DEVELOPMENT AND FUTURE OF SPACE CREATION TECHNOLOGY

— SPACE CREATION TECHNOLOGY FOR ENHANCING FOUNDATIONS OF RAILWAY AND LIFE SERVICES BUSINESSES AND FOR IMPROVING STATION FUNCTIONS AS TRAFFIC NODES —

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The words "space creation technology" emphasize "space" as the output of input construction and improvement work. Many requirements need to be met in the surveying, planning and designing processes for construction and improvement projects aiming at improving the foundation of railway and life services businesses and functional improvement of stations as traffic nodes. Those requirements in cost, safety, quality, work period and functions are met by employing civil engineering and architectural space creation technologies. In the twenty years since the formation of JR East, much development in civil engineering and architectural technologies to advance construction and improvement projects has been successfully undertaken. And those achievements have been utilized and deployed in the field. Here we will look back on the progress of developing such technologies and the history of space creation technology, and we will cover the perspective of space creation technology from the medium and long-term viewpoint.

1 Introduction

As of April 2007, twenty years have passed since the formation of JR East in 1987. Here we will look at the progress in those twenty years of mainly structural technologies in civil engineering and architectural technologies that are space creation technologies that have effects on improvement of the foundations of railway and life services businesses and functional improvement of stations as a traffic nodes. Also I will describe the background of technological development subjects in the special edition papers of this review and the perspective of space creation technology from the medium- and long-term viewpoint. For your information, the words "space creation" are used in the name of a section of our Frontier Service Development Laboratory. That is because those words stress space creation as output of the input of civil engineering and architectural construction and improvement work and are based on customer orientation; and we are keenly conscious of the linkage of research and planning sections with the life services section and the linkage human-oriented and maintenance technologies. In this paper, I will use the words "space creation technology" for civil engineering and architectural technologies collectively.

2 Space Creation Technology

I can point out the following matters as the background and characteristics of technological development subjects explained in the special edition papers.

(1) Conditions related to construction environment and construction time in constructing and improving railway facilities are often much stricter than in usual public works construction or private building construction. At the same time, certain expectations in areas such as cost, safety, quality, and work period must be met. Sometimes different technological challenges such as in lighting work and underground work in individual projects must be overcome. Accordingly, careful examination of design and work plans and new technological developments of structures, work methods and design methods are required to meet requirements with a higher level of satisfaction.

(2) In construction of artificial foundations for over-track space to achieve functional improvement of stations, design and work plans need to be considered with well-coordinated civil engineering and architectural technologies more than ever before. Particularly in the work up to construction of a concourse floor above the tracks between lines or on platforms, such technological coordination is very important in areas such as construction methods for temporary construction and installations and for piling. From the viewpoint of advancing life services business, sometimes earlier completion of facilities for the business is requested. And new technological developments are often required to overcome those technical issues.

(3) With lessons learned in the Great Hanshin-Awaji Earthquake, we are carrying out aseismatic reinforcement on columns of rigid-frame viaducts as an improvement of quake resistance for existing struc-

tures. Also, after the Sanriku Minami Earthquake in 2003 and the Mid Niigata Prefecture Earthquake in 2004, we have expanded the scope of aseismatic reinforcement and are proceeding with reinforcement of station buildings based on results of quake resistance assessments. For example, it is now an urgent issue to carry out aseismatic reinforcement involving lower cost, shorter work time, and easy work for structures under elevated tracks; and we are actively developing technologies addressing this issue and employing such development results.

(4) Underpasses and other structures for grade separation to cooperate with community formation are outside related work or commissioned work for railway operators. In the Railway Business Law, those structures are classified as bridges taking train loads that need to undergo design review. But we had not actively developed technologies for those, and rather prepared and improved guidelines to select various technical proposals by contractors and designed rules to secure safety as internal technical standards only. One of the reasons is that those structures are not capitalized as fixed assets of railway operators. But, as explained in "For Recognition of Technical Development" [1], it has become important that JR East in-house engineers take responsibility for development of construction methods, with an aim to securing train safety and transport stability as the biggest service or product of JR East (in other words, to secure quality of our own products) based on the lessons and experiences of many accidents and incidents in construction of buildings near railway tracks. In these efforts, we have developed and are widely applying HEP & JES methods (High Speed Element Pull and Jointed Element Structure) [2] as new construction methods. It also should be noted that the construction and production system environment is changing, and we cannot rely on outside parties for technological development to secure quality of our own products.

