# Speights brewery seismic strengthening, Dunedin

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**ABSTRACT:** When the 2010 and 2011 devastating earthquakes in the Canterbury region rendered their Christchurch brewery inoperable, Lion were left with a severely reduced capacity to produce draught beer in the South Island. The redevelopment of the Speight's Brewery was adopted by Lion as the means to restore, and increase, this capacity.

To redevelop and enhance the Speight's Brewery required the demolition, removal and reconstruction of a significant portion of the existing brewery, all while maintaining production of the brewery through the existing plant and the staged commissioning of new plant to supply draught beer to the South Island market.

In order to facilitate the redevelopment of the Speight's Brewery significant seismic strengthening was required to several buildings in the brewery complex. The 1939 Brewery building consisting of an 8 storey Unreinforced Masonry (URM) building was strengthened in a pragmatic cost effective way in keeping with the heritage values of the building.

The historic Cellar One building is a four story URM building dating from the1890's which was adapted to its required use with an internal skin of sprayed concrete shear wall while maintaining the Heritage façade.

The adjacent 4 storey URM Shamrock Building, home of the original Speight's Ale House, was also strengthened using an internal reinforced concrete shear walls with the objective of maintaining the heritage fabric of the building. The redevelopment of the Speight's Brewery has resulted in a new 21st century brewery while maintaining the heritage of continuous brewing on this site for the past 130 years.

## 1 INTRODUCTION

The Canterbury earthquake sequence of 2010 and 2011 effectively rendered the Christchurch brewery of Lion Beer Spirits and Wines New Zealand Ltd inoperable thus severely reducing their brewing capacity in the South Island. Lion embarked on a redevelopment program at their existing brewery complex in Rattray Street, Dunedin. The Dunedin Speight's brewery was an existing operating brewery using buildings, plant and technology of a limited capacity not particularly suited for a modern 21st century brewery operation. The brewery is also home to the historic Speight's brewery tour and the original Speight's Ale House pub.

The redevelopment of the Speight's Brewery consisted of the staged demolition and deconstruction of several portions of the existing brewery, earthquake strengthening of the retained brewery buildings, construction of a relocated Maltexo (malt extract) plant, upgrade and replacement of the plant boilers and the construction of a new Brew Process Area. The complexity of the redevelopment was defined by the severely constricted nature of the original brewery buildings over a steeply sloping site, the heritage nature of the brewery and the requirement to maintain the brewery operations during the entire redevelopment program.

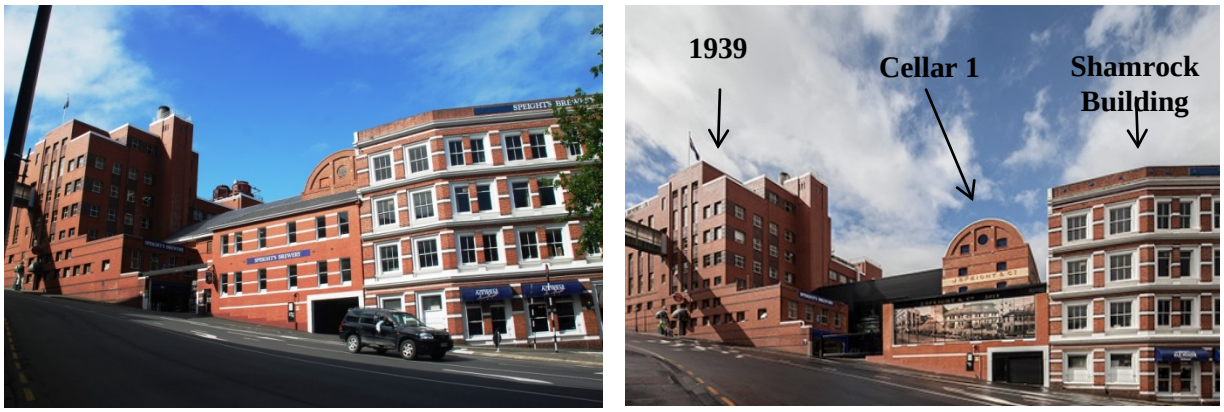


**Figure 1. Speight's Brewery street scape before (left) and after (right) redevelopment.**

### 1.1 Heritage values

A significant and thorough heritage evaluation and archaeological authority was undertaken by Jackie Gillies Architects of all of the buildings at the Speight's Brewery.

The buildings at Speight's Brewery are not scheduled in the Dunedin City Council District Plan. However, they partially lie within the North Princes Street/Moray Place/Exchange Townscape Precinct. Under this designation, the facades and bulk appearance of the building are protected.

