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Project No.: 1190039

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Seaspan ULC
10 Pemberton Avenue,
North Vancouver BC V7P 2R1

Attention: George Geatros, Manager – Special Projects

Reference: Boat Basin North East Infill and JSS Load-Out – Seismic Considerations

Introduction

Seaspan ULC (Seaspan) is in the process of developing permit applications for the boat basin north east infill and the JSS load-out gravel bed projects. This memorandum describes the expected performance of the proposed infill and gravel bed under various levels of seismic events and recommendations on ground improvement to improve seismic performance.

Geotechnical Analysis

The following historical ground investigation data from Seaspan's Vancouver Shipyards site has been used in assessing the liquefaction potential of in-situ soils:

- Swan Wooster Drawing No. U-1584-08-203 Rev A "Vancouver Tug Boat Company Ltd: North Vancouver Development – Topography and Test Holes"
- Swan Wooster Drawing No. U-3141-01-102 Rev 2 "Vancouver Shipyards Ltd: North Vancouver, B.C, Shipbuilding Berth – Soils Information"
- Swan Wooster Drawing No. U-3141-01-103 Rev 2 "Vancouver Shipyards Ltd: North Vancouver, B.C, Shipbuilding Berth – Test Piles"
- Sandwell/MEG Consulting Limited – "07-250-13: Geotechnical Investigation Report for JSS Facilities" dated December 2007
- Stantec Consulting Ltd – "1145-01528: Marine Geotechnical Factual Report: Vancouver Shipyard Facility Modernization Project – Load Out Pier" dated 25 January 2013

- Thurber Engineering Ltd – “Vancouver Shipyard Modernization - Load Out Pier – Ground Improvement” dated 30 October 2013
- Geopacific Consultants Ltd – “Field Test Data – CPT and SCPT data for proposed Seaspan Buildings” dated April 9, 2014

It is noted that SPT values from historical test holes located closest to the subject development areas were found to be lower than values typically observed in similar soils and should a project specific ground investigation program be adopted, more accurate estimates on seismic performance and ground improvement requirements can be developed.

Historical boreholes indicate that the site is underlain by loose sands that are prone to liquefaction and large displacements during earthquakes with return periods lesser than those recommended by current building codes:

- **1 in 100 years return period event:** The in-situ soil is generally stable during this level of seismic shaking, however there are zones of liquefaction that could cause lateral displacements in the order of 1m. Ground improvement of in-situ soils can reduce these displacements.
- **1 in 475 years and 1 in 2,475 years return period event:** Under these levels of seismic events, extensive liquefaction is expected to depths of 30m below seabed. Lateral movements in excess of several meters is expected, extending to more than 20m from the top of the proposed new slopes.

Lateral displacements can be reduced by ground improvement using vibro-replacement method. A densified perimeter ‘dyke’ of about 15m wide by 30 m deep located near the toe of the slopes could be used to limit lateral displacements. A typical cross section showing the proposed ground improvement scheme is presented in Appendix 1. It is noted that even after densification, sections of the infill and gravel bed located away from the densified ‘dyke’ could still be subjected to settlement in the order of 350 to 900 mm.

Seismic Design Philosophy

When subject to design seismic events, the performance objective of codes and standards is focused on life safety with the understanding that structures may sustain irreparable damage but will not collapse. The design event recommended by the British Columbia Building Code is an earthquake with a probability of exceedance of 2% during the life of the structure (return period of 1 in 2,475 years).

When constructing new structures to current seismic code requirements around existing structures that were not designed for seismic loads or were designed to previous seismic codes,

it is possible that the existing structures may fail during an event that is of lower magnitude than the design seismic event. Based on discussions with Seaspan, it is Westmar's understanding that most existing facilities at the site are likely not designed to withstand kinematic loads and soil flow loads due to liquefaction of surrounding soil.

Seaspan has advised that the north east infill will be primarily used for material storage with personnel operating in the area only when material is to be moved. Based on Seaspan's intended use of the area and a project specific ground investigation program, Westmar recommends the adoption of a suitable ground improvement scheme that will limit displacements in the North East Infill such that code intent of life safety is met.

The gravel bed is expected to be used over a 12 to 24 hour period during vessel load outs at intervals of 1 to 2 years. Further, life safety would not be compromised in the event of failure of the gravel bed as all personnel would be onboard the Seaspan Careen or the load out pier during vessel load outs. Based on this, it is proposed that the no ground improvement be undertaken at the gravel bed location.

It is also noted that there is a business risk associated with failure of both the north east infill and the gravel bed during seismic events and this will have to be internally assessed by Seaspan.

Conclusion and Recommendations

Based on a review of historical ground investigation data, a preliminary assessment of the liquefaction potential of the in-situ soils has been carried out. The in-situ soils are expected to liquefy to varying degrees depending upon the intensity of the seismic event. The North East Infill is intended to be used as a storage area and Seaspan's functional requirements for the area can accommodate relatively large displacements and settlement. Based on further design refinement and subject to a project specific ground investigation program, Westmar recommends the adoption of a suitable ground improvement scheme that will meet the code intent of life safety.

The Gravel Infill will be used infrequently, over a 12 to 24 hour period at 1 to 2 year intervals. Further, during vessel load outs, all personnel using the facility will be either onboard the Seaspan Careen or on the load out pier. Based on this, the gravel infill proposes no life safety risk to users and hence, no ground improvement is proposed in this area.

We trust the above meets your immediate requirements. Please do not hesitate to contact us at 604-729-8125 or via email at vramadhas@westmaradvisors.com should you have any questions or require additional information or clarification.

Sincerely,

Vignesh
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Appendix 1 – Preliminary Drawings