Based on the aforementioned background and characteristics, in this issue of the Technical Review, we will run papers that…

- Introduce the development of a new bridge beam travel-limiting device related to (1)
- Introduce a jacking down method, a response-controlled and linked structural system, a beam depth shortening method, a new form of viaducts to create amenity space under elevated tracks, and other general subjects for amenity of station space related to (2)
- Explain aseismatic reinforcement for civil engineering structures such as piers and foundations of viaducts and architectural structures such as stations related to (3)
- Explain the development of a new construction method to extend narrow underpasses under over-road railway bridges related to (4).

3 Progress of Space Creation Technology in the Past 20 Years

3.1 Characteristics of Technical Development and Points of Concern in its Promotion

The main characteristics of the technical development in the past twenty years are the following two points. One is that we have been aiming in such development to develop construction or design methods required for cost reduction, work period shortening, etc. in actual individual construction and improvement projects. The other is that we have been aiming to develop construction methods, materials, and design methods that can be applied across the board in other similar works.

The first point—technical development for cost reduction and shorter work periods to conduct projects smoothly—should be preceded always with consideration to the process of the project. In general, a project is promoted in the process from surveying and planning, deciding on matters related to conducting the project, overall basic designing, deciding on accompanying capital investment, actual detailed designing, work planning, design review and approval, to starting the actual work. When more cost reduction or shorter work time than in traditional construction methods are required due to factors such as cost-benefit, profitability or date of operation start, we examine the necessity and scenario of the technical development; and then commence development. During development, we must coordinate the development process and designing process to introduce development results into structural and construction planning; technically standardize development results and content; and make so they for designers, reviewers, workers, and site foremen appropriately understand the technology and administer that. Promoting technical development requires not only technical studies by sections in charge of development, but also close coordination with sections administering construction plans of the project. When such coordination and efforts of individual sections are insufficient, the expected effect will not be achieved, so technical administration is important.

As for the second characteristic mentioned above, while each project has its own nature, we promote technical development with an aim of introducing design or construction methods that can solve the many similar or common technical challenges among projects. As new issues sometimes emerge while accumulating experience in construction, we also have to conduct maintenance by continuously making improvements and modifications.

A recent trend is for the speed of work from surveying and designing to start of actual construction to be faster. So, setting and promoting subjects of technical development requires more promotion of organizational technical development, specifying individual targets and scenarios (i.e. issues in current cost, construction period, ease of work and safety, priority of developed methods, projects to be applied with those methods, well-coordinated design and development process etc.) (see Fig. 1).

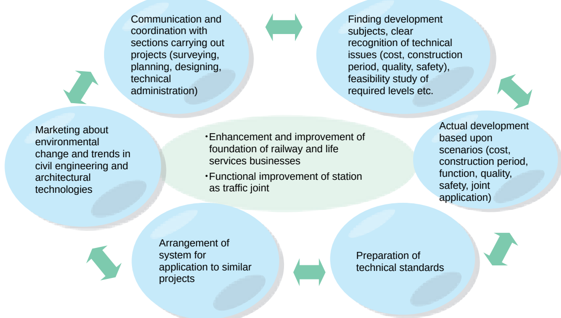

Fig.1: Points of Concern in Promoting Technical Development for Space Creation Technology

3.2 Technical Progress up to Now

Here I will outline the development of space creation technology in the past twenty years (see Table 1). For purposes of illustration, I have separated these twenty years into four periods of five years

(1987 - 1991, 1992 - 1996, 1997 - 2001, and 2002 - 2006) and classified the developments into four categories as (1) cost reduction, (2) safety and quality, (3) environment, new structures, tracks, and construction planning, and (4) architectural structure. As technical developments often cover multiple years and categories, the separation and categorizing here is for overview only. An outline of technical development in each period is as follows.

