Auckland Council
Auckland 1010
New Zealand

Job No: 62045
VL
5th October 2018

Attention: Warren Perkins

Dear Warren,

Review of Waikaraka Park Grandstand

1. Introduction

Babbage Consultants Ltd has been engaged by Auckland Council to carry out a review of the Waikaraka Park Grandstand. The review includes a site visit, a partial set of structural drawings and a Seismic Assessment Report prepared by Holmes Consulting.

2. Basis for the Review

The structural review has been based on the following information:

- Existing structural drawings – a partial set of drawings including the seismic strengthening drawings dated 10 January 1996;
- Holmes Consulting Group report dated November 2015;
- A verbal brief given on site as the grandstand should be designed to have a seating capacity of 1,500 people.

The review is also based on the following guidelines:

- The grandstand is assumed to have an Importance Level of 3;
- Both the Ultimate Limit State (ULS) and the Collapse Limit State (CLS) should be considered in the review;
- The likely collapse mechanism should be considered in the review.

The overall plan, elevation and typical details of the grandstand are shown as follows:

Fig 1 : Aerial Photo

Architecture
Building Surveying
Structural Engineering
Building Services Engineering
Planning
Project Management
Land Surveying
Civil Engineering
Environmental Engineering
Geotechnical Engineering
Process & Mechanical Engineering
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Fig 2. View from back of the grandstand

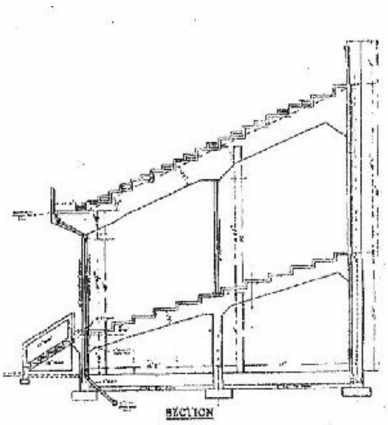

Fig 3. Typical frame elevation

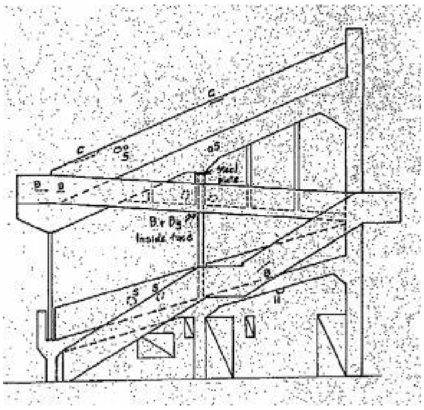

Fig 4. Northern end bay with access ramp/stair

3. Background

The grandstand was built in the 1930s with some strengthening work carried out in 1984. It is approximately 67m long and 10.5m wide with an upper level and a lower level. The access to the upper level is via two ramp/stairs at the northern and southern ends of the building. In 1984, two additional stairs were built at the back of the grandstand i.e. western side.

In 2015, Holmes Consulting Group was engaged to prepare a Detailed Seismic Assessment (DSA) report for the grandstand. In the report, the grandstand was identified to be "potentially earthquake prone" under the Building Acts Classification. It approximately has 10 to 20% New Building Standard (NBS) at Ultimate Limit State (ULS). In the report, it also listed four local structure vulnerabilities:

1) Stair detailing for drift not present;
2) Inadequate confinement of columns to accommodate Collapse Limit State (CLS) drift;
3) The ability of the tiered seating slab to act as a diaphragm;
4) The durability and condition of the existing concrete.

On the 10th September 2018, a joint site inspection was carried out with representatives from Auckland Council, Synergine and Babbage Consultants. The purpose of the inspection was to carry out an assessment of the grandstand to provide technical advice to Auckland Council on the required remedial work to enable the re-opening of the grandstand for public use.

