Will the repair of the Cairngorm Funicular Railway work (4)?

Description

Following on from my last post (see here), which looked at whether vibration from poorly maintained rails could have caused damage to the piers supporting the funicular, this post focuses on the concrete parts of the structure, especially the ends of the "I" support beams and the in-situ blocks. The "I" beams are described as such because of their shape, "I" , when viewed through vertical section while the "in-situ" blocks are so-described because they were poured "in situ" (rather than pre-cast like the "I" beams).

Figure 2-2 Passing loop
Photo credit the COWI report.

The picture above is probably the best one showing the layout of the tracks, including the passing loop, but also shows two piers referred to below. Pier 52 is the one showing to the left of the track with pier 51 just visible between the lower pulley and the next two. The photo also shows how the funicular destroyed Cairn Gorm's iconic White Lady ski run, one more reason why it should never have been built and should be removed asap.

Examples of what appears to have gone wrong with the insitu concrete blocks.

Plate 18 – General view of surface markings to Pier 51 Left Beam up

The coloured lines in all the photos have been added by engineering surveyors. Photo credit COWI report.

The picture above shows the join between the in-situ block and the left side (looking up the hill) of the concrete "I" beam of Pier 51. Although it is unclear exactly what is going on here as the photo has been taken so close to the pier, it provides ample evidence of the poor workmanship so often referred to in the COWI and ADAC structures reports on the state of the funicular. It looks as though the mould for the concrete joint, which is usually made from plywood and is called "shuttering", has been poorly constructed. As a result the surface to the right of bolts is sloping, rather than vertical, and appears warped (a consequence of using an old piece of plywood). While some of the concrete may have been patched later, it also appears to have almost covered the bolt holes used to secure the bracing steelwork between the beams (visible in the top photo). At least one washer under the bolt heads has had to be cut with an angle grinder to get it to fit.

There are also several marks showing. Some may be cracks but they could also have been caused by markings on the surface of the plywood when the insitu block was poured!

Compare the quality of the shuttering work on the insitu block illustrated above with that in plate 24(pier 53) below!

Plate 24 - General view of surface markings to Pier 53 Right Beam, left support up.

Green points to “I” beam, red to insitu block and black to crosshead on pier below. . Photo credit COWI report.

Note how the edges in the insitu block are straight and “clean” compared to those shown in plate 18.

Apart from the shuttering, there is evidence from the photos in Plates 18 and 24 that not enough care was taken when the concrete was poured to create the in-situ block, as shown by the surface markings. This is easier to see in plate 31:

Plate 31 - General view of surface markings to Pier 56 Right Beam down

Photo credit COWI report

These could have been caused by the concrete not being vibrated enough with a vibro-rod/ poker or from cold weather.

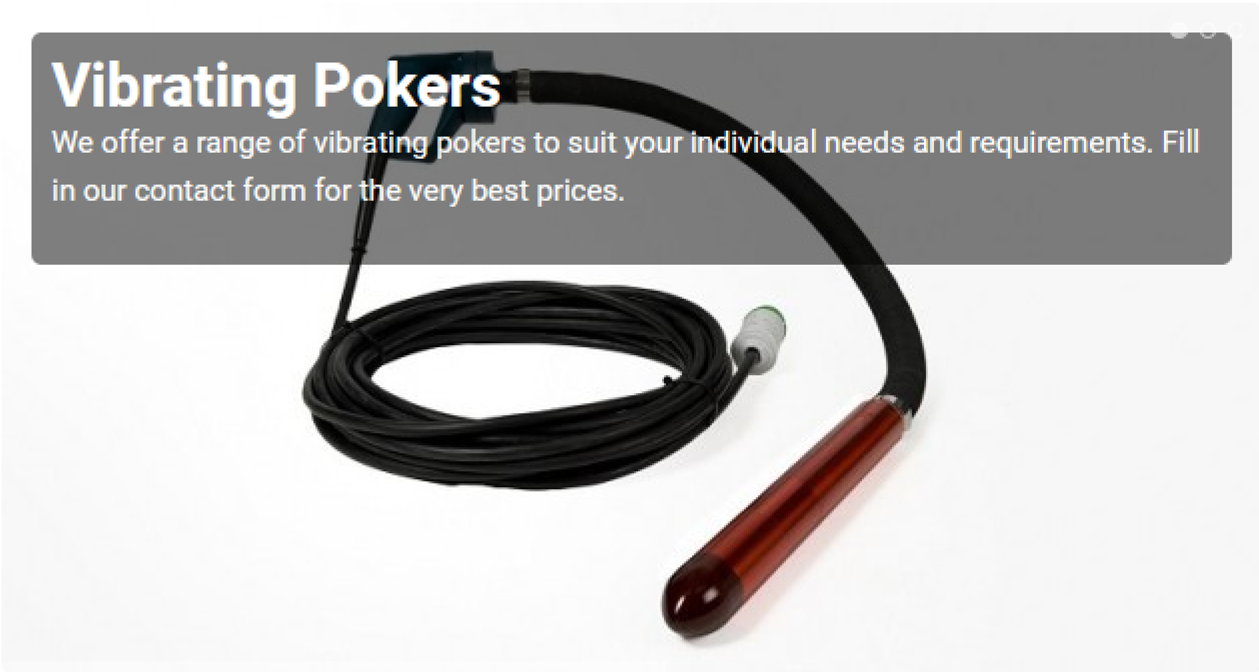

Photo credit Power Tool Suppliers.

Air has to be removed from the concrete pouring to enable it to reach its design strength!

