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Comparative approaches to rammed earth building standards in different nations

Earth, along with wood, was the first building material for human beings and has been widely used since before the civilization of humans. This was due to the economic advantages that earth, which had been forgotten for a while in the course of industrialization and modernization, began to attract attention again as a building material in the second half of the 20th century. However, in the 21st century, the perspective on earth has changed greatly from an environmental perspective. Since buildings built with earth have excellent sustainability with less environmental impacts and high energy efficiency through their entire life cycle, they deserve attention again as modern building materials now that there are increased concerns about the environment due to global climate change. On the other hand, earth has never been a part of the industrialization process of architecture. Therefore, in order to make earth prolific in modern architecture, it is imperative to go through the process of legalization via standardization of materials and technologies that the so-called industrial materials must-have.

This study started as a preliminary research to introduce a modern earth building guideline, and aims to understand the features of earth building standards and codes related to the rammed earth techniques of five countries in respective five continents by comparing and analysing their structures and contents.

Scope and method

This research limited the subjects to earth building standards and codes in New Zealand, Germany, India, the United States of America and Zimbabwe. Based on the list of H. Schröder (2012), which reviewed the earth building standards and codes from around the world, all five were authorized laws and representative regulations of each region. They also included the rammed earth techniques applicable to the realization of diversity in modern architecture.

In order to scrutinize standards and codes with different systems from a consistent point of view, an analytical framework was established by reviewing various references. First, there were four criteria that categorized the contents of the earth building standards. Three criteria, “soil”, “earth building material” and “earth building system” referred to the criteria by H. Schroeder (2012), and the fourth criteria, “general requirements”, was added. Then, the four cri-

01 La Masion pour Tous, Nord-Isere, France

02 École Veyrins-Thuellin, Veyrins-Thuellin, France

teria were classified again into ten lower level items according to the steps of earth building construction process. Eight items came from the preface of earth building codes of New Zealand and two more were added.

Comparative review of rammed earth building standards

Within the purview of this analytical framework, the following features were found:

General requirements:
1) General considerations
(2) select construction technique

The laws of all countries, except Germany, limited the scale of earth building to within two-storey. Those of Zimbabwe didn't mention the limitation of height or storey of earth buildings, but all the provided design values were assumed up to two-storey. On the hand, laws of New Zealand, Indian and the USA addressed additional seismic design as well as site drainage and flood level near the site.

Noticeably, different from the other four standards, the earth building code of Zimbabwe only dealt with the rammed earth technique, and was authorized as continent-wide standard among 15 countries of the SADC (Southern African Development Community) consisting of African Anglophone nations.

Soil:
(3) Select subsoil
(4) soil tests

In all the five standards, while the ratio of the soil components was highlighted as the most important property during soil selection, it was notable that the testing methods of checking soil composition were not clearly indicated or simple field tests were often mentioned, such as dropping and rubbing soil. In addition, the German standard allowed the utilization of recycled soil that has already been used as a building material. On the hand, the standards of India, USA and Zimbabwe described the use of amended soil that supplemented lacking constituents of raw soil.

Earth building material:
(5) Material requirements,
6) material tests

At the building material stage, securing compressive strength, which is essential for structural stability of a building, was commonly considered as the top priority of the material requirements. Various field and laboratory tests were specified to confirm this property in all five standards. Although other material requirements differed to a certain degree depending on the construction technique, in the rammed earth technique focused on in this study, plasticity (or consistency) that affects the workability and quality of earth ramming in the formwork, wall density after ramming and shrinkage after drying were prioritized. The USA codes didn't mention these three properties.

Meanwhile, the standards of New Zealand and Germany presupposed that soil, the building material, should not be stabilized by adding admixture to meet the material requirements. In contrast, Indian standards allowed to add straw to the soil mixture. Furthermore, the standards of India, USA and Zimbabwe took adding Portland cement and lime for granted.

