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Lower section

Funicular Railway

Inspection report - 2018

Job name: **FunInsp 2018**
Job number: **18011**
Client: **Cairngorm Mountain Ltd**
Engineer: [redacted]
Date: **July 2018**

Revision	Date	Comments
A	24/07/18	Initial information

Index:

1. Introduction:

1.1. At the request of Cairngorm Mountain Ltd, the Client, the writer carried out a visual inspection of the concrete support structures to the Funicular Railway at the Cairngorm Mountain resort. The writers brief was as follows: *"To carry out a non-disruptive visual inspection of those areas of the concrete support structure that are fully exposed and safely accessible and to report on the findings".* This report follows a similar format to that produced by this office in preceding years.

1.2. The scope covers the external support structure plus the track bed within the tunnel. This report specifically does not address the top or bottom station, the rails or their supports nor the running stock.

1.3. The purpose of this report was to comment on the integrity of the concrete components of those parts inspected, within the limitations of the brief and inspection techniques.

1.4. The inspections were carried out on a number of days and evenings through the Summer of 2018. The weather was generally fine.

1.5. The structural inspection was carried out by means of visual inspection and measurements, generally from ground level and where it was safe to do so from track level. No disruptive investigations, geotechnical investigations or materials testing were carried out, nor were any calculations carried out.

1.6. This report may not be relied upon by a third party for any purpose without the written consent of this practice. Furthermore, this report has been prepared and issued specifically for the benefit of the addressee and no responsibility will be extended to any third party for the whole or any part of its contents.

1.7. This inspection and report were carried out ahead of the 2018 repairs programme, so many of the items on the 2017 report will appear in this report as well. Many of the combined items will be addressed during 2018 summer work programme.

1.8. Items requiring attention are highlighted in yellow.

2. Executive summary:

2.1 The writer now has the insights from 4 years of inspections. The structures condition is disappointing for its age, regardless of its environment. There are various defects appearing that demonstrating an ongoing deterioration of the structure. The writer cannot project forward with certainty for 25 years but he is concerned for the Client if they are fully exposed to the maintenance and repairs liabilities of this structure for this length of time.

2.2 The writer feels there is a differential to be drawn between maintenance, repair of direct damage and repair of construction defects.

2.2.1 A concrete structure of this age should not require wholesale maintenance, occasional random repairs may be reasonable, but systemic defects are not. The exception to this may be the plinths due to the nature of loading experienced.

2.2.2 Repair of direct damage is clearly required. Examples would include damage to the beams due to impact from snow clearing equipment.

2.2.3 Repair of construction defects. These should not exist and the writter does not regard their repair as “maintenance”. The writter considers that much of the work being carried out historically and currently falls in this category.

2.3 All items of a “structural strength” nature have been addressed on an immediate basis and we have seen some of these. Most of the items being addressed currently, and planned for, relate to “serviceability issues”, in this case this means longevity due to cracking. If these issues are not addressed, then the deterioration will accelerate and may become of a “structural strength” nature, although this would take several years. More can be found on this within the body of the report.

2.4 Along with a range of seemingly random defects there are a number of items that recur at numerous locations along the track. The 2015 report identified numerous defective plinths and a number of defective grout packs to the Ancon bearings, it appears that this has been bought under control with none of these items found in this report. Other items that can be categorised as cracking, exposed reinforcement and Halfens are being found in increasing numbers. Some of this may be as we look harder for them specifically, but the impression is that there is ongoing deterioration. Instances of mechanical damage are also recorded, but these are to be expected when working close to the beams with snow clearing equipment – care in these operations should reduce the number of instances.

2.5 This report recommends numerous repairs to improve the longevity of the structure plus two items of greater significance, see below.

2.6 There are two locations where major repairs are being recommended to reinstate what is believed to be part failed continuity reinforcement over the supports. These repairs are intended to improve the longevity of the structure. These matters are being followed up under a separate **ADAC-***structures* job number, ref 18007.

2.7 Whilst out with the scope of this report, it was noticed during this year’s inspection that the Ancon sliding bearings are operating out with their design limits in some instances. This has led to damage to the bearings and is expected to be causing undesirable forces within the structure. This matter is being followed up under a separate ADAC-*structures* job number, ref 18013.

