Development and revision of technical standards for road structures

1. Outline of Studies and Activities

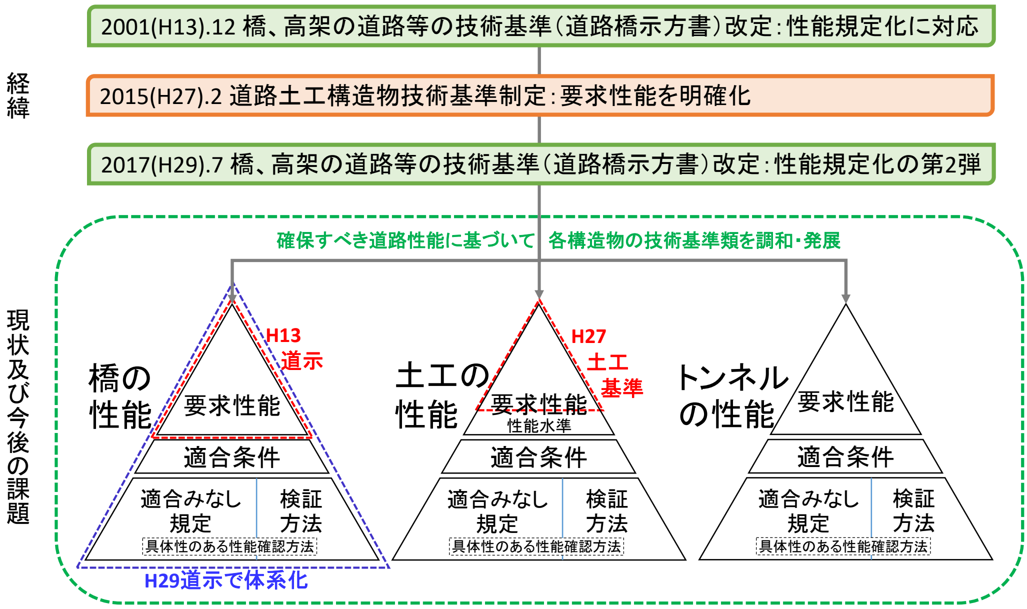

Figure 1: History, Current Status, and Future Tasks of Making Performance-Based Technical Standards for Road Structures

NILIM is developing and revising technical standards based on performance in order to harmonize the performance of each structure with the performance of the roadway, such as network functions, and its level of service and to provide concrete verification criteria for them. As shown in Figure 1, the performance-based standards consist of performance requirements, conformity assessment rules, verification methods, etc. However, the status of development of the standards differs depending on the type of structure that constitutes the main body of the road structure (bridge, earthwork, tunnel, etc.), and further revisions are being considered according to the status of development of each structure. In 2001, the pavement specifications were changed from specifications to performance standards, and we continue to work on the development and revision of technical standards to make progress.

Table 1 shows the main technical standards for road structures that NILIM is involved in developing and revising. In addition, NILIM is also working on technical standards for the design and construction of the repair of road bridges since the rational maintenance and management of many existing structural stocks have become an important social issue.

In formulating and revising draft standards, NILIM works proactively in cooperation with the Road Bureau, Public Works Research Institute, and other related organizations based on the knowledge it has accumulated through research, investigation of disasters and failures, and other technical support. NILIM also engages in various efforts necessary for the appropriate application of technical standards. In order to ensure that the standards that have been established or revised are properly applied, NILIM disseminates the background and purpose of the standards through cooperation in seminars and publication in technical journals and publishes the results of NILIM's research on which the standards are based in the form of papers and other publications.

