Dr. Motohide Matsui
Director,
Head of Materials Technology Division

The Materials Technology Division is currently working on extending the service life and developing high-performance materials for use in railways, identifying the causes of material deterioration, constructing deterioration evaluation and maintenance methods, and developing and researching new materials. We conduct research and development across diverse areas, from basic to applied research, on frictional sliding materials. In this article, we introduce the latest examples of our research and development efforts.

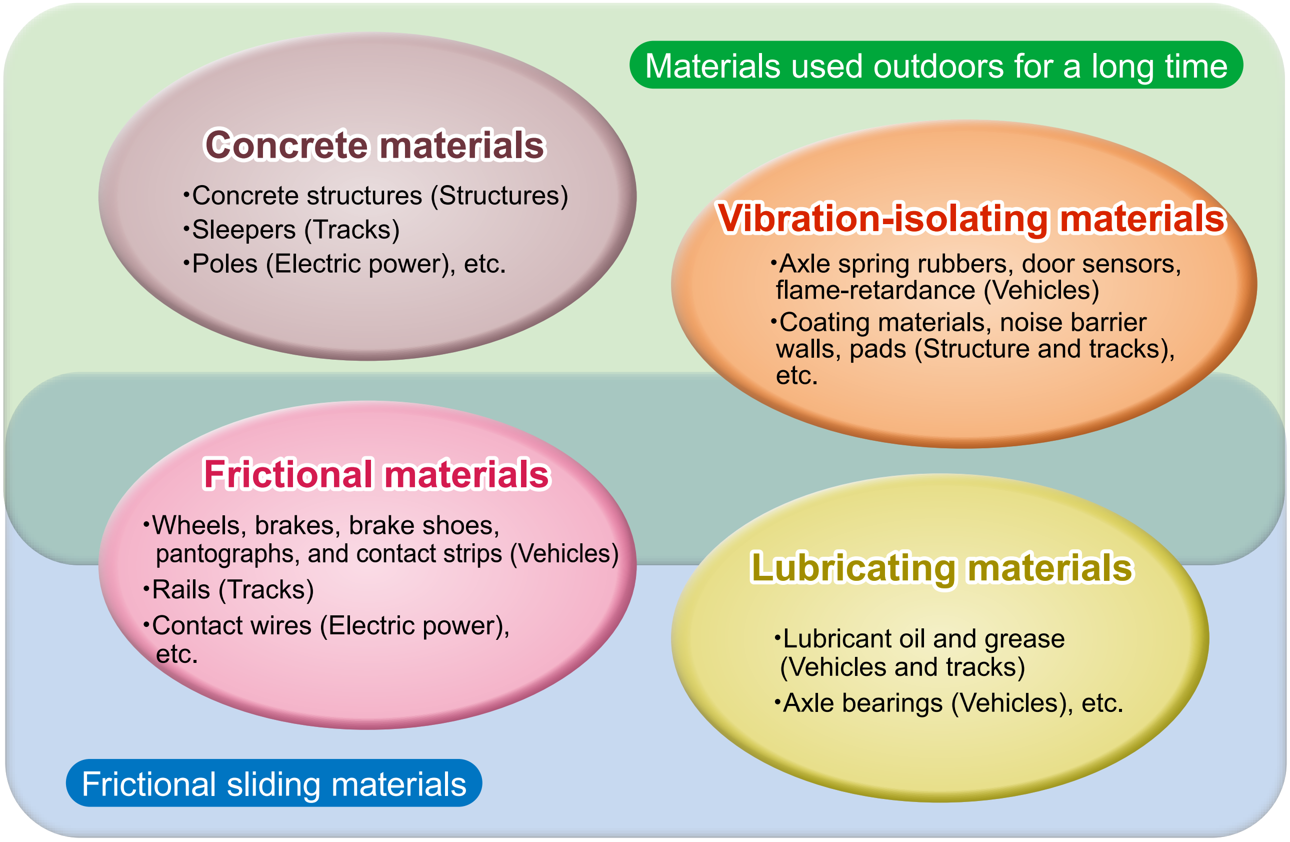
Recent Research and Development of Materials Technology Division

Introduction

Several combinations of metallic (iron and steel, aluminum, copper, etc.), inorganic (concrete, ceramics, etc.), organic (rubber, coating materials, lubricant oil, etc.), and carbon-based materials are employed in railways based on the specific structural and functional requirements and study objectives. These materials have been developed over 150 years of the Japanese railway history through persistent efforts for overcoming the lack of durability and meeting the demands for new functions. However, the environment surrounding railways has continued to change significantly owing to changes in working conditions, such as the decline in the working-age population attributed to the decreasing birthrate and aging population, coronavirus-induced changes in the working environment, digital innovations, and decarbonization. Therefore, future material technologies need to realize flexible responses to these changes in the surrounding environment.