The buildings are not included in the Heritage New Zealand List. The Speight's Brewery site is included in the New Zealand Archaeological Association Site Record Database as having existing buildings dating to before 1900.

## 2 HERITAGE SIGNIFICANCE OF THE SPEIGHTS BREWERY SITE

### 2.1 Historical

The Speight's complex of buildings have existed on the site since the early 1870s, and despite continuous use and modernisation of the plant and production methods, much of the original building fabric remains intact on the site. They are an important element of the development and growth of the city since its foundation in the 1850s.

James Speight and his business partners, William Dawson (brewer) and Charles Greenslade (maltster), were important figures in the development of the wealth of the city and were influential beyond their specific business interests.

A brewery has existed on this site since 1876 and has been in continuous production for all this time. While this probably stems from the abilities of the company founders in establishing the company with solid foundations, it is still a highly unusual characteristic of any large industrial activity in New Zealand and is highly significant.

It should be noted that the siting of the Speight's Brewery coincides with the ready supply of fresh clean water, a principal component in the production of beer. The Speight's brewery has its own independent well water supply which even now provides fresh water to the brewery and the public.

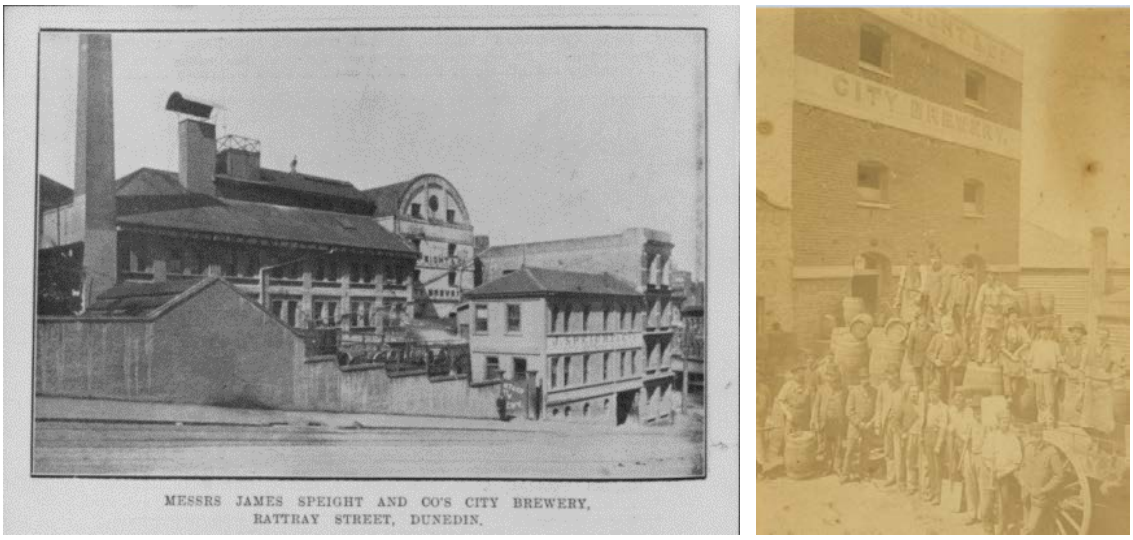


**Figure 2. Speight's Brewery 1912 (left); James Speight and Staff 1884 (right).**

## 2.2 **Architectural**

The buildings that remained were substantial brick built buildings with high architectural qualities. The tall barrel vaulted building facing Rattray Street was designed by one of Dunedin's most prominent architects of the time, R.A. Lawson, who was also responsible for a number of significant Dunedin buildings including the Dunedin Municipal Chambers, First Church and Knox Church and Larnarch's Castle. The commission of an architect of this standing indicates the aspirations of the company and the degree of success already achieved by the Speight's Brewery only five years or so after its inception.

Lawson's building was designed with a flat parapet and was only three storeys high when first built, yet it still demonstrated its industrial purpose without compromising the architectural qualities that Lawson was respected for. The expression of the function and purpose of the building was further enhanced when an extra storey and arched parapet with vaulted roof behind was added to house the new functions proposed.

With the inception of New Zealand Breweries in 1923 further development of the site was undertaken with the design and construction of a new brewhouse in 1939 designed by Dunedin Architects Mandino and Fraser.

The buildings step up the street and emphasise the steepness of the hill. Placing the taller buildings back on the site and retaining two storeys at street frontage, with the Sales Office, avoids a feeling of dominance of the buildings on passers-by.

