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bda
facade consultants

External Envelope: Glass & Aluminium and Stone Façade Elements

CADENZA METROLINK INTERFACE

Credenza, Earlsfort Terrace, Dublin

Info

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For
Irish Life Assurance plc.

By
Billings Design Associates Ltd.

REVISIONS

Revision	Date	Issue Status	Change Description	Author	Check
C01	03.03.2024	Final	-	CB	CB

CONTENTS:

1 INTRODUCTION

I am Colman Billings (BDesHons), owner, and managing director of Billings Design Associates Limited (BDA). I am an industrial designer, specializing in the design, procurement and inspection of façade systems for buildings. I have been working as a façade consultant, involved in the detail design and specification of bespoke curtain walling and other façade systems for the last 30 years. I have worked on projects ranging from high-rise residential towers in the UK in excess of 50 floors, to designing the unitised curtain walling for hurricane and earthquake resistant office buildings in the Caribbean.

Billings Design Associates Limited (BDA) were the façade consultants on the Cadenza project, located 19-20 Earlsfort Terrace and 65A Adelaide Road. We performance specified the façade elements of the Cadenza building. Final detail design, manufacture and installation was carried out by a specialist façade contractor, Gunn Lennon Fabrications Limited (GLF).

BDA has been asked to review the installed façade with regard to the potential effects of the MetroLink construction works and operation and to prepare this document in response to TIIs replies to the submission made on the Metrolink on behalf of Irish Life Assurance plc in connection with the Cadenza building, Dublin 2.

2 EXECUTIVE SUMMARY

BDA has reviewed TII's replies to Irish Life's submission and we respectfully disagree about the characterisation of damage to the building as described as being 'slight' in the application documentation and are concerned, for the reasons set out below, that damage to the building has been underestimated and that the building will be damaged as a result of settlement or vibrations.

2.1 Ground Settlement

1) The window wall system EWS-001 is susceptible to damage, breaking glass, if there is differential deflection of the primary structure at one column. The worst-case condition is at the South-East corner where there is a glass to glass corner. This is likely to be over-stressed if the predicted settlement noted in ML1-JAI- EIA-ROUT-XX-DR-Y-21146 rev P02 occurs.

2) The stone veil EWS-002 which is suspended from Level 05 slab is susceptible to damage, over-stressing of bracket assemblies, and possible stressing of stone if there is differential deflection of the primary structure at one column. The worst-case condition is on the South-East corner. The stone veil steel sub-structure will suffer stresses outside of its original design intent.

3) The recessed South and East elevations, EWS-003, are clad with a toggle glazed stick curtain wall. This is susceptible to damage. The worst-case condition is on the western end of the South elevation where it approaches the core. The predicted settlement noted in ML1-JAI- EIA-ROUT-XX-DR-Y-21146 would result in glass racking and impacting aluminium frames causing breakage.

4) The ground level entrance glazing EWS-006 stands on Level G slab. It is susceptible to damage, breaking glass, if there is differential deflection of the primary structure at one column. Due to the tight tolerances of the system we believe any movement outside of the current design intent could cause failure. In theory it is not affected by ground settlement based on the current TII tunnel location. However, if the tunnel alignment moves to the West, even within its permitted LoD, it is likely create settlement conditions under this screen causing damage.

2.2 Vibration

1) There is insufficient information available to assess the risk of damage due to vibration. We ask that the TII provide detailed information on the proposed frequency and quantum, and duration predicted at the Cadenza location during the MetroLink works
2) There is limited guidance on design for vibration other than design for earthquake conditions. The building envelope has not been designed for vibration or earthquake conditions.
3) Vibrations can cause loosening of fixings, dislodging of packers and movement of components, outside of their design parameters which could potentially cause damage.

3 FAÇADE TYPES

There are several different façade types located on the building. The principle façade types that would be potentially effected by the MetroLink works are indicated below, EWS-001, EWS-002, EWS-003 and EWS-006.

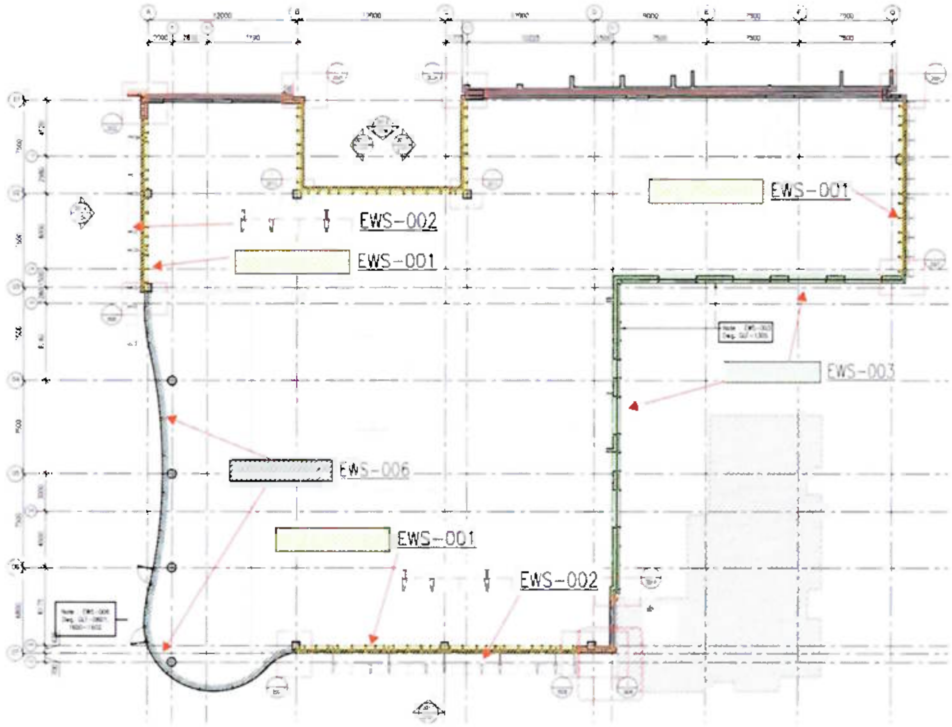

Figure 1 Cadenza Ground level plan

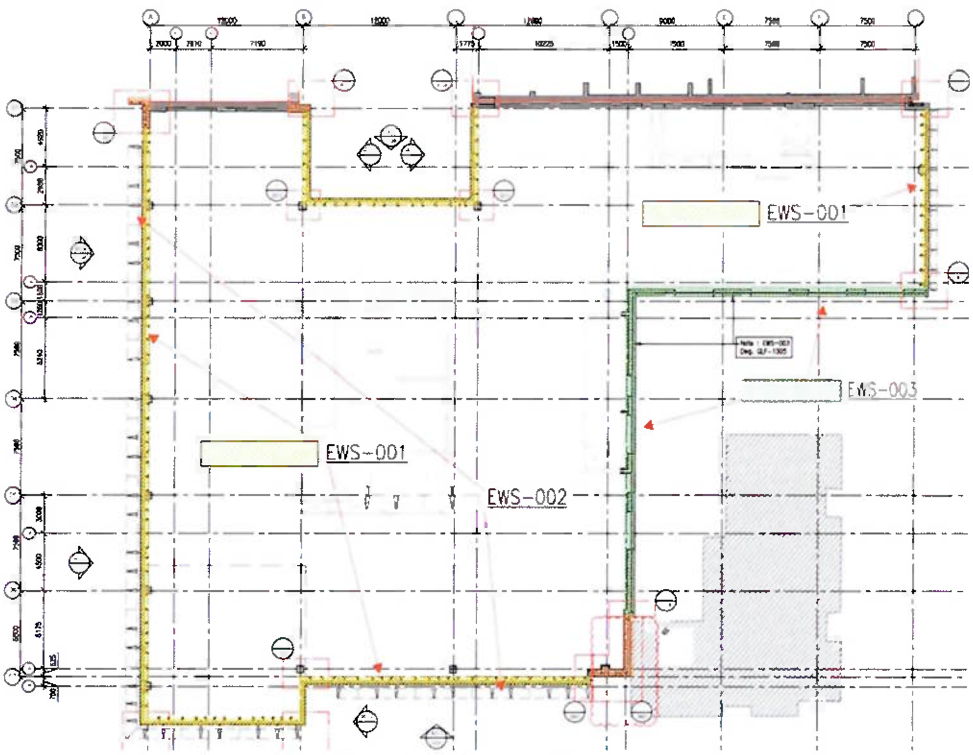

Figure 2 Cadenza Level 3 plan

3.1 EWS-001, Free Spanning Window Wall

The free spanning window wall system is totally bespoke to the Cadenza project. It consists of large double glazed units free-spanning from floor to floor. Each pane of glass is only restrained by hidden toggles at the top and bottom edges of the double glazed units. The panels are all 3.5m tall. Panel widths range between 1.2m and and 3m.