3. Scope and references:

3.1 An inspection schedule was set up to look at the following areas:

3.1.1 Thrust blocks

3.1.2 Pier

3.1.3 Pier crosshead

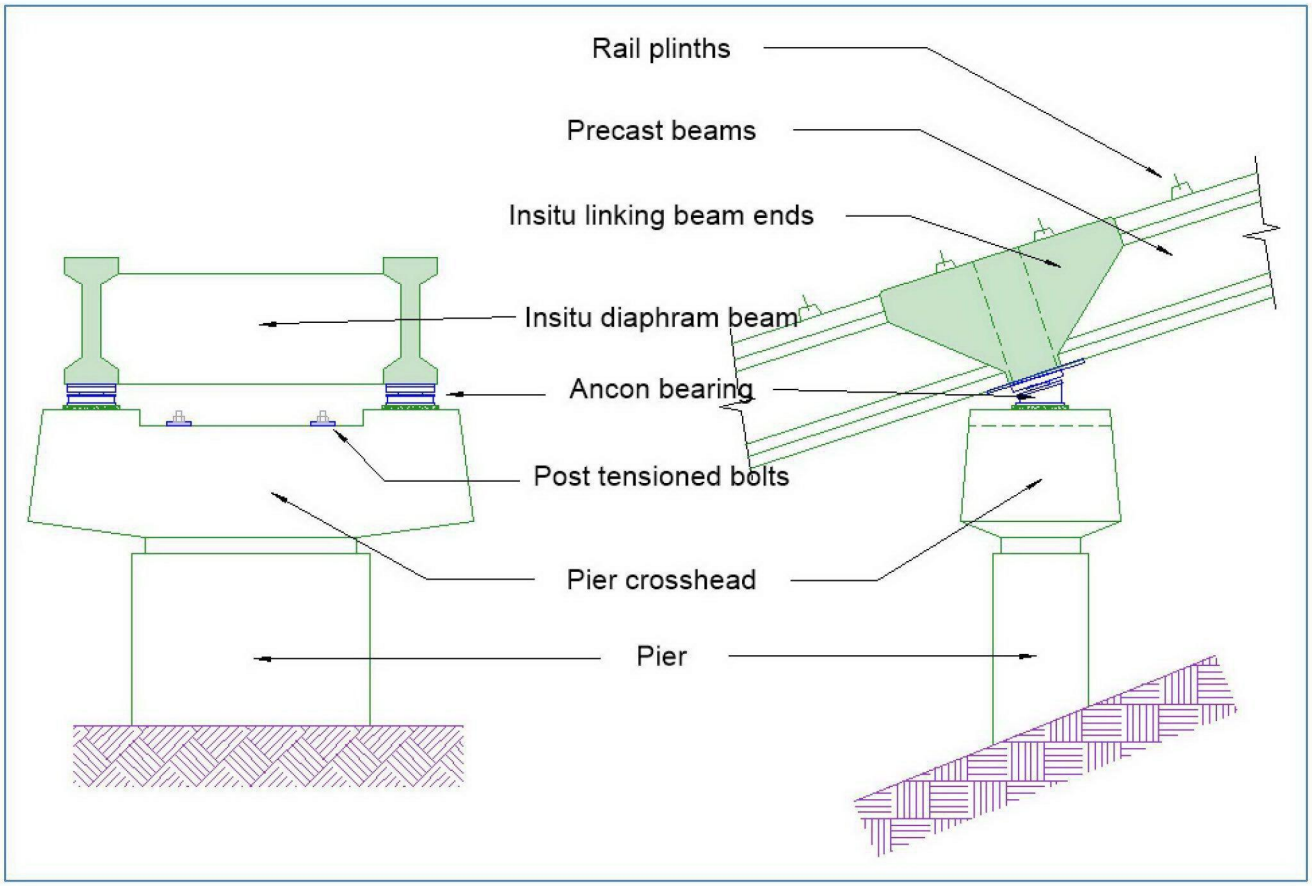
3.1.4 Ancon bearing plate grout

3.1.5 Insitu crosshead

3.1.6 Insitu to beam ends

3.1.7 Precast beams:

3.1.8 Rail plinths:



Sketch showing structural elements:

3.2 The referencing system is as follows:

3.2.1 Elevated length of railway (most of it):

A. Upper refers to the part highest up the mountain

B. Lower refers to the part lowest down the mountain

C. Left refers to the left-hand side as viewed looking up the mountain

D. Right refers to the right-hand side as viewed looking up the mountain

E. All numbering relates to the nearest pier below that point.

3.2.2 Tunnel section:

F. Within the tunnel the plinths sit on a continuous ground bearing slab.

G. The tunnel is broken into lengths for referencing purposes. Each length starts at a sheave in a similar way to the pier referencing system.

H. The numbering starts at the tunnel mouth where there is no sheave, so this point is referred to as SH00. The first sheave inside the tunnel is referenced SH01 etc.

I. The plinths are numbered consecutively from each sheave.

J. Left and right are as for the elevated length.

4. Funicular Railway observations:

The writer inspected the items listed in the schedule at item 3.1 of this report. It was reported that the installation had been completed in 2001, making it 17 years old. The general condition was thought to be poor for a structure of this age with wide spread minor deficiencies giving a general impression of poor quality control during the construction phase.

4.1 Thrust blocks:

4.1.1 Over the approximately 1600m of elevated track outside the stations and tunnels there are a total of 7 thrust blocks, including the lower end. These are at varying spacing from approximately 250 to 300m. The general piers have slip bearings parallel to the longitudinal axis of the track so all longitudinal forces are resisted by the thrust blocks. These forces can be substantial, particularly on the steeper sections where they carry a significant portion of the gravitational load of the relevant 300m section of concrete beams.

4.1.2 Thrust blocks are located at the following piers:

Pier 0
Pier 14
Pier 29
Pier 48
Pier 65
Pier 78

4.1.3 Horizontal shear cracking was observed between the upstand block and the main bulk of the foundation at: Ref photo [1]

Pier 48
Pier 78, this was repaired in 2017

4.1.4 The top surface of the main bulk of the foundation had surface cracking that appeared to mirror the reinforcement grid below at 200mm c/c at:

Pier 65
Pier 78

4.1.5 On top of each thrust block there is a rail movement joint. This includes a large steel plate that has a grout pack underneath. There is some deterioration of this grout. The top end of at all these locations were sealed in 2017, however it is recommended that at pier 29, on the right side, the grout pack be sealed all around.

