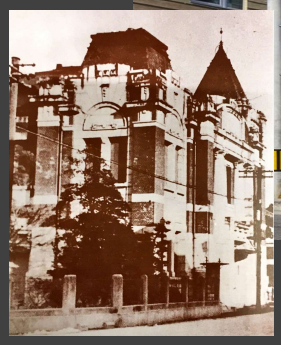
Practical Jack-up-less Seismic Isolation Retrofit utilizing BIM for The Okazaki Shinkin Bank Museum

【Building Summary】

Site	: Okazaki-City, Aichi, Japan
Owner	: Okazaki Shinkin Bank
Original Design	: Teiji Suzuki
Retrofit Design	: STARTS CAM Co., Ltd. Tsutomu Nakanishi
Construction	: STARTS CAM
Building Area	: 330.69㎡
Total Floor Area	: 646.05㎡
Number of Floors	: 2 stories above ground
Height	: 13.7 m
Structure Type	: Brick + RC
SI Device Mfr.	: SHODEN Co., Ltd Dynamic Design Inc.
Year Completed	: 1917
Year Retrofitted	: 2020

【Organizational Support Structure of STARTS】

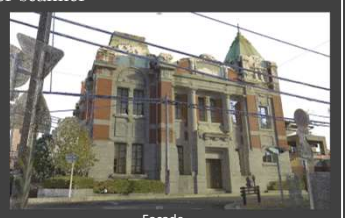
Sesimic Isolation Research Institute
...Seismic isolation structure design
BIM Production Design Team
...Create design drawings from BIM models
Engineering Dept.
...High-Fluidity Concrete Technology Follow-Up
Digital Design Team
...Verification and creation of point cloud data and BIM models
Construction Dept.
... Construction planning and implementation using BIM

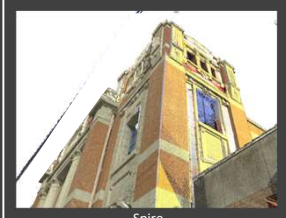


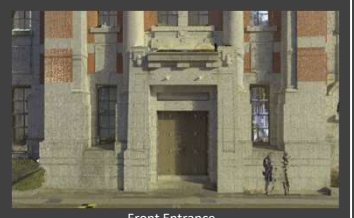
Inherits the Original Design①

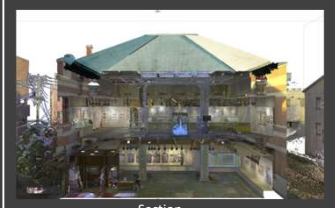
Point cloud data from 3D Laser scanner

Bird's-eye View


Facade

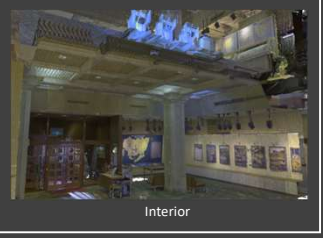

Spire


Front Entrance


Section

Detail

Introspection


Interior

Inherits the Original Design ②

【Accurate 3D Surveying of real space using 3D Laser Scanning and Drones】

LiDAR technology (Light Detection and Ranging) was used to accurately measure the complex interior and exterior geometry of the building. A 3D laser scanner was used for ground surveying and drone surveying was used to create point cloud data. The shape and color information of the existing building was recorded as digital data.
And the data was used not only for data storage of the exterior appearance and exhibition conditions before the renovation, but also for renovation planning studies and as a base for the BIM model.

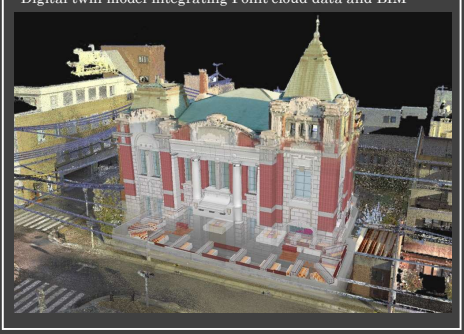
【Utilizing Digital Twin Models with 3D Surveying and BIM for Structural Design and Construction Planning】

BIM models of the exterior and interior were created based on point cloud data. The survey results were superimposed on the BIM model to verify accuracy and accurately record and preserve the current exterior and interior conditions. At the same time, the data was optimized and attribute information was added to create a digital twin model suitable for renovation and post-construction maintenance.
The project used the model to calculate building weights during structural design and to verify construction procedures and risks during construction planning. The model was also used for preliminary studies such as seismic isolation EXP (expansion) sections to ensure the building's exterior design.

