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By email:
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Independent Review of Risks associated with temporary nature of Precast Deck System

14 April 2020

Dear [redacted]

We write further to the issue of the report dated the 27th of March 2020 regarding the independent review of the Okahu & Puhoi Viaduct Precast Deck Systems, along with subsequent correspondence to this and the online Skype meeting which was held on the 7th April 2020 with yourselves.

As discussed in the Skype meeting on the 7th April 2020, and whilst we understand FAJV are satisfied with their own temporary works design checks on the precast deck system, which we understand have been checked by another third party (understood to be CaSE Design), we present this letter to summarise the key risks that we have identified, along with some further supporting information and calculations to demonstrate why they remain a concern for us.

We suggest that the FAJV acknowledge and mitigate these key risks in the construction of the project and satisfy themselves of their duties to address these risks under the Health & Safety at Work Act.

The content of this letter assumes that the reader is familiar with the work completed in this independent review to date.

1 Risk of buckling failure of TRT top chord

As part of our independent review we have undertaken two separate sets of calculations, one by hand, and given the nature of the situation a separate finite element model too. These have been completed independently, by different engineers based in our Wellington and Auckland offices respectively.

Both the hand calculations and finite element analysis have found that the Temporary Reinforcement Truss (TRT) top chord elements have insufficient factors of safety which may result in a risk of a buckling mode of failure, which could potentially lead to a collapse during construction.

When comparing results of these independent design checks with those completed by the Acciona Ingerieria (A-ING) Temporary Works Engineers (TWE), it was clear that the methods of analysis were different, leading to different results both in terms of the axial demand in the TRT top chords, along with the calculated deflection of the Precast Deck system itself.

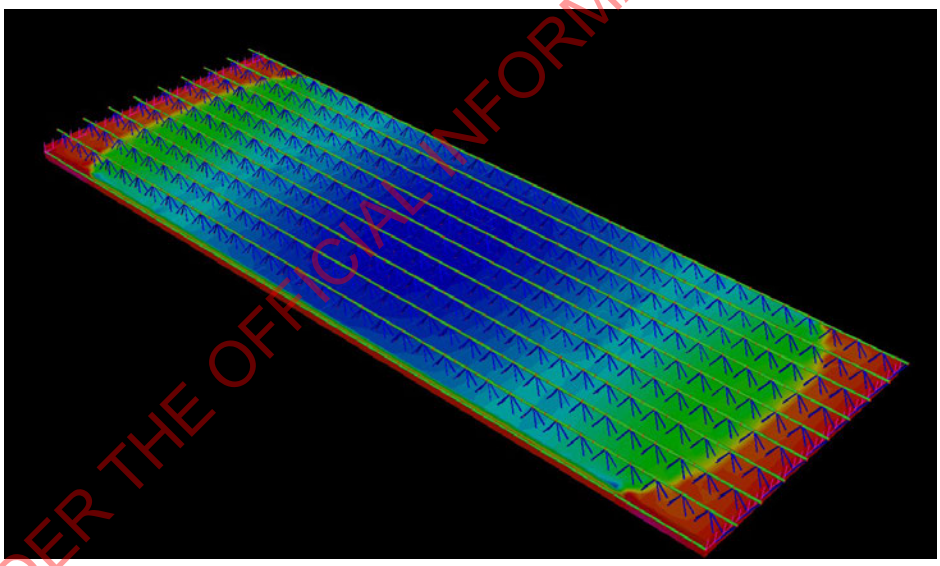
Whilst independent analytical results can be expected to have some difference in the computed output, the scale of difference (in the order of 50% less demand to

the TRT top chord, and a 2.5x stiffer performance) is large enough to warrant further interrogation.

The case put forward as to the reason for this difference is that A-ING have taken into account the 'stiffening' effect of the precast concrete 'biscuit' of 130mm which envelops the TRT bottom chords.

Whilst it was debated in conversation as to the likely stiffening effect of this element of concrete given the ratio of its moment of inertia and neutral axis with respect to that of the TRTs alone, the MM team decided to expand on the finite element analysis completed in Strand7 to take into account the contribution of this element of precast concrete.

A key point of note is that the finite element analysis (FEA) undertaken by MM has utilised a nonlinear analytical approach with all elements inputted in the design geometry (with no imperfections), with nonlinear material properties included. The loading has been applied to the model "unfactored" with this loading then incrementally increased until failure. The FEA model has found this failure to occur at a load factor of between 1.35 and 1.4 which we believe does not allow sufficient factors of safety for construction loads or the potential for imperfections.



Non-linear Strand7 Finite Element Analysis model

The difference in axial demand in the TRT top-chord, and the deflection of the Precast Deck system itself is summarised in the table below. As these results indicate, the independent analysis does not demonstrate a significant 'stiffening' effect by the precast concrete.

