Auditorium of Only Concrete
— Waseda University Senior High School —

コンクリート現しの講堂
— 早稲田大学高等学院　講堂棟 —

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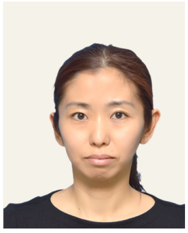 **
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Synopsis
This building is an auditorium designed as a reinforced concrete structure because of the relationship with existing concrete buildings on the campus, sound insulation, and structural rationality.
The feature of this building is an architectural expression to maximize the attractiveness and characteristics of cast-in-place concrete and to satisfy highly the required performances as an auditorium from the viewpoint of the integration of acoustics, building facilities, design, and structural rationality.
The authors challenged a new possibility for concrete in the design of this architecture.

Structural Data
Building Name: Waseda University Senior High School, Auditorium[1] [2]
Location: Nerima-ku, Tokyo, Japan
Owner: Waseda University
Designer: Nikken Sekkei Ltd.
Contractor: Tokyu Construction Co., Ltd.
Construction Period: Oct. 2012 – Oct. 2014
Site Area: 57,558.34m^2
Total Floor Area: 2,412.52m^2
Number of Stories: 2, above ground
Maximum Height: 14.21m
Main Structure: Pre-stressed reinforced concrete

1. Introduction
This paper introduces the architectural scheme, structural scheme, and construction of this auditorium. Section 2 discusses the conditions required for this auditorium and their architectural solutions. Section 3 shows the structural design that fulfills the above conditions. Section 4 introduces the finishes on the concrete surfaces and the tensioning of the pre-stressed concrete steel wires at the construction site.

Photo 1. Overall view

2. Architectural Scheme
In conventional auditorium design, it is very common to use wooden materials to control the acoustics, namely to reflect and absorb sounds. Using timber with a polyhedral design would have a high cost. For this auditorium, the authors chose a purely concrete design as optimal.