## 2.3 **Technological**

The buildings that remained (with the exception of the Sales Office which is domestic in scale and construction) demonstrated an understanding of the structure and construction of tall multi-storey buildings of industrial function and scale in the 19th century. Walls were thick, brick masonry (though unreinforced), and the roof structures were substantial.

The internal network of posts, beams and floors had been removed in the 1950s and 60s but if the reports written at the time are correct, the construction of timber posts, iron beams, corrugated iron vaulting and concrete floors would have been ground breaking in New Zealand, and follow the development of industrial warehouses and factories in England during this time.

The original design of the buildings closely reflected their industrial function, with wide open spaces for malting floors, kilns for drying hops, and a boiler with tall industrial chimney for hot water and steam supply. As production methods have changed, the spaces within the old buildings have been considerably modified, but they still demonstrate the specific function and requirements of the process of brewing.

The Shamrock building, constructed in 1912 was originally utilised as part of the main brewery at the time within the vertical integration of the brewery. The construction consisting of URM walls in conjunction with vaulted sections of reinforced concrete floors and internal cast iron columns allowed for a reasonably open space for brewery operations.

The construction of the 1939 brewery building using a structural steel concrete encased gravity frame with URM infill panels created one of the few vertically integrated gravity feed breweries remaining in the world. The construction allowed for relatively open spaces with hygiene requirement inherent in the design.

### 2.4 **Social**

James Speight and his partners became highly respected members of Dunedin's society and their success and prosperity demonstrate the opportunities that were available in the new colony and the settlement of Dunedin in the mid 19th century.

The company would have been a major employer of labour and contributed to the breadth and depth of prosperity across all social classes in early Dunedin.

The history of brewing is often closely tied to the success or development of a new and growing community, especially in association with the gold mining rushes of the 19th century. After the needs of food and accommodation are satisfied, provision of outlets for relaxation and social interaction are often seen to follow and pubs, hotels and breweries spring up to cater for the needs of the population. Speight's was not alone in brewing beer in Dunedin at this time, but the company was fortunate in having the right people, the right skills and the right business acumen to remain and prosper in the industry right to the present day.

### 2.5 **Archaeological**

The site has been in use for purpose of a brewery since the 1876. It has seen a number of different waves of function and development since then, and each one may have left tangible remains within the ground. Above ground, all of the buildings which remain on the site and which were affected by the redevelopment, also have archaeological values in their ability to add to our understanding of early New Zealand history. This has been the subject of an Archaeological Assessment prepared by Jackie Gillies Architects. Detailed archaeological recording of all the buildings was carried out prior to or during demolition or modification.

### 2.6 **Seismic Strengthening**

As stated above the redevelopment of the Speight's brewery required the demolition of several buildings and the earthquake strengthening of the buildings to be retained in the redeveloped brewery. The following is a brief description of the assessment and strengthening undertaken on the three principal buildings retained in the redevelopment. It should be noted that the retention and strengthening of these buildings was undertaken with consultation with Heritage New Zealand and the Dunedin City Council Heritage Planning department.

**The Seismic Assessment and Strengthening Program**

The initial seismic assessment of the Speight's brewery buildings were undertaken using a combination of the NZSEE Initial Evaluation Procedure (IEP) and a preliminary seismic assessment to determine the relative seismic capacity and risk associated with the existing buildings. The following table represents the initial assessed capacities of the various buildings

**Table 1. Initial Seismic Assessment**

| Building Name | Date | Construction | %NBS and IEP grade |
|---|---|---|---|
| Brew House | 1937 | Steel Frame with masonry infill | Grade E |
| Boiler House | 1937 | Steel Frame with masonry infill | Grade E |
| Chimney | 1937 | Reinforced concrete with masonry internal lining | Grade B |
| Sales Office | Pre 1935 | URM | Grade D |
| Fermentation and Cellars | Pre 1889 | URM | Grade E |
| Shamrock Building | 1912 | URM | Grade E |

Of the above buildings, only the fermentation building, the sales office and several of the original cellar buildings were demolished. All of the remaining buildings were strengthened in line with the redevelopment objectives and to comply with the Lion minimum requirements for building seismic capacity being a target of a Grade B Building.

## 2.7 **1939 Brew house strengthening**

### 2.7.1 *Existing Building Description*

Built circa 1939, the brewhouse building functions as a working brewery as well as a heritage tour and museum open to the public. The building is an 8 storey structure approximately 36m x 39m in plan and approximately 25m in height. It is located on a relatively steep slope, with the bottom 2 storeys cut into the slope to form a partial basement.

The gravity load resisting system comprises a steel gravity frame with full concrete encasement. The floors are reinforced concrete slabs, typically either 130mm or 150mm thick. The building sits on shallow pad foundations, generally on basalt rock.