(1) 1987 - 1991

・After the formation of JR East, we continued the Keiyo line extension work into Tokyo station that started in the JNR era by introducing many new technologies. We also developed technologies for structures for viaducts and precast reinforced concrete (PRC) beams, taking into account future projects such as elevating the railway near Akabane station and continuous grade separation between Mitaka and Tachikawa.

(2) 1992 - 1996

・Along with promotion of design such as for elevating the railway near Akabane, we carried out development of elastic-ballasted track as new laborsaving track, rapid construction method for viaducts, extended viaducts, and new types of viaducts using PC components.

・Based on the accident at Okachimachi station caused by chemical injection and on deformation of tracks by construction under the track, we carried out development for quality control of chemical injection systems and basic development for under-track new construction methods.

・We carried out development of large span structures for over-track space and noise and vibration control construction methods for buildings in over-track space, forming the basis for many technologies for a later "Station Renaissance".

・To reduce the cost of foundation work in underground construction such as the construction of the Yokohama underground station, we carried out development of under-street caisson type machine piling construction methods, between-line piling construction methods, and underpinning construction methods.

・To secure safe and stable transport in construction near tracks and running of trains without slowing down, the need to form technical standards increased for construction planning, effect forecasting, and designing and construction methods. And accordingly, we carried out development needed to solve those issues.

・We carried out development such as that for track laying methods for the project for Shinkansen operation through to conventional lines and for a site foreman support system to check work status and hold safety meetings for remote sites via the Internet.

(3) 1997 - 2001

・We actively carried out development of a pile-end preloading method (applied to continuous grade separation crossings between Mitaka and Tachikawa and other works), HEP & JES method (applied to No. 2 Hiromachi tunnel on the Waterfront Area Rapid Transit Rinkai line and other works), and various forms of aseismatic reinforcement. Those successes contributed to cost reduction and later resulted in fruitions such as an award received from Japan Society of Civil Engineers and dissertations by in-house engineers being published.

・With the increase in open-cut construction using construction beams, we carried out development of low-cost construction beams. Also, we reviewed construction beams themselves used as temporary structures, and proceeded with development of a method to use them as permanent structures. We carried out technical development in the area of track laying work related to insertion of Shinkansen turnouts for the Honjo Waseda Shinkansen station.

・To expand application of formed mortar embankments with an aim to applying that to the approach of continuous grade separation (and to transport improvement projects such as multi-layering of existing viaducts), we carried out development of ultralight formed mortar embankment.

・Along with promoting artificial foundations in over-track space that contributes to functional improvement of stations and promoting plans for using space under viaducts, we developed revolutionary suspension-type seismic isolation methods and also carried out development of efficient methods of construction of passenger sheds and architectural facilities.

(4) 2002 - 2006

・The Frontier Service Development Laboratory was established in the R&D Center of JR East In December 2001. With that, the laboratory has carried out its own wide range of technical developments together with the technical development by field offices and Construction Dept. that had traditionally been in charge of construction work, closely communicating technical information and needs among the parties. In particular, the laboratory put priority on development of low-cost construction technologies in over- and under-track space. That included the sky piling

Table.1: Progress of Development of Space Creation Technologies (Civil Engineering and Architectural) in Construction (Important Subjects Only)