The Materials Technology Division has directed its research and development (R&D) efforts in "concrete materials," "vibration-isolating materials," "lubricating materials," and "frictional materials" laboratories to improve railway safety and respond to the changing surrounding environments. To this end, these laboratories have focused on extending service life, developing high-performance materials and frictional sliding materials that can be used outdoors over extended periods, investigating the causes of deterioration, constructing evaluation and maintenance methods for deterioration, and applying the new materials for construction (*Technical fields targeted by the Materials Technology Division*).

We report on some recent examples of our R&D efforts: mitigation measures for responding to changes in working conditions, measures against aging caused by decarbonization, adding high functionality to materials for improving railway safety,



Technical fields targeted by the Materials Technology Division

and improving simulation technologies for applying new materials in the future.

Simulation Technologies for Applying New Materials in the Future

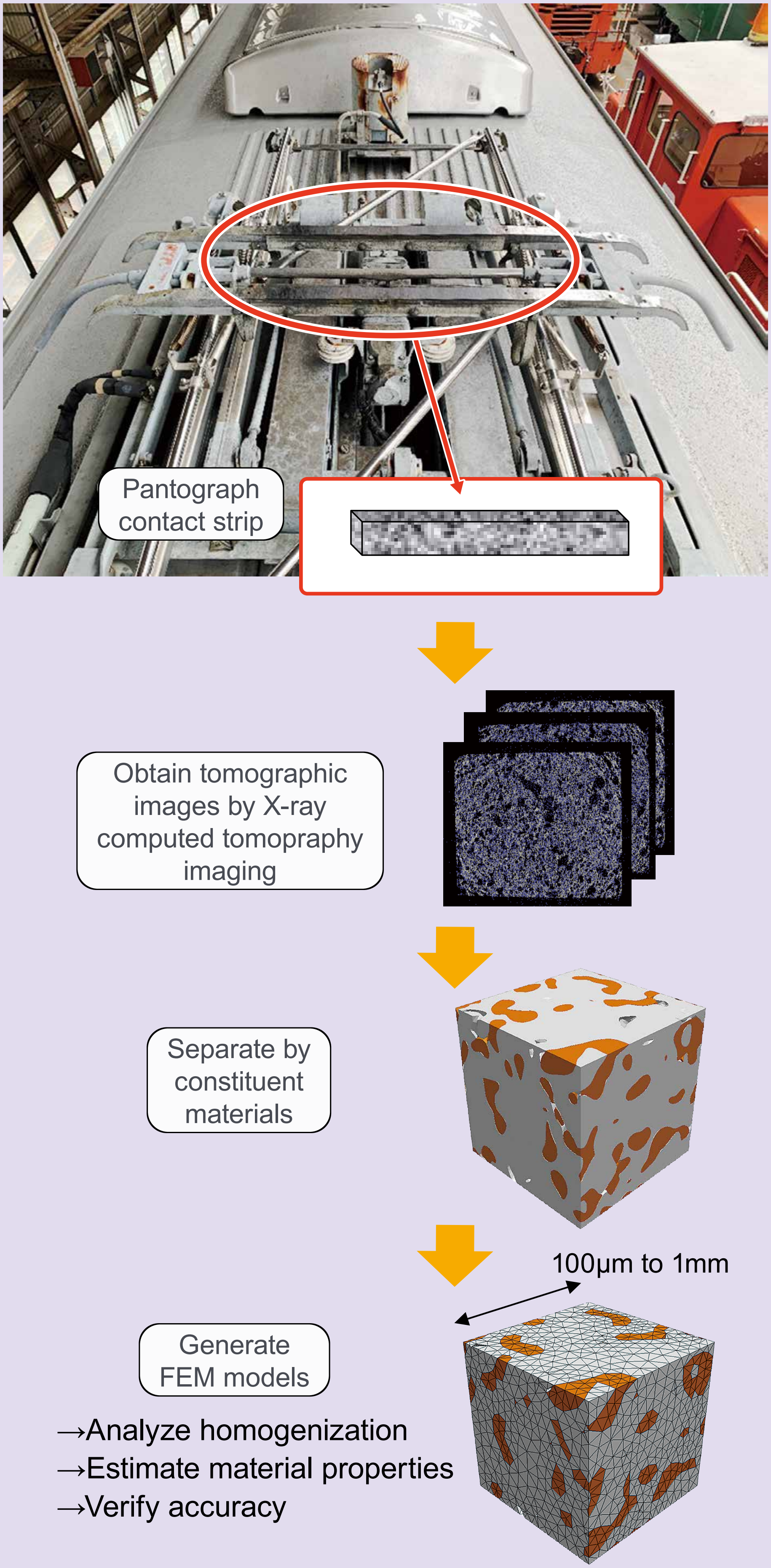
"Material simulations for developing abrasion-resistant materials."

