CHRISTCHURCH NORTHERN CORRIDOR: WINTERS ROAD PEDESTRIAN SUBWAY

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SUMMARY

The Christchurch Northern Corridor (CNC) is one of the NZ Transport Agency’s three works programmes which make up the Christchurch Roads of National Significance. This paper focuses on the design and construction of the Winters Road Pedestrian Subway as part of the CNC project. The design of the subway was heavily driven by urban design objectives which led to several design and construction challenges. The design has been delivered using Revit which enabled inter-discipline clash detection to be undertaken using Navisworks, streamlining construction on site.

INTRODUCTION

The Christchurch Northern Corridor (CNC) is one of the NZ Transport Agency’s (Transport Agency) three works programmes which make up the Christchurch Roads of National Significance (RoNS). These projects provide access to and from the Christchurch Central Business District (CBD), Christchurch International Airport and the Port of Lyttelton.

The CNC involves the construction or modification of sixteen structures in total comprising five new mainline bridges, three local road bridges, two new subways, three pedestrian bridges, improvements on two existing subways and widening of the Waimakariri River Bridge. This paper focuses on the design and construction of the Winters Road Pedestrian Subway at the southern end of the CNC project as shown in Figure 1.

![Figure 1 The CNC Alignment and location of Winters Road Pedestrian Subway](Error! Reference source not found.)
The project is designed and constructed by the CNC Alliance, an alliance between the NZ Transport Agency, Christchurch City Council (CCC), Fulton Hogan, Aurecon and Jacobs, and the first alliance contract of this size in the South Island of New Zealand.

**Urban Design Vision**

The CNC is a legacy project to connect communities and Canterbury businesses for generations to come. The CNC Alliance is passionate about building a legacy; the Urban and Landscape Design response demonstrates this commitment and is infused with a significant range of features and enhancements throughout the project. As the primary entrance experience into the Christchurch City, the ‘Tōtara Highway’ design concept embraces and builds further on the established Garden City character. An attractive visual design approach uses abstract botanical forms - Tōtara, Raupo and Kahikatea - representative signature species within this natural receiving environment. This visual character is reflected on a range of urban design elements along the corridor, creating a parkland experience for all corridor users, and including the surface textures and finishes of Winters Road Pedestrian Subway, see Figure 2.

![Figure 2](image)

**Error! Reference source not found.** Figure 2 The urban design concept for Winters Road Pedestrian Subway

Key objectives for the subways are to create a safe, attractive environment which helps to connect pedestrian and cycleway users with the surrounding local area. Improved amenity through urban design will realise these beneficial outcomes for pedestrians and users of the Winters Road Pedestrian Subway. As subways are typically dark and confined spaces, specific measures were adopted to improve the aesthetics of the subway and to integrate with the ‘Tōtara Highway’ design concept, including:

- ‘Open’ pentagon shape of the subway implemented by inclining the subway walls outwards at 30° to the vertical, and providing a slight apex to the roof. In this way the 5 m by 2.5 m tall minimum clearances are achieved whilst enhancing the feeling of space and openness in the subway and was driven by the objective of maximising pedestrian sightlines for Crime Prevention Through Environmental Design (CPTED) purposes.

- The internal subway walls and wingwalls have a relief pattern surface finish for aesthetic effect which is an abstraction of the vertical lines of tree bark. The relief pattern was also selected as these are known to be less desirable surfaces to graffiti and to prevent skateboarding on the wall slopes.
• Lighting – internal LED lighting will be installed in the subway to enhance the user experience and comply with lighting requirements, reducing the likelihood of graffiti and anti-social behaviour. The subway lighting will be supplemented with overhead lightwells to provide natural daylight.

• The entrance areas of the subways will integrate with the subway structures and the landscape context and include planting, signage, and safety railing.

• Other small inputs such as the botanical themed grate for each of the lightwells to generate patterned shadows in the subway, the subway name imprinted on the headwall, and the exposed aggregate floor help to contribute to the experience of SUP users.

Ground Conditions and Programme

The ground conditions along the project are typified by soft, compressible soils overlying liquefiable layers, then competent gravels. The soft layers experience long term settlements under embankment or structural loading, with up to 2m of settlement expected at the subway location. Typically, the settlements are accelerated by surcharge preloading where appropriate on the project. Due to project programme requirements, however, Winters Road Pedestrian Subway was required to be constructed, and opened to the public, before completion of the preloading in the QEII construction area and was required to be in place to allow the haul route to be established over it. There were also a number of services, new and existing, that were to be accommodated along Winters Road which had a low tolerance to ongoing settlement.

In meeting these urban design and programme objectives in challenging ground conditions, a number of design and construction challenges were overcome.

GENERAL DESCRIPTION OF WINTERS ROAD PEDESTRIAN SUBWAY

Winters Road Pedestrian Subway is 50.6 m long and is located on the pre-existing Winters Road adjacent to the Northern Arterial interchange with Queen Elizabeth II (QEII) Drive. The north and southbound carriageways of the new arterial road and the southbound on ramp departing the QEII Drive interchange pass over the subway which is constructed at grade to tie into the existing Winters Road. The Navisworks model extract shown in Figure 3 illustrates the subway’s local context.