3D Laser Scanner Surveying
Point Cloud Data

Drone Photogrammetry
High Resolution Image Data

Digital twin model integrating Point cloud data and BIM



BIM model with data optimization and attribute information

Facade

Section

Interior

Conducting Surveys of Existing Building

① Tensile Testing of Brick Anchor Rebars
To determine the tensile strength of anchor bars in brick-RC joints constructed in 1980 by field tests. The tensile strength and the seismic force acting on the anchor bars were used to examine safety.
Survey Details ： Partially dismantle the RC body on the interior side , apply tensile force to the exposed anchor bar, and measure the tensile strength of the brick anchor bar.

② Calculation of Poisson's Ratio for Bricks
During seismic isolation, the PC steel rods apply compressive forces to the brick foundation. In this case, the stress-deformation relationship of the brick foundation is calculated to properly manage the tensile force of the PC steel rods.
Survey Details ： Brick cores taken from the exterior wall surface are loaded and the amount of longitudinal and transverse strain is measured to calculate Poisson's ratio.

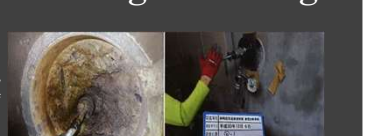
③ Shear Testing of Brick Joints
To measure the shear strength of brick masonry for seismic evaluation.
Survey Details ： The test is performed by taking a brick core from the exterior wall surface and applying shear forces to the horizontal joints between the two bricks.

④ Sampling and Testing of Concrete Cores
The compressive strength of concrete is measured to evaluate its seismic resistance, and the depth of neutralization, which is a measure of durability, is also measured.
Survey Details ：Concrete cores are taken from the RC frame inside the building to measure compressive strength, Young's modulus, and neutralization depth.

⑤ Check the Condition of the Chimney.
The chimney (located to the northwest) may have been severely damaged prior to the earthquake, check its condition and structural components.
Survey Details ：Assess the condition of the chimney from the exterior and the attic. And check the structural components of the seismic reinforcement.

⑥ Confirmation of Foundation Geometry
The design of seismic isolation structures requires an understanding of the shape of the foundation. Excavate the exterior to reveal the shape of the foundation.
Survey Details ： Excavate a part of the exterior structure. Visually observe and take shape and dimensional measurements and photographs of the foundation.

⑦ Comparative Survey of Drawings
Compare the details of the various drawings with the current building.
Survey Details： Confirm the condition of each part (cross-sectional dimensions of RC and bricks, opening dimensions, etc.) necessary for seismic evaluation by actual measurement, etc.


①Tensile Testing of Anchor Rebars

②③Test Samples

④Sampling and Testing of Concrete Cores

⑤Check the Chimney Conditions　⑥Confirmation of Foundation Geometry

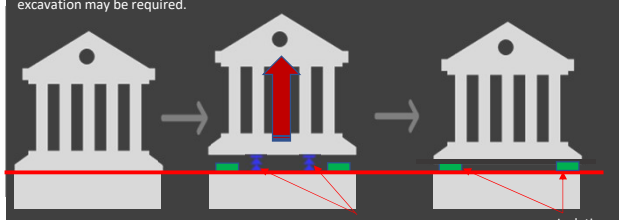
Overview of Seismic Isolation Structure Design ①

【Development of the Jack-Up-Less Method】

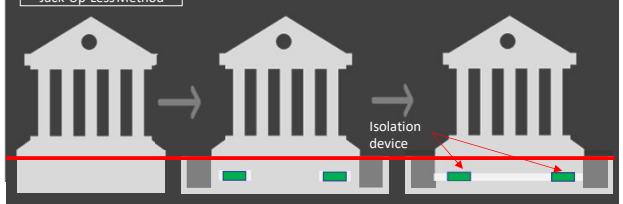
The general jack-up method involves cutting the existing structure before the seismic isolation device is installed and then performing a jack-up. However, in the jack-up-less method, the seismic isolation device and flat jack are installed as one unit beforehand. After pressurizing the flat jack, the existing structure is cut. The typical jack-up method incurs significant costs due to the jack-up process. To address this, we developed the jack-up-less method, which omits this step. An opening is created from the side of the existing strip foundation, into which the seismic isolation device and flat jack are installed together. The flat jack is pressurized to support the load of the upper floors.

