STRUCTURAL DESIGN OF UNPRECEDENTED LARGE RM (REINFORCED－MASONRY) STRUCTURE IN JAPAN

Tomoya SHITANISHI
Nikken Sekkei Ltd
Osaka City, JAPAN

Abstract

Toyonaka Performing Arts Center (T.P.A.C) is designed as Reinforced Masonry (RM) structure building, which is mainly comprised of two music halls, and exhibition and conference spaces. In Japan, RM is usually used only for small buildings. We employed the RM system for large-scale building for the first time in Japan, which consists of as many as 50,000 RM blocks. In the construction project, we developed huge-size RM blocks and its construction method, which was unprecedented in Japan. By using this method, we realized innovative structural frame system, high seismic performance, and attractive architecture. By conducting a number of structural experiments, we confirmed that the existing formula for small-section RM system can be applied also to the large-section RM system, and that any critical destruction mode will not be caused in this construction method. We ensured high construction quality by conducting many construction and mock-up tests as necessary. As a result, with the realization of the new RM design and construction method, we believe that we successfully expanded further possibilities of RM structures in Japan.

Building Overview

The building is a complex cultural facility for citizens, with large and small halls, exhibition rooms, meeting rooms, a café, etc. The construction site is a quiet residential area in the northern part of Osaka. The client's request was a building which, by visiting it, would bring citizens closer to culture and the arts, and induce cultural and artistic activities. In order to achieve this, the plan was for the entrance to be set through the adjacent medium hall and community center via a plaza, with RM construction making the circulatory open foyer space and external appearance attractive (*Figure 1*). By giving the RM construction of the circulatory space a surface appearance evoking the pyramids, we created a cozy space that is both extraordinary and attractive (*Photograph 1*). The plan was to put visitors in contact with the exhibits and events in the large and small halls in the back while they continue to walk about the foyer, and thus induce consciousness of culture and the arts. The aim was to use the RM-constructed facade not usually seen in Japan to stir up interest in passers-by and draw them in for unplanned visits.

Photograph 1. Surface appearance of RM-wall.

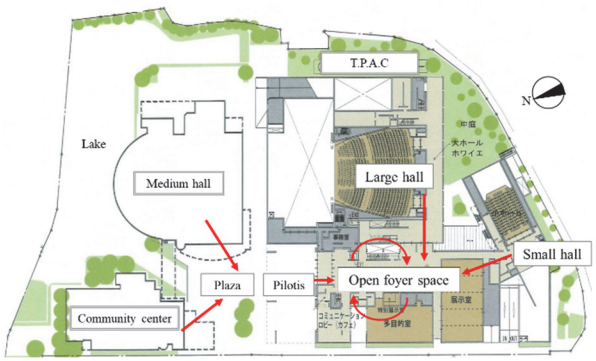


Figure 1. Plan and concept.

An overview of the building is given in *Photograph 2 and Table 1*. Approximately 50,000 RM blocks were used to build the largest RM-construction building in Japan.

Building	T.P.A.C
Owner	Toyonaka City
Site Area	Approx. 6600 sq.m
Floor Area	Approx. 13500 sq.m
Height	Approx. 26 m
Number of Floor	+3/-1
Design Architect and Structural Engineer	Nikken Sekkei
Completion	2016.8

Photograph 2, Table 1. Building overview.

Background of Development of Large-Cross-Section RM Construction

Since RM construction is a structural material and design finish material, it can lead to reduced costs and because it can also be used as the form, it can also reduce environmental loads. In addition, because the thickness covering the steel framework is larger than for RC construction, durability is also high. In Japan, RM construction is used mainly for small-scale structures such as homes. The mainstream is wall thicknesses of 200mm or less, and since it requires a wall amount which is greater than regulations, it tends to be used for closed structures and for facades in many cases.

However, since it is not possible to realize an attractive space in this way, for this building we developed a new large-cross-section RM construction with a wall thickness of 360mm. By using this new construction, a structural plan which gives more emphasis to the inherent masonry strength of RM construction while incorporating a highly design-oriented framework and large spans became possible.

Structural Design Overview

As shown in *Figure 2*, this building is an integrated structure comprising three zones: Large Hall, Small Hall, and Exhibit Space. It is planned that almost all seismic forces will be borne by shear walls. The Large Hall zone has a height of approximately 24m, and the main structure is SRC construction with steel-framed trusses having spans of approximately 30m over the hall audience seating area and proscenium section. The main RC shear walls have wall thicknesses of 300mm to 600mm. Due to regulatory restrictions related to the building height, it was not possible to use RM construction for the Large Hall zone.

The Small Hall and Exhibition Space zones both have heights of approximately 8m, and the main structures are RM construction. By using the newly developed large-cross-section RM construction method, it became possible to achieve frame structures that could not be built with conventional RM construction, such as an independent 6m-high wall (*Photograph 3*), a large rectangular opening with a length of 8m (*Photograph 4*), entrance pilotis supported by independent walls (*Photograph 5*), etc.