Table 1: Major Technical Standards for Road Structures

Road bridge	Technical Standards for Bridges and Viaducts, etc. (July, 2017)
Road earthwork structure	Technical Standards for Road Earthwork Structures. (March, 2015)
Road tunnel	Technical Standards for Road Tunnel. (May, 1989)
Pavement	Technical Standards for Pavement Structures (June, 2001)
Underground Utility	Installation Standards for Buried Electric Cables and Other utilities (February, 2016)

2. Major Research Results

(1) Technical standards for road bridges

The Specifications for Highway Bridges, the technical standards for road bridges, has been revised in December 2001, February 2012, and July 2017 during the 20 years since NILIM was established. During this period, there has been an ever-increasing societal demand to meet diversifying needs for roads, to further reduce construction costs, to reduce life-cycle costs and maintenance burdens, and to facilitate international technology transfer. Therefore, NILIM has decided to work on performance prescriptions that are based on performance, have clear principles for evaluating the reliability and application methods of new materials and construction methods, and flexibly respond to social demands. For example, the study focused on the method of specifying the requirements including the hierarchy of clauses, the method of clarifying the required performance using a performance matrix, and the limit state design and partial coefficient method as standard methods to verify the reliability of bridge safety and durability and to incorporate them into technical standards in conformity and harmony with the desired system of specifying. The study was conducted to incorporate these methods into the technical standards in conformity and harmony with the desired prescriptive system.

The effectiveness of a performance specification is established with both a systematized provision for requiring, evaluating, and ensuring performance and the establishment of criteria for evaluation and judgment. Failure processes and durability of materials and members vary and depend not only on the strength and durability of the materials and members but also on the stability of the ground. Therefore, technical standards need to have a system and contents that allow evaluation and control of performance not only by material or member unit but also as a result of the combination of multiple members and other structural elements. In addition, in order to combine new materials and members as part of a road structure, it is necessary to be able to evaluate differences in their behavior and durability obviously and reproducibly, as well as to control their performance as a bridge.

In order to achieve these goals, the 2001 (Heisei 13) revision addressed two main issues: first, the establishment of performance specifications on an article-by-article basis as shown in Figure 2 (1); and second, the establishment of a standard method of achieving performance that can be regarded as satisfying the performance requirements of the relevant items. The calculation formulas and methods that had been used as assumptions for stress calculations and the structural details that had been established through experiments and experience were positioned as standard methods for achieving the performance that is deemed to satisfy the performance requirements of each relevant item. The intent of the original standard was then established as a system in which the required performance is clearly stated as a new superordinate article. By adopting this structure, it becomes clear that there is a degree of freedom in the method of achieving the required performance as long as the required performance is satisfied, and at the same time, it is possible to compare new proposals with the standard means of achieving performance and to evaluate their adequacy. Another is to include not only safety but also durability and ease of maintenance as performance requirements for road bridges and to introduce fatigue design and enhanced salt damage prevention for concrete bridges.

The 2001 revision focused on speeding up the process of increasing transparency and explanation of the standards. On the other hand, while each article constitutes a method to achieve the performance of a road bridge, the deformation and strength of each member unit that is verified in the actual design is also only an indirect proof to satisfy the performance as a bridge. As mentioned above, considering that road bridges as a whole are subjected to complex three-dimensional behavior and stress conditions, it is necessary not only to specify the performance of each article but also to present methods and criteria for evaluating and judging the validity of new proposals, but this was left as an issue to be addressed. In 2012, NILIM was revised to reflect the technical knowledge gained up to that point and to revise the defaults related to earthquake ground motions in light of the March 2011 off the Pacific coast of Tohoku earthquake (Great East Japan Earthquake), but the method of performance specification remained unchanged. NILIM continued to work with related organizations to resolve the issues.

