equipment such as earth tanks.

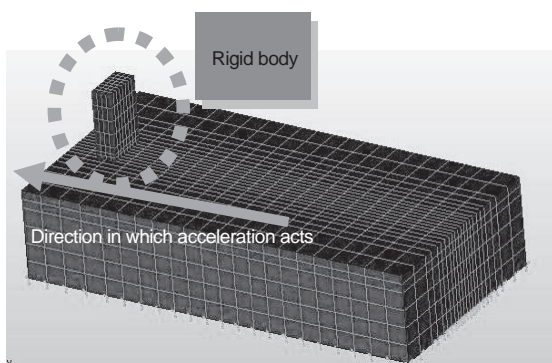


Fig. 11 Research on Assessment Method for Critical Limit of Older Structure Overturn

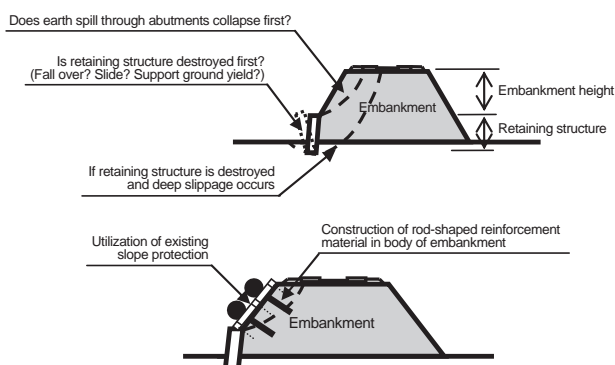


Fig. 12 Research on Embankment Structure Reinforcement

The 2011 Tohoku Earthquake brought on unprecedented damage such as from tsunamis as well as ground liquefaction. We thus believe that we need to conduct R&D on countermeasures against those for new structures as well as existing structures.

R&D has been done on using seismic isolation materials on low-rise buildings as protection measures for new above-track buildings. Application of those to high and medium-height above-track buildings may also be possible. We will therefore conduct R&D while verifying the effects of seismic isolation materials on high and medium-height above-track buildings.

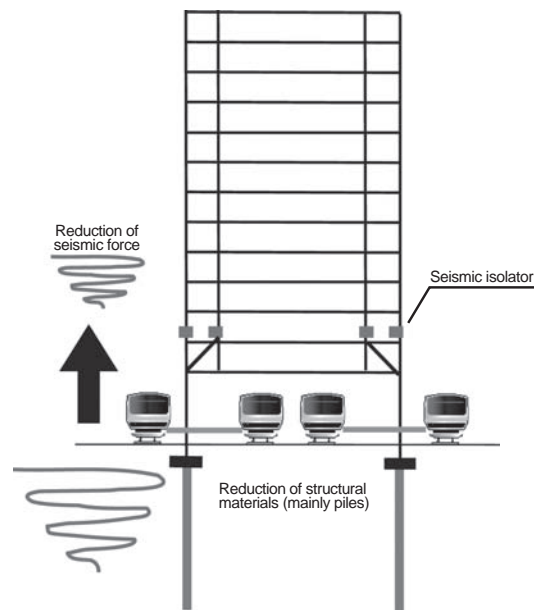


Fig. 13 Research on Seismic Isolation and Vibration Control for High and Medium-height Above-track Buildings

3.2 Technical Development on Improving Stability and Reliability of Structures

3.2.1 Improving Quality of Structures

With concrete structures, contraction of concrete can be large depending on coarse aggregate properties, the construction environment, material conditions and the like. Durability can be affected and cracks occur due to that contraction. We have thus started research to establish methods of predicting and dealing with cracks by identifying the mechanism by which those cracks occur.



Fig. 14 Research on Method of Preventing Weak Points when Building in Sections

It is also difficult to construct beams, slabs, and the like all together when building concrete structures near tracks. For that reason, components are often constructed separately. When building in sections, the locations where components are joined may become weak points. We have thus also started research such as on countermeasures against such joint cracking and on rust prevention methods for rebar.

ICT is being utilized for quality control in a variety of fields, and we are considering applying those methods for structure management in the construction phase. For example, we are

researching a control method whereby the structure under construction can be compared with the finished form. That is done by building a system for placing IC tags on the structure to verify structure information through those and register quality control records and by building a system that can project dimensional model images on industrial television.



Fig. 15 Research on Structure Management Utilizing ICT

3.2.2 Improvement of Safety During Construction

When building underground spaces near structures such as station and viaduct foundations, the nearby structures may be deformed due to ground loosening during construction. To avoid affecting those nearby structures, we have started research to predict with high accuracy the ground loosening during construction with non open-cut as well as open-cut excavation methods.

3.3 R&D on Market Expansion such as that for Over- and Under-track Spaces

There is increasing demand to utilize spaces under stationhouses and commercial lines when going forward with station improvement and barrier-free conversion. However, many restrictions when doing work under stations and commercial lines and poor efficiency of construction mean that there are many issues currently in terms of work period and cost. We have thus started research on an efficient underground space building method for open-cut excavation using safe retaining walls that allows construction in a short period of time.

Over-track building construction normally needs to be done in the short work period at night when the tracks are closed because the work is done directly over the track if in the daytime. And that results in a longer period of time before construction is completed. For construction to be done while trains are operating, safe countermeasures against falling of suspended loads are needed. To establish reasonable protection, we are conducting drop tests with parameters such as load form and weight, drop height, and impact face. We are also developing protection design rules that can be applied to construction over-track buildings of a variety of sizes.

3.4 R&D on Protection of the Environment along Tracks

Regarding conventional line noise prediction methods for steel railway bridges, we have hitherto established a method of predicting noise including structure noise through R&D. We are now working on deploying that prediction method and on research for a prediction method that allows the sound reduction

effects of sound source countermeasures such as damping materials to be identified.

We are also researching applying developed devices such as Shinkansen noise reduction devices (NIDES) to reverse L shaped and other noise barriers. The purpose of that is to allow application to work such as Shinkansen speed increase and to places that need countermeasures against noise.



Fig. 16 Research on Countermeasures Against Conventional Line Noise of Steel Railway Bridges

4 Conclusion

In R&D concerning space creation technology, it is important to sufficiently identify the worksite situation including worksite restrictions and technologies used at the worksite. For that reason, day-to-day research must go beyond deskwork. The worksite must be frequently visited and sufficient exchange of opinions made with those in charge at the worksite. Researchers also need to have a broad view, keeping an eye on technical trends at other companies and overseas, on trends at laboratories of other institutes and on research trends at universities and the like.

Prompt and efficient promotion is also needed in R&D on space creation technology. The Frontier Service Development Laboratory has thus enhanced experimental equipment to allow efficient experiments on our own. Particular examples of that enhancement include additions in 2010 to previous experimental equipment such as our cyclic load testing machine and bending testing machine to include large testing equipment such as a large fatigue load tester, pseudo-dynamic load testing machine, lateral vibration tester and material degradation acceleration testing machine. And in fiscal 2011, we added an earth tank testing machine for efficient development of foundation structures and underground structures.

Efficient R&D requires more than just an enhanced R&D work environment and testing equipment. The Frontier Service Development Laboratory plans to continue working on R&D while fostering human resources who are sensitive to field worksite issues, operating our own testing equipment and insatiable for knowledge.