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22 June 2001

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Subject: Response to the Port of Seattle's comments on the GeoSyntec Consultants letter of 16 February 2001

GeoSyntec Consultants (GeoSyntec) has been retained on behalf of the Airport Communities Coalition to provide a technical review of investigation, analysis and design relating to construction of the embankment fill and West Mechanically Stabilized Earth (MSE) Wall elements of the proposed Third Runway Expansion Project at the Seattle Tacoma International Airport. This letter summarizes GeoSyntec's response to the Port of Seattle's comments contained in their April 30, 2001 response to GeoSyntec's February 16, 2001 letter.

GeoSyntec is highly qualified to perform this review. GeoSyntec's personnel in charge of the review include Patrick C. Lucia, Ph.D., P.E., G.E., and Edward Kavazanjian, Jr., Ph.D., P.E., G.E.

Introduction

The size and scope of the proposed West MSE wall is extending the state of practice for this type of design and construction. National building codes relied upon by the Port as a basis for preliminary design are typically intended as minimum design standards and are not applicable for a project such as the proposed MSE wall. The performance of smaller walls subjected to lower intensity seismic loading than the

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design standards for the West MSE Wall may be considered encouraging, but is not sufficient evidence to allow for less than the most rigorous standards for the proposed wall.

While the Port appears to have made additional efforts to address several of the comments made in our 16 February 2001 letter, a number of our original comments have still not been addressed satisfactorily. These issues are fundamental and must be given more consideration and thorough analysis before a regulatory decision is made and the wall is constructed. Among the issues of concern are the following:

- there is insufficient laboratory strength data for proper characterization of foundation soils;
- the extent of the potentially liquefiable material may have been underestimated;
- seismic stability analyses are being performed incorrectly;
- insufficient documentation is being provided for a proper and thorough regulatory decision to be made.

Therefore, as stated previously in our 16 February 2001 letter, the Port has yet to demonstrate that a stable wall can be economically constructed or that the wall, if constructed, can withstand the seismic loads to which it may be subjected without large, unacceptable deformations.

The following sections provide commentary on specific responses made by the Port to our letter of 16 February 2001.

Comment 1B. ***"The Size of the MSE Wall is Accurately Reported"***

We are aware that there are existing walls of substantial height, each with its own configuration of slopes and tiered walls to achieve the required height. Some of these walls have been constructed in seismically active areas. However, we are not aware of any walls approaching the size of the proposed MSE wall having been subjected to significant seismic loading.

Comment 2. ***"The Port has Conducted Sufficient Laboratory Testing of Soils"***

Given the scale of the West MSE Wall, although a significant number of soil borings may have been performed in the vicinity of the wall, an insufficient number of

laboratory strength tests have been performed. We have not been given the opportunity to review the correlations that have apparently been made between cone penetration tests and the limited laboratory results in the vicinity of the West MSE Wall, as well as with testing at other areas of the Third Runway Project. Without reviewing this information, we remain concerned that there is insufficient testing data to form a sound basis for design. Additionally, we continue to have the same concern regarding the level of testing performed for the other MSE walls.

Comment 3. ***"The Port has Accurately Interpreted Laboratory Strength Test Results"***

We did not comment on the Port's methods for performing laboratory strength tests. Rather, the comment was directed at the chosen interpretation of the test results, where calculation of strength at 20% strain is not standard practice and is potentially unconservative. We would caution the regulatory agencies and the Port on one statement in particular made in the Port's response to our comment. The statement made is as follows:

> "The difference in shear strength values at 10% and 20% strain is generally less than 15% and has already been taken into account in the Port's design."

We question how this reduction in strength has been taken into account in the design. While a typical geotechnical engineering project will include conservatism, it is generally not wise to release some of this conservatism during the design phase of the project. If the project was designed for a static factor of safety of 1.5, a 15% reduction in strength may correspond to a designed static factor of safety of 1.3. This type of reduction may be even more significant in a seismic design where relatively small changes in strength can have a large impact on the results.