4. Site Observations

Widespread concrete damage has been observed on site as shown in Appendix A. Most of the wall damage is found at the northern end of the western wall. Considerable amount of damage is due to water penetration through the eastern edge of the upper deck, which is used as a storm water gutter to collect surface water on the upper deck. The storm water penetrates the slab causing severe corrosion damage to the slab as well as to the supporting beams.

Usually concrete provides long term protection to reinforcement bars because of its alkaline property. As long as this alkaline property is maintained, the corrosion of the reinforcement bars will not take place. As concrete ages, it subjects to weathering and environmental effects. It allows chlorides, carbon dioxide and oxygen slowly permeates the concrete to reach the reinforcing bars. By then, the concrete alkaline property is neutralised and the reinforcement bars starts to be corroded. As the corrosion products, i.e. rust develops, it increases its volume more than five times of the base material, i.e., steel. The expansive forces generated by the volume change leads to tensile cracking of the surrounding concrete as shown in Fig 5.

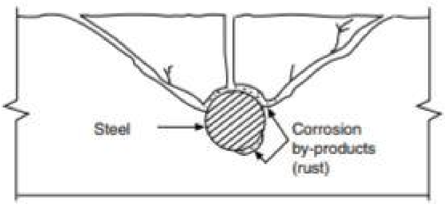

Fig 5: Tension crack due to rebar corrosion

The important issue is that when a tension crack appears, there are likely to have many more places where reinforcing bars are in the process of being corroded in a lesser extent which may not be able to be detected from surface. In other words, the tension crack is shown only at the final stage of corrosion process.

The concern is not only the loss of tensile strength of the corroded reinforcing bars, but more importantly, the loss of bonding between the reinforcing bars and concrete. When the bonding loss occurs, the concrete structure loses most of its strength, and it will be difficult to estimate the extent of its loss of strength by calculation. Extensive intrusive investigation is required to estimate the likely remaining strength of the concrete structure.

5. Discussion Based on Site Observation and the Review of the DSA Report

Based on our site observation and the review of the DSA report, we concur with the four structure vulnerabilities identified in the DSA report. Due to these vulnerabilities, if the grandstand is to be strengthened, then the following strengthening strategy is recommended:

1) The seismic strengthening should be carried out to prevent collapse in Collapse Limit State (CLS);

2) The torsional vibration mode has to be controlled to minimise drift demand to the column support of the upper deck;

3) The beam/column joint under the upper deck is to be strengthened to enhance its capacity to match the rotational demand to prevent potential collapse of the upper deck;

4) The upper deck needs to be strengthened and new weatherproof measure is to be applied to prevent any further corrosion damage to the upper deck;

5) Any additional stiffening element installed should be installed at more than one place to avoid high level localised load transfer through the upper deck;

6) The first flight of the upper deck and the eastern balustrade are to be replaced as it seems to be beyond repairable;

7) Extensive intrusive investigation should be carried out to verify the exact damage and the strength of the remaining structure prior to seismic strengthening work is being designed.

6. Discussion about the Queries from Auckland Council

There are a number of queries from Auckland Council subsequent to the issue of the Babbage Consultants Limited draft report. These queries are:

1. *Given your comments about the cracking occurring at the end of the corrosion process, what would the remaining life of structure be after any repairs?*
2. *Given also that it may not be possible to repair 100% of the buried corrosion, what would the effect of that be? Would the buried corrosion continue?*
3. *If the structure was repaired, what confidence would you have (as the Structural Engineer providing the repair methodology) to provide a Certificate of Public use?*
4. *In Section 7.0 you say that Option 1 'requires a certain degree of compromise on public safety'. What is the compromise?*
5. *Can the structure still be used for intended purpose?*
6. *What is your view on the close proximity of the temporary seating to the front of the structure and the public toilets to the rear? Is there a danger to the public in those areas if the structure was to collapse?*
7. *Is the Grandstand a dangerous building under the Building Act?*

8. *It is noted that the temporary seating and WCs are in the 'fall zone' of a moderate earthquake. Under normal circumstances is allowing public access to the temporary seating and toilets to the rear of the grandstand a safety issue?*

In order to answer these queries, it is necessary to understand the corrosion assessment and the remaining structural strength of a structure with corroded reinforcement bars.