Developing new materials requires considerable trial-and-error efforts for identifying target materials. Unlike this traditional approach, which is labor intensive, time-consuming, and expensive, we effectively employ material simulations to proceed with our research and development. When used effectively, material simulations can minimize the need for trial-and-error experimentation and facilitate the material design required for developing new materials and estimating material properties.

An example of the material simulations currently under study are shown in *Examples of material simulations*. As shown in *Examples of material simulations*, tomographic images of pantograph contact strips made of frictional sliding materials are obtained using X-ray computed tomography imaging. Microscopic models constructed based on the obtained images are incorporated into the simulations and homogeneously analyzed for estimating material properties. The estimated accuracy of the simulations of known material properties are currently being verified. The results confirm that the simulations can successfully estimate the Young's modulus and electrical resistivity, which are important material properties associated with abrasion-resistant materials. In the future, we plan to apply the aforementioned simulation technologies to other abrasion-resistant materials and contribute to more in-depth research.

Enhancing Material Performance to Improve Safety

"Oil for axle bearings of Shinkansen trains that offers excellent low-temperature performance and maintainability"



Examples of material simulations

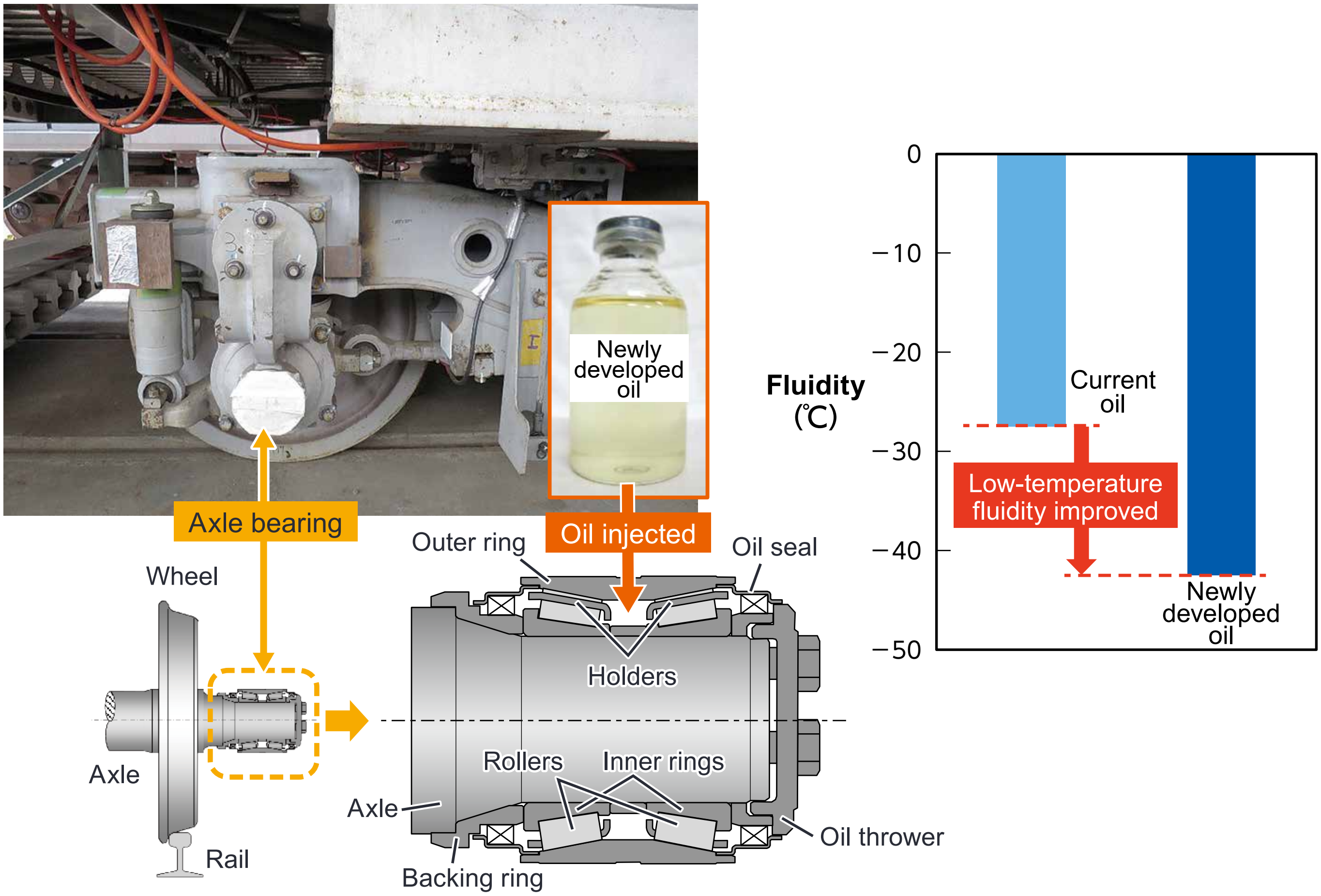
Axle bearings, which consist of frictional sliding materials, support the rotating axles from both sides and lubricate the inside of the bearings with oil to ensure smooth axle rotation. Improving the fluidity[*1] of the oil for axle bearings has become necessary with the expansion of the Shinkansen network into extremely cold regions.