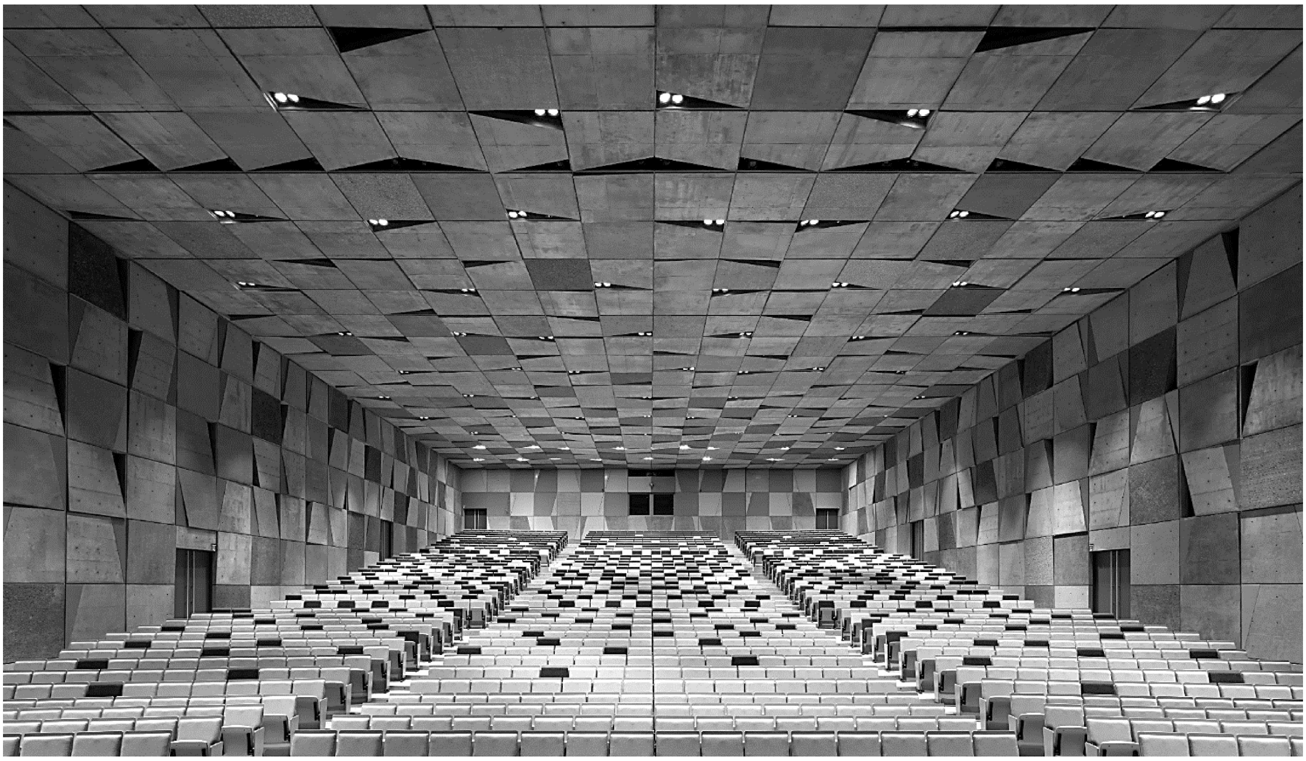

Photo 2. Interior of auditorium

The performances required of this auditorium were first a capacity of 1,500 people and second to set the optimum reverberation time for different purposes, such as concerts and students ceremonies. The authors must satisfy the above two requirements under securing both the maximum space within the constructible area and the legal maximum height. Based on the above, the authors planned as follows:

- Fair-faced concrete
- Double walls and double slabs to ensure sufficient air space
- Inclining the concrete faces
- Finishing the concrete surfaces on site
- Entering the auditorium directly from outside without a foyer

The authors set the reverberation time to roughly 1.2s so that the auditorium could be used for concerts and ceremonies (**Fig.1**).

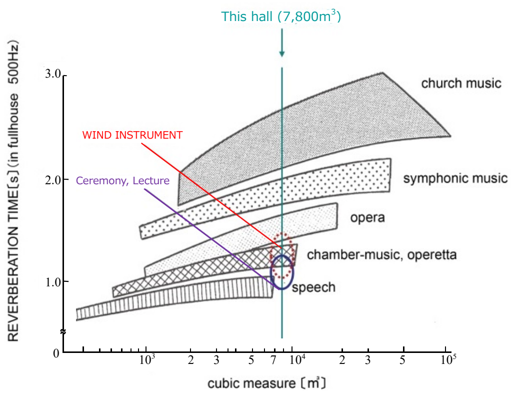

Fig.1 Relation between cubic measure and optimal reverberation time for various applications

To satisfy this reverberation time, the authors made triangular openings in the walls, inclined the faces of the walls, and roughened the concrete surfaces by hand at the construction site. By precise acoustic simulations, the authors arranged the various finishing surfaces and inclination of each wall (**Photo 3**).

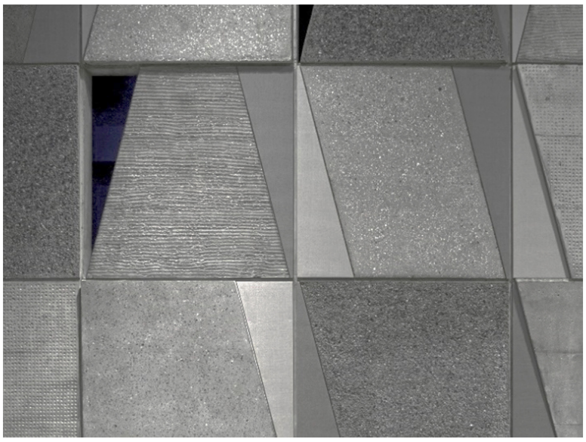

Photo 3. Finishes of concrete wall surface

3. Structural Scheme

The authors adopted a long-span rigid frame as the structure to cover such a large space. Pre-stressed reinforced concrete girders and beams were installed in the ceiling, which had double slabs to ensure sufficient air space, and columns were used in the double walls (**Fig.2**).

The optimum acoustic arrangement of the triangular openings in the walls was determined under the following structural conditions:

- Double walls and double slabs to ensure sufficient air space
- Not arranging the triangular openings on columns
- Not connecting two or more sharp angles in triangular openings
- Connecting walls and columns reasonably

The double walls comprise an inner and an outer wall. The inner walls are not structural walls, but the outer walls are considered as structural walls and are 250mm thick (**Figs.3**, **4**, **7**, **8**).

Because this auditorium is a box-shaped structure, the authors gave it sufficient seismic capacity by designing the outer walls as sequential structural walls as far as possible.