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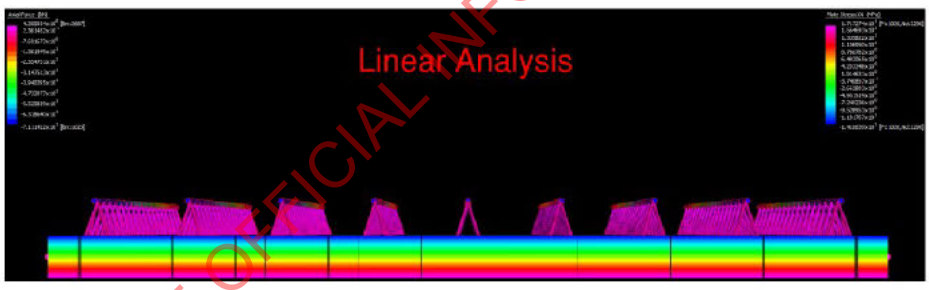
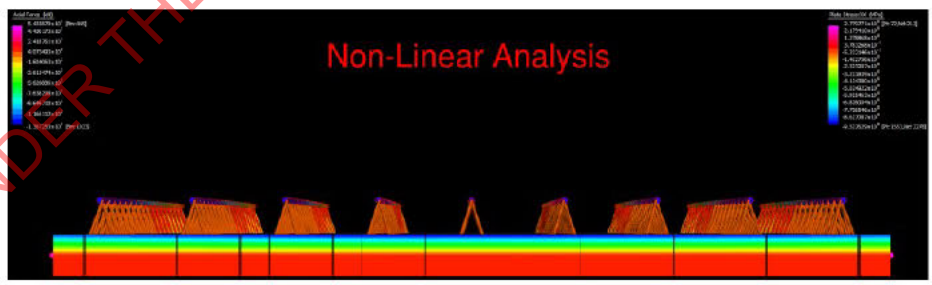
	MM Truss only (linear)		MM Linear		MM Non-Linear		Acciona Report	
	TC Axial Load (kN)	Defln. (mm)	TC Axial Load (kN)	Defln. (mm)	TC Axial Load (kN)	Defln. (mm)	TC Axial Load (kN)	Defln. (mm)
SB1	100		48.4		89			
SB2	146.9		71.1		132.3		75.4*	
SB3	158		68		126.5			
SLS SB1		35.2		15.7		39.0		15.6
SLS SB2		50.5		22.9		57.6		23.3

Table comparing analytical results

In the interest of getting to the root of the difference between the analytical models, the MM team has tried to replicate the output that A-ING has calculated using a different analytical process. We have concluded that we can in fact replicate the analytical results by using instead a linear-elastic model to represent the precast concrete. This arbitrarily assumes a linear distribution in stress across the concrete section, leading to a peak stress in the bottom fibres in the order of 14MPa. This unfortunately does not represent the true nature of how concrete will perform, as once the tensile capacity of the concrete is reached, the section ceases to perform in a linear-elastic manner.





The differences in the analytical approach is thus in our opinion something that should be resolved in the interests for all parties involved, so that the true nature of the risk of a buckling failure of the TRT top chords can be assessed.

The MM team has also developed some practical mitigation measures to address this risk and we would be happy to share those with the FAJV team should this be of interest, or to assist in other ways.

2 Risk of un-representative panel load testing

We understand that some load testing of the precast panel system has been completed, and that the results of these tests would tend to support the view that the actual deflections that can be expected are closer aligned with the analytical results determined from the A-ING team.

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Whilst this could be considered as a supportive mitigating factor, we have also outlined some concerns with the risk of the panel load testing being un-representative. These concerns are outlined in the report of the 27th March, and summarised again below:

- Potential for plywood sheets providing additional composite action to TRT top chords by the kentledge during load testing, providing a rudimentary but effective composite top flange to stiffen the precast panels.
- Potential for nature of loading to also limit buckling of the TRT top chords.
- The load testing should really have been completed to failure so that the ultimate failure modes were recorded and such that a factor of safety with respect to these can be confirmed.

3 Risk of fracture of TRTs during Service Loading

Whilst there is common acceptance that the TRTs are assumed to become redundant during service loading due to fatigue considerations, the risk of their fracture during Service Loading could lead to a sudden change in the effective stiffness of the precast decks.

The risk of this sudden change in the effective service life stiffness of the deck system may lead to a sudden increase in cracking in the cover concrete. This risk of increased cracking could be a durability concern for the long-term performance of the decking system, and as such we recommend that the permanent works engineer satisfies themselves as to the durability design implications with a risk of fracture of the TRTs during the service life of the viaducts.

Summary

In summarising, and whilst we appreciate that our current commission to the Fletcher-Acciona Joint Venture team for our independent review role on this project is complete, we have taken the time to record these risks identified above to satisfy our duty of care to the public and ethical obligations under our industry accreditation.

We remain open and willing to help close out these risks to the satisfaction of all parties involved in a supportive and collaborative manner, and we would be happy to present practical mitigation measures should this be of interest.

Yours sincerely,

For and on behalf of Mott MacDonald,

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