4.2 Main piers:

4.2.1 Generally these items appeared in good condition.

4.2.2 Description: Fractures of the main piers were observed at a number of locations. The available drawing show that the piers were pre-cast shells that were infilled with insitu reinforced concrete. It is therefore concluded that cracks to the shells are of no grave consequence, although they should be reviewed at each annual inspection. Ref photos [3], [4].

Location: Pier 3 vertical crack in bottom downhill face casing, repaired.
Pier 32, horizontal crack showing efflorescence near bottom downhill face.
Pier 43, horizontal crack showing efflorescence at mid height right face.
Pier 44, efflorescence showing on side faces, RHS bottom and LHS top.

Pier 45, vertical crack showing efflorescence at mid height downhill face.
Pier 46, horizontal crack showing efflorescence at mid height on downhill and left face
Pier 51, horizontal crack near bottom downhill face. Also spalling at joint on uphill face.
Pier RHS 52, small vertical crack mid height left face.
Pier RHS 53, small spall at mid height uphill face.
Pier LHS 54, spall at mid height upper left corner, plus mid height on uphill face.
Pier 69, minor spalling at top on downhill face.
Pier 72, lowest unit showing signs of frost damage and seepage through horizontal crack. Vertical crack on downhill face of lowest unit. Vertical crack on left and right face, mid height.
Pier 91, cracks with calcite bleeding on all faces.
Pier 92, right face of mid shell cracked with calcite bleed.
Pier 93, uphill face of top shell cracked.

Recommendation: There is no cause for concern at this time.

4.3 Main cross heads:

4.3.1 Generally these items appeared in good condition.

4.3.2 Description: Cracks, chips and missing chunks were seen in some cross heads.

Location: Other than pier 93, the following items were recorded in previous years:
Piers 52 and 55.
Pier 58, lower corner chipped. Crack in upstand.
Pier 63, uphill face, chip bottom middle.
Pier 75, chip on top side of top face.
Pier 81, lower face at junction with pier an old chip.
Pier 83, two minor chips.
Pier 84, W upstand cracked around base, possibly a construction joint.
Pier 87, W downhill corner breaking up.
Pier 93, see below.

Recommendation: Patch repairs are recommended to match the existing. This is not thought to be urgent.

4.3.3 Description: Crack through pier cross head, running up one face and through the PT bolts holes on the top and down the other side, this is apparent on the line of both PT bolts. This appears to be a development on the previous year, when the cracks were only recorded on the line of one bolt. Ref photos [5].

Location: Pier 93.

Recommendation: This would not be a concern in its self as the cracks are of a minor nature, but the appearance of a developing situation is of concern. Crack monitoring studs have been installed and will be monitored until a feel for the situation is achieved.

4.4 Specialist Ancon bearing plate grout:

4.4.1 Generally these items appeared in good condition.

Description: In previous years a number of these items were seen in a poor condition and were repaired. No items were identified for repair this year.

Location: N.A.

Recommendation: N.A.

4.5 Insitu concrete joints:

4.5.1 Description: The construction drawings made available for the insitu area are stamped "preliminary" leaving doubt over the construction details. The drawings show a system for mechanical coupling of the reinforcing bars to provide continuity at some locations. One of these couplers is specified as an Ancon PB32, which involves an onsite grouting operation, this would be susceptible to poor quality control. For operational reasons close quarters examination of this joint as a train passes was limited to one location, pier 56, during the 2016 inspection. Here the crack was clearly seen opening then closing again, by an estimated 1mm, as the train passed. The concern here is that the coupler may have failed leading to a redistribution of stress to the midspan of the beams. Correspondence with A F Crudens, Consultant Civil and Structural Engineers for the scheme, confirm that the beams were designed to have sufficient strength as a simply supported beam, but that continuity reinforcement was added to restrict deflections. If this coupler has failed then greater than desirable deflections would be expected at mid span leading to compromised durability of the structure. This appears to be happening. Ref photo [7], [8], [9].

During 2018 there was an opportunity to take measurements whilst the train was fully laden with test weights. This work was carried out as part of ADAC-*structures* project 18007 and is reported in there. In brief this demonstrated that there was continuity of structural action over the supports, but that this was significantly compromised at pier 56.

Location: Opening of the joint line between the precast beams and insitu fill. This was wide spread although not universal. The worst location was at pier 56 which has featured in most reports since 2008 (the earliest report available).

Recommendation: Reform the insitu joint at beams 9 and 56. This is currently being worked on under ADAC-*structures* project number 18007.

Elsewhere inject the joint with resins to prevent water ingress and consequent rusting of embedded reinforcement.

4.5.2 Description: Significant shear cracking on top of insitu concrete. This appears to indicate the failure of lapped reinforcement. This is most likely either due to inadequate lap or poor quality concrete. Ref photo [11].

Location: Above pier 9.

Recommendation: Break out the top half of this insitu and ensure reinforcement arrangement meets requirements for continuity and reform in good quality concrete, see 4.5.1 above.

4.5.3 Description: Cracking within the insitu fill, between the precast beam ends. This generally appeared as vertical cracks, often with considerable calcite bleed, sometimes white, elsewhere stained brown. Ref photo [10], [11].

Location: Insitu fill, between the precast beam ends generally.

Recommendation: Monitor for developing problems.

4.5.4 Description: Fracturing of the flange ends of the precast beams, usually the bottom flange. At the time of writing some work had started to adress this. The crack lines were drilled and resin injected to seal them. In most cases the described block of concrete fell away at the interfance with the reinforcement – these then became local mortar repairs. It appears that this block of effectlvely unreinforced concrete is fracturing off at the bearings possibly due to some minor eccentricities of the bearing. In some instances the failure is seen in the top flange Ref photos [12], [13], [14].