The building is clad with masonry walls, comprising a 110mm thick inner skin (single brick), and a 230mm thick outer skin (double brick). The 2 skins are separated with a 50mm cavity. The internal walls are a mix of masonry and reinforced concrete. Both the internal walls and the perimeter walls provide the lateral load resistance for the building.

The arrangement of the building is relatively convoluted and irregular, with a complex arrangement of levels and floor plates, and significant variations in the plan extent of the building up the height of the building.

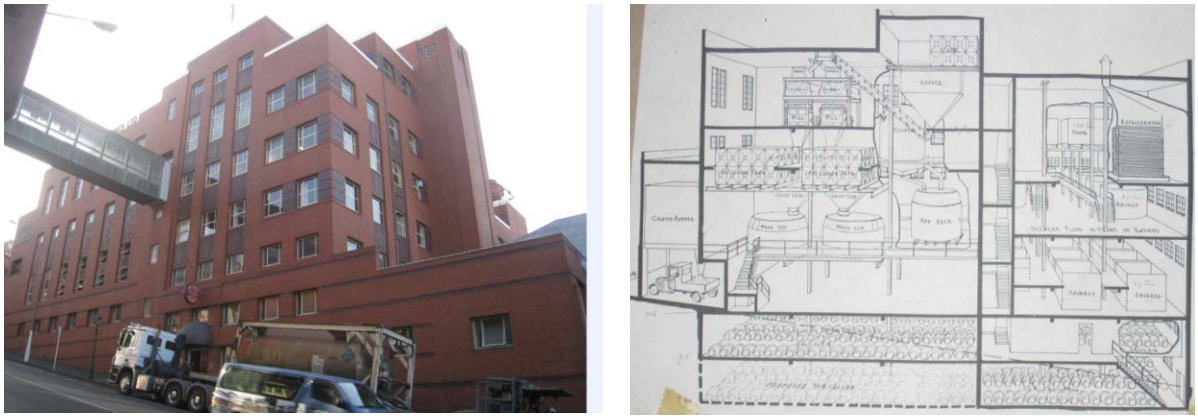

**Figure 3. Brewhouse Building Rattray Street (left); Historic section through Brewhouse (right).**

### 2.7.2 *Observed Structural Issues*

The following outlines some of the key structural issues that were identified as potentially affecting the buildings seismic performance.

- All the walls are constructed as infill between the steel frames, with the gravity load being carried down the steel columns. This means the vertical load on the masonry, which would normally contribute to the shear capacity of the wall through shear friction, is almost non-existent. The shear capacity of the masonry is therefore only provided by the cohesion of the mortar, which is of limited strength and can be quite unreliable. Additionally the perimeter walls have significant penetrations for windows. This greatly reduces their strength and their ability to act as shear walls. Preliminary analysis found the capacity of the walls to be in the order of 10-20% of the required shear capacity for the 100%NBS earthquake
- There are significant steps in the floor at each level. Particularly between the northern and southern sections of the building where there is no alignment between the floor levels of the two sections. This creates discontinuities in the floor diaphragm, compromising its ability to distribute the seismic loads to the shear walls. The floor plates also contain significant voids to house the brewing plant, further compromising the strength of the diaphragms.
- A significant length of wall in both directions had been removed from the bottom 2 storeys at some stage. This would have severely reduced the lateral load resisting capacity of the building and created a vertical discontinuity.
- Above the 6th storey a portion of the building terminates, with the upper 2 levels having a substantially smaller plan area. This floor therefore needs to act as a transfer diaphragm to distribute the lateral loads from the upper levels to the external wall below level 6.
- The parapets above the roof line were found to be at risk of toppling during an earthquake.

### 2.7.3 *Structural Analysis*

A modal response spectrum analysis was used for design of the shotcrete lining. Due to the difficulty in both predicting and modelling the in-plane stiffness of the masonry infill under seismic loading, it was assumed the masonry has negligible stiffness and the lateral loads are taken completely by the shotcrete walls. This is a conservative approach giving the lower bound masonry stiffness and hence an upper bound for the design actions in the shotcrete. A separate model was also created assuming the same stiffness modifiers for the masonry as for the shotcrete in order to bound the solution and assess the effects of possible increased stiffness on the building.

### 2.7.4 *Shotcrete Lining*

Two of the key drivers for developing the seismic strengthening scheme were to provide a solution that would allow the continued operation of the brewery within the building, while limiting the impact to the heritage value of the street frontages. To achieve this, a reinforced shotcrete lining was applied to the internal face of selected masonry walls to form a framework of shear walls and spandrels that will provide the lateral load resistance for the building. The aim being to improve the seismic capacity of the building to a minimum of 70%NBS.