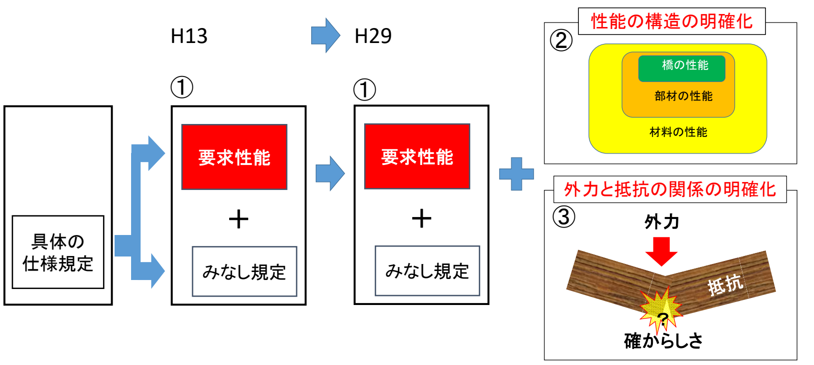

Figure 2: Deepening of performance specification

And the 2017 revision was the second stage of the performance specification process. The results of the research up to that point were reflected in the introduction of a new article system symbolized by the pyramid shown in Figure 1, a revision of the relationship between the Common Section and each section, and the introduction of verification formulas using limit states and partial factors instead of design using the allowable stress method. In addition to the performance specification introduced in 2001 for each article (Figure 2, ①), a hierarchy of performance has been established, which specifies the performance required for the entire bridge system, superstructure, substructure, upper and lower joints, members, and materials (Figure 2, ②). In each tier, the safety of the relationship between external force and resistance and the reliability of the load-bearing function are required to be clarified in the design stage (Figure 2, ③). In proposing the above series of performance specifications, NILIM has also been consistent with the ISO 2394 *General principles on reliability for structures*. The NILIM proposal for the above series of performance specifications is consistent with the ISO 2394 *General principles on reliability for structures*. While these are systems related to load-bearing capacity, we were also able to clarify the definition of durability performance. Durability performance was positioned as a prerequisite for load-bearing performance, satisfying the reliability of the period of time during which the condition of the members and materials assumed in the load-bearing performance of the bridge will be maintained against the cumulative effects of age. The introduction of partial coefficients to allow quantitative evaluation of the reliability of the estimation of actions and the evaluation of the progression of deterioration remains an issue to be addressed in the next revision.

(2) Technical Standards for Road Earthwork Structures

The Japan Highway Association's road construction guidelines have long served as the de facto standards for road earthwork structures, but this is thought to be due to the fact that the performance of embankments and cut and fill structures, which are mainly composed of soil, has historically been ensured through improvements in construction methods rather than design methods, and that they are not clearly defined as structures in the road structure ordinances. This is thought to be due to the fact that the performance of cut-and-cover soil has been secured by improving construction methods rather than design methods. On the other hand, as design and construction technologies have advanced, large-scale and technologically advanced structures have been constructed for road earthwork structures, and these structures have become important elements of structures. After deliberations by the Subcommittee on Road Technology of the Subcommittee on Roads of the Council for Social Infrastructure Development, the Technical Standards for Road Earthwork Structures was established in March 2015 as a national technical standard. The main points of the Technical Standards for Road Earthwork Structures are as follows.

・Define road earthwork structures and clarify the scope of application

・Define actions as normal, rainfall, seismic, and other required actions

・Define performance requirements according to the degree of impact of damage to road functions of road earthwork structures and their repairability, such as how quickly functions can be restored.

・Clarify the implementation of drainage design because drainage is an important issue for road earthwork structures (see Figure 3).

In addition, it is required to consider the performance requirements of the structures contiguous or adjacent to the road earthwork structure (see Figure 4), certainty and ease of maintenance and management, harmony with the environment, and economic efficiency.