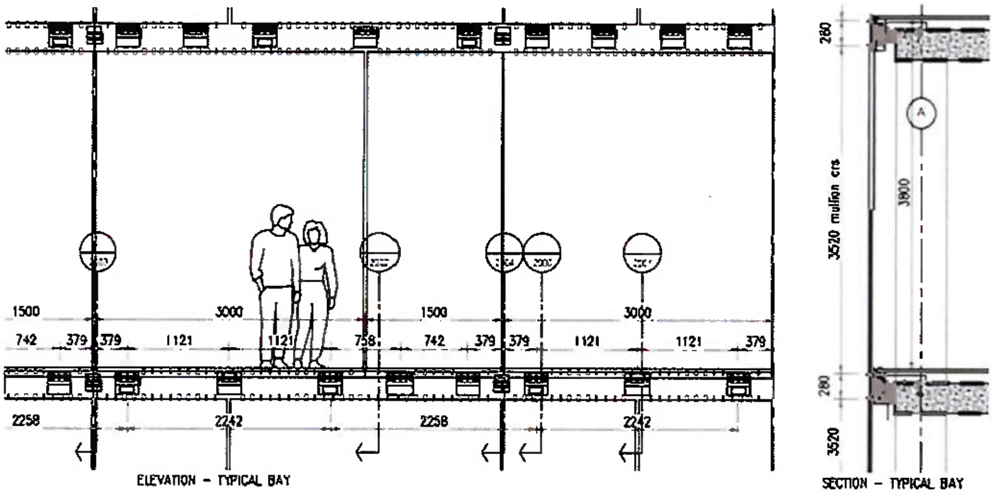

Figure 3 EWS 001 typical bay

Figure 4 EWS 001 East and South elevations

Each panel of glass sits on a dedicated horizontal profile at each floor level. Vertical differential movement of floor slabs supporting panels of glass is accommodated by silicone pointing externally and gaskets internally. Vertical differential movement capacity is limited by the lengths of the toggles at the head of each glass panel, and the silicone pointing. Lateral differential movement (racking) is accommodated by the toggles sliding in the top edge profile of the double glazed units. The glass-to-glass corners are restricted by the limits of silicone pointing.

3.2 EWS-002, Stone Veil

The stone veil is supported from the terrace slab at fifth floor level. The veil consists of individual pieces of hand-set limestone with undercut anchors and aluminium support rails fixed back to a bespoke stainless steel and galvanised steel suspension structure. The suspension structure is restrained against wind loads at each slab level with local stainless steel brackets at approximately 4.5m spacing on-plan.

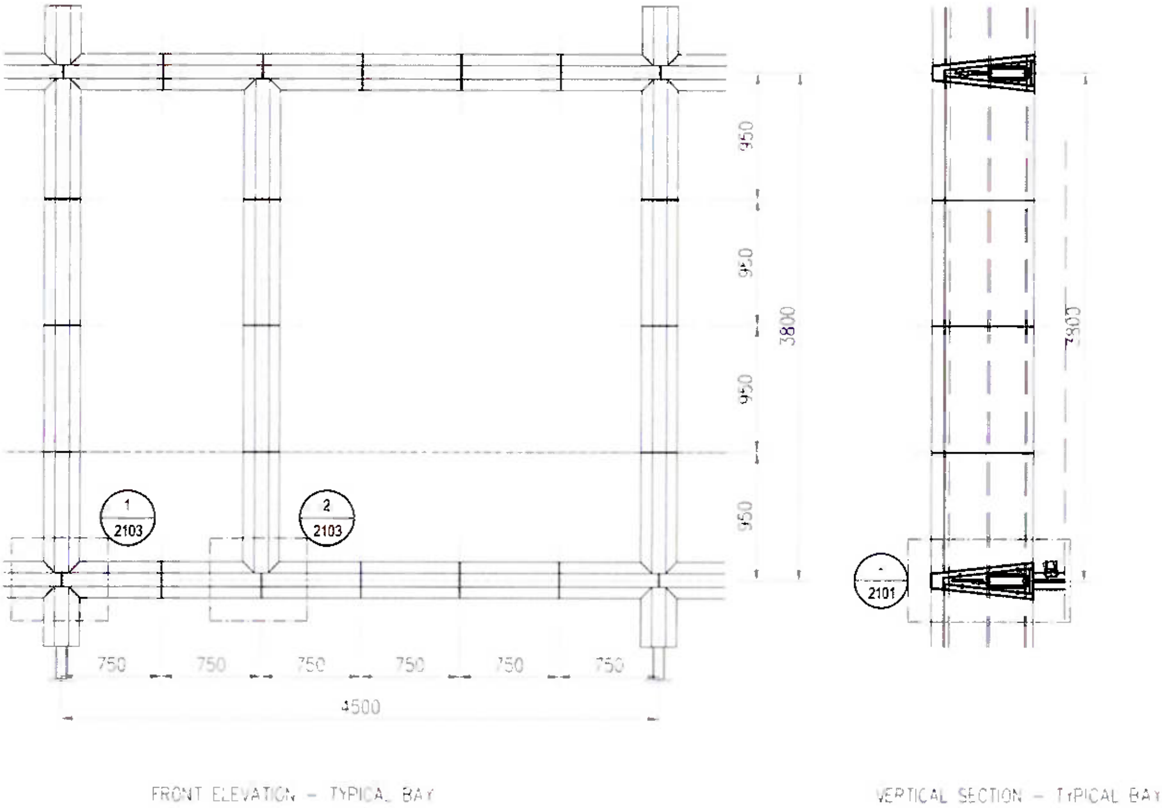

Figure 5 EWS 002 Stone Veil typical bay, elevation and section

Figure 6 EWS 002 Stone Veil East and South elevations

Vertical differential movement of floor slabs is accommodated by sliding brackets as the veil moves independently to the slabs in the vertical direction. Vertical differential movement capacity is limited by the lengths of the slots in the restraint brackets at each floor level.

Deflection of the Level 5 slab directly effects the shape of the veil on elevation as it is all suspended from this slab. Vertical deformation of the veil from the rectilinear grid installed on-site is accommodated by the flexing of horizontal members and silicone pointing between stone pieces.

Differential movement (racking) of the primary structural floors causes the veil suspension structure to deform out of square. Flexing at horizontal to vertical frame joints is restricted by flexing of the interlocking bracketry and the silicone pointing in stone to stone joints.

3.3 EWS-003, Stick System Curtain Wall

EWS-003 is located on the recessed South and East elevations. It is a bespoke solution dead-loaded at each slab. It consists of large double glazed units, some opacified with insulated panels behind, toggle-glazed into aluminium profiles on four sides. Each pane of glass is restrained by hidden toggles around the perimeter of each double glazed unit. The panels are all 3.5m tall. Panel widths range between 1.5m and and 3m.