	Cost Reduction	Safety and Quality	Environment, New Structure, Track, Construction Planning	Architectural Structure
1987 - 1991	H-section steel and soil cement composite piling Composite floor slabs Rationalization of foundations of viaduct electric poles	PRC beams High-strength steel designing method Behavior of shield tunnels under vibration by trains	Civic design of viaducts Viaducts to use of space under elevated track Concrete using new materials Durability of concrete	
1992 - 1996	Building large span beams in over-track space Large span light-weight beams Extended viaducts Precast viaducts Low cost underground diaphragm walls Composite steel pipe pillars Under street caisson type piling Space-saving underpinning Piling between lines Under-track underpass construction Rapid construction of viaducts Elevation of embankment using PC steel pipe concrete Bored precast piling	Labor-saving tracks on soil roadbed Chemical injection control system Ground anchors under high pressure Design considering dynamic load Underground diaphragm walls built near tracks High-density reinforced pillars Details of field welding of steel bridges Open-cut method near tracks Underground diaphragm wall resistance against uplift Countermeasures against groundwater for underground structures	Quality of concrete in cold regions Exploration of underground objects Easy laying of underground crossing piping Structure of track roadbed Insertion of turnouts Turnouts to cross 3 - 4 lines Construction of automated crossings Speeding up of change of gauge High performance concrete Field construction control using IT Elastic-ballasted track Low-maintenance of steel bridges	Large span structure Isolation of noise and vibration of buildings in over-track space
1997 - 2001	Steel railway bridge supports Cast-in-place piling under limited head clearance Steel pipe piling under limited head clearance Low cost construction beams, permanent use of construction beams Extended structure of viaduct piers Ultralight foamed mortar embankment H-section steel piling under limited head clearance Rapid framing of underground beams of viaducts PC Langer bridge with low rise ratio	HEP & JES method Measuring method for deformation of existing structures Pile-end preloading piling Soil cement walls and piles Drilling precision control for chemical injection Large span structure under tracks Steel beams joined with high strength bolts Column material with improved deformation performance Aseismatic reinforcement of columns and piers	Structure of intermediate sections Mold for PC beams Elastic-ballasted tracks Cast-in-place piling using strands Insertion of Shinkansen turnouts Elastic-ballasted tracks on foamed mortar embankment Earth retaining walls (using steel sheet piles, new supports)	Lowering of noise and vibration in adjoining buildings Installation of drainage to track floors Joining of pillars and piles of passenger sheds Suspension type seismic isolation method
2002 - 2006	Permanent use of construction beams Ecological recharging Foundation of foamed mortar embankment on liquefied ground RC structure in narrow underground space Light-weight composite beams RC stopper COMPASS method Steel pipe piles with reinforced tips Thin-slab composite beams Foundation of elevator pit	HEP & JES method Removal of existing piles under limited head clearance JES element underground diaphragm wall Spiral steel pipe joints Beam and Pillar joint structure Small cast-in-place piles Aseismatic reinforcement of pillars and piers Prevention of rail buckling	Joining of pile heads Removal of deteriorated concrete Elevated structure on liquefied ground Viaducts with better environment beneath Piles with deterrence of horizontal displacement Self-repairing concrete Construction beams that require no cutting of long rails Actions for Shinkansen speed increase	Sky piling Jacking down in over-track space Replacing pillars between lines with PC pillars Seismic isolation of roofs of buildings under elevated tracks Response-controlled and linked structural system Roof with waterproof function for buildings under elevated tracks Floor structure in over-track space Aseismatic reinforcement of station buildings

method that is characterized by piling from the over-track space, the jacking down method for more streamlined framing of steel, the COMPASS method for making a small-section underground space, and small cast-in-place piling method.

- As one of the continuous efforts for cost reduction and work period shortening for aseismatic reinforcement in the civil engineering field, we developed construction methods for columns and piers of rigid-frame viaducts in different work environments. In the architecture field, we carried out development of damage control reinforcement methods for station buildings using adjoining buildings and reinforcement methods using escalator trusses.
- To reduce the cost of medium term transport improvement projects such as through operation on the Tohoku line, we proceeded with development of construction methods to increase quake resistance of existing square steel pipe masts, quake resistance improvement methods using foundation slabs, and a new bridge structure with thinner slab beams. We also carried out development of vertical supporting methods of foamed mortar embankment for cost reduction in railway elevation on liquefied ground, thinner pillar components for new construction in narrow spaces such as in elevation of existing embankments, and rapid work construction methods for viaducts.
- Against the background of quality problems of chemical injection work etc., we are proceeding with development of ecological recharging methods based on ground water control technology and piling methods for steel pipe piles with reinforced tips that allow for safe piling in narrow spaces between tracks. Those development results were immediately introduced into actual works.
- In the company-wide project of increasing Shinkansen speeds, we are proceeding with research and development in the civil engineering and architectural subjects such as beams, station buildings, tunnel entrance hoods, low noise construction, and low foundation vibration construction.