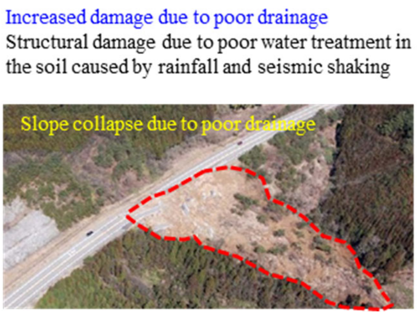

Figure 3: Example of damage due to poor drainage

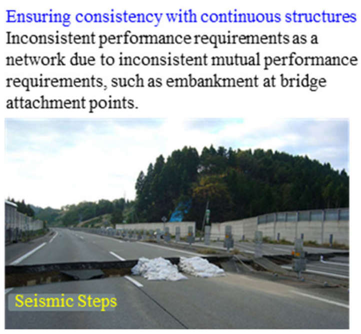

Figure 4: Example of step occurrence

(3) Technical Standards for Road Tunnels

The Standards for Installation of Road Tunnel Emergency Facilities, technical standards for emergency facilities in road tunnels, was revised in March 2019 for the first time in about 40 years, since 1981. In conjunction with this revision, the Standards for Installation of Road Tunnel Emergency Facility and Commentary (Japan Highway Association) was revised in September 2019. The main revisions are as follows.

・Clarification of installation conditions based on the role of evacuation corridors and smoke exhaust systems

・Improved description of operations, collaboration, etc.

・ Consideration for the introduction of new technologies and reflection of the latest findings etc.

In revising the standard, NILIM conducted experiments (Figure 5) and analysis (Figure 6) on the occurrence of fires in road tunnels and smoke behavior during tunnel fires. Based on the results of these analyses, the revised standards specify the conditions for the installation of evacuation passageways and smoke exhaust systems.

Figure 5: Fire experiment

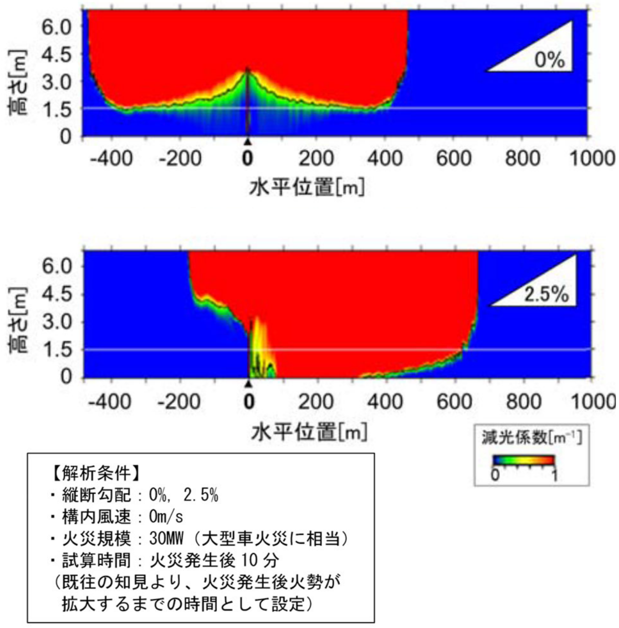

Figure 6: Example of distribution of longitudinal slope and attenuation coefficient 10 minutes after fire (Top: 0% longitudinal slope, Bottom: 2.5% longitudinal slope)

(4) Technical Standards for Pavements

In 2001, the Technical Standards for Pavement Structures was released for pavements, and the concept of performance specification was introduced earlier than any other road structures. After that, the *Pavement Performance Evaluation Method*, *Pavement Design and Construction Guidelines*, *Pavement Design Handbook*, and *Pavement Construction Handbook* were