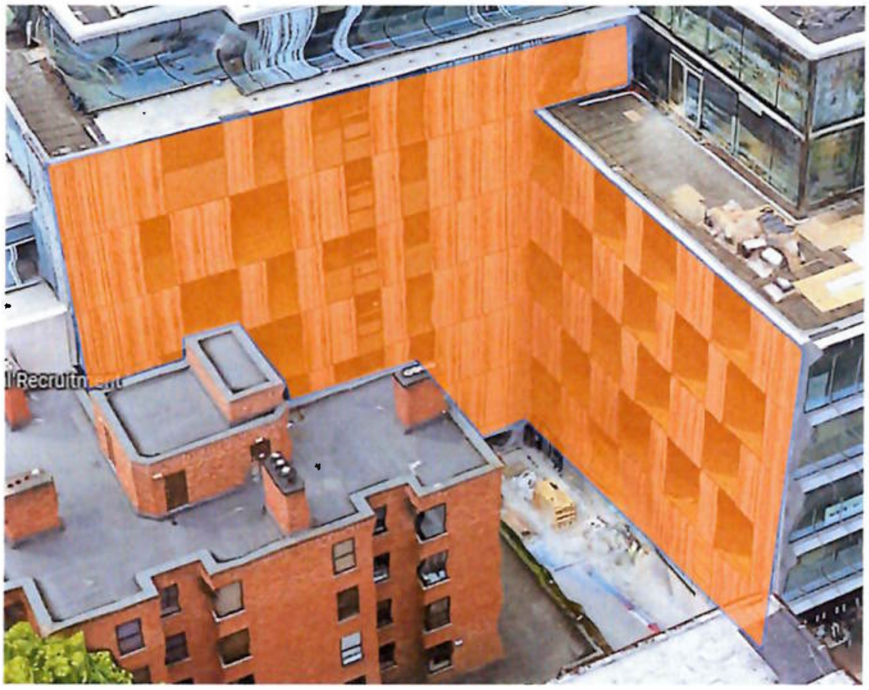

Figure 7 EWS-003 South and East elevations

Each panel of glass sits on a dedicated extruded aluminium horizontal profile at each floor level. Vertical differential movement of floor slabs supporting panels of glass is accommodated by silicone pointing externally and gaskets internally. Vertical differential movement capacity is limited by the lengths of the toggles at the head of each glass panel, and the silicone pointing. Lateral differential movement (racking) is accommodated by the toggles sliding in the top edge profile of the double glazed units. Racking of glass in the aluminium grid is restricted by the vertical mullions and associated toggles restraining the glass.

3.4 EWS-006, Entrance Glazing

The entrance glazing is a bespoke glazing system formed from curved double-glazed units up to 6.7m tall restrained by stainless steel flat plates at glass to glass joints. Due to their size and shape, the double glazed units are formed from laminated annealed glass rather than heat treated or toughened glass. This makes the glass particularly susceptible to breakage due to localised stresses.

Each panel of glass is supported on two deadload brackets at the base. The perimeter of each double-glazed unit is restrained by toggles. Stainless steel fins span vertically 6.7m between glass panels providing restraint against wind loads.

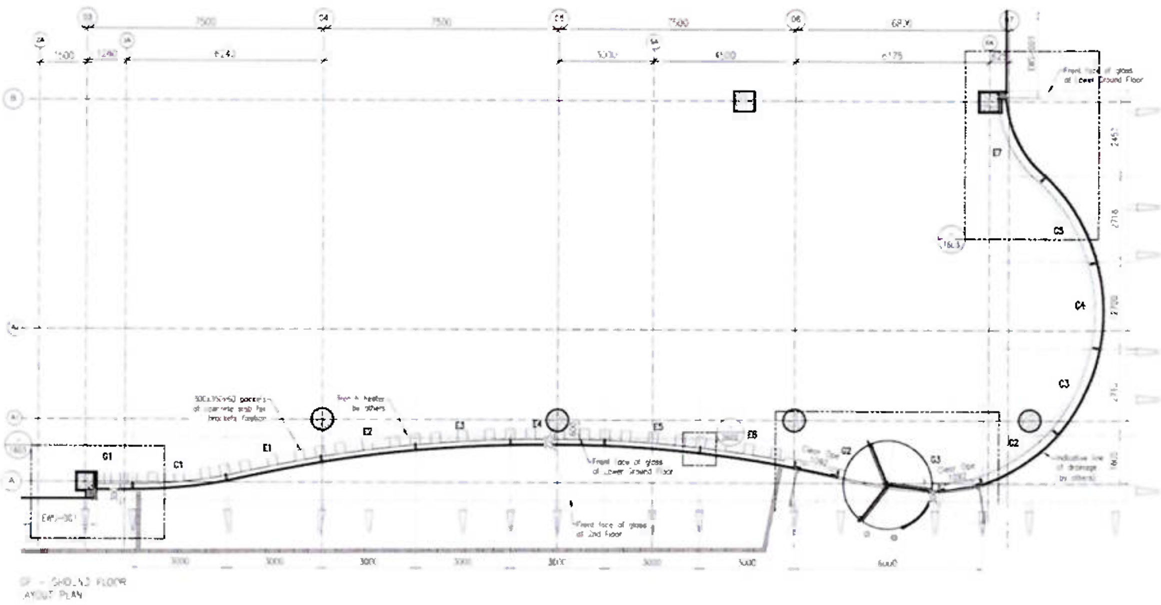

Figure 8 EWS 006 Entrance Glazing Double height curved glass. Plan view. (South is to the right of this image).

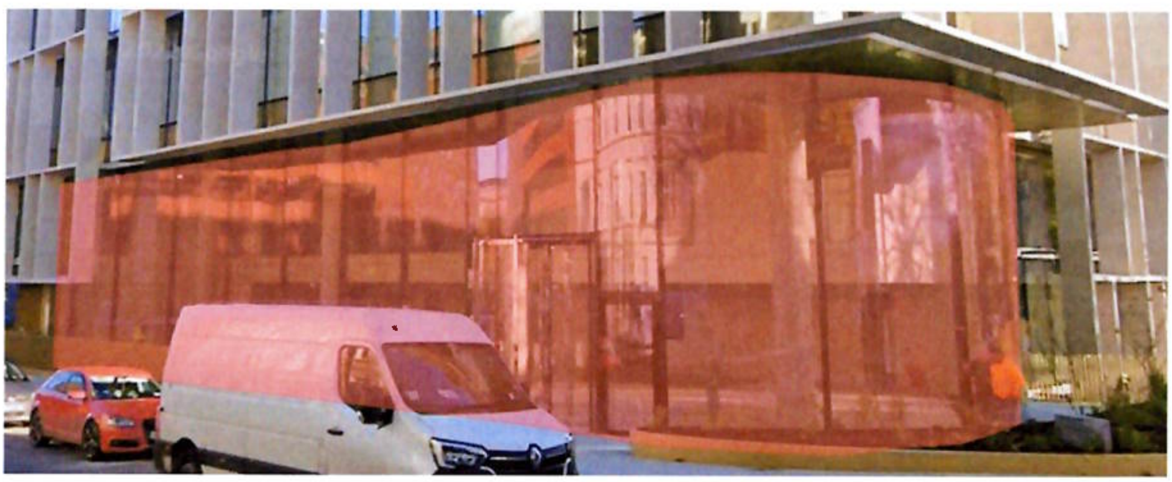

Figure 9 EWS 006 Entrance Glazing elevation scope. 6.7m bespoke curved glass screen

Vertical differential movement of floor slabs is accommodated by sliding brackets at the head of the screen. Vertical differential movement capacity is limited by the lengths of the slots in the restraint brackets at the underside of Level 2 slab. Deflection of the Level G slab directly effects the curved glass units on this elevation as they are all standing on this slab. Vertical deformation of the Level G slab is accommodated by rubber packers between glass panels and the steel vertical fins.

Lateral differential movement (racking) of the primary structural floors causes the entrance glazing screen to 'rack' out of square.

4 EFFECTS OF METROLINK CONSTRUCTION WORKS

4.1 Ground Settlement

TII Reference: Submission Number 129. Irish Life Assurance Submission 1, Page 3, and TII response. We refer to TII's document EIAR Appendix 5.17 Building Damage Report page 126 of 158 indicating significant differential settlement across the site of the Cadenza Building.

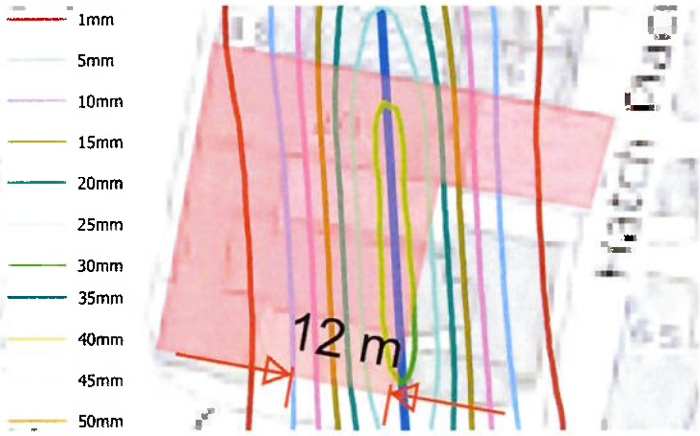

Figure 10 Plan of Cadenza with TII predicted ground settlement

MetroLink has assessed the predicted "Settlement" and presents its findings on drawing no. ML1-JAI- EIA-ROUT-XX-DR-Y-21146 rev P02. This drawing indicates MetroLink will be causing a <u>30mm</u> settlement directly under the location of our client's building which is unacceptable. Settlements of this magnitude cannot be accommodated by the building's facades. Such settlement, particularly if introducing differential settlement between columns, will cause damage.