Comment 4. ***"The Port has Employed Conservative Strength Values in Its Stability Analyses"***

Given the scale of the project, and the limited testing data and information available for review, we remain concerned that strengths selected for use in the stability analyses are not sufficiently conservative and may mask potential problems. Sound engineering practice calls for performance of necessary strength testing under the appropriate testing conditions prior to performance of significant design work. What would the impact be on the project if the high stress laboratory testing which the Port

has said "will be completed as part of final design" reveals lower strength values than the Port is anticipating? There is potential for strength reduction both under higher confining stresses, and from the previously discussed 15% reduction due to interpretation of the existing test results. The Port has stated that "subsequent analyses demonstrated factors of safety greater than 1.0 would result from using even lower values [of strength]." Have both sources of strength reduction been considered in these analyses? Even if they have both been accounted for, the final design must have appropriately conservative factors of safety, and not simply be greater than 1.0.

Comment 5. ***"The Port's Liquefaction Analysis Methodology Is Accurate and Supported by the Scientific Literature"***

The referenced document which discusses the Monte Carlo type approach (*Hart Crowser, 2001. DRAFT Geotechnical Engineering Analyses and Recommendations, Third Runway Embankment, Seattle-Tacoma International Airport, SeaTac, WA. March 2001*) post-dates the 16 February 2001 letter by the reviewers. As of the writing of this response, we have not received a copy of this document and thus have not been given the opportunity to properly evaluate the analyses. We have no way of judging whether "analyses using the most conservative interpretation showed stability exceeded the target factor of safety."

The included Figure 2 does show a cross section with a continuous "weak layer" however no details are provided that show "how the Port conservatively modeled" liquefaction. No soil properties are given, and the analyzed failure surfaces are not shown. Has the failure surface with the lowest factor of safety been forced to travel completely within the "weak layer"? More details are required for a proper review. An undocumented claim of conservative modeling is insufficient as a basis for approval of a wall of this scope and magnitude.

In reference to the implementation of the Chinese Criterion, it is our opinion that the Port is continuing to not apply them appropriately. There are soils that are commonly found in the Seattle area (e.g., glacial soils with high "non-plastic" fines content) that may be susceptible to liquefaction, and yet would be identified as non-liquefiable according to this screening method. Failure to identify potentially liquefiable soils in the wall foundation is a potentially fatal flaw in the seismic stability assessment.

Comment 6. ***"The Residual Shear Strength Values Used by the Port's Design Team Are Appropriate"***

We are pleased that the Port has recognized that the residual shear strengths used in previous analyses were not appropriate. However, without seeing the details of the revised analysis, we cannot comment on them.

Comment 7. ***"The Port Utilized the Correct Methodology for Pseudo-Static Analyses"***

The Port continues to employ an incorrect methodology in performing pseudo-static stability analysis. The purpose of the analysis is to locate the potential failure surface under seismic conditions with the greatest potential for seismic deformation. This is not necessarily the surface with the lowest static factor of safety. Based on our past association and recent conversations with Professor Idriss, a member of the Port's Technical Review Panel, we are certain he agrees with this statement. The analyses described in both of the referenced Hart Crowser reports do not do this. The sliding block analyses shown in the Hart Crowser memorandum (*"Stability Review of RECo 30% Design – Third Runway Project" November 9, 2000*) depict failure surfaces which only pass through the weaker subsurface materials for a brief distance before rising into the compacted fill. This type of failure surface is not equivalent to the "sliding block" analyses referred to and depicted in the reviewers' comments of 16 February 2001.

The Port analyses have not captured a potentially more critical failure mechanism as depicted in our letter of 16 February 2001. This failure mechanism must be carefully examined when there is a weak seam that extends below the ground surface.

A weak unimproved soil lying beneath the massive fill embankments can provide a path of least resistance for the failure surface extending farther back into the embankment, picking up a larger pseudo-static driving force. In fact, it is the existence of the "very strong glacial till" below the weak layer which prevents the failure surface from traveling deeper and instead forces the surface to pass through the weak material. Failure surfaces can be much more complex than the simplified circular surfaces and wedges that many engineers routinely analyze, and the conditions believed to exist for the Third Runway Project must be analyzed for these more complex failure modes. We are confident that under the conditions described the pseudo-static factor of safety would *decrease* as the failure surface extends further back through the weak layer.

Therefore, the stability analyses performed to date continue to overestimate the resistance of the wall to seismic loading for this mode of failure.