Figure 3 View of Winters Road Pedestrian Subway in context taken from the project Navisworks Model
Internally the subway structure is an irregular pentagon with a 400 mm thick base slab that is 5.0 m in width as shown in Figure 4. The two walls are inclined at 30° to the vertical and are 475 mm thick including an additional 25 mm for a protruding relief pattern. At the centre of the subway cross section the minimum vertical clearance of 2.5 m is provided with an additional 300 mm which dictates the internal height of the roof apex. The roof is 550 mm thick and sloped at approximately 4° to the horizontal to meet the inclined walls. The wall panels are precast and both the base slab and roof were cast in situ. The structure is a monolithic frame seated on improved ground. The wingwalls were designed to cantilever from the apron slab and the headwall cantilevers from the roof slab.

Figure 4 Cross section of Winters Road Pedestrian Subway

Foundations

Up to 2 m of settlement is expected due to the embankment construction over Winters Road. Ground improvement is provided under the subway, consisting of a Load Transfer Platform (LTP) that contributes to spreading the load to an array of settlement reducing timber piles allowing the structure to be completed at the front end of the programme.

Figure 5 Three dimensional representation from an early Revit model highlighting the main elements of the design
Adjacent to the subway settlement reducing timber piles are not installed and the settlement will be accelerated through the use of wick drains and 2 m of surcharge fill preloading. This surcharge fill will also be placed above the subway to provide an even surface for construction vehicles to navigate, introducing significant temporary loads onto the roof of the opened structure. The settlement reducing piles and LTP were extended beyond the subway structure to protect the subway walls from the downdrag associated with settlement from the adjacent surcharged embankments.

**Lightwells**

Two lightwells were constructed as part of the subway to provide natural light to the day time users of the Winters Road Shared Use Path (SUP). One lightwell is in the median of the north and southbound carriageways and the other between the main carriageway and the onramp, as shown in Figure 6. Vehicle safety is ensured by limiting the level of the top of the lightwell to closely match that of the median, and a vehicular grate is installed to provide a continuous, traversable median. The grate was also used as an opportunity to provide shadow effects in the subway that were aligned with the project urban design theme through the installation of a fabricated leaf pattern (shown in Figure 13). A similar principal applies to the lightwell between the mainline and the on ramp, although the level is less critical in that location and a small upstand is provided to prevent water ingress.

![Figure 6 Long section of Winters Road Pedestrian Subway](image)

The lightwell openings do not extend over the imprinted walls below in order to avoid water staining. A relatively low volume of water will enter the subway through the lightwells and is managed by gentle crossfalls of 1% toward each wall, and falls of 1:200 toward each entrance from a crown point under the southbound carriageway. Water is then discharged externally into the network drainage system. For the median lightwell twin catchpits are installed on the mainline immediately upstream of the subway to intercept the stormwater flow and minimise the inflow into the subway during design storm events.

**Articulation**

To allow the subway to accommodate any unexpected differential settlements, particularly during significant seismic events, three movement joints are provided along the length of the subway. The precast wall panels are approximately 4.6 m long and the movement joints are provided at the location of three of the precast panel construction joints. At the movement joint locations, the base slab and roof are discontinuous with shear transfer only.
DESIGN AND CONSTRUCTION CHALLENGES

Structural modelling

The structure has been analysed as a simple monolithic frame using nonlinear elastic soil springs. The reinforced concrete structure was modelled as an elastic frame with rigid offsets where the roof and floor slabs meet the inclined walls. The overhanging nature of the walls introduces the possibility of a loss of soil contact due to differential settlement, so two structural models were developed based on two sets of boundary conditions. These were: 1) support provided by fill, 2) no support provided by fill. Foundation stiffness was modelled based on an increased timber pile spacing under the centre of the subway cross section, where ground loading is least, providing space for a service trench to be installed under the structure. A longitudinal model was developed to analyse the structure for the differential settlement along the length of the subway and determine required movement joint locations. Loadings were determined to comply with the NZTA Bridge Manual.

Precast wall panels to floor slab joint

The use of precast wall panels provides a high quality finish but complicates the wall to floor slab connection, which is a particularly highly stressed region due to the geometry of the subway. Typically, couplers would be installed in the base of the precast wall to provide continuity with the floor slab reinforcement. There was significant congestion in this area, however, and the required bend radius for the installation of couplers on the main bars could not be achieved. The solution was to install drossbach ducts in the precast units for the floor slab reinforcement to pass through and anchor into an insitu beam cast at the outside base of the walls, as shown in Figure 4. The ability to cast concrete into the ducts was confirmed by testing; an 8 mm max nominal size aggregate mix was flowed into a sample duct using a low 100 mm head pressure. The bar was also purposely placed at a skew within the duct and the duct skewed such that the far end was higher, giving a worst-case scenario. The primary concern with the duct concrete was for durability of the reinforcement as the anchorage occurs in the external beam, and the tests indicated only small areas of minor aeration, the concrete otherwise flowing well around the bar (see Figure 7). A 5 mm max nominal size aggregate mix was used in the permanent structure which would have improved flow properties.