From the published response received from TII, we understand they will be reviewing in more detail, the potential for ground settlement. The notes below are intended to assist TII in understanding the effect ground settlement could have on the facades at Cadenza.

4.1.1 EWS-001, Free Spanning Window Wall

Should the primary structure deform due to tunnelling below the building, there is a likelihood the façade system will suffer damage. Damage can occur due to differential settlement of a column along the elevation. With the current tunnel position as illustrated in Figure 10 above, the highest risk location for damage to EWS-001 is the SW corner as there is a predicted differential settlement of 25mm between gridlines C and D along the South elevation . If the tunnel were to be positioned 15m to the West, which is still within the maximum proposed horizontal LoD, the worst case differential deflection would be mid-elevation on the Southern elevation.

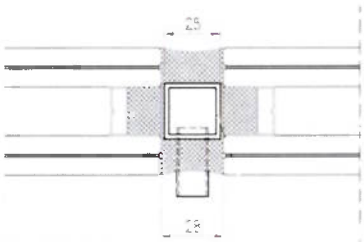

Figure 11 EWS-001 typical silicone joint. Plan view.

The vertical joint between double-glazed panels consists of 28mm silicone pointing with a 25mm PVC drainage tube. The silicone pointing can take small amounts of compression and tension. The PVC tube can accommodate small amounts of compression. If one column settles differentially, the glass panels either side of that column will rotate in plane compressing the silicone seal.

Due to the aspect ratio of the panels closest to gridline D on the South elevation, the TII predicted differential settlement of 25mm from Gridline C to D would result in 1.75m wide panels rotating in plane not less than 3.6mm at their base. As each panel is 3.5m tall this translates into 7mm rotation at the top corner of the panel. Such rotation would exceed the design parameters of the structural sealant at the glass to glass joint crushing and tearing the sealant and inducing stress in the glass. It may not cause breakage but will apply long-term stress into the structural sealant joint which may cause failure of the structural connection.

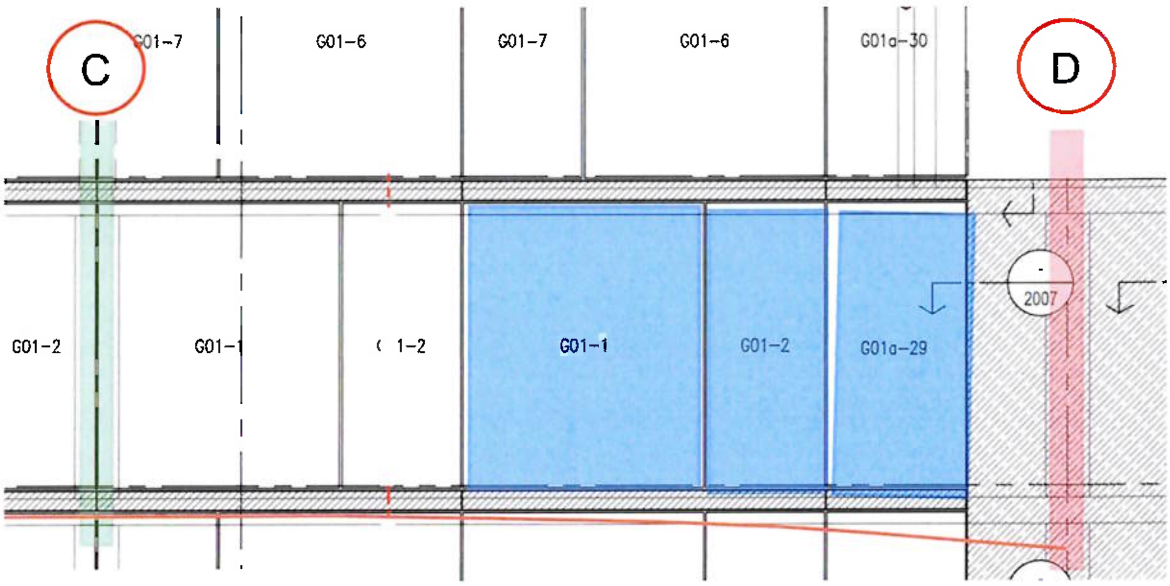

Figure 12 EWS-001 glass rotating due to differential settlement of one column (South elevation)

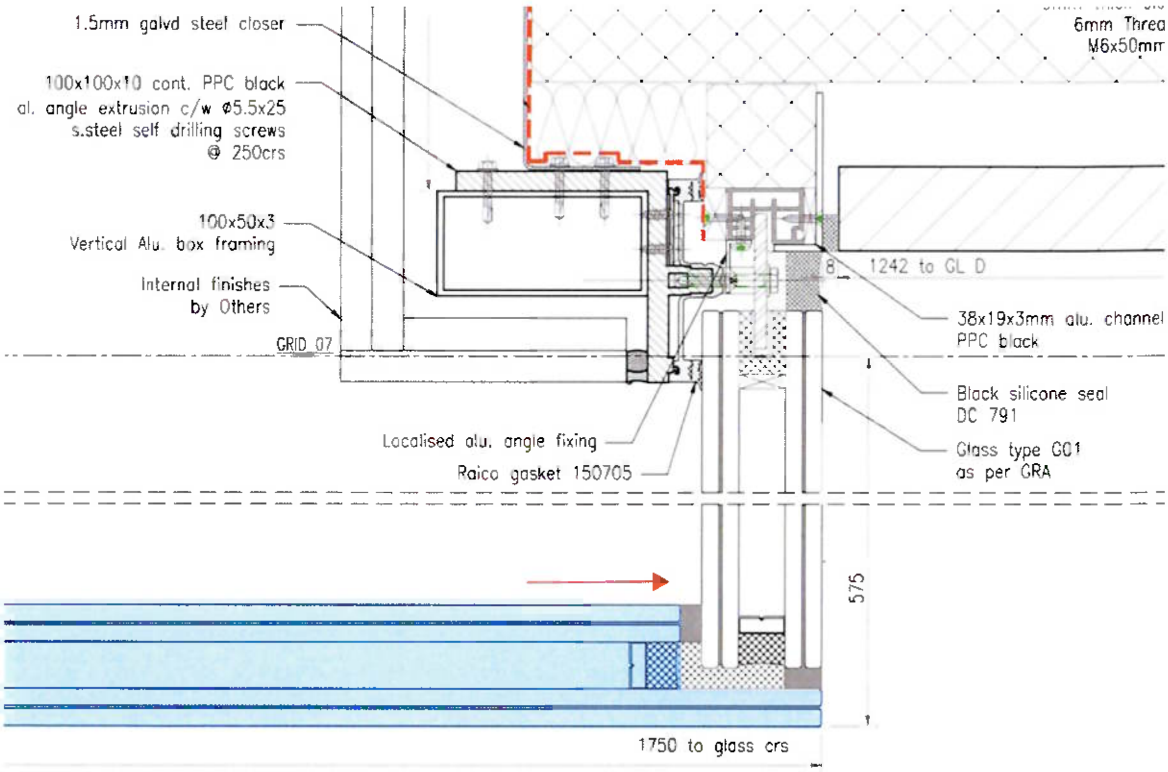

Figure 13 EWS-001 Plan view, glass-to-glass corner condition adjacent to Gridline D, South elevation.

4.1.2 EWS-002, Stone Veil

Similar to EWS-001, above, the worst-case condition for the stone-clad veil is differential deflection of a primary structure column. The diagram below indicates the gridwork of steel framing with stone cladding applied. All deadload is carried at Level 5, and wind-loads are accommodated at discrete brackets to the slab edges below.

