4. STATE OPERA HOUSE – UPGRADING

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INTRODUCTION:

The Local Government Act allows local bodies to take powers requiring building owners to upgrade masonry buildings to a reasonable level of seismic capacity.

The State Opera House is one such building. The theatre was built in 1913 and allows for seating for 1300 patrons on three levels. The building is of brick construction with walls up to 685mm thick and 23,000mm high without intermediate support. Although the Wellington City Council generally requires buildings to achieve two thirds of the standard laid down by NZS 1900 Chap. 8:1965 the City Engineer requested that the Opera House be upgraded to full compliance with that standard. As a preliminary to detail design, tests were made on brick beam samples to determine what quality of brickwork existed within the building and what levels of stress could be reliably used in panel configurations. From these tests we determined a bond strength of 0.1MPa in mortar joints and F'c (Brick) 10MPa. This investigation was coupled with an extensive structural survey to supplement the meagre amound of information from drawings and original specification.

Design Philosophy -

We considered that failure of the building would most likely occur due to progressive failure of the brick walls due to face loading under seismic attack. The flexural capacity has been increased by reinforced concrete columns, walls and bands which transfer the lateral forces into the plane of adjacent walls through extensive bracing systems.

The columns are designed as pinned columns carrying the triangular distributed seismic face loads. To improve resistance against sliding failure at the base the columns are dowelled into the existing foundation beams.

The walls have been strengthened against shear failure by tying the columns together with reinforced concrete bands. Careful detailing ensured an adequate connection at wall junctions.

These bands were designed by assuming that a diagonal crack formed up the wall and then considering the requirements to transfer forces across the crack. The bands and columns were considered to act in a similar form to reinforcement in a reinforced concrete shear wall. The bands were designed for the worst case which occurs at upper levels. Bands at bracing levels were governed by secondary bending effects.

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The original roof structure was inadequate to act as a diaphragm across the building. A separate bracing system was designed to pick up forces from the bands and columns. Individual loads in members varied from 500-800kN.

The basis seismic coefficient is taken from NZSS 1900 Chap. 8 table 1a.
C = 0.16 (Zone) K = 4.00 (Normal to face)
K = 1.00 (in plane loading).

Strengthening Methods -

In essence the building consists of three separate compartments each of which required a separate technical solution.