In order to carry out appropriate repair work for the damaged grandstand, an extensive intrusive investigation has to be carried out to identify the damage. It is unnecessary to capture 100% of the corrosion damage in reinforcements in the repair scheme. As long as the concrete structure can be effectively protected from weather, for reinforcement bars with only minor corrosion damage, the corrosion will be greatly slowed down but it is unlikely to have it completely stopped. This means the investigation work is only to target the significant corrosion damage.

To understand the statement "certain degree of compromise on public safety", Auckland Council needs to understand that, in New Zealand, there is no commonly acceptable assessment method for structural strength of concrete building with corroded reinforcement.

There has been significant amount of research work been carried out in America. An empirical procedure has been developed to access shear strength of a column with corroded reinforcing in ASCE/SEI 41-31, but, the empirical equation for flexural strength has yet to be developed. In general, for localised corrosion rate less than 5%, the loss of strength is not significant. The corrosion rate can be defined by minimum residual diameter of reinforcement bars, or average residual diameter as defined by measurement procedure in ASTM G1-03. It involves taking enough sample of corroded reinforcement bars for measurement in an intrusive investigation. The empirical equation developed has a relatively large deviation because it is based on the test results of large range of experiment samples. To give a certainty of the load capacity of the grandstand as an Importance Level 3 structure, we have to use a relatively conservative approach, i.e., providing an extra safety margin for the capacity estimated. This means the estimated load capacity will likely to be very low and unlikely to be worth the trouble to have the grandstand upper deck strengthened. The more practical approach is to either remove the upper deck or to build a new grandstand. Since the damage in lower deck is not significant, it will be highly likely that it can be restored and strengthened as an IL3 structure for public use.

In the DSA report, the torsional mode dominates the dynamic behaviour of the grandstand. It is our opinion that its collapse mode is likely to be coupled with torsional twisting. This means, if it is not repaired or strengthened, then, in a moderate earthquake event, the grandstand will likely collapse onto the temporary seating to the front and the public toilets to the rear because of their close proximity to the grandstand.

Whether this is an issue or not is dependent upon Auckland Council. It is the same issue that other Earthquake Prone (EQP) buildings are subject to under Auckland Council's Earthquake Prone Policy. Currently, Auckland Council allows EQP building owners 35 years in which to have a building strengthened. There is however no restriction on their right to have the building occupied for its normal use during that period. Only if the building is deemed to impose an immediate risk to its occupants and to public, Auckland Council take necessary step to remove the danger in accordance with the Dangerous and Insanitary Buildings Policy.

It is our opinion that the grandstand shouldn't be occupied unless it is repaired and strengthened. Whilst the grandstand can be categorised as a 'Dangerous Building' under the 2004 Building Act, it is difficult to determine whether it can be considered as immediately dangerous or not in terms of its potential risk to the temporary seating and toilet. This is because there is no clear guideline on the definition of "immediate danger" from IPENZ or Auckland Council.

7. Summary

After reviewing the grandstand and the DSA Report, it is our opinion that there are three possible options:

1) Strengthen the existing grandstand and it may include:
   (a) Replace/strengthen the north end of the west wall;
   (b) Replace the northern and southern access ramp/stairs;
   (c) Strengthen the upper deck to match the diaphragm demands;
   (d) Install additional structural element to minimise torsional effects on the building, e.g. Install Buckling Restrained Braces (BRB) or Tectonus RSFJ connectors etc., at some bays in the front of the grandstand to stiffen and to damp out seismic energy;
   (e) Strengthen the upper deck beam and beam column joints;
   (f) Strengthen the foundation and the back walls at grid 6 and 7;

   This option allows the existing structure to be retained, but, it is a very expensive option. It also requires certain degree of compromise on public safety because the strengthened structure is unlikely to be as safe as a new structure, due to the uncertainty of the nature of the corrosion damage, i.e., hidden and difficult to detect the loss of bonding of the re-bars. **Theoretically** if the structure was fully repaired it could be certified for Public use as an IL3 Building however uncertainly over concealed damage would make this practically and financially unviable.