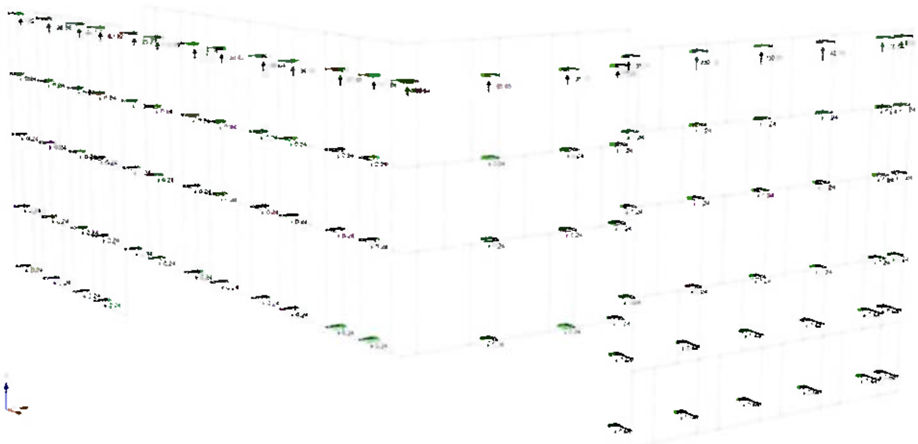

Figure 14 EWS-002 Steel frame with bracket locations.

The steel frame is designed to accommodate live-load deflections of the Level 5 slab and to withstand wind loads. The stone-to-stone joints are all 8mm with a non-staining silicone. Stone to bracket joints are 23mm to allow for differential movement between slabs of approximately

10mm. Horizontal stones are individually fixed to the steel structure via aluminium profiles and under-cut anchors. Vertical stones are connected back to the veil structure using stainless steel dowels into the edges of 40mm limestone pieces.

There are different stone profiles used depending on locations around the elevation. The three typical vertical profiles are shown in the image below.

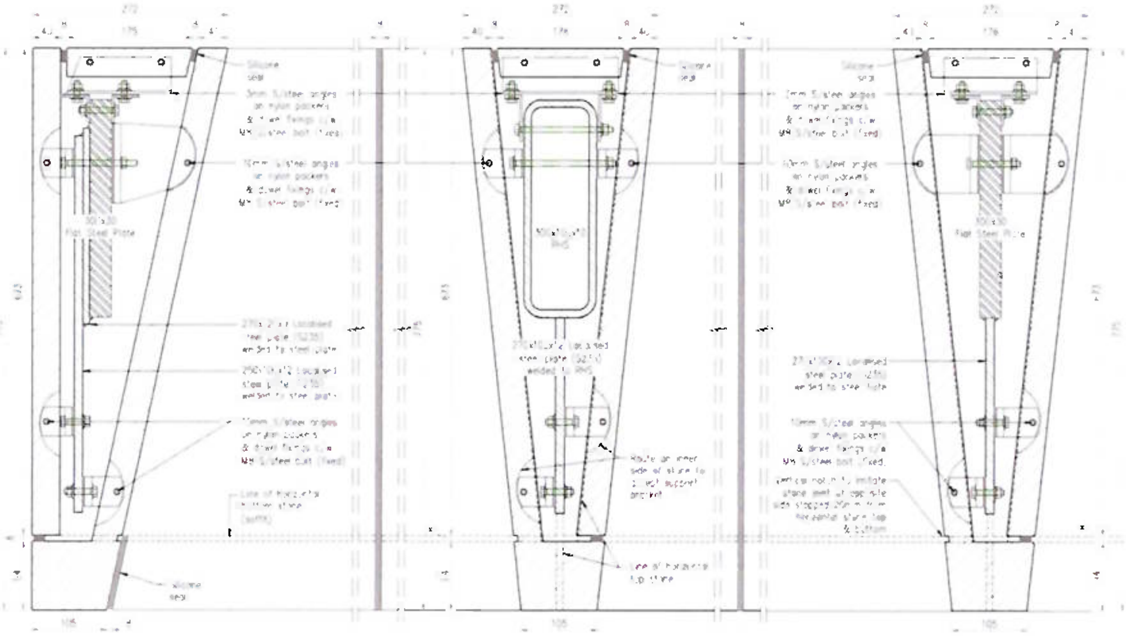

Figure 15 EWS-002 Plan section of stone profiles with support structure.

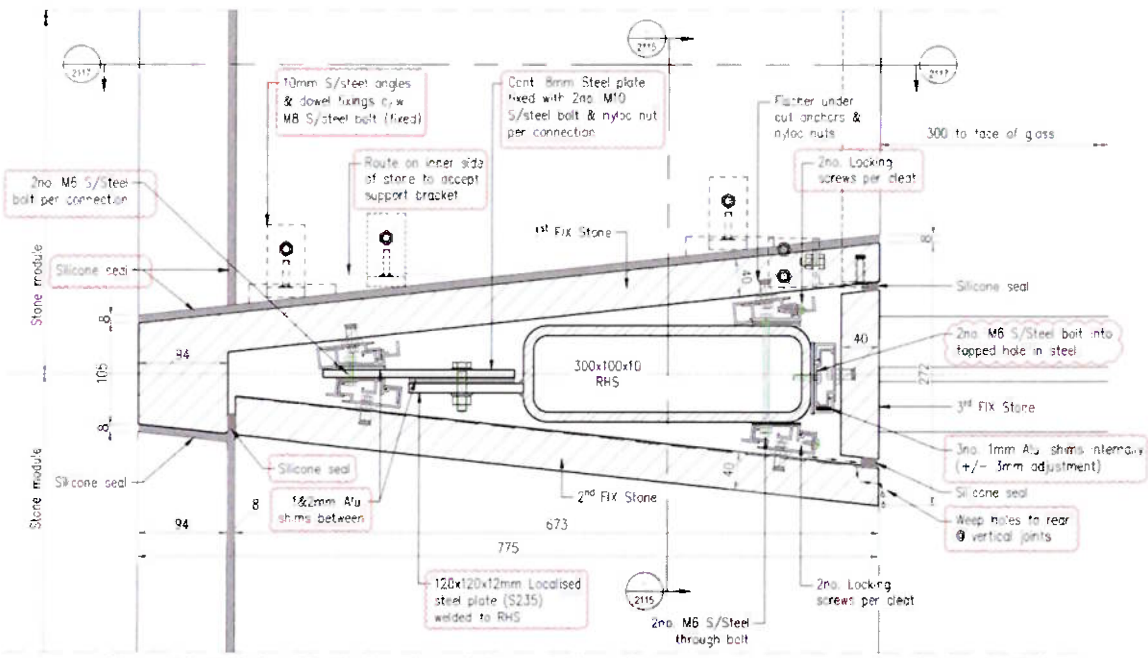

Figure 16 EWS-002 Vertical section of stone profiles with support structure (typical horizontal fin)

As can be seen from the diagrams above, the structure supporting the veil is entirely bespoke. Stone, being a fragile material, is extremely limited in its capacity to accommodate movement.

The diagram below looks to illustrate the effects of differential settlement of the column at Gridline D. As the Level 5 slab deflects, the veil goes out of square.

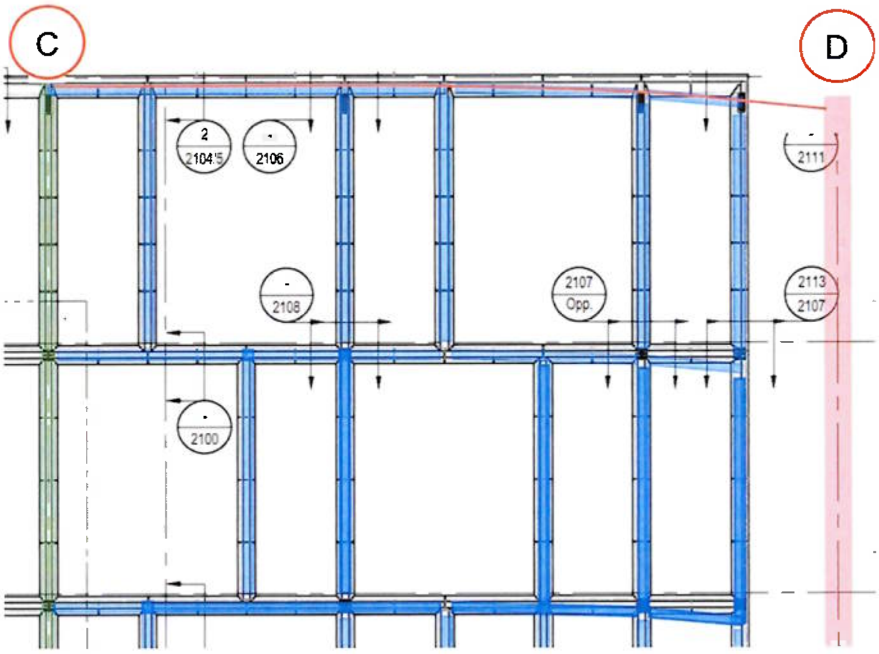

Figure 17 EWS-002 partial South elevation. Differential settlement of structure at Gridline D

The differential settlement of a column causes rotation of the connection between horizontal and vertical veil elements. These connections are typically formed with countersunk fixings tapped into a block of stainless steel. These connections were not designed to accommodate significant rotation. Detailed analysis would be required to determine how these connections react and whether the horizontal beams of the veil would rotate at these connections or be forced to go into bending ('S' shaped bend on elevation). If over-stressed the connections could fail.