4 Future Perspective

4.1 Environmental Change Related to Future Space Creation

Here I will cover some environmental changes to be noted about future civil engineering and architectural space creation technology.

(1) Functional Improvement of Stations as Traffic Nodes

Stations will be more important as traffic nodes due to close relationship between the railway network and urban renewal projects in the greater Tokyo area as well as enhancement in convenience and functional improvements to advance life service businesses. For instance, the infrastructure improvement of the Shinjuku station south exit area is being carried out with this project being characterized by "a massive renewal that combines the a national policy aiming to improve traffic nodes, create enough space around the station and give the area features for which people want to walk about it, and JR East's management policy aiming to implement improvement of station facilities and the station terminal building development plan" [3]. From the viewpoint that "community creation and town liveliness in urban renewal can be achieved by coordination with railway stations" [4], we will need structures and construction methods based on higher functionality of stations and closer relationship between station and urban facilities.

(2) Making Stations into Destinations [5]

In consideration of the requirement level of functions and structural plan of station space and buildings in over-track spaces, we will have to pay attention to the higher social expectation that "stations should be people's destination more than a simple transit point (making stations into destinations)... and how we should create high quality station space." [5]

(3) Collaboration Between Civil Engineering and Architectural Technologies [6]

Life service businesses under elevated sections, stationfront plazas, and the relationship to urban space will be more important than ever before in areas such as station viaducts. We will have to enhance collaboration between civil engineering and architectural technologies [7] and study a kind of hybrid structure of those technologies, departing from the conventional under-viaduct space design based on the construction design incidental to civil engineering design.

(4) Technology to Design Construction Work and Maintenance [8]

In recent years, infrastructure developers are "required to design" work process and structural maintenance in the designing stage [8] based on quality problems in design and construction. That is due to the deterioration of worksite ability in designing and construction and the evidence on durability differences of structures due to construction quality. JR East also needs to develop work methods based on the new idea of minimizing the risk from construction work and quality problems, considering recent changes in construction systems and the railroad industry environment where work has to be done when tracks are closed at night. Also, in the area of concrete structures, material, structure, and casting technologies will be more and more important to minimize maintenance resources during the usual designed service life of 100 years.

(5) Higher Safety Expectation Level

As the safety level expected for social infrastructure becomes higher, the level required for railways increase too [9]. There are many new technologies to raise the level of safety that had not been employed much until five to ten years ago but are becoming common now. One of those in the architectural structure field is damage control structures such as seismic isolation structures and damping structures [10], [11]. There will be technical and systematic challenges to be overcome; for example, enhancement of socially required reliance level such as maintaining functions and easy recovery of highly utilized track and station space in case of an earthquake. On the other hand, efforts will be need for new technologies in the areas of cost reduction, expanded application and application to existing facilities. As for the train operation safety in case of an earthquake, the Ministry of Land, Infrastructure and Transport has specified the criteria for the running limit on newly constructed structure against L1 design vibration in the "displacement limitation standard" (railway and other structure design standard) as an interpretation standard. And the level of expectation regarding operation safety in case of an earthquake will become increasingly higher.

4.2 Future Space Creation Technology

Here I will explain space creation technology for the future, classifying that into five fields of (1) enhancement and improvement of station functions (buildings in over-track space, under-track underground space), (2) cost reduction, (3) safety improvement, (4) quality improvement and rational construction methods, and (5) environment and amenity (see Fig. 2 and Table 2). This classification is for illustration convenience only, and some topics relate to multiple fields.

(1) Enhancement and Improvement of Station Functions (Over-track Buildings)

① Low-Rise Over-track Buildings

So far we have constructed low-rise (lower than four stories and 20 meters) over-track building at Omiya, Shinagawa, and other stations to enhance station functions. For future applications, we are planning to address the following technical challenges, considering introduction of those new technologies into difficult construction environments.

- Structures easier to build with little construction near tracks (thinner building frame of the part in over-track space by expanding application of the coupling system of structures with different fixed periods, basic construction methods, application of new structural materials, etc.)
- Amenity improvement such as reduction of vibration and noise in over-track building (utilization of new damper materials, development of suspension structures and floor structures that enable large spans to improve visibility in platform spaces, etc.)
- Improvement of quake resistance and recoverability of over-track building (expansion of application of seismic isolation structures, damage control methods, etc.)