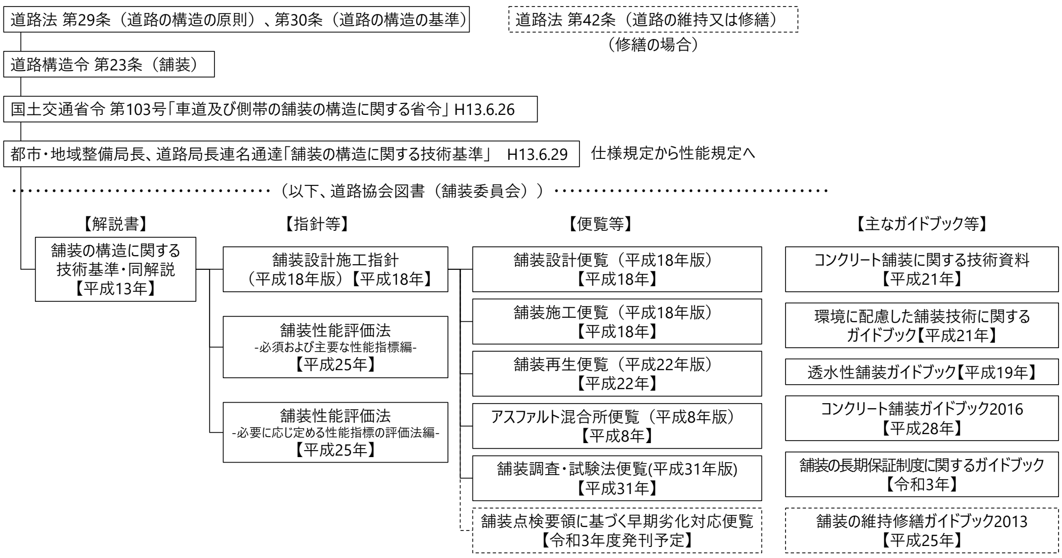

Figure 7: System of technical standards for pavement

published as practical books that engineers should refer to when designing, constructing, and evaluating the performance of pavements (Figure 7).

Since the establishment of the Road Structures Research Department, the latest research results have been reflected in technical books, such as the *Concrete Pavement Guidebook*, which summarizes concrete pavement design, construction, and maintenance in one volume, and the *Guidebook on Long-Term Warranty System for Pavements*, which describes the operation method of long-term performance warranty system for asphalt pavements, respectively.

(5) Technical standards for disappearance of utility poles

The Installation Standards for Buried Electric Cables and Other utilities were revised in February 2016 to allow the distance between the tops of electric cables and the road surface to be shallower than before on residential roads with low traffic volume.

The disappearance of utility poles is expected to create a favorable landscape, to improve pedestrian safety and comfort by increasing the width of sidewalks, and to prevent utility poles from collapsing in the event of a major disaster. However, the rate of progress in eliminating utility poles is lower than in other countries, and the most commonly used method, the shared cable trench method, is often difficult to install on roads with narrow sidewalks or no sidewalks, and its application is limited by its high maintenance costs. In order to further promote pole-less roads, further cost reductions were required.

Therefore, NILIM conducted vehicle driving experiments on pavements with buried power lines and communication lines to verify the effects on road functions, power transmission, and communication functions when power lines and communication lines are buried directly in the pavement, or when pipes or small boxes protecting them are buried in the pavement (shallow burial) (Figure 8). (Figure 8). As a result of the experiment, it was confirmed that it is possible to bury the wires shallower than the previous standard, and the results were reflected in the revision of the installation standard.

Figure 8: Construction experiment on shallow burial of cable

3. List of related reports and technical documents

1) Road Structures Department Policies for Research and Activities, NILIM Website
http://www.nilim.go.jp/japanese/organization/kouzou/houshin_dourokouzou.pdf

2) Establishment of Technical Standards for Road Earthwork Structures and revision of Standards for Road Sign Installation and Technical Standards for Road Greening, Ministry of Land, Infrastructure, Transport and Tourism Press Release March 31, 2015, https://www.mlit.go.jp/report/press/road01_hh_000495.html

3) Revision of the Standards for Installation of Emergency Facilities in Road Tunnels and its Commentary, Japan Tunnelling Association, *Tunnels and Underground*, Vol. 51 No. 11, pp. 57-68, November 2020

4) Interim Summary of the Technical Review Committee on Low-Cost Methods for disappearance of utility poles (December 25, 2015), NILIM website
http://www.nilim.go.jp/lab/ucg/koho/k151225.html

4. Future Outlook

(1) Technical standards for road bridges

In the future, while addressing the remaining issues, it is considered that the role of NILIM, which developed the original draft of the standard, is to enhance the technical data for both proposers and evaluators of new technologies to propose, evaluate, and compare new technologies in accordance with the system of road specifications. In addition, regarding the fact that there are currently no technical standards specifically for repair design and that the standard is to apply the Specifications for Highway Bridges mutatis mutandis, efforts are underway to shift the series of performance prescriptive systems to a series of performance prescriptive systems as standards by applying them to the diagnosis and repair of structures as well. Especially in the case of existing structures, it is becoming a social requirement to systematize specific standards so that various service periods, materials, and construction methods can be selected depending on the condition of the existing structure, its structure, and other factors while at the same time ensuring accurate reliability. To this end, research has begun, for example, to present a methodology for adjusting partial coefficients according to conditions.