Location: Mostly lower flanges of the precast beams where they bear on the bearing plates. Refer to appendix A for a schdule of observations.

Recommendation: Where applicable, resin inject cracks to seal against water ingress and to reduce the risk of corrosion problems. Where the block of concrete falls away as described above then the repair is do be done in mortars with stainless steel reinforcing dowels.

4.5.5 Description: Small cracks were observed running down the top flange of the precast beams and also in some of the insitu fill areas in line with the rail fixing points.

Location: This was observed particularly in the upper part of the system.

Recommendation: This should be part of a watching brief, no action is recommended at this time.

4.6 Problems with the precast beams, general.

4.6.1 As a point of reference a couple of beams are offered as in "good" condition. From pier 49 up and pier 78 up right. All beams would be expected to be of this standard.

4.6.2 General comment: Cracking >0.2mm width is present in a large number of the lower flanges of the precast beams. However, the majority of cracks do not exhibit rust staining and do not appear to be 'live' i.e. they do not appear to open and close under different load conditions.

1 The majority of precast beams have slightly larger cracks in the lower flanges at about the third points – the exact locations vary, but there are usually cracks at about one-third of the span, measured from either end. Typical crack widths vary upto 0.7mm, with an average of 0.4mm. These cracks are usually open i.e. they have not self-sealed over the years due to calcium carbonate formation. In a significant number of cases, these larger cracks are associated with rust-coloured deposits on the soffits of the beam, indicating the probability that some corrosion is occurring to the reinforcing steel within the lower flange area. Where these larger cracks occur approximately 50% have some associated rust staining.

2 The majority of precast beams have slightly larger cracks at their junction with the in-situ concrete of the crossheads. Usually the cracks are larger at the upper flange, tapering to zero by mid-web. Typical crack widths vary upto 1.0mm, with an average of 0.5mm. In a significant number of cases, these cracks are associated with rust-coloured deposits on the surface of the precast concrete web, indicating that some corrosion has occurred of the reinforcing steel which originally protruded from the precast beam prior to being surrounded by in-situ concrete.

BS 8110-2 section 3 clause 3.2.4.2 states that to prevent corrosoin in aggressive environments the crack width should not exceed 0.3mm. There are many instances where this limit is exceeded and it is no surprise that rust staining is being seen.

The possibility of ongoing corrosion of the reinforcing steel should be considered, together with the long-term consequences of this, should it be left uncorrected. It is recommended that measures should be taken to seal any cracks where rust-staining is apparent, so as to eliminate oxygen and water ingress.

A detailed assessment of what has caused this cracking has not been carried out, but it seems likely that there is more than one cause.

Location: Cracking to the bottom flange of the precast beams - general. Ref photos [19], [20], [21]

Recommendation: A detailed assessment of what has caused this cracking has not been carried out, but it seems likely that there is more than one cause. It is recommended that a capilliary and

crack sealing product be applied to one or two particularly bad beams as a trial and monitored for performance, if it proves satisfactory then it be rolled out to all problem areas.

4.6.3 Description: Mechanical damage to the main beams, presumably from snow clearing activities. The recommendations below apply to anywhere this sort of damage occurs both now and into the future.

Location: Refer to appendix B for a schdule of observations.

Recommendations: It is recommended that where they extend to a depth exceeding 10mm that repairs are carried out to ensure the life expectancy of the structure is not compromised. .

4.6.4 Description: Some reinforcement exposed in the precast beams, these appear to be shear link leg tail ends. The number of instances of this appears to be increasing.

Location: These have been found mostly in the webs of the beams, but also on the soffit. Refer to appendix C for a schdule of observations.

Recommendation: Any exposed reinforcement should be fully exposed, assessed for ongoing capacity, cleaned and a patch repair carried out that will provide the bar with corrosion protection in the long term.

4.6.5 Description: A repeating pattern of micro cracking was observed between the bolts through the web of the precast concrete beams at the cross bracing connections.

Location: This was wide spread, but an example can be seen at beam 4 up and illustrated in photos [15], [16].

Recommendation: None of these observations were of a scale or nature to give rise to concern.

4.6.6 Description: A number of beams showed longitudinal cracking in the top flange. It is thought that these are cold joints – a dissappointing feature in a factory made item. Ref photo [17]

Location: This issue was seen at the following locations, each occurrence was slightly different:

43 – R/B, top flange inside face, longitudinal fracture approximately 150mm.
51 – this item was repaired in 2017.
93 – T/L, top flange under plinths L17 & L18.

Recommendation: At this stage beams 43 and 93 are not a concern.

4.7 Problems with grout plinths to the rails.

4.7.1 Refer to appendix D for a schedule relating to matters related to the plinths. This schedule includes historic observations and actions for reference. Ref photo [22], [23], [24]

4.7.2 Following on from work programmes in the preceeding two years it appears that the worste of the plinth problems have been adressed and no new problems requiring repair were found this year.There are a number of items that have been recorded as requiring action but we have not found record of when these were done. These items were not seen as a problem during this years inspection. Recommend a review of these items.

4.7.3 There are Halfen channel details cast into the upper face of the beams with protruding bolts which run up through the plinths and secure the rails. Movement in this area is evidenced by rust staining on the top of the beams immediately below the plinth giving the appearance that a “pumping action” has been happening. It is not clear at this stage if the movement is of the cast in item or of the bolt in the chanel. It is recommended that the torque on the securing bolts is checked and if this is

found to be fully tightened then the concrete around the chanel to be injected with resin to secure it.