Earth construction system:
(7) Building design,
(8) building construction,
(9) certification,
(10) maintenance

At the building design stage, besides the compressive strength, density and shrinkage that determine the structural stability of a building, it was evident that there was emphasis on the shear strength to withstand lateral force caused by external forces, including earthquakes and wind, and the water resistance to endure the negative effects of water (e.g. rain, splash-back, humidity), which significantly threaten the durability of earthen buildings. It was noteworthy that the standards of New Zealand, India and the United States included additional seismic design. They provided adequate materials of foundation and footing (e.g. concrete cement), design principles (e.g.

size and detail) and reinforcing methods (e.g. bracing and buttress) according to the different seismic zones, rather than designating the target value of structural design properties. Moreover, all the five standards provided design principles and construction details to prevent weather erosion caused by rain and wind, and water erosion caused by the moisture inside or on the earthen walls and foundations. The major differences were that the standard of New Zealand, India and Zimbabwe covered weathering protection and damp proofing in detail throughout the design and construction process and stipulated that such properties should be obtained via conformity tests, such as direct spraying or dropping water onto the earthen structure. On the other hand, the U.S. standards dealt with them relatively short and simple. The German standards mainly considered them in terms of the effects of weather changes in the construction process and quality of indoor environment in buildings. Moreover, among all building components, other than main structures, the openings and lintels were commonly included in the five standards. Other components, such as roof, ceiling and floor, were only mentioned as part of construction details connected to the earthen structure.

Meanwhile, it was unexpected that only the code of Zimbabwe stipulated the frameworks in detail in spite of the importance of framework in rammed earth technique. Although references to compaction, curing and moisture content could be found in the standards of New Zealand, India and Germany, they didn't focus on the framework itself, which affects the process and results of the construction critically, but mainly on the materials and results of the rammed earth technique.

Finally, certification and maintenance were not covered in-depth in all five standards. In German standards, though earth materials produced by standardized manufacturers, such as compressed earth block and earth mortar were required to be designated by certification procedure, nothing was required of on-situ rammed earth buildings. Moreover, the codes of India and Zimbabwe only recommended plastering, painting or other considerate designs for protection in the construction process, but didn't mention anything about maintenance considering long-term use.

Discussion

Through this study, it was revealed that earth is still not sufficient to be used as a modern building material. The standards of five countries involved in rammed earth were generally applicable to buildings of up to two-storey in height. However, to limit modern architecture characterized by various purposes, scales and shapes to this extent conveys the fact that earth building technology itself is not yet sufficient to be recognized as a modern architectural technology. Additionally, even though the properties required for structural stability of the building were not different from other building materials, additives, such as cement and lime, used to obtain the required strength would make earthen building impossible to be recycled at the time of disposal, which is the final stage of the building lifecycle. This is fatal to the most intrinsic aspect of sustainability, which has made earth building worthy of. This is as good as a dead end.

03 Rammed earth formwork (source: sirewall.com)

Moreover, in order for the building materials to be universally used in every construction, they necessarily go through the industrialization and standardization processes. In order to confirm each performance of earthen architecture, the standards and codes of countries other than Germany largely showed field tests, dimensions, shape and materials, etc., rather than indicated eventual property design values of performance. However, it makes it difficult to produce consistent building performance only complying with empirical guidelines. Even if it is necessary to prepare local and national earth building standards and guidelines because the required performance of earth buildings may vary depending on the regional location, earthquake zones and climate characteristics (including precipitation), inconsistent standards and criteria for physical properties, verification, evaluation and construction methods would make the industrialization of modern earth construction delayed. Particularly, it needs to be prioritized that the standardization of the formworks in rammed earth technique at the level of reinforced concrete, which consists the essence of rammed earth technique. Currently, Germany is leading the industrialization and standardization of earthen construction. The more regions, countries and associations get interested in enlarging the limits of earth construction, the faster earthen architecture would benefit the earth.

Buildings made of the so-called "modern" building materials that have filled with modern cities don't deserve to stand for the anger of global environment, which is increasingly unfriendly to mankind. Earth building ought to go through this process in order to suggest a meaningful alternative to modern architecture that creates long and dark shadows as much as they are glittering and grand.

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04 Rammed earth construction (source: sirewall.com)