General Jack-Up Method

In this method, the first-floor level rises by the height of the seismic isolation device and the reinforcement of the upper and lower seismic structures, creating a step. Alternatively, deep excavation may be required.



Jack-Up-Less Method



【Accurate Weight Measurement from the 3D Model】

Based on the BIM model, we calculated the volume of each structural component, multiplied it by the density, and obtained the weight of the structure. Additionally, we added the load-bearing capacities of the detailed structural elements and the floor design to precisely calculate the weight used in the structural analysis.

Structural BIM Model

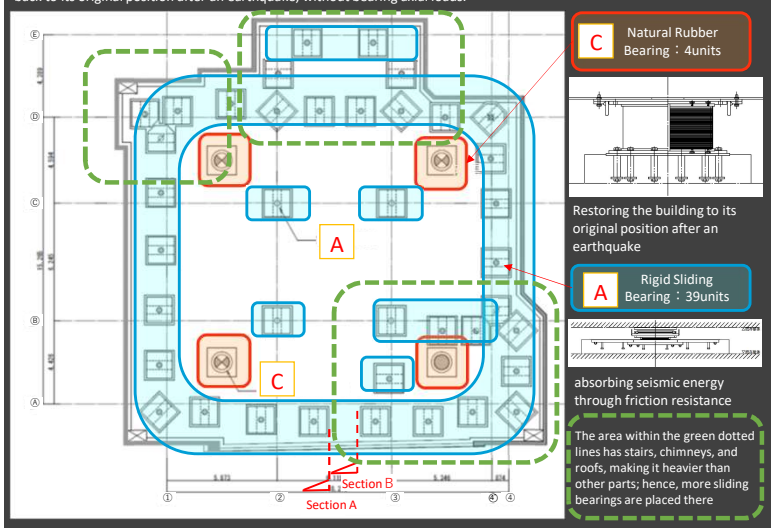
Section	Volume (m3)	Quantity (obj)	Specific gravity	Weight (ton)
Element Slab Floor	390.09	734	2.4	936.23
Element Independent Foundation	9.75	4	2.4	23.40
Element Column	43.86	99	2.4	105.27
Element Beam	204.80	3553	2.4	491.52
Element Parts 3D General Parts 3D	255.86	3006	1.5	383.80
TOTAL	648.51	4390	-	1940.22

Weight Table Calculated from BIM

Overview of Seismic Isolation Structure Design ②

【Isolation Device Layout】

Rigid sliding bearings are placed under the exterior and internal columns to support the building, aiming to extend the seismic isolation period. Natural rubber laminated bearings are used purely as restoring materials to bring the building back to its original position after an earthquake, without bearing axial loads.



C Natural Rubber Bearing：4units

Restoring the building to its original position after an earthquake

A Rigid Sliding Bearing：39units

absorbing seismic energy through friction resistance

The area within the green dotted lines has stairs, chimneys, and roofs, making it heavier than other parts; hence, more sliding bearings are placed there

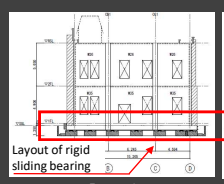
【Strategy of Seismic Isolation Device Installation】

• The layout was devised to minimize eccentricity in the seismic isolation layer. Since natural rubber laminated bearings do not bear axial loads, their positions can be freely arranged to control the stiffness center. By placing them as close to the exterior as possible, the torsional rigidity of the isolation layer was increased.