4.7.4 Garaventa stated that any plinths that have failed should be replaced at the earliest opportunity and that the failure of two adjacent plinths is not acceptable. It is recommended that guidance in greater detail is obtained, asking the following questions:

A. Given that repeated instances of plinth failure are being observed, what are the criteria under which the railway should be closed pending plinth repair? (eg cracked plinth, one failed plinth, two adjacent failed plinths).

B. Can steel shims be used to create a short-term repair?

C. Do steel shims provide all the same support and restraints that the grout plinths do?

D. Can the steel shim arrangement be left in position permanently?

4.8 Miscellaneous:

4.8.1 The rock anchors that are seen protruding from the thrust blocks and their associated bearing plates have no applied corrosion protection. Discussions with the manufacturers in 2015 indicate that this is acceptable due to the type of steel used in manufacture. The bearing plates do not bear evenly and any grout under them is crumbling. It is assumed that these components are fully anchored within the mass of the concrete thrust block and that this is not an issue.

4.8.2 The original metal lifting eyes cast into the tops of the precast beams are exposed in many instances. These do not appear to be corroding and this is not thought to be an issue.

4.8.3 There is a partial walkway along the length of the railway for inspection and maintenance. It would appear that the components to complete the walkway are on site and lying on the ground. It would make inspection and maintenance work significantly safer and easier if this walkway was completed. Additionally there are a number of loose retaining clips on this walkway, these should be secured as they present a trip hazard. It is my recommendation that this work be carried out.

5. Recommendations general:

The writer inspected the items listed in the schedule at item 3.1 of this report. It was reported that the installation had been completed in 2001, making it 16 years old. The general condition was thought to be poor for a structure of this age with wide spread minor deficiencies giving a general impression of poor quality control during the construction phase.

5.1 Implementation of recommended repairs generally:

5.1.1 There are numerous repairs recommended within section 4 of this report.

5.1.2 The implementation of a number of the repairs recommended within this report risk affecting the stability of the overall structure and must be addressed with careful planning and implementation.

5.1.3 It is strongly recommended that the implementation of the various repairs within the bulk of the report are carried out under the guidance and supervision of a suitably qualified Engineer.

5.2 Structural integrity:

5.2.1 A number of observations collectively suggest that the structural integrity of the continuous concrete beams is not performing as expected.

5.2.2 Enquiries of A F Cruden's in 2016 indicated that the design had been governed by deflection calculations and that the structure was reliant on the effective continuity over the supports to achieve the recommended deflection limits.

5.2.3 Crucially A F Cruden's stated that any failure of the continuity reinforcement would not affect the structural strength of the beams as they were adequately reinforced to perform satisfactorily spanning simply between their two supporting piers.

5.2.4 There is no recommended action.

5.3 Structure durability:

5.3.1 Crack patterns seen within the span of the beams, opening joints over the supports and rust staining at a number of these locations all indicate that the recommended deflection criteria are not being met and that corrosion of the reinforcement has started. There is no evidence of extensive corrosion at this stage, but it is of concern that corrosion has initiated at this relatively young age.

5.3.2 The following actions are recommended:

A. Check the calculations independently.

B. Check the required reinforcement has been provided.

C. Check cracks and deflections onsite to verify performance.

D. At two key locations breaking out and reforming of concrete is recommended to ensure reinforcement continuity. Else where measures should be taken to minimise the impact of excessive deflection and to seal cracks against water ingress..

Appendix A:
Schedule of fractured flanges
Ref clause 4.5.4

Beam ref	LHS/ RHS	Bottom or top end	Inside or outside	Top or bottom flange	Comment	First recorded	Injected/ repaired
1	L	T	I	T	Minor	2018	
1	R	T	O	T	Seal by injection	2018	
9	R	T	O	T	Minor	2018	
18	L	B	Both	B	Minor	2018	
18	R	B	O	B	Minor	2018	
18	L	T	I	B	Seal by injection	2016	
18	R	T	O	B	Minor	2018	
21	R	B	I	T	Seal by injection	2015	
21	L	T	Both	B	Seal by injection	2016	
21	R	T	O	B	Minor	2016	
23	L	B	I	B	Seal by injection	2016	
23	R	B	O	B	Minor	2016	
24	L	T	O	B	Minor	2018	
25	L	T			Minor	2015	
26	L	T	I	T	Minor	2018	
27	L	T	O	B	Minor	2015	
27	R	T	I	B	Seal by injection	2015	
32	R	B		T	Minor	2015	
35	R	T			Seal by injection	2017	
37	R	B	O		Seal by injection	2015	
37	L	B	I		Seal by injection	2015	
45	L	B	O		Minor	2016	
50	R	B		L	Minor	2016	
52	R	B			Seal by injection	2016	
70	L	B			Remove and repair	2017	
72	R	B		T	Minor	2015	
76	R	B			Minor	2015	
76	L	T			Minor	2015	
80	R	T			Minor	2015	
81	L	T			Minor	2015	
90	L	T		T	Minor	2017	
91	R	M			Minor	2015	
92	R	T		T	Minor	2015	