Entrance, Foyer, Administration Area -

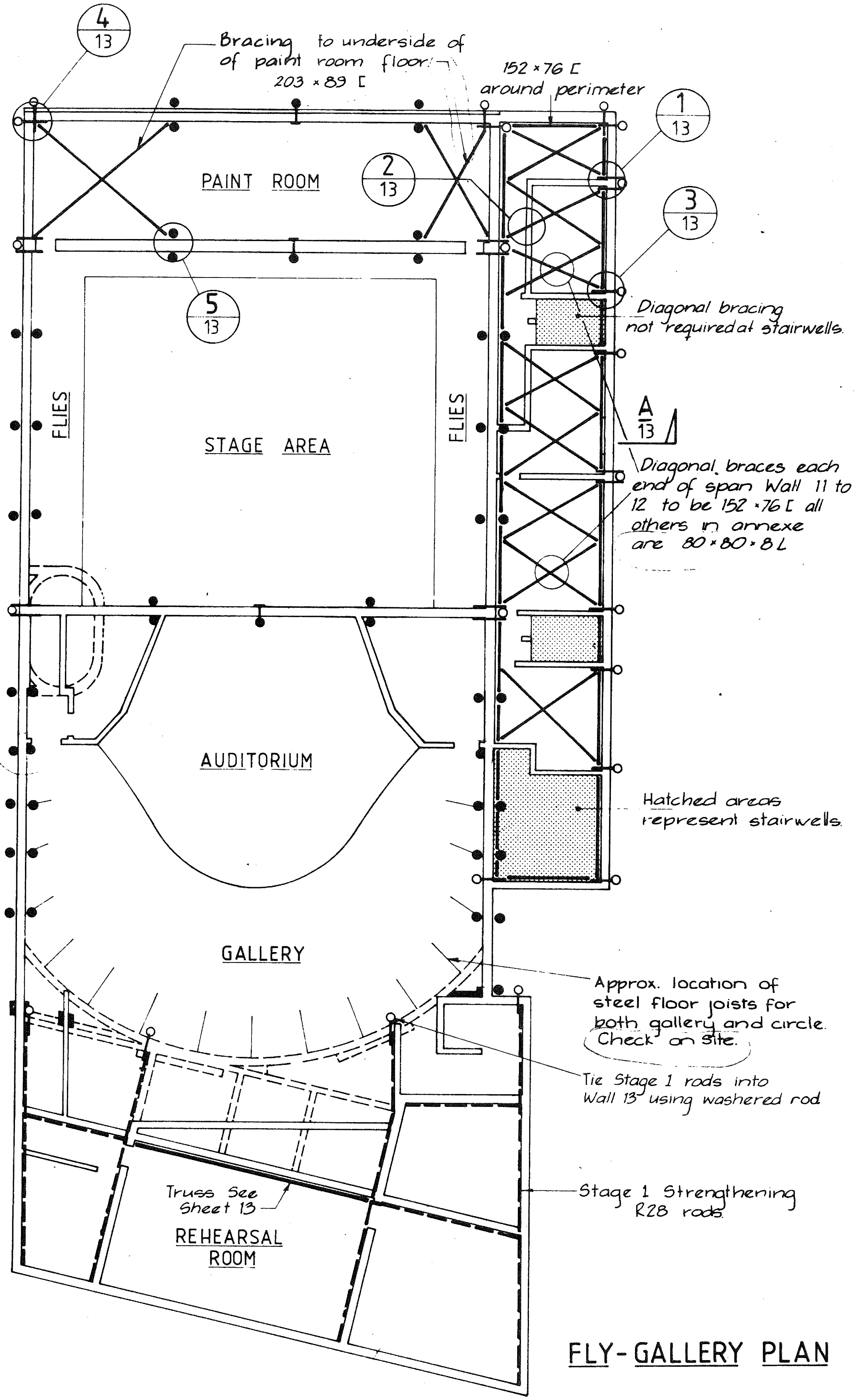
The stabilising of this area was proceeded with as a Stage 1 contract since it is a relatively straightforward structure but constituted a significant risk. This section of the building, on three levels, is slightly skewed to the auditorium centre line. Its facade is surmounted by a parapet 4.00m high which had to remain to retain the visual balance of the building.

The interior of this section has elaborate decoration with an abundance of Italianate plaster work. The restrictions imposed by these architectural features dictated a structural approach which required all strengthening to be hidden. Accordingly the building was stabilised by tying it to the rear wall of the auditorium through a system of perimeter ties and braced floors. The floors were resheathed in flooring grade particle board.

The facade and its parapet were stabilised by the use of 152 x 102 RHS members mounted on the outside face of the existing columns extending up to the columns capital. At this point the forces were transferred to a similar structure inside the roof space and extending up to the top of the parapet. The whole facade was tied to the auditorium using new trusses at roof level.

Auditorium -

The auditorium is roughly square in plan 23 x 22m with a curved wall converging with the foyer rear wall. There are three levels of seating, the upper two being supported on cast iron columns which in turn support rivetted steel beams set radially into pockets in the perimeter walls. The balconies form horizontal arches buttressed against the stairwells adjacent to the proscenium arch opening. There was no evidence of the balconies punching through the perimeter walls as witnessed in several other Wellington theatres following earthquakes of damaging magnitude. A decision was made to use the steel works in the balconies as a plane diaphragms incorporating



FLY-GALLERY PLAN

upgraded perimeter connections into the braced external walls. The external walls were braced using sandwich construction reinforced concrete columns approximately 1000 effective depth. The columns were extended down to foundation level. Their form of construction was dictated by the requirement to keep theatre aisles clear whilst maintaining the driveway width in a right of way at the side of the theatre. Shear walls were created in the void formed by the curved auditorium rear wall. All concrete in the auditorium columns and shear walls was placed using gin blocks and small buckets as the method of concrete transport. Very little of the structural concrete is visible within the auditorium and no theatre site lines have been affected. Considerable accuracy was required during construction in the placing of through wall reinforcing to enable bars to be placed correctly. All windows in the auditorium walls were bricked up to eliminate unnecessary weaknesses.