If the horizontal beams or vertical mullions go into bending due to differential settlement, this could cause over-stressing of the fixings in the stone exceeding permissible safety factors and/or causing cracking of the stone.

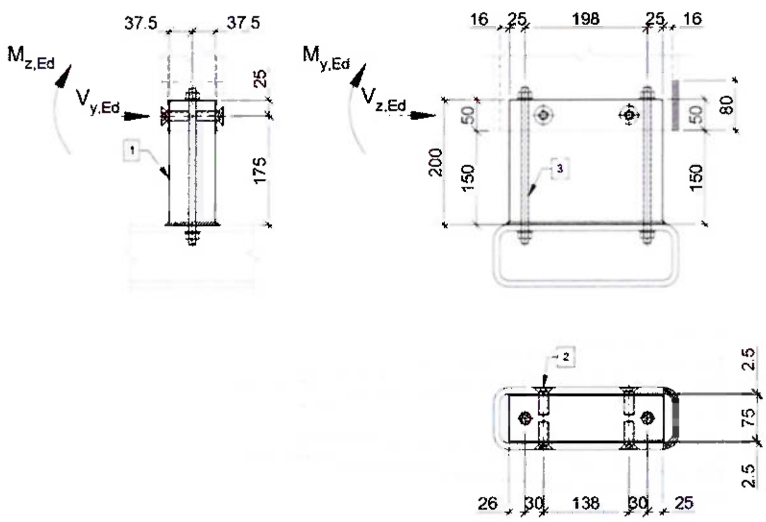

Figure 18 EWS-002 Example of veil steelwork connections

4.1.3 EWS-003, Stick System Curtain Wall

According to the TII's document EIAR Appendix 5.17 Building Damage Report page 126 of 158 the South elevation of EWS-003 will suffer differential settlement of 30mm from one side of the screen to the other.

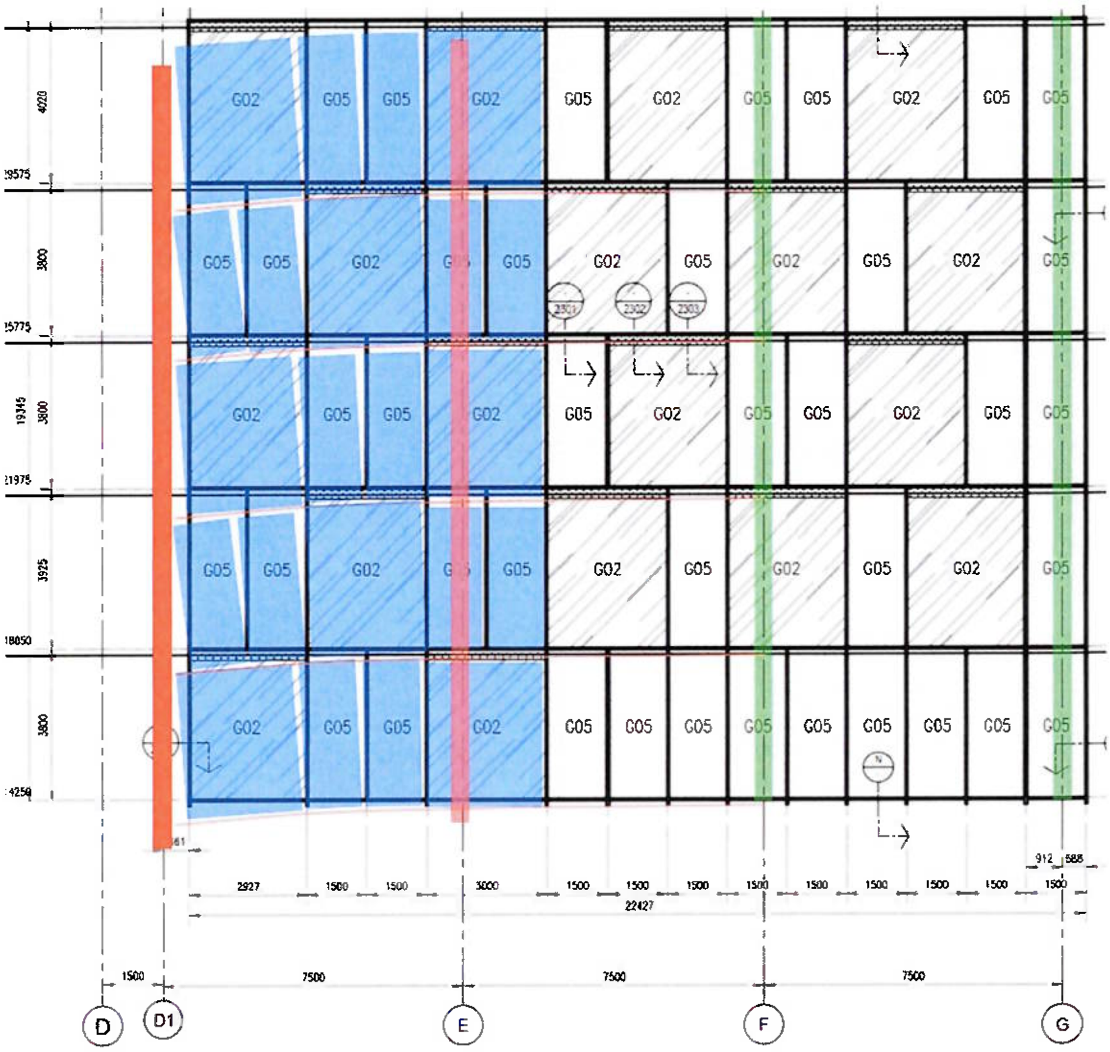

Figure 19 EWS-003 South elevation. Deformation due to ground settlement

The curtain wall system has very little capacity for racking of the glass on elevation. When the structure moves differentially as per the diagram above, the mullions remain vertical and the transoms rotate in plane. As each glass unit sits on a transom, the glass rotates with the transom. Based on the TII diagram there is approximately 30mm of differential settlement across quite a small width of approximately 10m.

Due to the aspect ratio of the panels closest to gridline D1 on the South elevation, the TII predicted differential settlement of 30mm in this area would result in 1.5m wide panels rotating in plane not less than 4.5mm at their base. As each panel is 3.8m tall this translates into 11mm rotation at the top corner of the panel. The toggle glazed system does not have capacity for this degree of movement. The mullion detail below shows the proximity of glass to metal. If the glass rotates too far, the inner glass impacts the aluminium mullion profile. The design gap, excluding glass tolerances and installation tolerances would be less than 6mm.