To meet this demand, we developed an oil for axle bearings that exhibits excellent low-temperature fluidity. The developed oil is based on highly purified mineral oil that is not susceptible to oxidation and shows little change in viscosity at temperatures ranging from low to high (*Oil for axle bearings of Shinkansen trains with excellent low-temperature fluidity*). As shown in *Oil for axle bearings of Shinkansen trains with excellent low-temperature fluidity*, the newly developed oil for axle bearings has a lower fluidity than the currently used oil, and it can retain its fluidity at temperatures below -40℃ . We conducted a bench test with real axle bearings operating for 800,000 km of travel and verified the superior durability of the newly developed oil with no abnormalities. We realized efficient maintenance by facilitating the visual management of oil for axle bearings. Thus, we controlled the reddening of oil in axle bearings caused by ultraviolet light, thereby making it easier to promptly locate changes in oil color caused by abnormalities in axle bearings.

Countermeasures Against Aging for Responding to Changes in Working Conditions

“Prefabricated noise barrier walls for railway viaducts”

Planning replacements is a suitable countermeasure against the aging of noise barrier walls in railway viaducts that have been used outdoors over extended periods. High workability and good sound insulation properties are necessary to efficiently



Oil for axle bearings of Shinkansen trains with excellent low-temperature fluidity