The dressing room structure formed a lean-to annexe to the auditorium. This was attached piggy-back style on to the auditorium perimeter wall. A variety of anchors were used to fix columns reinforcing and ties to brickwork. Where adequate fire protection could be ensured resin bonded anchors were used. In other locations parallel action expanding anchors performed this function.

Stage -

The stage and stage workshop areas were treated in a similar fashion to the auditorium except that little or no freedom of strengthening location was possible due to the congested nature of the theatrical operating equipment such as switchboards, fire curtains, counterweights, paint frames and stage rigging. Where possible sandwich construction columns and reinforced concrete perimeter beams were used in particular for the laterally unstiffened wall 23,000 high at the rear of the stage. For operational reasons this wall does not have intermediate support. New reinforced concrete columns provide lateral strengthening and stability was achieved by bracing this wall to the theatre rear wall. Plates were fixed either side of the proscenium arch to form a truss over the arch. The brickwork took the compressive forces.

Architectural Works -

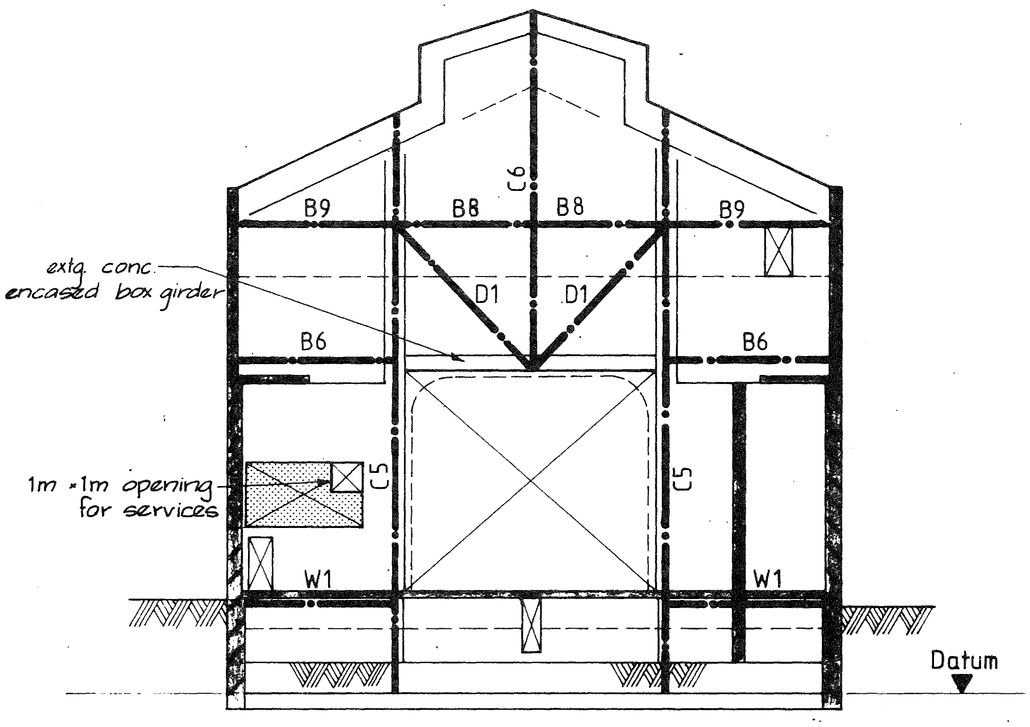
There were as stated earlier severe constraints on the location of strengthening members within the theatre areas accessible to the public. Little new architectural work was therefore required in these areas although extensive repainting has been carried out.

However as part of the contract works the Architect has been able to create new public toilets, an advance booking area and additional administration areas.

With the exception of a period when bracing was being installed over the stage the theatre remained operational at all times.