The structures of girders and beams (width: 350mm; height: 1,800mm) covering the roof of this building are pre-stressed concrete structures that support the double slabs in spans of 25.7m (**Figs.5**, **9**). Each pre-stressed concrete steel wire was post-tensioned to roughly 1,300kN.

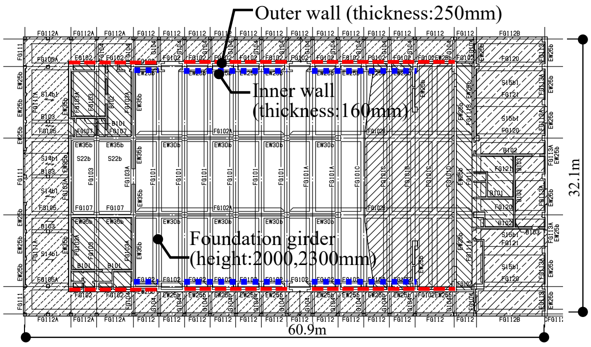

Fig.3 Footing-girder framing plan

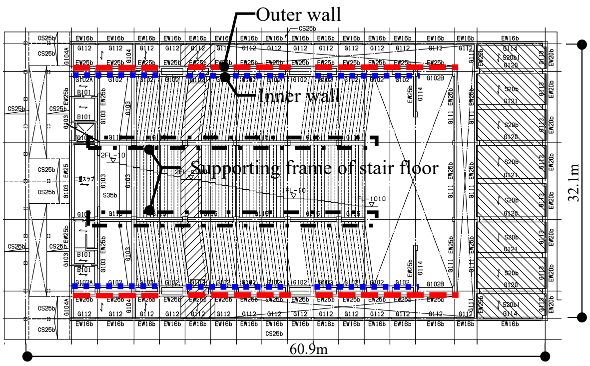

Fig.4 Stair-floor framing plan

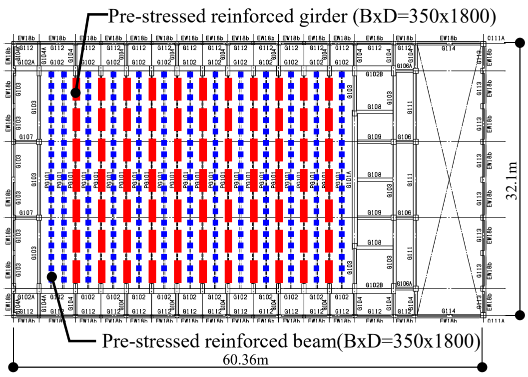

Fig.5 Roof-floor framing plan

The foundation girder (**Fig.3**, span: 25.7m; height: 2,000mm or 2,300mm) offers stress distribution along three spans by supporting the ground pressure with a two-layer stair floor frame (**Figs.4**, **6**, **8**). This idea enabled the foundation girder to be designed as an ordinary reinforced concrete girder.

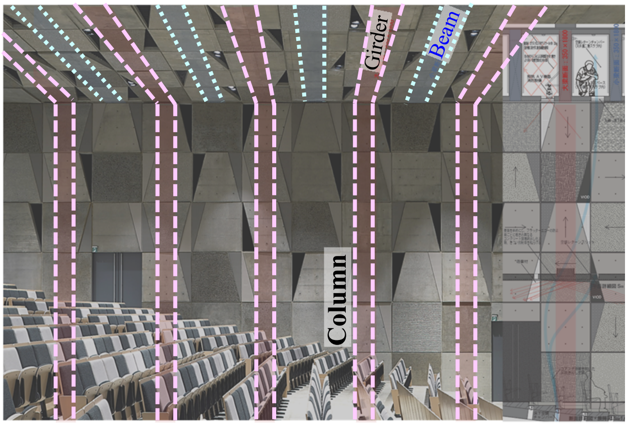

Fig.2 Wall face and structural frame

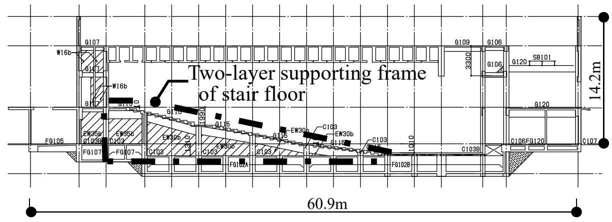

Fig.6 Framing elevation at A-A'