2) Remove the upper deck and repair the lower deck. This is a more cost effective option and it also provides a higher level of certainty on public safety. It will however result in significantly reduced viewing spectrum.

3) Demolish and replace the grandstand.

It is our opinion that while Option 1 and 2 are theoretically achievable, they impose either significant practical or financial constraints that make them difficult to support. It is therefore likely that there is no reasonable practicable alternative to Option 3

If you have any queries, please feel free to contact us at (09) 379 9980.

Yours faithfully

Prepared By: ……………………………………………… Victor Lam

Reviewed By: ……………………………………………… Gerard Ball

Principal (Structural)
Babbage Consultants Limited

Principal (Building Surveyor)
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APPENDIX A:

Photo record taken on 10th September 2018

Fig 6: Northern column of the western wall

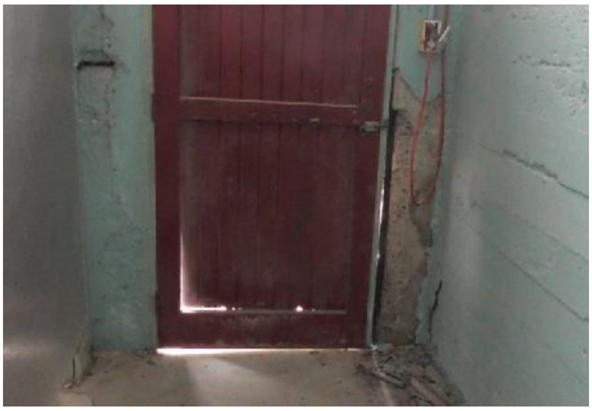
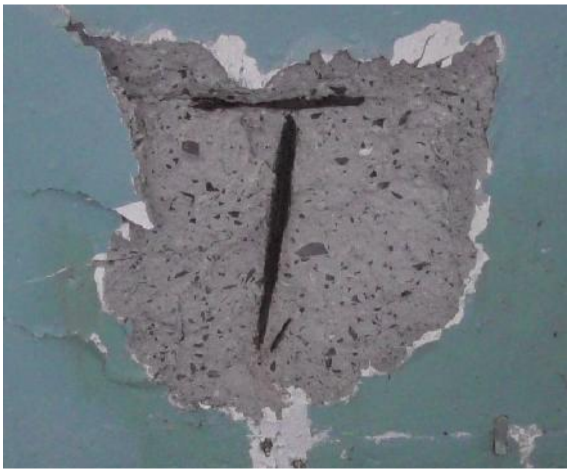


Fig7: Inside view of the Western wall

Fig. 8: Typical inside view of Western wall damage

Fig 9: Northern end wall tension crack



Fi.10: Wall damage shown in Fig. 8

Fig 11: Upper deck beam crack


Fig 12: Upper deck beam crack


Fig 13: Upper deck beam column joint


Fig 14: Upper deck beam surface tension crack


Fig 15: Upper deck beam surface tension crack


Fig 16: Upper deck beam and post deterioration


Fig 17: Upper deck beam surface tension crack

Fig 18: Upper deck ramp beam damage

Fig 19: Upper deck slab damage

Fig 20: Upper deck slab damage

Fig 21: Upper deck slab damage

Fig 22: Upper deck slab damage

Fig 23: Upper deck balustrade bottom edge

Fig 24: Lower deck slab tension crack

Fig 25: Damage shown in Fig 22

Fig. 26: Lower deck slab damage

Fig 27: Lower deck balustrade corrosion

Fig. 28: Lower deck slab damage

Fig 29: Lower deck slab damage