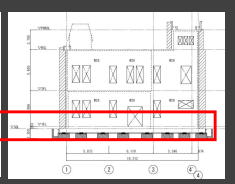
• Rigid sliding bearings, which have lower heights, were placed under the exterior walls. Since natural rubber laminated bearings are taller, placing them under the exterior walls would reduce the beam depth of the existing foundation or raise the first-floor level, so they were placed under the first-floor slab to avoid this issue.

• The seismic isolation layer can deform up to 36.45 cm when considering performance variability. Since natural rubber laminated bearings do not rotate during deformation, they were securely fastened to the first-floor slab and foundation, considering both as beam elements. The surrounding structure was also designed to ensure safety.

• The placement of rigid sliding bearings follows the principle of placing them where there are no openings in the exterior walls, and the walls are continuous from the first to the second floor, ensuring that the load from the upper floors is transmitted straight to the ground through the sliding bearings. Where the span between sliding bearings was long, additional bearings were placed in the middle. The gray squares in the structural diagram on the right show the placement of the sliding bearings, ensuring that they do not exceed allowable surface pressure.



Frame 1


Frame A

【Innovation in Seismic Isolation Devices】
- Reinforcement Beams and Cross Beams Clamping the Existing Foundation -

Rigid sliding bearings are placed under the exterior and internal columns to support the building, aiming to extend the seismic isolation period. Natural rubber laminated bearings are used purely as restoring materials to bring the building back to its original position after an earthquake, without bearing axial loads.

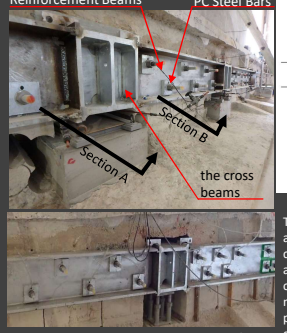
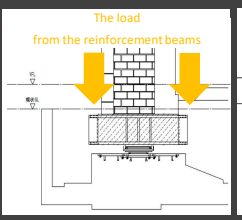
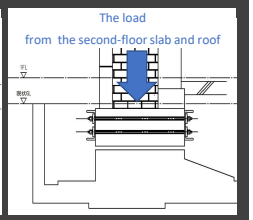


Photo looking at the lower part of the exterior wall from the inside



Section A

The load from the reinforcement beams acts on the arrows at both ends of the cross beams shown in the diagram above. The force is applied to both ends of the cross beam as part of the seesaw mechanism. Using BIM data, the exact position of the rigid sliding bearings was determined to ensure they were evenly distributed.



Section B

The load from the second-floor slab and roof, along with the self-weight of the exterior walls, is transferred to the lower foundation beams. Pre-stressing the foundation beams with PC steel bars prevents tensile stress from acting on the lower end of the foundation beams, thereby avoiding bending cracks. The building load is transmitted through the foundation beams to the U-shaped steel reinforcement beams as shear force.

【Innovation in Seismic Isolation Devices】- Dividing the Sliding Plate -

When installing Sliding Bearing A, the sliding plate is divided into three parts. After pressurizing, the core in the blue-painted area is drilled, and Sliding Plate B is installed. This process allows for a smaller opening in the structure before jack-up pressurization.

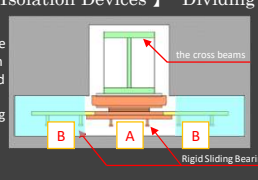
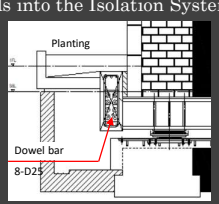
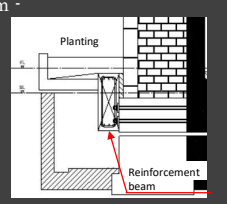


Photo of installation status at B

【Innovation in Seismic Isolation Devices】
- Integrating Exterior Flower Beds into the Isolation System -





In the flower bed area shown in the upper photo, RC cantilever slabs were extended for support. To ensure the rigidity of the cantilever slab ends, additional RC beams were installed instead of steel reinforcement beams, integrating them with the cantilever slab. In the cross beam, the steel web was extended to the outside, and eight dowel bars (D25, L=500mm) were installed to transmit shear force to the cross beams, forming a structure that reliably transmits force even when the reinforcement beams are RC.