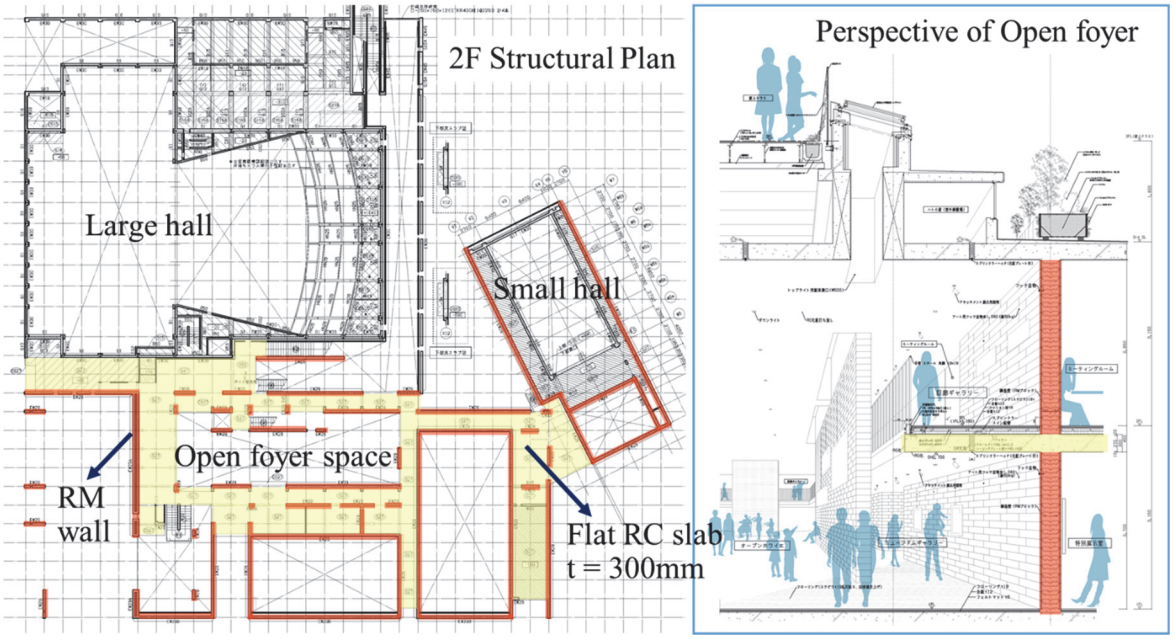


Figure 2. Structure plan overview.

Photograph 3. 6m-high RM-construction walls.

Photograph 4. RM-construction wall with large, 8m-wide opening.

Photograph 5. Entrance pilotis.

Development of Large-Cross-Section RM Construction

Until now, in Japan RM construction methods were wall thicknesses of 150 to 200mm with a single reinforcement grid, but the RM construction method developed this time enables wall thicknesses of 360mm with double reinforcement grids (*Figure 3*). The RM block sizes are as shown in *Figure 4*. A single RM block weighs 250N, and this size was set for workability by enabling a site worker to stack the blocks working alone while also providing the necessary wall thickness for structural strength.

For the concrete fill, the necessary filling characteristics were determined through filling characteristic verification tests. Since the construction is also used for exterior walls, shrinkage-reducing admixtures were added, which increased water-blocking performance by suppressing shrinkage cracking.

Since the construction method is completely different from general RC construction, a new method was devised for accurately fixing the position of steel reinforcement grids while performing verification by creating mockups on the site.