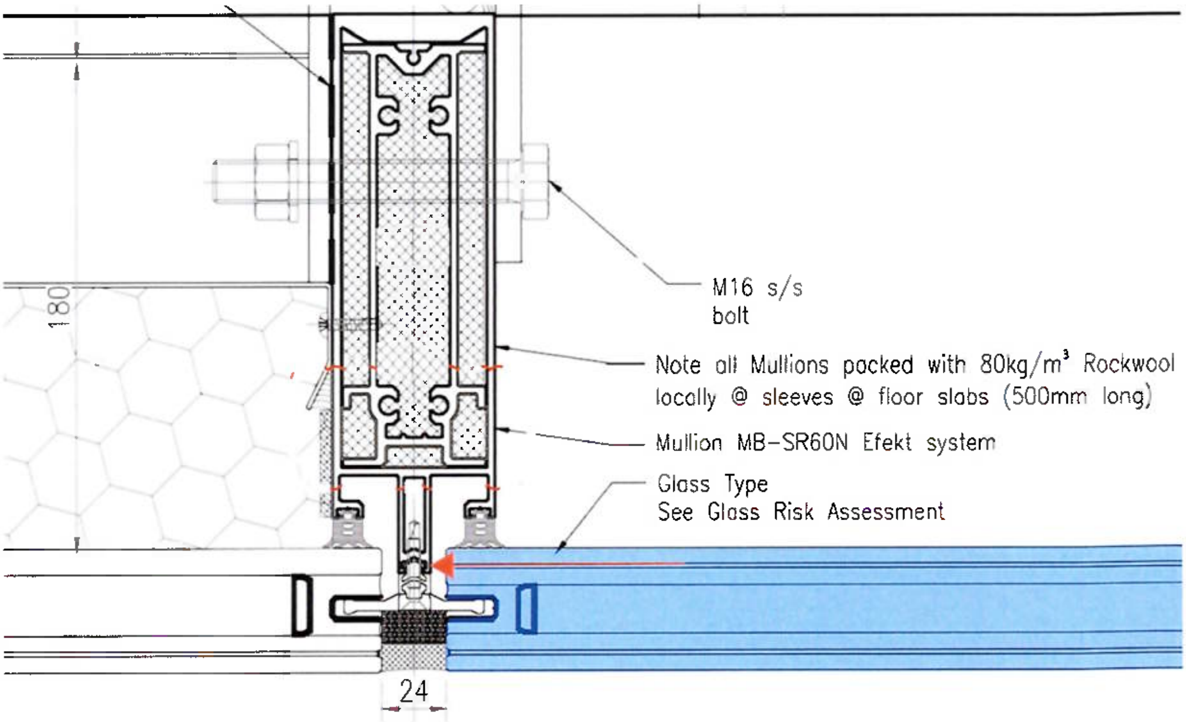

Figure 20 EWS-003 Plan section of glass to mullion interface.

4.1.4 EWS-006, Entrance Glazing

The entrance glazing is the most challenging façade system on the project and the most likely to suffer damage should there be differential settlement of the primary structure. As illustrated in Figure 10, if the TII works are positioned as intended, the entrance glazing should not suffer differential settlement. However, If the tunnel were to be positioned up to 15m to the West, which is still within the maximum proposed horizontal LoD, the worst case differential settlement would be applied to this screen across the South elevation where the glass is tightly curved and least able to accommodate racking on elevation.

The curved panels of glass are approximately 6.7m tall. The widest panel is 3.188m wide. To put this into context, 6m x 3.2m is the largest standard size of glass available. In order to get glass 6.7m tall, the float-line where the glass is changed from molten material to solid sheet, requires a special instruction to cut over-sized pieces. These then require specialist transport to the glass processor's facility as standard glass transporting trucks (called 'floatliners') are set up for carrying 6m lengths. Due to their size, the glass processor requires specialist equipment to convert the individual sheets of glass into laminated curved glass and then assemble into curved double glazed units. Due to the geometry of the building, each double-glazed unit in EWS-006 is unique.

The drawing below sets out the curved panel locations and dimensions.

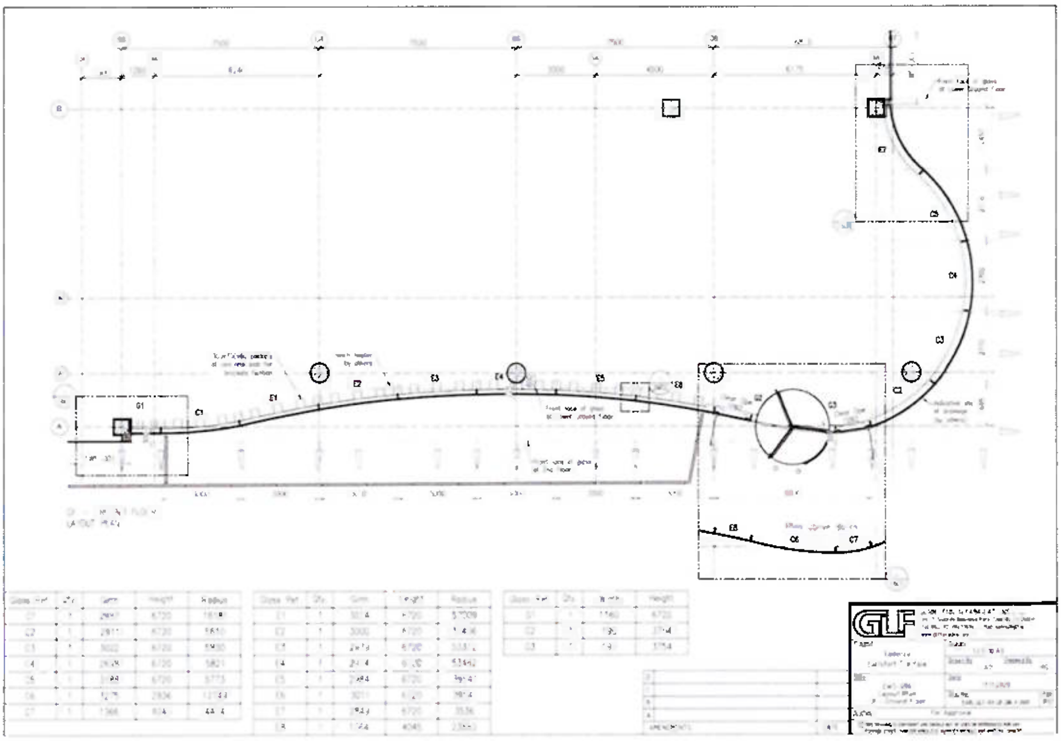

Figure 21 EWS-006 General arrangement and panel dimensions (South is to the right of this image).

The EWS-006 screen has been designed to stand on the Level G slab. Deflections of the slab were agreed by the designers and accommodated in GLF's detail design of the support system. The diagram below indicates the long-term deflection of the Level G slab taking into account live loads and long-term creep. The maximum deflection figures were derived from this.

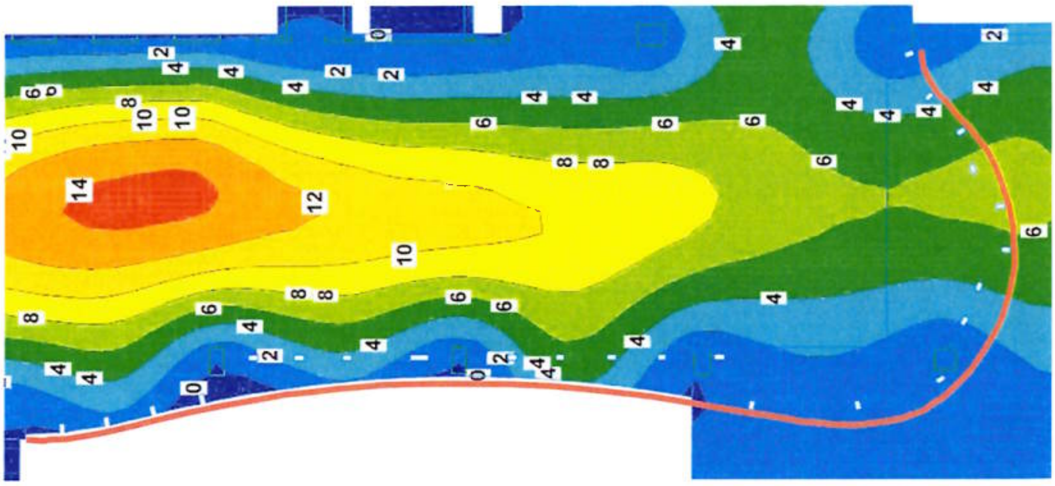

Figure 22 EWS-006 Level G slab deflections taking into account all design loads and creep.

The EWS-006 screen was plotted onto the deflected slab profile to determine the precise deflections at each point of support under each panel of glass. The glass stands on hard plastic packers adjacent to the two bottom corners of each panel. The table below indicates the plotted figures. Each double-glazed unit is named C1 to E7 as illustrated in Figure 16. The 'fins' noted below are mild steel fins which are located in each vertical joint between panels.

Tb. 15 – Ground floor slab displacements at supports.

