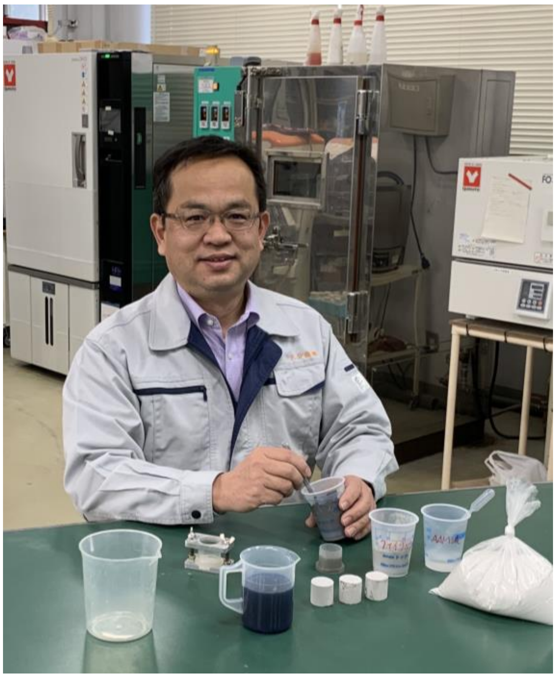
Research Subcommittee on Infrastructure Construction in Low-Carbon Society Using New Alkali-Active Materials (Priority Research Program for FY2021, Subcommittee 233)



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1 . Purpose and Outline of Subcommittee Establishment

Alkali-active materials (AAMs) including geopolymers (GP) harden by condensation-polymerization reactions of Si, Al, and Ca-rich powders (active fillers) and alkali-silica solutions such as water glass. They are cement-free but have the same basic performance as cement, which hardens through the hydration reaction.

AAMs are superior to cement-hardened materials in terms of their low carbon content (some estimate that CO2 emissions from cement production account for about 8% of total emissions), ability to fix hazardous materials, such as radioactive waste, reduced harm to the geological environment, and resistance to acid, high temperatures, and the alkaline aggregate reaction. In addition to fly ash (FA) and blast furnace slag fine powder (GGBS) as active fillers, volcanic sediments and biomass ash can be used. In other words, it is expected that AAMs can be produced from currently unutilized resources.

Research and development for social implementation is currently underway in Japan and overseas. In Australia, it has been used to construct the aprons of airport runways, while in Japan the number of applications of AAMs is increasing, especially in the field of factory-made precast concrete.

The Concrete Committee has established a research subcommittee (Committee 361) for the practical application of the FA-GGBS combined system of GP, mainly consisting of experts in materials systems. In contrast, the aim of this subcommittee (Committee 233) is to expand the scope of investigation beyond FA and GGBS.

For this purpose, in addition to experts in materials, researchers specializing in environmental issues, engineers responsible for the practical design and implementation of structures, engineers with management experience in the introduction of new materials, and engineers involved in the development of civil engineering technology in the new frontier were invited to participate. After clarifying performance requirements for each intended use, they collaborated to collect and collate information to match these requirements against the characteristic material performance of AAMs.

2. Main Activities

Committee 233 was active from April 2021 to March 2022 as a Type 2 Committee of the JSCE's Priority Research Program and Concrete Committee for fiscal year 2021. Although active for only one year and operating mainly in the form of online meetings, a close exchange of information among members was made possible through eight general committee meetings and six executive committee meetings.

The results of the committee's research are freely available in a report: (https://committees.jsce.or.jp/s_research/taxonomy/term/6). Further, in September 2022 a research discussion session was held at the national convention of JSCE entitled "Frontiers of the Development of Alkali-Active Materials (AAMs) as New Functional Materials" at which the contents of the report were explained.

The survey covered the following areas:
(1) Material properties and manufacturing methods
(2) Examples of test construction
(3) Application to reinforced concrete structures and other types of concrete structures
(4) Effects on the environment
(5) Efforts to promote the use of AAMs
(6) Application in severe environments
(7) Questionnaire to identify issues affecting the practical application of AAMs and the results of a literature review.

In (1), the basic properties of GP, the results of basic experiments on GGBS-based AAMs, domestic and international trends in effective use of unutilized resources (such as volcanic ash and woody biomass ash), effective utilization of landfill coal ash, and the reactivity of each GP were investigated.
In (2), the application of these materials to PC sleepers and related issues (such as efflorescence, cracking due to shrinkage and expansion during repeated dry and wet cycles) are explained.
In (3), mechanical properties and design of GP concrete structures, development of GP mortar and its application to 3D printed materials were explained.
In (4), the environmental impact assessment, fixation of hazardous substances, improvement of the geo-environment, and recycling methods are described.
In (5), as an example of how the introduction of a new material is managed, the past development of high-performance concrete, the social implementation process, and the functionality and performance issues that should be addressed in future material development are explained.
In (6), applicability to the space, underground, submarine and marine environments is explained.

In (7), the results of a web-based survey of technical personnel in various civil engineering-related industries and 31 review papers from overseas are summarized and presented with basic information (title, authors, bibliography, etc.), abstracts, and conclusions translated into Japanese.

3. Summary

The essence of the activities described in the summary of the report is as follows

(1) AAM concrete

The material properties of AAMs differ from those of the cement used for cement concrete, and it is possible to produce concrete whose fluidity and mechanical properties vary greatly depending on the quality of the active fillers (such as blast furnace slag fine powder and fly ash) and how they are combined. The flowability and compressive strength of AAM concrete also vary depending on the concentration of the alkali-silica solution and other factors.

Although these phenomena are recognized from a material perspective, domestic and international research is currently looking at the design of structural members on the premise of establishing a material composition and mix that yields concrete with a certain level of compressive strength.

(2) Applications of AAM by characteristics

The reactions undergone by AAM until hardening differ from the hydration reaction of cement, with a condensation-polymerization reaction of ions such as Si and Al proceeding when the alkali-silica solution and active filler come into contact. During this process, certain elements (harmful materials) can be incorporated into the phase formed by the condensation-polymerization reaction and adsorbed, resulting in a certain immobilization effect. This characteristic is expected to be used in the application of AAMs.

In addition to volcanic ash, fused slag from sewage sludge, biomass ash, and existing ash from coal ash landfills are promising as active filler raw materials in AAMs that can leach and diffuse elements such as Al into the alkaline silica solution. Further in-depth research is expected toward practical application.

Although material combinations and formulations must be adjusted for the purpose, it is possible to produce concrete and coating materials with the ability to control chloride penetration. For this reason, AAM concrete is expected to find application in environments where salt resistance is required.

Research has been underway since around 2015 to look into the possibility of construction materials using geopolymers that could be produced on the Moon and Mars. It has been shown that hardened materials can be produced by adding sodium silicate solution and NaOH to simulated lunar soil. Since the amount of sodium is low on the lunar surface, it would have to be supplied from the Earth.

(3) Dissemination efforts

For social implementation, it is necessary to accumulate basic data (through laboratory tests using test specimens), actual results (through on-site test construction), and additional data (through technical review by public organizations to develop standards for AAM concrete).

In aiming for standardization, it is essential to reach a technical consensus among concerned parties and neutral parties. To this end, it is desirable to implement activities such as those of this committee on a regular or occasional basis.

Geopolymer concrete walkway-roadway boundary block placed in highly acidic hot spring soil

(Behind is the Beppu-Myoban Bridge, Oita prefecture)