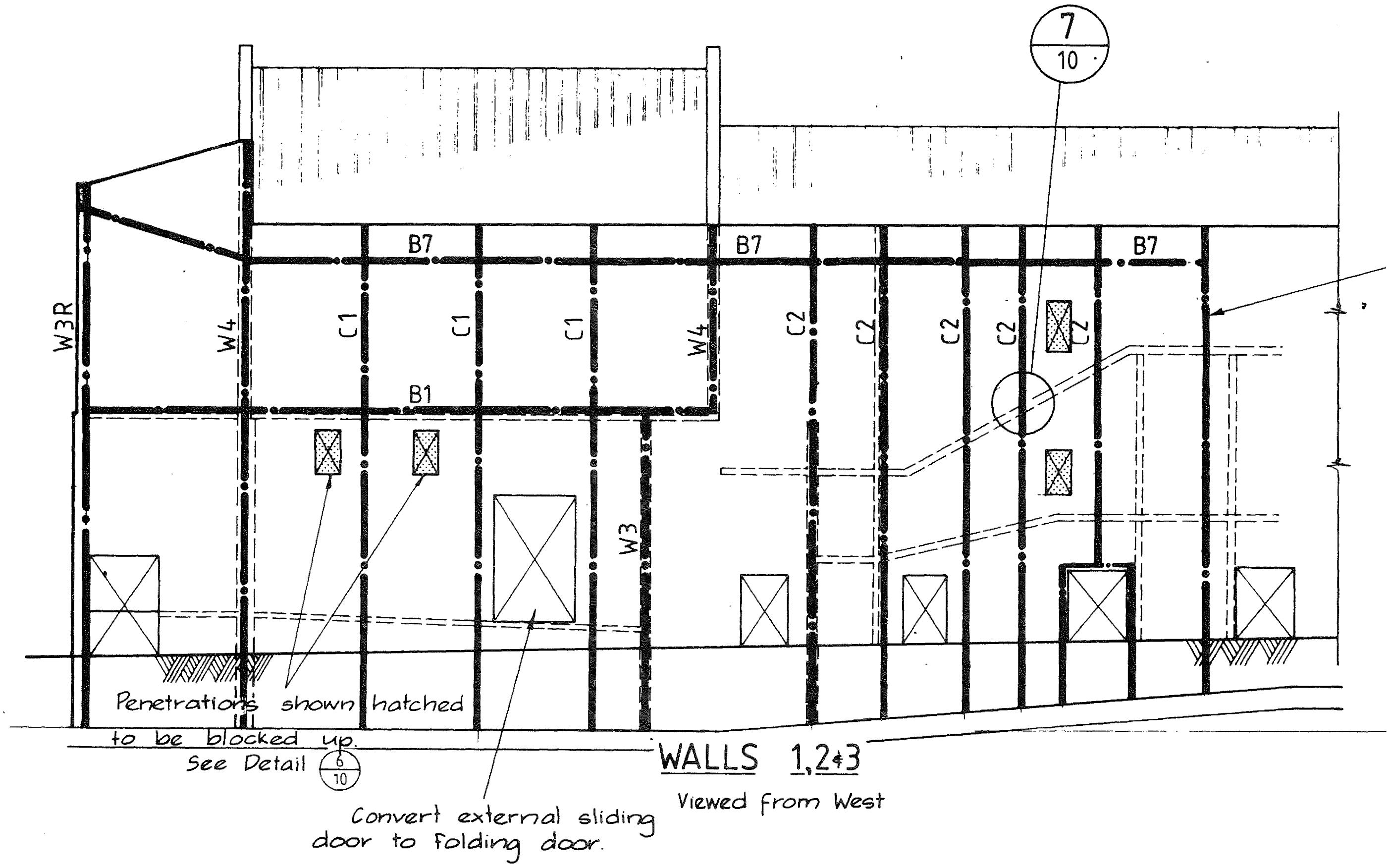
Summary -

The age and layout of the building resulted in dirty and very cramped working conditions for the construction crew. In spite of these facts works were satisfactorily completed on time by the Contractor Fletcher Construction. The Principal Consultant was Stephenson & Turner, Structural Engineer Brickell, Moss & Partners, Quantity Surveyor Russell Drysdale & Thomas. The Principal was the State Insurance Company whose permission to publish this article is acknowledged. By its decision to retain, rather than demolish, the State Insurance Company has made a significant contribution to the preservation of one of Wellington's most graceful old buildings whilst at the same time maintaining a significant community asset. The costs involved have been small when compared to the full cost of replacement.



WALL 12

TYPICAL STRENGTHENING LAYOUT



TYPICAL STRENGTHENING LAYOUT