Ref.	Girth (mm)	Support position (mm)	Concrete disp. Left (mm)	Concrete disp. Right (mm)	Ref.	Girth (mm)	Support position (mm)	Concrete disp. Left (mm)	Concrete disp. Right (mm)
Interface			0.0		E6	3006	635.7	2.7	0.2
G1	1160	246.0	0.0	0.0	Fin 8			0.0	
Fin 1			0.0		Fin 9			0.2	
C1	2987	631.8	-0.2	0.7	Fin 10			0.9	
Fin 2			1.1		Fin 11			1.1	
E1	3030	640.8	1.0	-0.5	C2	2912	616.4	1.3	1.6
Fin 3			-0.8		Fin 12			1.7	
E2	2995	633.4	-0.9	0.1	C3	3021	639.4	1.8	3.2
Fin 4			0.9		Fin 13			4.4	
E3	2975	629.1	1.6	1.5	C4	2697	570.8	5.1	6.2
Fin 5			0.8		Fin 14			6.4	
E4	2970	628.1	0.1	0.1	C5	3187	674.5	6.4	5.4
Fin 6			1.0		Fin 15			4.5	
E5	2979	630.0	2.4	4.4	E7	2800	593.6	3.6	1.3
Fin 7			3.7		Interface			1.0	

(1) Girth and support position measured from the glass edges.
(2) Downward displacements are positive. Upward displacements are negative.

Figure 23 EWS-006 Level G displacements at glass support points, after installation.

As can be seen from the table above, the maximum predicted deflection after installation of the glass is 6.2mm. This does not take into account deflection of the slab which occurs during the loading of the glass onto the slab. This was included, and the total deflection, worst-case is less than 10mm as illustrated in the diagram below.

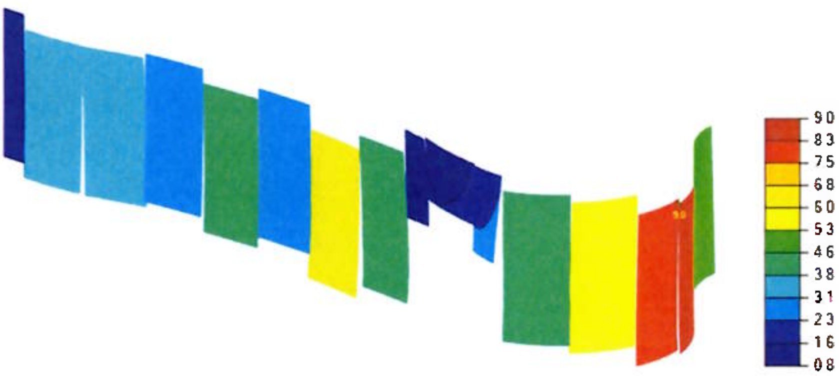

Figure 24 EWS-006 Total displacement of glazing panels including movement due to self-weight

The differential deflection of the slab due to the design loads has been reviewed, and the in-plane rotation/deflection of each individual panel plotted. Although the worst case vertical displacement is on the South, the worst-case rotation due to differential deflection across the width of a single panel, occurs on the East elevation. This is illustrated in the diagram below.

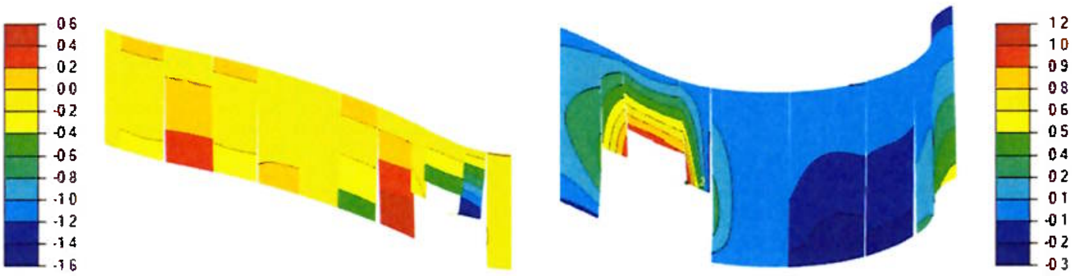

Figure 25 EWS-006 Horizontal displacement due to vertical deflection of Level G slab.

The double-glazed panels are restrained to only move vertically when the slab deflects. This lateral restraint is provided by a factory applied curved angle assembly structural silicone bonded to the glass (structural silicone shown red in the diagram below) at the head of each unit. This in turn engages with a local bracket fixed to the soffit of the slab above. The bracket has vertical slots are shown in green below allowing for deflection of the L01 slab while restraining movement along the screen (in and out of the page in this diagram).

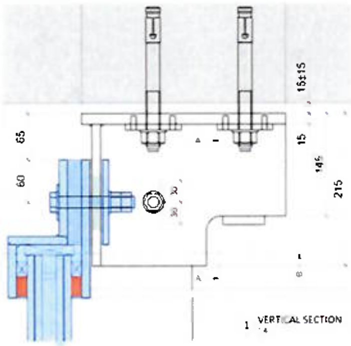

Figure 26 EWS-006 Head restraint detail.

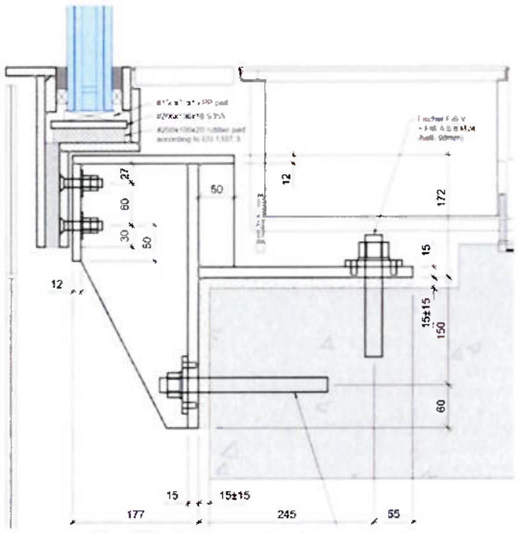

Figure 27 EWS-600 Base detail, deadload support.

The glazing system has vertical fins between each double glazed unit. The fin is intended to provide resistance to wind load but has limited capacity to resist lateral in-plane loads. As can be seen in the diagram below, should the glass restraint at the head fail and the glass rotate in plane, there is a high risk the perimeter internal silicone seal would be crushed resulting in glass to metal contact.

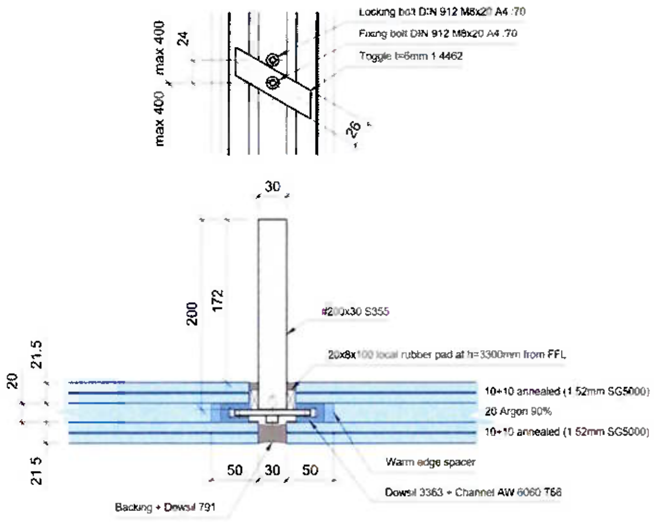

Figure 28 EWS-600 Plan detail of glass to glass joint with steel fin

Should settlement due to MetroLink works cause the Level G slab deflect more than anticipated in the current design, it is possible the permissible long-term shear load in the structural silicone at the head detail will be exceeded. If the head restraint were to fail, allowing the panel of glass to rotate in plane (along the elevation), there is a high risk of glass breakage due to metal to glass contact and/or glass to glass contact.

It is also possible the concentration of load on one deadload support at the base of the glass would over-stress the glass causing failure.

4.2 Vibration

As can be seen from the notes above, the envelope on Cadenza is bespoke and has been designed to suit the project specific performance criteria, including structural movements. We note there is limited information available as to what vibrations will act upon the building during the MetroLink works.

Vibration can cause working loose of fixings, working loose of shims, and movement of components where they would otherwise not be at risk. There is limited guidance available for design of façade systems for specific vibration events other than earth-quakes. As the facades have not been designed for earthquake conditions, we cannot ascertain whether vibrations from MetroLink works would cause damage to the facades on Cadenza.

We ask that TII provide detailed confirmation of the predicted vibrations for this to be assessed.