Appendix B:
Schedule of mechanical damage to arrises
Ref clause 4.6.3

Beam ref	LHS/ RHS	Fifth location	Inside or outside	Top or bottom flange	Comment
2	L	4	I	B	OK
12	R	3	O	B	Slight damage, OK
14	R	2	O	B	Honey combing, no rust, accept for now
16	R	3	I	T	Small ding, OK
26	R	4	I	T	OK
27	L	5	O	T	2 dings, OK
31	L	3	I	B	Spalling
44	R	5	I	T	Spalling, patch repair
45	L	5	I	T	Small spall, OK
48	R	2,3,4	O	B	Various small dings
50	L	5	O	B	
50	R	3	I	B	Spalling - repair
53 LHS	L	5	I	T	Minor dings, patch repair
53 LHS	R	3,4,5	I	T	Various scrapes and dings, OK
53 RHS	L	1	I	T	Ding, repair
55	L	3	O	B	Ding, repair
56	L	5	O	T	Dings, OK
57	L	3	I	T	Dings, OK
57	L	1	O	T	Loose lump of concrete, remove and repair
62	L	3	O	T	Series of dings, OK
64	L	2,5	O	T	Ding, OK
67	R	3,5	O	T	Ding, OK
71	L	4	I	T	Ding, repair
74	L	4,5	O	T	Dings, repair
75	R	3	O	T	Scrape/ding along top, OK
87	R	2	O	T	Ding, repair
89	R	3	O	T	Ding, OK
90	R	3	O	B	Old repair cracked.
91	R	4	I	T	Ding, OK
93	L	2	I	T	Chip, OK
93	L	2,3,4	O	T	Many minor dings, OK

Appendix C:
Schedule of exposed reinforcement
Ref clause 4.6.4

Beam ref	LHS/ RHS	Fifth location	Inside or outside	2016	2017	2018	Comment
6	R	4		ID & Rep	/	/	
8	R	5	O	/	ID	ID	
12	R	2		ID & Rep	/	/	
26	R	2		ID & Rep	/	/	
54 RHS	R	1	I	/	ID	/	
55 RHS	R	2	O	ID	ID	ID	
55 RHS	R	3,4	Soffit	/	/	ID	3 items
58	L	4	I	/	/	ID	
62	R	2	O	/	ID	ID	
66	R	3		/	ID	/	
68	R	4	O	/	ID	ID	
72	R	2	I	/	/	ID	2 items
83	R	5		ID & Rep	/	/	In insitu
86	R	3	O	ID	ID	ID	
87	L	4	Soffit	/	/	/	
88	R	3	Soffit	/	/	ID	2 items honey combed holes, pos rf
91	L	3		ID	ID	/	2 items
93	L	5		ID	ID		noted minor no repair
93	L	2,3	O	ID	ID	ID	2 items
93	R	4	O	ID	/	/	

- Fifth location indicates which fifth of the beam the items was seen in. Note the fifths are generally punctuated by the steel cross bracing bolts.
- ID indicates when the problem was seen
- Rep indicates when the problem was repaired.

Appendix D:
Schedule of rail pack observations
Ref clause 4.7

This appendix includes all items listed in previous reports (repaired and otherwise) plus additional items identified during the 2018 inspection.

Entirely new items are highlighted in blue.

Items requiring repair action are highlighted in yellow.