② Medium and High-Rise Buildings in Over-track Space

In the medium and long term, it will be necessary to study higher use of over-track space other than just low-rise building use. Thinking on technical standards differs depend on building foundation with or without underground beams, and we are planning to address the following technical challenges specific to medium and high-rise buildings.

- Applicability of new foundation structures for structures without underground beams and technologies to reduce costs of temporary and foundation construction that account for a considerable percentage of the total construction cost of structures with underground beams
- Seismic isolation and damping structures that take into account maintaining functions and recoverability after earthquakes (intermediate seismic isolation, foundation seismic isolation, etc.)

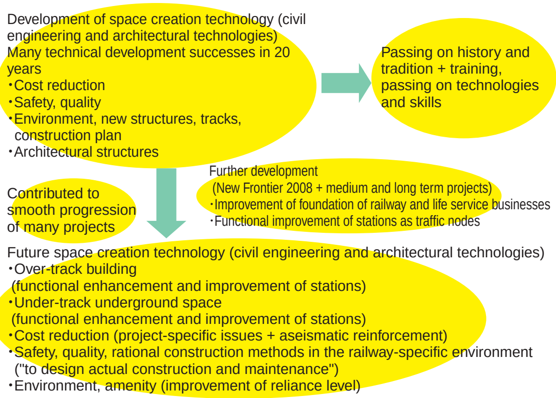

Fig. 2: Future Space Creation Technology (Civil Engineering and Architecture)

- Lowering environmental burden by studying the possibility of longer functional life in a construction environment different from general architecture (multi-layer structures that enable change of internal structure, etc.)

(2) Functional Enhancement and Improvement of Stations (Under-track Underground Space)

The need for stations to create underground space is expected to increase. That will be done by means such as widening of existing concourses and elevating of embankment as a part of functional improvement and coordination with urban projects. Since the construction environment in stations is different from usual sections between stations (insufficient free construction space, foundation of platform sheds, etc.), the open-cut method is often selected. In recent years, we have applied the results of technical development for permanent use of construction beams in many construction works, with an aim to reduce cost as well as control noise and vibration by trains in underground space. Based upon these construction results, we will sample issues and study improvement construction methods. We also plan to proceed with technical development on foundation construction that accounts for significant percentage in underground space creation and construction methods to reduce cost of temporary construction in excavation of ground under the ground water level. And we are planning to sample technical issues and study the solution to expanding application of existing trenchless methods such as the widening of existing abutments explained in this issue to construction for moving track underground in places such as stations.

(3) Cost Reduction

Aseismatic reinforcement is ongoing with aim of quake resistance of existing viaducts and other structures. Taking aseismatic reinforcement for entire track sections into account, the possibility of improving quake resistance of many different existing structures (unreinforced concrete piers, steel piers, soil structures, masonry structures, etc.) and station buildings must be studied. Since there are so many existing structures, we need construction methods that enable reduction of reinforcement cost. We are now giving priority in reinforcement of concrete columns and piers to those that will have general shear failures first, but reinforcement needs of those that will have bending failures first and those with failures on the border will also probably be studied. So, we will continuously need cost reduction technology in aseismatic reinforcement for a fairly long time. We will also have to continue cost reduction by overcoming project-specific technical issues as plans and projects proceed.

(4) Safety Improvement

Continuous pursuit of safety is important in railway civil engineering and architectural fields that inevitably involve construction near tracks. We will plan to promote development of HEP & JES methods to decrease track deformation, next-generation space creation under tracks, and safety improvement of cast-in-place large aperture piling.