**Figure 4. Shotcrete lining before (left), during (centre), and after (right).**

The arrangement of the shear walls and spandrels was carefully developed to suit the following factors:

- To avoid areas where access and installation would not be practical due to the presence of the brewery plant and pipework, or where it would significantly impede operations.
- As well as providing increased strength, it was also important to provide sufficient stiffness in the system in order to prevent significant damage, and hence localised collapse of the masonry. The lateral displacements have therefore been limited to no more than 0.4% (NZSEE 2011 guideline – section 8.6).
- To avoid uplift in the foundations by engaging sufficient gravity load in the building.
- To provide an optimised arrangement with minimal extent in order to minimise the cost of the strengthening works.

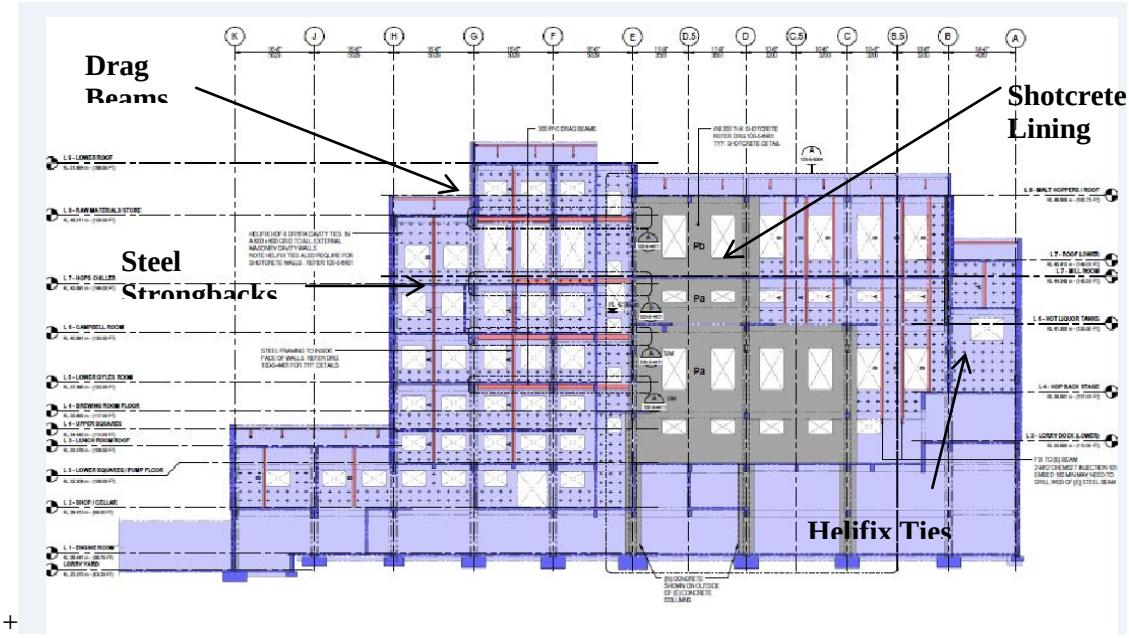


**Figure 5. Typical internal elevation of shear wall and drag beam strengthening.**

### 2.7.5 *Steel drag beams*

The significant level changes and discontinuities in the floor slabs in conjunction with the localised extent of shotcrete shear walls meant a number of floor plates were not connected to the new lateral load resisting system. Steel drag beams were therefore required to provide a load path from the floor diaphragms to the new shotcrete shear walls.

### 2.7.6 *Steel Strongbacks*

In areas with no shotcrete, steel strongbacks have been fixed to the inside face of the masonry walls to give the walls sufficient out of plane strength. These strongbacks are fixed top and bottom to the floor slabs.

The required spacing of the strongbacks was determined by checking the ability of the masonry to span horizontally Material testing of the masonry and mortar was carried out to confirm the assumed properties for the wall.

As well as designing for strength, the lateral deflections due to the ULS earthquake loads were limited to height/300 (as per Table C8.2 NZS1170.5 Supp) in order to limit damage and potential localised collapse of the masonry walls.

### 2.7.7 *Helifix wall ties*

Helifix wall ties have been installed for all perimeter cavity walls to provide connection between the inner and outer layers of masonry. The intention is that the closely spaced helifix ties allow the cavity brick construction to act as an integral wall. Generally these wall ties have been installed from the inside face due to better access and to minimise the impact on the external face.