ID indicates the year in which the problem was identified

Rep indicated the year in which the repair was carried out

Plinth ref	2015	2016	2017	2018	Damage recorded	Outstanding action
02/03/L		ID	/	/	Slightly cracked	No action
03/04/L	ID	/	/	/	Vertical crack on inner face	Watching brief
03/04/R	ID	/	/	/	Vertical crack on inner face	Watching brief
04/16/L			ID & Rep	/	Vertical crack on inner face	NA
04/19/L	ID	/	/	/	Vertical crack on inner face	Watching brief
05/20/L	ID	Rep	/	/	Total disintegration	
06/04/L	ID	/	/	/	Chip out upper face	Acceptable at this stage
06/05/R			ID	/	Chip out upper face	NA
06/07/L			ID	/	Poor repair, leave for now	NA
08/20/L			ID & Rep	/	REPAIR	
09/19/R				ID	Loose Halfen channel	Instructed resin injection 2018
11/01/L	ID	Rep	/	/	Rotten wood inclusion	
12/01/R	ID	/	/	/	Corner fractured off	Acceptable at this stage
12/08/L	ID	/	/	/	Upper face sheared off	Acceptable at this stage
12/15/L	ID	Rep	/	/	Upper face sheared off	
12/16/L	ID	/	/	/	Upper inner corner missing	Acceptable at this stage
12/18/L			ID	/	Flake missing but stable	NA
13/08/L	ID	/	/	/	Threaded bar inclusion	Watching brief
14/03/L		ID & Rep	/	/	Extra plinth done by CRL	
14/04/R	ID	Rep	/	/	Outer edge broken off	
14/06/L	ID	Rep	/	/	Upper face spalling	
14/14/L	ID	Rep	/	/	Upper face spalling	
14/20/L	ID	Rep	/	/	Gaps	
14/20/R	ID	Rep	/	/	Grout largely failing	
15/02/L			ID	/	Cracked but stable	NA
15/20/L	ID	???	/	/	Damaged	Review
15/20/R	ID	/	Rep	/	Damaged	
16/01/L	ID	Rep	/	/	Ref pic	
16/02/R		ID	/	/	Cracked	Monitor
16/03/R		ID	/	/	Crack in plinth and flange below	Monitor
16/04/R		ID	/	/	Crack in plinth and flange below	Monitor
16/05/L			ID	/	Cracked but stable	NA
16/05/R		ID	/	/	Crack in flange below	Monitor
16/07/R	ID	/	/	/	Crack in plinth and flange below	Watching brief
16/08/R		ID	/	/	Crack in plinth and flange below	Monitor
16/09/R		ID	/	/	Crack in plinth and flange below	Monitor
16/12/L		ID	/	/	Shrinkage cracks	Monitor
16/13/L		ID	/	/	Shrinkage cracks	Monitor
16/18/L		ID	/	/	Cracked.	Monitor
16/20/L	ID	Rep	/	/	Pos timber inclusion	
17/01/L	ID	Rep	/	/	Pos timber inclusion	
17/01/R	ID	/	/	/	Damaged	Review
17/02/L		ID	/	/	Grout in poor condition	Monitor
17/03/L	ID	Rep	/	/	Pos timber inclusion	
17/03/R		ID	/	/	Grout in poor condition	Monitor
17/04/L	ID	Rep	/	/	Poor repair	
17/04/R		ID	/	/	Plinth spalled	Monitor
17/07/L		ID	/	/	Vert crack and efflorescence	Monitor
17/09/L			ID	/	Halfen/concrete crack, too small a crack to inject.	Monitor for now.
17/10/L			ID	/	Halfen/concrete crack, too small a crack to inject.	Monitor for now.
17/11/L			ID	/	Halfen/concrete crack, too small a crack to inject.	Monitor for now.
17/12/L		ID	/	/	Halfen/concrete crack, too small a crack to inject.	Monitor
17/14/L		ID	/	/	Vert crack and efflorescence	Monitor
17/15/L		ID	/	/	Vert crack and efflorescence	Monitor
18/02/R		ID	/	/	Minor crack	Monitor
18/05/L		ID	Rep	/	Part fractured off	
18/05/R		ID	Rep	/	Crack	
18/06/R		ID	Rep	/	Crack	
18/13/L	ID	Rep	/	/	Damaged outer edge	
18/20/R		ID	/	/	Crack in flange below	Monitor
19/03/L	ID	Rep	/	/	Pos timber inclusion	
20/03/R			ID	/	Cracked but stable	NA
20/18/R	ID	Rep	/	/	Damaged	
22/04/L	ID	Rep	/	/	Spalled upper face	
24/01/L	ID	Rep	Rep	/	Disintegrating. CRL 2016 repair failed – repair foc	
24/06/L	ID	Rep	/	/	Poor repair	
24/08/L	ID	Rep	/	/	Poor repair	
24/20/R	ID	Rep	/	/	Outer corner damaged. CRL Rep, no QC sheets.	

Excel file ref: 18011 - plinth schedule

Plinth ref	2015	2016	2017	2018	Damage recorded	Outstanding action
26/01/L	ID	/	/	/	Chipped corner	Note
26/08/R	ID	/	/	/	Grout block split	Repair
26/13/L	ID	/	/	/	Old repair, pos damage to inside top flange.	Replace or repair
27/20/L			ID & Rep	/	Damaged	
28/01/L	ID	/	/	/	Grout block split	Repair
28/04/R	ID	/	/	/	Grout block split	Repair
29/00/L	ID	/	/	/	Grout block split	Repair
29/01/R	ID	/	/	/	Rail movement block upper inside corner fractured and part missing. Disintegrated	Infill missing area. Repair priority
29/03/L	ID	/	/	/	Disintegrated	Repair priority
29/19/			ID	/	Slight spalling, OK	NA
36/20/L					Possible issue	Requires closer inspection
36/20/L					Possible issue	No action
36/20/L					Possible issue	NA
40/01/R					Lower face, minor spalling	No action
40/01/R					Lower face, minor spalling	NA
41/01/L	ID	Rep	/	/	Missing corner	
48/04/L	ID	/	/	/	Upper top edge missing	Note
52/01/mid		ID	/	/	Upper face spalled	Do not breakout, but strengthen.
56/15/R			ID	/	Cracked but stable	NA
57/01/L			ID	/	Loose Halfen	Monitor
57/18/R			ID & Rep	/	Damaged	
58/01/L	ID	Rep	/	/	Pos timber inclusion	
58/19/R	ID	/	/	/	Grout fractured but firm	Note
58/20/L	ID	Rep	/	/	Pos timber inclusion	
58/20/R					Damaged	Replace or repair
61/01/R	ID	Rep	/	/	Pos timber inclusion	
61/03/L	ID	/	/	/	Damaged	Note
61/12/R	ID	Rep	/	/	Damaged	
61/17/R			ID & Rep	/	Loose Halfen - done 2017	Instructed resin injection 2018
61/18/R			ID & Rep	/	Loose Halfen - done 2017	Instructed resin injection 2018
61/20/L	ID	Rep	/	/	Pos timber inclusion	
61/20/R	ID	Rep	/	/	Damaged	
62/01/R			ID	/	Cracked, OK	NA
62/02/L				ID	Loose Halfen	Instructed resin injection 2018
62/03/L			ID & Rep	/	Loose Halfen	
62/19/L		ID	ID & Rep	/	Crack in flange below, loose Halfen	
62/20/L		ID	/	/	Top face missing	Repair
63/20/R	ID	Rep	/	/	Damaged	
63/20/L			ID & Rep	/	Damaged	
64/01/L		ID	Rep	/	Upper face cracked	
69/03/R	ID	Rep	/	/	Beam chipped	
73/01/L	ID	/	/	/	Horizontal crack	Note
77/01/			ID	/	Top face fractured but stable	NA
78/01/L			ID & Rep	/	Damaged	Instructed resin injection 2018
78/02/L			ID	/	Loose Halfen	Resin injection
81/01/L	ID	Rep	/	/	Fractured upper face	
90/01/L		ID	/	/	Top face flaked off	Monitor
91/08/L	ID	/	/	/	Flake off upper face	Note
93/07/L	ID	/	/	/	Flake off upper face	Note
93/17/L	ID	/	/	/	Chipped	Note
93/20/R	ID	Rep	/	/	Large chunk missing	
SH00/01/R		ID & Rep	/	/		
SH00/02/L		ID	/	/	Fractured but stable	No action
SH00/03/L		ID	/	/	Fractured but stable	No action
SH00/04/L		ID & Rep	/	/		
SH00/05/L		ID & Rep	/	/		
SH01/03/R		ID & Rep	/	/		
SH01/04/R		ID	/	/	Lower face fractured but stable	No action
SH01/05/L		ID & Rep	/	/	CRL Rep but no QC sheets.	
SH01/06/R		ID	/	/	Side face fractured but stable	No action
SH01/07/L		ID & Rep	/	/		
SH01/09/L		ID	/	/	Slab cracked through, plinth OK	No action
SH01/10/R		ID & Rep	/	/		
SH01/11/R		ID	/	/	Damaged	Monitor
SH01/24/R		???	/	/	???	Review
SH02/08/L		ID	/	/	Chipped but OK	No action
SH02/14/R			ID & Rep	/	Damaged	
SH04/15/L		ID	/	/	???	Monitor
SH08/11/L		ID	/	/	Fractured, OK	No action
SH08/13/		ID	/	/	Chipped but OK	No action
SH12/14/L		ID	/	/	Cracked on MJ, OK	No action
SH15/08/L		ID	/	/	Chipped but OK	No action
SH15/17/R			ID & Rep	/	Damaged	