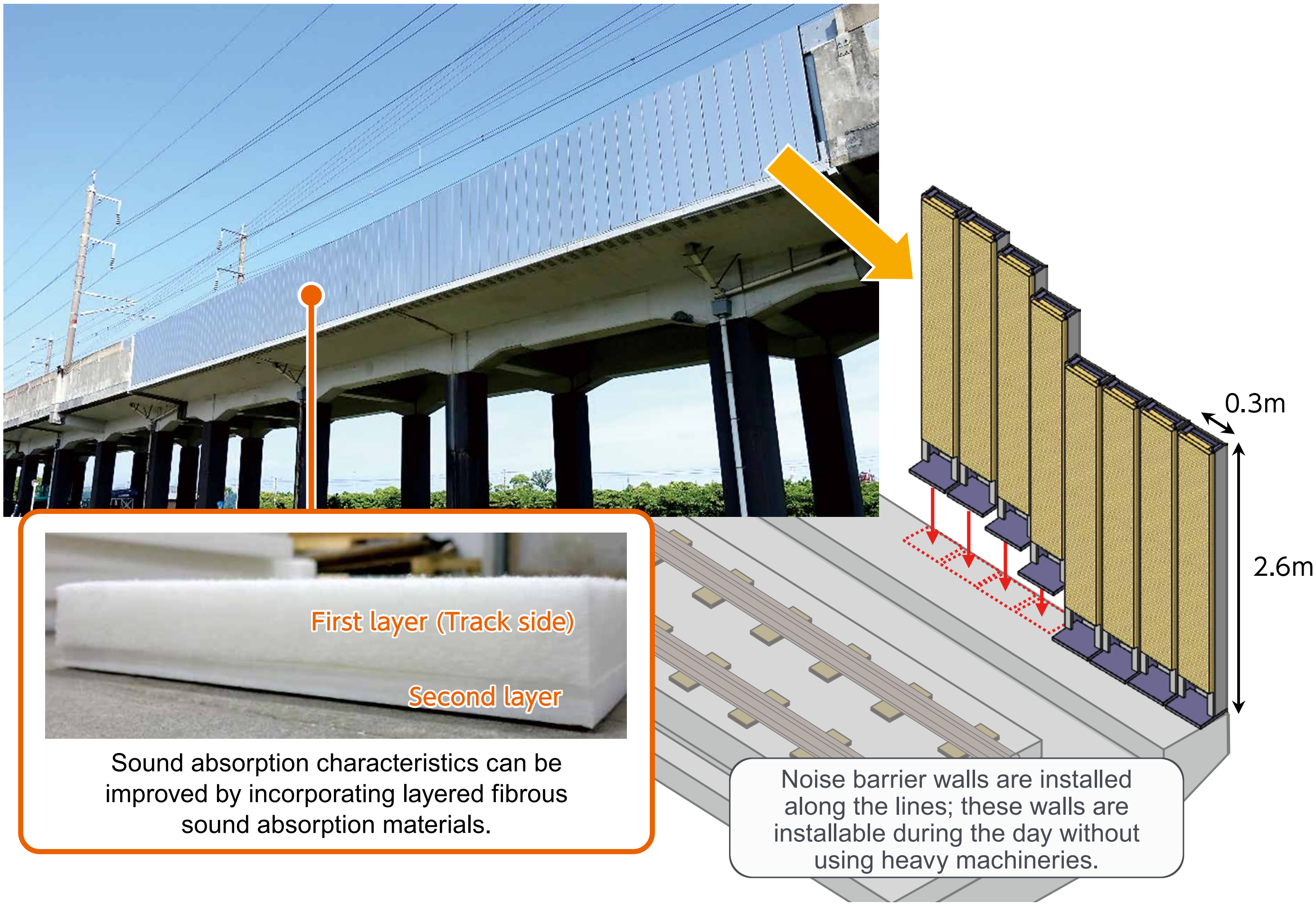
perform replacement work when installing new noise barrier walls.

To meet these requirements, we co-developed a new sound-insulating wall with a prefabricated steel noise barrier wall containing fibrous sound absorption materials (*Prefabricated noise barrier walls for railway viaducts*). The new-sound insulating walls consist of columnar members with predetermined widths connected to each other and installed along the lines to form noise barriers. Each columnar member formed one unit, and sound absorption materials with layers of polyester fibers were used inside columnar members. These materials sufficiently improved the sound absorption performance and satisfied the performance requirements for noise barriers in Shinkansen trains. In addition, heavy machinery is not required to install the newly developed noise barrier walls because their weight is approximately one-third that of concrete noise barriers of the same height. Thus, the new noise-barrier walls can be installed during the day without the use of heavy machinery if appropriate security measures are implemented. We plan to conduct further research and development to realize further noise reduction in commercial railway lines and surrounding areas using the newly developed prefabricated noise barrier walls.

Countermeasures Against Aging for Responding to Decarbonization

“Geopolymer mortar for repairing plastering damage with low CO_2 emissions.”

In tunnels used over a long period, acidic underground water can seep out or exhaust gas soot particles emitted from die-