### 2.7.8 *Other seismic strengthening works*

A number of other seismic strengthening works were also required including the following:

- Steel bracing to the roof parapets around the perimeter of the building.
- Steel bracing across various floor voids to provide seismic restraint to the brewing equipment
- Steel portal frames were installed within the Malt Delivery Room to form the lateral load resisting system for this portion of the building
- Widening of selected pad foundations where the new shotcrete framework significantly increased the foundation loads.

## 2.8 **Cellar 1 strengthening**

### 2.8.1 *Existing Building Description*

The cellar 1 building was originally constructed circa 1890 as one of the early buildings of the newly founded Speight's Brewery. The cellar 1 building is a 4 storey URM building which originally had internal timber floors at various heights. The cellar 1 building, originally constructed as the brewery malthouse was extensively altered circa 1959 where the internal floors were removed and the building was converted to a refrigerated bulk cellar in conjunction with the operation with the adjacent fermentation building. These alterations included some degree of strengthening and securing to the building consisting of external tie beams and columns, new reinforced concrete foundations and an internal concrete wall constructed at the east end of the cellar building.

The original building consists of blue stone and brick construction up to ground level and multiple skin brick construction above to the parapet level and the circular vaulted façade. The roof was a combination of steel and timber roof trusses with light weight metal cladding. The façade of the Cellar 1 building was largely unchanged from the original construction except where original openings had been blocked with subsequent changes in use around the brewery.

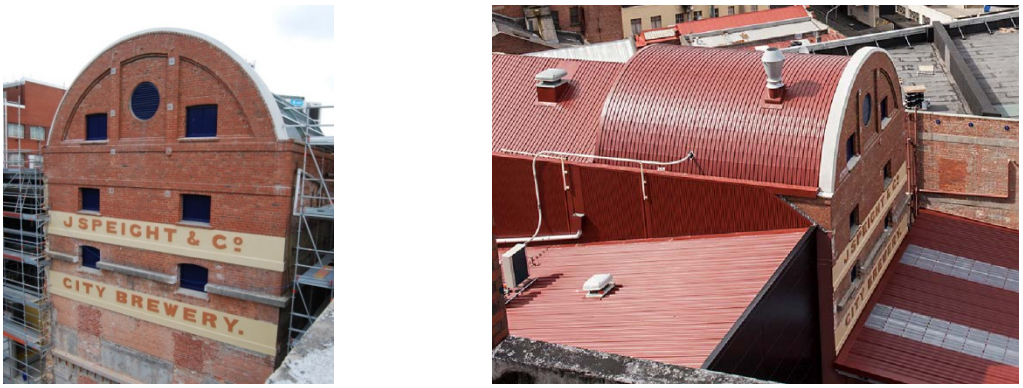


**Figure 6. Refurbished Cellar 1 during construction (left), at completion (right).**

### 2.8.2 *Seismic Strengthening*

The seismic strengthening of the cellar 1 building was driven by the Heritage value of this building and the adaptive reuse of the building for a modern brewery function. The building wall adapted for use as the milling tower for the new brewery which consists of three internal levels of reinforced concrete and structural steel construction. The ground floor level was adapted for use as the relocated keg filling line. The reuse of this building also required strict limitations on floor vibration from the milling plant and a hygiene requirement for both the milling levels and the keg filling line.

The original qualitative assessment of the building indicated that the cellar 1 building was potentially earthquake prone particularly due to the removal of all internal floor support and irrespective of the apparent strengthening undertaken circa 1959. The analysis and design of the strengthening of the building effectively ignored the in-plane strength inherent in the URM construction and relied on the construction of the new internal reinforced concrete walls to provide the lateral load capacity of the building. This both fulfilled the requirement to seismically strengthen the building and meet the demands for hygiene and useable space for the adaptive reuse of the building. The target strengthening for this building was to achieve a minimum of 70%NBS.

The strengthening measures undertaken for the building comprise the following:

- Application of a 200mm thick shotcrete reinforced concrete wall to the entire inside surface of the building including parapets and west wall vaulted façade.
- A tie is created between the new internal concrete structure and the existing URM walls with helifix ties at regular centres. Floor diaphragm ties were installed at each new internal floor level with grouted reinforcing bars and threaded rod with external patris plates to the URM walls.
- Degradation of the original brick façade was repaired using where possible like material to the original construction and discrete use of helifix ties to provide reinforcement to parapets and the vaulted end wall.
- A new structural steel and reinforced concrete mezzanine floor was constructed at level 3 in the building with a part mezzanine floor at level 2 and level 4 at the west end of the building to house the new grain milling plant. This area was required also to be explosion vented for the milling plant.
- A new slab was poured at level 1 (ground floor) over the existing slab above the basement level.
- A reinforced concrete wall is constructed between the mill tower and the remainder of the building supported at level 2
- All new walls and floors provide an internal diaphragm to support and distribute the lateral loads to the external walls of the cellar 1 building.
- The circular vaulted roof was reinstated over the Mill tower portion of the building with the rear portion of the roof reinstated as a pitched roof to replicate the original roof profile.
- All of the existing opening in the west façade wall were reinstated in the URM wall with the major openings at level 1 used for the plant access for the relocated keg filling line.