Excel file ref: 18011 - plinth schedule

Appendix E:
Photos:

Ref clause 4.1.3

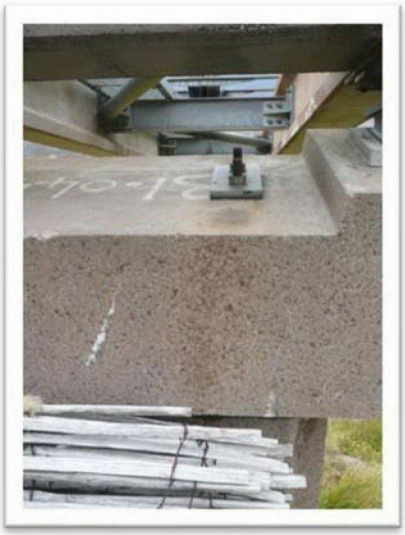
Photo [1] Construction joint / shear fracturing where thrust block upstand meets main foundation.

Ref clause 4.2.2

Photo [3] Main pier 91 showing cracks in shell.

Ref clause 4.2.2

Photo [4] Significant chip out of pier shell.



Ref clause 4.3.3

Photo [5] Pier 93. Crack rising up through pier crosshead and passing through bolt group. This was the only cross head where this was observed.

Ref clause 4.5.1

Photo [7] Pier 56, an overview showing previous repairs carried out.

Photo [8] Pier 56 crack near top of flange unloaded.

Photo [9] Pier 56 crack near top of flange as train passes. Estimate increase in crack width = 1.0mm.

Ref clause 4.5.4

Photo [10] Pier 9, one of the poorer insitu infills. Showing joints opening between Insitu and precast plus cracking within the mass of the Insitu, both inclined and near vertical.

Ref clause 5.5.3

Photo [11] Pier 9 from above.

Ref clause 4.5.4

Photo [12] Diagonal cracks through the lower flange of the precast bead bearings.

Photo [13] Showing bottom corner fracturing away.

Photo [14] Flange fracture also seen at top of beams. This was less often.

Ref clause 4.6.5

Photo [15] Typical crack patterns around bolt groups.

Photo [16], ditto

Ref clause 4.6.6

Photo [17] Longitudinal cracking of the top flange of the PCC beams, here short.

Ref clause 4.6.7

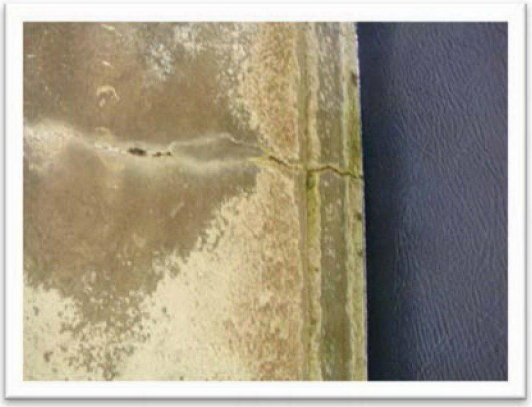


Photo [19] View of crack on typical mid-span underside of beam.

Photo [20] The above photographed crack as it appears on the side of the beam.

Photo [21] Crack at mid span of beam exhibiting rust staining.

Ref clause 4.7.1

Photo [22] Typical grout plinth, exhibiting crazing, but stable

Photo [23] Typical case of a flake off one face of plinth. This regarded as stable.

Photo [24] Grout plinth showing fracture. Regarded as stable at this time.