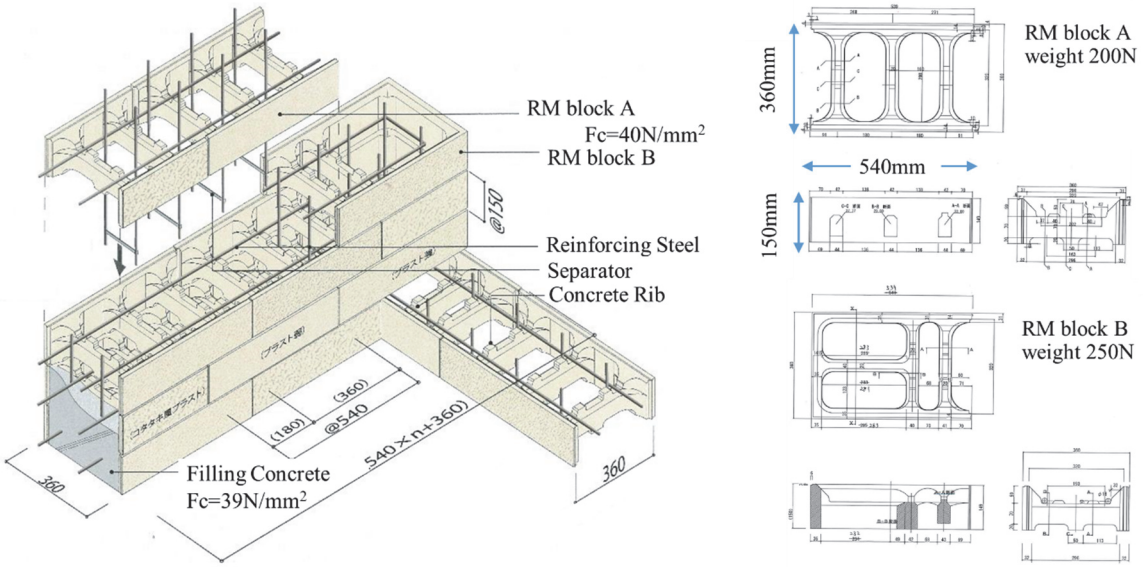
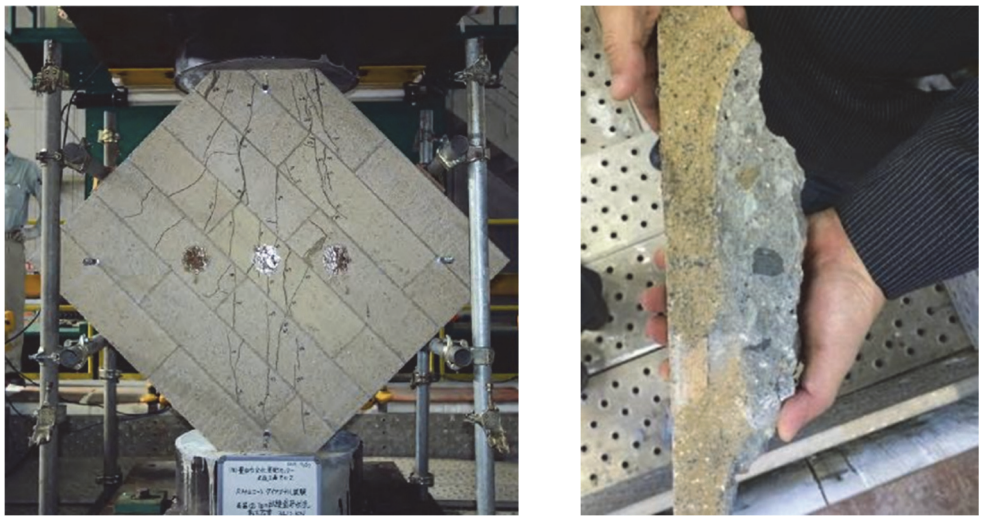


Figure 4. The large-cross-section RM blocks developed this time.

In the end, structural performance testing was performed and it was verified that the formulas used until now for RM construction methods could also be applied to the newly developed large-cross-section RM construction method, and that no hazardous failure modes occurred. (*Photograph 6* and *Figure 5*)



Photograph 6. Structural performance test

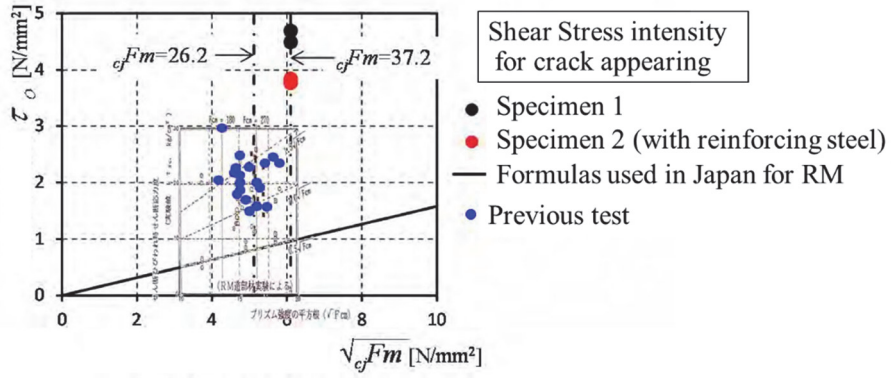


Figure 5. Comparison with past formulas

Conclusions

RM construction methods are extremely useful methods from the viewpoints of seismic resistance, durability, cost, and environmental load, but there are few actual examples in Japan, and their use has been limited to small-scale buildings.

This time, by developing and actually using large-scale and large-cross-section RM construction methods, it was possible to open up new possibilities for the employment of RM construction in Japan. In addition, the building also enables renewed recognition of the attractiveness of RM construction.
However, since the number of actual examples is still small, it is necessary to increase construction verification and structural testing like those performed this time. It is expected that research will also progress in the future.

Furthermore, this building experienced the M6.1 earthquake with the epicenter in northern Osaka that occurred on June 18, 2018, and there was absolutely no damage such as cracking, etc. to the RM construction, and performances in the large hall were reopened as normal on the following day. I would like to express my appreciation to the construction workers whose efforts during construction resulted in the high construction quality of the RM construction.