Figure 7 Test sample to confirm concrete flow through wall ducts

Precast wall panels and movement joints

Precast concrete construction has several benefits that most will be aware of, finish, quality, speed of erection to name a few. For Winters Road Subway precast concrete construction was desired for the wall panels to ensure the highest quality and consistency of relief production and for erection speed. However, due to the length of the subway movement joints were required for differential settlement affects mitigation. When movement joints are required,
subways will usually contain insitu stiches to install waterbar correctly. The insitu stiches will often disturb the seamless relief patterns afforded by precast concrete construction.

For Winters Road Pedestrian Subway the team wanted to implement an uninterrupted relief pattern and to do so used a partial insitu stitch that was located on the back of the precast panels only as shown in Error! Reference source not found. Figure 8. Also, to ensure the relief on the front face of the panels was seamless the panels were cast by hanging reinforcement from a frame above the mould as shown Figure 9.

![Figure 8 ‘Half’ insitu stitch for movement joints](image1)

![Figure 9 Casting of panels by hanging reinforcement from frame above to prevent any chairs or marks on the front face of the panel.](image2)

Additionally, the 30° inclined wall panels were originally going to require extensive temporary propping until after the insitu roof was completed. Instead only minor propping was required through the introduction of two ‘buttresses’ on the back of each panel as shown in Error! Reference source not found.. These were insitu cast elements on the rear of the panels and allowed the individual panels to be self-supporting when stood in place on the blinding concrete. The buttresses were assumed not to contribute to the structural capacity of the completed subway.

![Figure 10 Wall panel buttresses](image3)
Insitu roof works

The formwork for the external side faces of the insitu roof also posed potential issues as they were approximately 2.8m from the ground and significant falsework would be required if the formwork was to be installed with the subway construction in that state. Instead a change to the construction methodology was proposed where the wall panels would be backfilled (following adequate curing time of the base slab to provide support to the wall panels) to the height just below the roof such that no falsework was required. This construction change was developed between the designer and constructor and resulted in significant cost savings. This change also eliminated a fall from height risk that would have been present had the walls not been backfilled first.

Additionally, to construct the insitu roof of the subway extensive propping on the inside of the subway was required. The internal propping was not to be supported by the precast wall panels to ensure no damage to the panel reliefs.

URBAN DESIGN OUTCOMES

The structure is nearing completion and is currently partially open to the public (not the full width) as lighting and other finishes are completed. The images below illustrate how the urban design vision has been brought into reality. Figure 12 also illustrates the effectiveness of the lightwells which were covered for haul route access in Figure 11.

Figure 11 Maximised pedestrian sightlines and open feel. Note that the lightwells are covered.

Figure 12 Bright interior with uncovered lightwells (and prior to lighting installation). The subway is partially open to the public.

Figure 13 Lightwells and traversable vehicle grate with botanical leaf pattern which creates shadows on the subway floor

Figure 14 Wall panel tree bark relief pattern
DIGITAL INITIATIVES

Several digital initiatives were implemented on the CNC project including use of Navisworks which is a useful tool that can be used to combine 3D models and data from various sources such as 12D, Revit, and MX into one place for advanced design review, clash detection, and co-ordination. The key to getting the most out of Navisworks is including as much information as possible.

For Winters Road Pedestrian Subway Navisworks provided a valuable tool to co-ordinate disciplines as the design package incorporated the subway structure, ground improvements and new and existing services. By being able to combine the MX, 12D, and structural Revit models in Navisworks we were able to ensure no clashing of utilities with ground improvements and check that embankment and road surfaces align with the structure extents. This includes the subway lightwells that must be aligned to tight tolerances within the carriageway median.

One of the benefits of Navisworks is that the Navisworks Freedom Viewer is a free software so anyone can access the model and anyone has the ability to measure, interrogate, and understand how the different disciplines interface on a 3D level. The model was shared with...
all Alliance partners and was also used for a project wide Safety in Design workshop where the ability for all disciplines, the constructors, maintainers and the client to travel the length of the project model was of great benefit to the identification of issues. An example of Navisworks in use in the Winters Road Pedestrian Subway area is shown in Figure 16.

CONCLUSION

This paper focuses on the design and construction of the Winters Road Pedestrian Subway as part of the CNC project. The design of the subway was heavily driven by urban design objectives which led to several design and construction challenges. The urban design objectives included; a 5 m minimum clear width, inclining the subway walls outwards at 30° to the vertical and providing a slight apex to the roof, including a relief pattern surface finish on the precast walls, and incorporating two lightwells for natural light during the day time. By meeting these objectives the subway has a feeling of space and openness. Challenges included waterproofing at movements joints whilst using precast wall panels, construction of the seamless relief pattern for the precast walls, placement and erection of the inclined wall panels, and requirements for complex temporary works for the insitu roof and lightwells. The design has been delivered using Revit which enabled inter-discipline clash detection to be undertaken using Navisworks, streamlining construction on site.