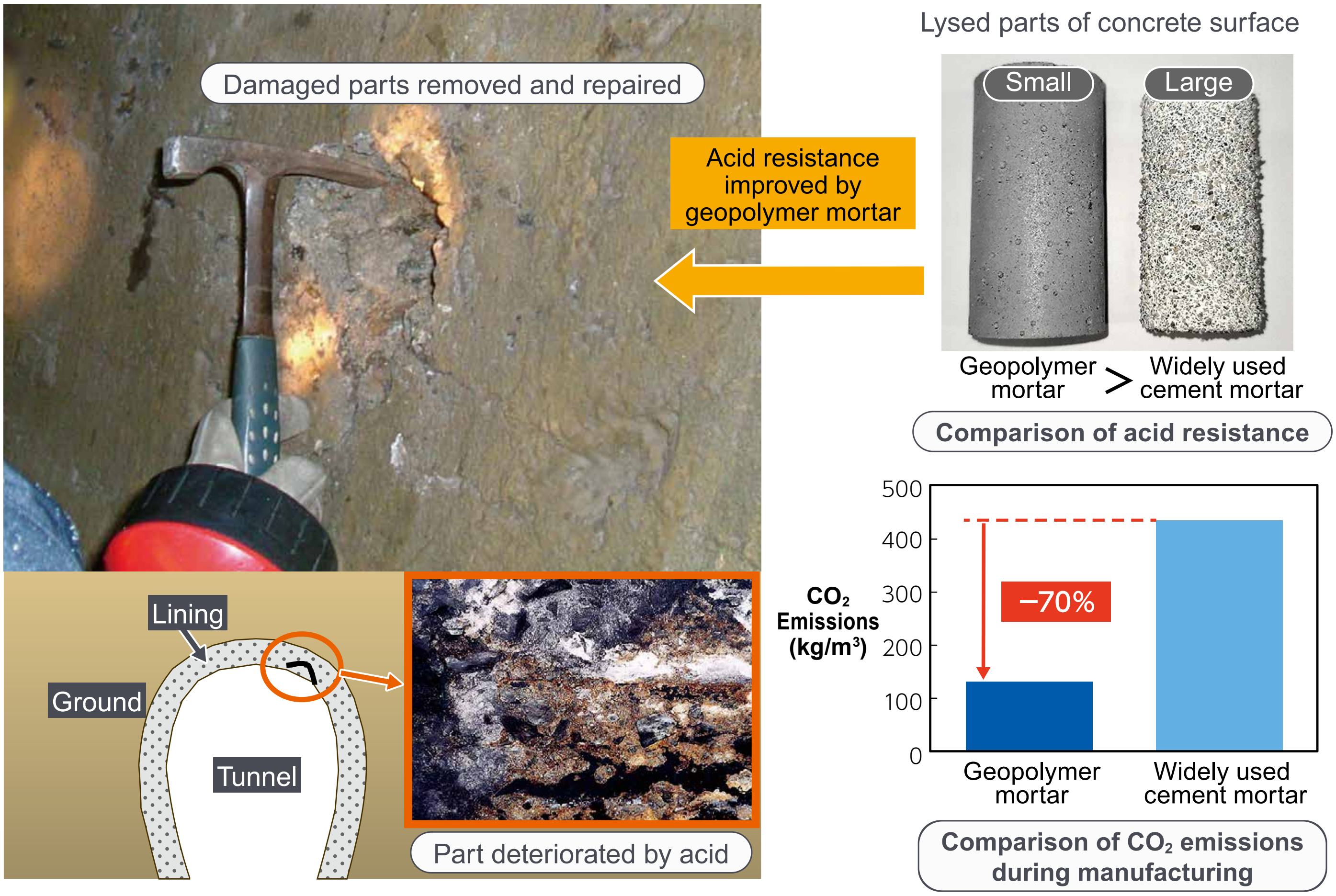
Prefabricated noise barrier walls for railway viaducts

sel vehicles can adhere to the wall, thereby causing the concrete tunnel walls to be lysed by the acid adhering to the tunnel walls. The lysed and damaged parts of the concrete surface need to be removed and repaired using mortar. Although cement mortar is frequently used for maintenance and repair, a highly acid-resistant mortar is required to repair acidified locations.

To meet this demand, based on the acid resistance of geopolymers[*2], we developed a mortar for repairing plastering damage. Compared to the cement mortar widely used for maintenance and repair, geopolymer mortar is rarely lysed and maintains a high acid resistance (*Improved acid resistance of (newly developed) geopolymer mortar and comparison of CO_2 emissions during manufacturing*). Compared to the widely used cement mortar for repair, the geopolymer mortar can reduce CO_2 emissions during production by ~70 %, which helps meet the increasing social demands for decarbonization (*Improved acid resistance of (newly developed) geopolymer mortar and comparison of CO_2 emissions during manufacturing*). Further, we confirmed that the same amount of workability as that of the widely used cement mortar can be maintained by adjusting the types and blending ratios of raw materials in the geopolymers.

Conclusions

We presented examples of the latest research and development approaches in the Materials Technology Division. For further information on other research achievements, please refer to the RTRI website (https://www.rtri.or.jp/rd/division/rd49/).



Improved acid resistance of（newly developed）geopolymer mortar and comparison of CO_2 emissions during manufacturing

*[1] **Fluidity**
The temperature at which the lubricant is less likely to flow.

*[2] **Geopolymer**
Inorganic polymer prepared with an amorphous pulverized body containing silica, alumina, and alkaline solution.

*[3] **Homogenization analysis**
A method to analyze a heterogeneous micro-structure as an equivalent homogenous model.

References

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