(5) Quality Improvement and Rational Construction Methods in the Railway-specific Environment

Due to spalling and chipping of concrete on viaducts and tunnels in recent years, JR East has amended civil engineering work standards and is working to secure quality. With an aim of further quality improvement on concrete structures, we will pursue development of construction methods to maintain concrete fitness equivalent to that

Table.2: Space Creation Technology Development (Civil Engineering and Architectural) in Future Construction (Important Subjects Only)

Functional Enhancement and Improvement of Stations			Cost Reduction	Safety	Quality, Rationalization of Construction	Environment, Amenity
Buildings in Over-track Space		Under-track Underground Space				
Low-Rise Buildings in Over--track Space	Medium and High-Rise Buildings in Over-track Space					
○Reduction of work near tracks ・Thinner building frame in over-track space ・Coupled structure, suspension structure ・New structure material ・Installation and foundation construction methods ○Improvement of amenity in over-track space ・Quiet space by seismic isolation and vibration control ・Fewer columns on platforms ・Floor structure ○Quake resistance and maintaining functions ・Damage control methods	○Foundation methods ・Large aperture piles to reduce work load ・Construction methods that help deter ground deformation ○Quake resistance and maintaining functions ・Seismic isolation structure (foundation, intermediate structure) ・Facilities applicable to seismic isolation structure ○Functional long life ・Multi-layer skeleton structure ○Installation methods	○Open-cut method ・Improvement of construction beam method ○Trenchless method ・Improvement of trenchless method ○Ancillary construction methods ・Rationalization of excavation under water table	○Aseismatic reinforcement ・Unreinforced concrete piers ・Steel piers ・Masonry structure ・Soil structure ・Station buildings ○Bridges and viaducts ・Rapid construction methods ・Elevation of embankment ・Reengineering of existing elevated sections ○Project-specific issues	○Construction near tracks ・Excavation under tracks ・Open-cut method near tracks ・Piling near tracks ・Framing of beams near tracks ○Measurement control system	○Concrete structures ・Correction of initial defects ・Self-repairing material that deters water effects ○Rationalizing construction in railway—specific environments ・Construction near labor-saving tracks ・Construction system using muddy water ・Track change-over ・Excavation near turnouts ・Construction methods near tracks (precast, composite structure)	○Noise reduction of conventional lines ・Study of state of vertical direction noise and possibly for improvement ・Low noise steel composite structure ○Elevation of stations ・Interaction between civil engineering and architecture ・Large space elevation ・Construction structure under elevated tracks

of newly cast concrete even if concrete defects do occur, self-repairing concrete material that stops water leaking even in case of cracking, and effective use of surface impregnant to deter water effects that cause early deterioration of concrete.

In order to improve quality and safety and reduce cost, rationalization of construction methods for some construction is expected the environment particular to railroads where work must be done mainly at night when tracks are closed. From this perspective, we are planning to study more rational construction methods such as excavation near tracks in sections of labor-saving tracks, track change-over work, and more rational excavation near turnouts, as well as more rational construction systems using muddy water in construction within stations, crushing existing concrete with lower noise, more efficient methods to check status of construction, rapid work by methods such as framing and constructing precast material and composite structures in narrow spaces.

(6) Environment, Amenity

For further formation of the railway network in the future, requirements to maintain or improve on upward direction noise will increase in urban areas. Accordingly, we plan to carry out development based on studies on how to maintain or improve noise levels in high-rise buildings near tracks and on low-noise structures made of steel and composite materials.

We are conducting research to increase added value of the space under elevated tracks and create an environment there with many possibilities for use and amenity-rich station space through the elevation of stations (elevation of existing facilities and embankments). Specifically, that is development for rational coordination of civil engineering and architectural technologies and new structures using interaction between those technologies for elevation of stations and new elevated structures to create quiet large spaces.

5 Conclusion

Space creation technology is directly related to areas such as civil engineering and architectural design and construction methods. We need to pass down the history and traditions of those who did their best to overcome many technical challenges in the past while making efforts to develop human resources and have those inherit our techniques and skills through technical development. Aiming to deal with future environmental change and make breakthroughs in traditional technologies, we plan to address individual issues such as selecting technical issues even in the planning of a project, forming necessary technical development scenarios and systems, improving technical standards for smooth introduction of development results and clarifying intellectual properties for wide application of development results [12]. And we will further the enhancement and improvement of the foundation of railway and life services businesses and the improvement and construction of terminal stations as traffic notes for space creation which we can be proud to pass on to the next generation.

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