## 2.9 **Shamrock building strengthening**

### 2.9.1 *Existing Building Description*

The Shamrock Building, located on Rattray Street, was constructed circa 1912. The ground floor level is currently occupied by the Speight's Ale House pub and restaurant. Structural strengthening modifications to the building was to bring the seismic strength up to 75%NBS (percentage of new building standard).

The existing building is a four storey structure approximately triangular in plan shape and has a floor area of 434m2 per floor. The external structure is of multiple skin solid unreinforced masonry (URM) with reinforced concrete floor plates. Internally a gravity cast iron column and steel beam system consisting of steel plates and rolled steel channel (RSC) sections riveted to form a squat beam supports the floor and roof plates which consist of reinforced concrete insitu slabs formed on permanent corrugated iron arched formwork. External load bearing URM walls support the slabs along the perimeter, which then bear concentrically to existing strip footings.

The Rattray street frontage (has considerable openings throughout the full height of the building with 1.4m high URM parapets, all other sides of the building have 1.1m high URM parapets.

The existing lateral load resisting systems in in the transverse direction (parallel to Rattray St) consist of the limited URM external wall and spandrel assemblies. These walls were noted to be weak relative to the seismic load they could be subject too due to the extensive number of penetrations in the wall, and therefore lateral resistance in this direction was considered the main target of strengthening.

The existing lateral load resisting systems in the longitudinal direction (orthogonal to Rattray St) consist of the extensive URM walls which are effectively devoid of openings. The two main walls are angled at approximately 65 degrees to each other. Although the walls are constructed as infill between the concrete floors, with the floor slab spanning onto the walls the vertical load on the masonry contributes to the shear capacity of the wall providing the walls with sufficient capacity to meet the minimum targeted strength considered acceptable.


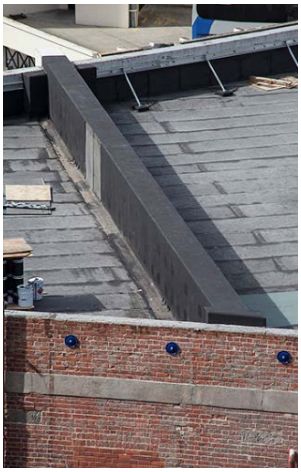

**Figure 7. Shamrock Building Elevation (left); Roof level beam element (right).**

### 2.9.2 *Structural Analysis*

The building was analysed using a number ETABS models with differing loading, material and foundation conditions to determine the building sensitivity to torsion and drift. The recommended limitation on drift levels (1% of the free span of the element for URM construction) was the critical design criteria and was therefore subject to some investigation. The analysis determined that the drifts could be limited to just over the recommended limitation using reasonably conservative assumptions.

As the new wall/beam strengthening element was located in the transverse direction coinciding with the centre of mass and rigidity, the torsional effects on the building were minimised. Fortunately this location also coincided with an internal transverse wall at ground floor level reducing the impact of the strengthening on the building use.

With the new concrete structure detailed to support 100% of the lateral loads expected, and with the stiffness of the system modelled to limit drifts to 1% assuming it behaved as the only lateral resisting mechanism under 75% NBS, provided the design team with sufficient confidence the building would perform well accounting for ductility and redundancy not included in the theoretical modelling of the new system