If performance of a correct pseudo-static analysis indicates unacceptable factors of safety and excessive deformations, the likely solution will be to expand the zone of soil improvement and ensure that the depth of improvement is sufficient to cut off any potential failure surface below the improved zone. Expansion of the zone of foundation improvement may have significant detrimental impacts on both the cost and schedule for wall construction as well as increasing the environmental impacts of wall construction.

Comment 8. ***"The Probabilistic Seismic Hazard Analysis (PSHA) is Consistent with Standard Industry Practices"***

The Port's response highlights the inconsistencies in the PSHA that concern us. The Port agrees with the reviewers that the acceleration response spectra used by Hart Crowser agree remarkably well with the USGS values yet state that the magnitudes used are more conservative than the USGS publication. These statements are contradictory, as changes in the magnitudes employed in the analysis will almost certainly result in changes to the acceleration response spectra. This inconsistency between the magnitudes used in the PSHA and the acceleration response spectra continues to cast suspicion upon the results of the analysis.

Comment 9. ***"Three Time Histories are Being Used on the MSE Project"***

We do not feel that sufficient information has been provided to properly evaluate the accuracy of the Port's response. If the three time histories had been provided for review, the reviewers could either agree or disagree with the Port's statement "the time histories used in the analyses are appropriate for the proposed construction conditions at the site." Without knowing the details of the time histories used in the analysis, including how their acceleration response spectra compare to the target spectrum, it is impossible to say whether or not analyses are being performed properly or not. Therefore, we remain concerned that the time histories used in the analysis are deficient in the period range around the resonant period of the wall, leading to underestimation of the seismic forces on the wall.

Comment 10. ***"The MSE Wall Design Team Has Considered and Incorporated Seismic Performance Criteria into the Design"***

We are comfortable with an approach that sets performance criteria as stated in the 30 April 2001 letter and evaluates the seismic condition that produces that result. However, in applying this approach caution must be exercised in interpreting the results of a limited number of deterministic finite element analyses such as FLAC. Degradation of performance of the wall can occur very rapidly as deformations occur. We believe it is essential to evaluate wall performance at higher seismic loading levels to evaluate the sensitivity of the wall to the effects of increasing deformation.

Comment 11. ***"Use of FLAC for Seismic Analysis is Well Documented in the Scientific Literature"***

The reviewers are not attempting to dissuade the Port from using the FLAC code for analysis of the walls. In fact, numerical analysis using FLAC or a similar code is essential in a project of this magnitude and importance. However, extreme caution must be exercised in performing the analyses and in developing conclusions from the analysis. Whatever numerical model is employed in the analysis should be "benchmarked" by comparison to physical model tests, well documented case histories, or closed form solutions, prior to application on a project as important as the Third Runway Expansion. Benchmarking should include the same features of the numerical model (e.g., element types, constitutive models, types of loading) that will be employed in the design analysis. While some verification modeling may have been conducted by others between scale models of MSE walls and FLAC analysis results (e.g., modeling by Bathurst and his co-workers), they were not made for walls of this size. Additionally, while the Port states that "default constitutive models & elements were used" in their analyses, it is unlikely that many of the previous FLAC studies referenced by the Port used "default" constitutive relationships, or standard interface elements for steel strips. Once again, we reiterate our belief that insufficient documentation of the FLAC modeling efforts has been provided to demonstrate that the results of the analysis can be used to reliably predict the behavior of the wall in the design earthquake.

Comment 17. ***"There Will Be No Material Impact on Existing Contaminated Groundwater From the Construction of the Third Runway"***

We do not feel that sufficient information has been provided at this point to properly evaluate whether there will be material impact on existing groundwater.

Conclusions

The Third Runway Project as a whole, and in particular the West MSE Wall, are projects of such magnitude that they demand adherence to the most rigorous analysis and design standards, and not simply to building codes. While the Port appears to have made additional efforts to address several of the comments made in the 16 February 2001 letter, a number of our original comments have still not been addressed satisfactorily. These issues are fundamental and must be given more consideration and thorough analysis before a regulatory decision is made and the wall is constructed.

Sincerely,

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Principal

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cc: Peter Eglick, Helsell Fetterman LLP
Kimberly Lockard, Airport Communities Coalition

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