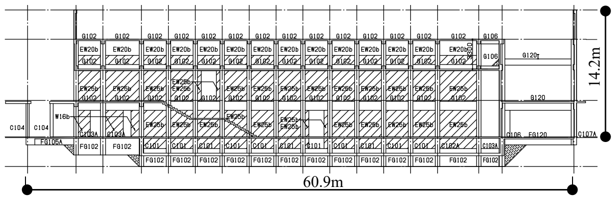

Fig.7 Framing elevation at B-B'

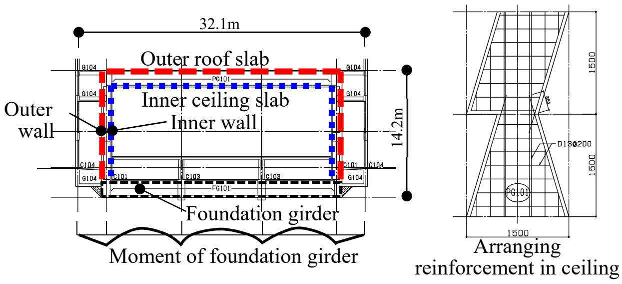

Fig.8 Framing elevation at C-C'

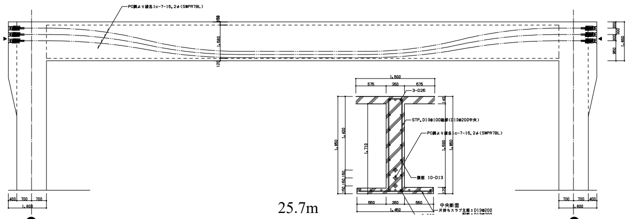

Fig.9 Detail of pre-stressed concrete ramen frame

4. Construction

(1) Finishes of Walls and Ceilings Surface

The special finishes of the concrete surfaces are all the work of craftsmen. The authors tried many types of mock-up on site and confirmed the optimal construction method before construction by visual inspection of surface roughness, then improving the casting of high-quality concrete.

Photo 4. Mock-ups at the construction site

Photo 5. On-site process of finishing the concrete ceiling surface. This situation resembled that of Michelangelo's fresco ceilings at the Sistine Chapel

(2) Tensioning of Pre-stressed Concrete Steel Wires

The pre-stressed concrete steel wires were post-tensioned to support the roof. Three steel wires were installed in each girder and beam (**Fig.9**). The authors took into consideration cracks due to tension. First, the middle steel wire of each girder and beam was tensioned continuously, then the other wires were tensioned too. In addition, to control concrete cracking while tensioning the steel wires, reinforcing bars were added to the parts connecting to the roof slabs and the columns.

Photo 6. Situation of reinforcement arrangement and sheath for pre-stressed concrete steel wires at the construction site

5. Conclusions

For this building, the authors tried to design an auditorium made of only concrete. By having the elements necessary for t he auditorium not added to the space but put inside of the space, the authors integrated the acoustics, building facilities, designs, and structures into the space of a simple concrete box.

This architecture won the Award of the Japan Concrete Institute in 2017.

6. Acknowledgements

The authors thank the owners and all the contactors and craftsmen involved in the construction of this auditorium.

References

[1] A. Iijima: "*A hall with bare concrete finished on site*," DETAIL Magazine, Vol.203, 2014.12, pp. 26–28. (in Japanese)

[2] "*Scratching The Surface*," Concrete Quarterly, Winter 2016, Issue No.258, p. 15.

概　要

本建物はキャンパス内に数ある既存コンクリート造建物との関係や，遮音性，構造的合理性を考慮してコンクリート造として計画したホールである。本建物の特筆点は，大空間である学校の講堂を現場打ちコンクリートの魅力や特徴を最大限に生かして，コンクリートによる空間表現を追求し，かつホールとしての要求性能を音響的，設備的，意匠的，構造的合理性を持って高いレベルで融合した点にあり，コンクリートの新たな可能性への挑戦を示すものである。

現場打ちコンクリートの表面を職人の技術によって様々に表情を持たせ，かつ空間表現を音響上の性能向上にも寄与させ，ホール全体として現場打ちコンクリートの構造体を現しにするダイナミックで静謐な空間表現を目指した建築物である。