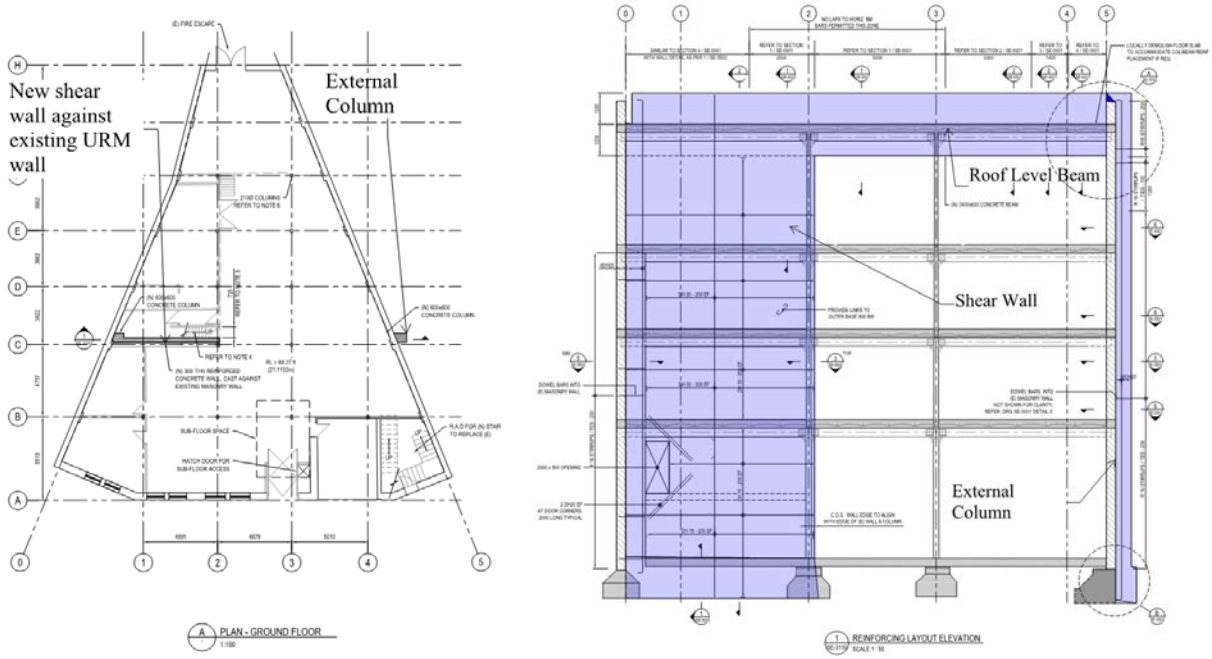


**Figure 8. Shamrock Building Strengthening.**

### 2.9.3 *Seismic Strengthening*

Given the ground floor constraints for potential additional structural lateral load elements (the existing historic bar layout; beam, column and floor aesthetics; need to retain on-going hospitality services), the proposed new structural form to provide seismic strengthening in the transverse direction included:

- A reinforced concrete shear wall extending the full height of the building. This wall was cast up against parallel to an existing ground floor masonry wall, effectively resulting in a thickening of an existing wall rather than introducing a new wall element. This also required widening the existing foundation at the same level as the original masonry wall. Door openings through the existing wall were maintained not to compromise access to the ground floor mezzanine areas.
- A reinforced concrete column structure extending the full height of the building was located on the external face of the building, allowing all work to occur on the outside of the building. This column was tied to the adjacent URM wall to mobilise hold down mass and spread axial compressive loads to the supporting foundations.
- A reinforced concrete beam element extending the full width of the building at roof level, projecting both above the roof and below the ceiling level of the third floor connected the wall to the new column, thereby forming a large propped cantilever shear wall system, with the new wall and beam forming a moment connection at roof level.
- Strengthening of the roof parapets was achieved through installation of hidden structural steel frames tied to the walls through a series of wall ties.

## 3 **CONCLUSION**

Although the approach to the assessment, analysis and strengthening design was reasonably simplistic in execution, the completed strengthening work met the project objectives of a pragmatic and economic strengthening system with the least intrusion into the existing building fabric and use while maintaining the function of the brewery throughout the construction phase. Challenges faced with phasing the work around the operating brewery, demolition of parts of the brewery and construction of new buildings were incorporated into the designs to ensure the least disruption possible.

The concepts developed and implemented for the redevelopment of the Speight's Brewery including the strengthening and adaptive reuse of the existing buildings combine to express the long established heritage values of the Speight's site, the unbroken chain of continued use of the site by Speight's since 1876 and the need for industrial technologies to be updated and modernised at regular intervals through history.

## 4 ACKNOWLEDGMENTS

The authors of this paper would like to acknowledge the following for their foresight and commitment to this project.

Lion Beer Spirits and Wine New Zealand Limited for undertaking such a challenging project and their commitment to preserving the heritage of brewing in Dunedin with the resultant preservation of these iconic buildings.

Heritage New Zealand, the Dunedin City Council Heritage Planning department and Jackie Gillies + Associates for the practical and pragmatic approach taken to allow for the retention of these building whilst sacrificing some facets of the original brewery buildings.

Naylor Love Construction for the practical and innovative approach taken to the challenging conditions of undertaking the redevelopment and strengthening work in an operating brewery.