While the funicular was built over the summer months the COWI report says that the temperature range on Cairn Gorm can vary from as low as -27deg.C to +29deg. C, a range of 56deg. C and that a temperature of -9deg.C had been recorded in July 2018!

I am reliably informed that when construction recommenced in April 2001 Cairngorm was still ski-able. The foundations, poured the previous summer, may not have been subject to such a range of temperatures, as the ground around would help to stabilize temperatures and protect the foundations from the elements, but the same cannot be said for the pouring of the in-situ concrete blocks and could account for the damage. Wind and direct sunlight are also variables that should be considered.

Concrete takes at least 24 hours to cure in normal conditions, which are rarely encountered on a mountain like Cairn Gorm, so except in very settled weather protection would need to have provided in the form of heated blankets or temporary shelters. The following article, taken from a magazine called Probuilder, explains the problems and remedies in more detail.

Preparing for frost

A critical factor for works carried out in cold weather is ensuring that the mortar or concrete has adequate heat for normal cement hydration. The usability and strength of mortar is affected by temperature, and additional care must be taken when working with a mortar mix in colder conditions. Cement will not hydrate sufficiently at low temperatures (hydration will virtually stop below three degrees Celsius), which increases the likelihood of slow setting and poor strength gains, as well as frost damage and freeze-thaw attack on hardened mortar or concrete.

It seems obvious, but this can be easily managed by avoiding mixing or laying the mortar or concrete when the air temperature is below 5ºC. It's also important to keep the mortar or concrete protected for three to seven days. Cement curing is an exothermic chemical reaction, so the coverings you use will not only trap the moisture required for hydration of the cement but additionally some of the heat generated; this helps to ensure the mortar or concrete remains above 5ºC and allows it to continue to gain strength.

Also, freezing temperatures significantly reduce the compressive strength, the bond strength and also decreases the resistance to water penetration of masonry. If the newly placed mortar does fall below freezing before developing enough strength, it will often result in cracking, scaling and crumbling of the product.

Although the best advice is to wait for temperatures above 5ºC before doing these jobs, the formation of cracks and spalls are annoyingly unpredictable. In any case, when getting the job done is essential, and there is a risk of frost, protect the mortar with an insulation quilt sandwiched between two sheets of polythene sheeting.

The elements

It's not just frost that you need to consider. A great deal of judgment is required to perform construction projects in wind and rain.

Severe wind can cause premature drying as a result of increased evaporation. For this reason, it's important to make the necessary arrangements to tackle the risk before laying concrete or placing mortar in a windy area. Consider putting up wind barriers to protect your work and secure the area with plastic sheeting.

The in-situ concrete used at Cairn Gorm was made in the car park area and then carried by helicopter to where it was needed. This raises another potential issue. There would be times when the helicopter lift would have a shortage or an excess of concrete to fill one of the moulds and an in-situ joint may not have been finished in one pour. This would result in partial setting of the concrete already in place leading to a poor joint. The next picture, especially in the lowest part of the in-situ concrete block, shows what that might look like:-

Photo credit COWI report Page 293, plate 38, pier 69, arrow points to possible earlier pour.

Although this apparent difference in the composition of the concrete, which may have weakened the whole structure, could also be caused by ineffective use of the vibro-poker!

Returning to Plate 24, observe that the end of the precast concrete “I” beam is angled, sloping forward from the top edge to the bottom. This gives a much superior join than a vertical joint. But if you look at the plate which carries the top half of the sliding bearing, that plate only supports the last 50 – 75cms of the end of the “I” beam and, in some cases, due to poor construction, not even that:

Figure 2-9 Bearing misalignment (refer defect 5)

Photo credit COWI report

Note the gap between the two beams and the support plate above the ancon bearing. It appears that the concrete poured to form the insitu block above has partly filled the gap.

Aside from the workmanship, the design itself is in my opinion poor for two reasons:

(1) The plate should have extended far enough to support the "I" beam from the leading edge of the top flange. The lack of support may account for the damage to the lower flanges of the "I" beams, damage that appears at several different piers.

(2) The plates should also have rounded corners and edges to prevent stress points.

The likely consequences are illustrated by the photo below:

Figure 2-8 Typical crack leakage and bearing misalignment (refer defects 3 and 5)

Photo credit COWI report

The red arrow marks what appears to be a crack leading diagonally upwards from the edge of the plate, just where you would expect this to happen if too much weight was placed on an inadequate sharp edged support.

The planning application for the funicular stated that replacement of the Ancon bearings below the plates is part of the repair work, so it will be interesting to see if this includes new longer plates. If so, all the in-situ joints will need to removed as the support plates have concealed vertical sections that project into the concrete above. That could help explain why the cost of the funicular repairs comes to an extraordinary £16.16m.

The significance of the faults in the concrete

While it is hard to believe that a company like Balfour Beatty would agree to undertake repair work that could damage its reputation, the big question to be asked is "Are the repairs guaranteed to last for thirty years, the timescale used to justify Highland and Island Enterprise's Business case?" (see here).

There are serious questions about that because the causes for the structural failure do not appear to have been investigated and, without that, no-one can be confident as to how long the repairs will work!

While HIE still appears to be in the process of a legal case concerned with the “design and build” aspects of the funicular railway, many of the problems with the concrete structures may stem from the £2m cost cutting exercise imposed by HIE on the contractors 20 years ago in order to bring the funicular into budget. If so, we are all paying for that now and even more reason for HIE to come clean about what has really gone wrong with the funicular.

More to follow next week!

Category

1. Cairngorms

Tags

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