(2) Technical standards for road earthwork structures

In the future, we will further deepen the performance specification aspect of the Technical Standard for Road Earthwork Structures by examining the required performance itself, specific verification methods based on the performance requirements, setting of conformance conditions, and deemed conformance conditions and verification methods, aiming for further harmonization with the standards for bridges and tunnels (see Figure 9).

(3) Technical standards for road tunnels

The Technical Standards for Road Tunnels, technical standards for the main structure of road tunnels, has not been revised since 1989. Currently, the Technical Standards for Road Tunnels is undergoing revision based on performance specifications to harmonize its performance with that of other road structures.

(4) Technical standards for pavements

Looking ahead, since the current technical standards provide only specific performance indicators, it is necessary to establish specific performance requirements for pavements based on the needs of various road users, and then develop a design methodology that incorporates these requirements. In addition, it is necessary to try to match the damage targeted in the current design with the damage that actually occurs in the field. To this end, we plan to conduct studies based on the results of ongoing fixed-point surveys etc.

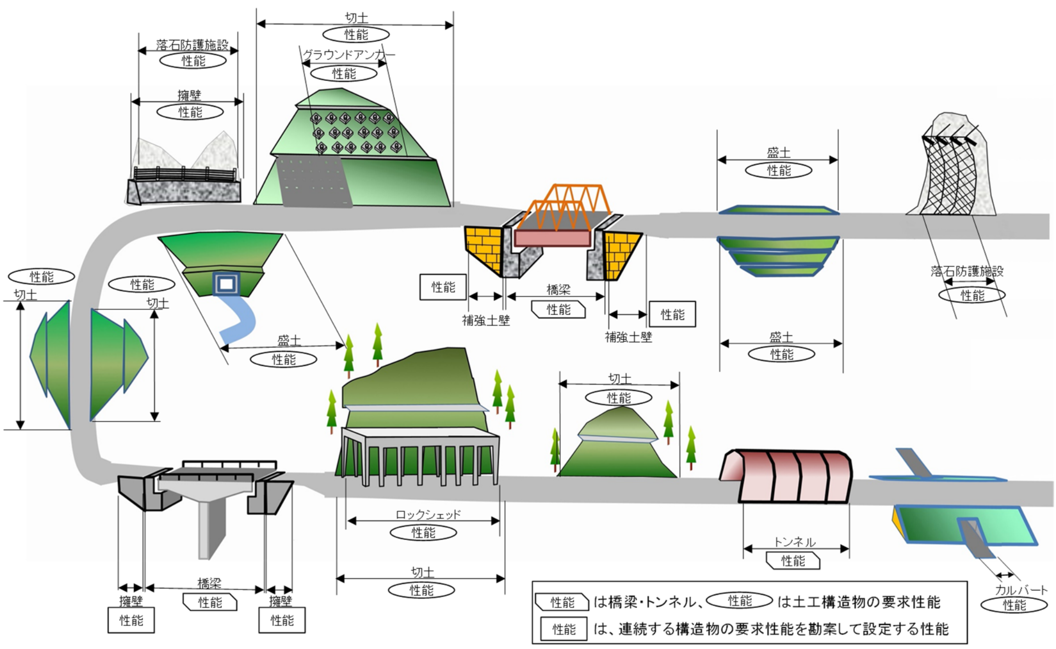

Figure 9: Harmonization of road structure performance requirements within a route