IGES

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July 17, 2009

Mr. Chip Pratt
Northstar HOA c/o Blooming Enterprises, Inc.
650 South 2021 West
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IGES Project No.: 01304-001

RE: **Rockery Analysis and Design**
Northstar Subdivision Road
Northstar Community
Park City, Utah

Mr. Pratt,

As requested, IGES, Inc. has evaluated the three proposed rockeries to be constructed as part of the Northstar Subdivision Road project located in the Northstar Subdivision of Park City, Utah. The project consists of widening and re-aligning the existing Northstar Subdivision Road to increase safety and expand the existing storm drain system. The three rockeries will be constructed to protect cuts along the widened road alignment. The locations of the proposed rockeries are shown on Plate A-1, *Site Plan*, included with this report in Appendix A.

As planned, Rockery No. 1 is located along the proposed rock cut in the northeast portion of the site, is approximately 68 feet long and 2 to 15 feet tall. Rockery No. 2 replaces an existing timber wall located to the west of the rock cut, is approximately 69 feet long and 1 to 2 feet tall. Rockery No. 3 replaces an existing timber wall along the south side of the upper portion of the Northstar Subdivision Road, is approximately 76 feet long and ranges from approximately 3 to 6.5 feet in height. The Northstar Subdivision Road is located at the toe of each rockery and due to the cut nature of the rockeries, all back slopes were considered to be the existing site grades.

The rockery design was based on discussions with the Client and our understanding of the project site geometry and soil conditions as observed during a site visit on June 22, 2009 and in the project plans, *Revised Proposal for Road and Storm Drain Improvements, Northstar Subdivision Road*, prepared by Alpentech, Inc. dated September 20, 2008. The rockery analysis included in this report was completed in accordance with the accepted industry standards of care including global stability, internal stability and external stability. The following paragraphs further describe the analysis and design procedures.

Soil and Rock Parameters

The native site soils were observed by hand-excavating several test holes in the area of proposed Rockery Nos. 2 and 3. The soil consisted of moist, light to dark brown Lean CLAY (CL) with some gravel. The soil appeared to be consistent and homogenous across the site. No fill soils were identified and no groundwater, seeps or springs were encountered at the site. A sample of the Lean CLAY (CL) soil was obtained for direct shear (ASTM D3080) laboratory testing. Laboratory test results included in Appendix D report a friction angle of 17 degrees with a cohesion value of 450 psf. These values were used in the global stability analysis. Due to theory limitations, a friction angle of 29 degrees with a cohesion value of 0 psf was used in the rockery stability calculations.

The rock exposed in the existing rock cut was visually classified as Pennsylvanian Carboniferous pale gray and tan limy sandstone and quartzite (Weber Quartzite). Based on the observed Hoek-Brown rock characteristics, a Mohr-Coulomb correlation of 48 degrees friction with a cohesion value of 800 psf were assigned to characterize the rock strength behind Rockery No. 1. A printout of the Mohr-Coulomb fit to the Hoek-Brown Criterion is included in Appendix D.

Horizontal Ground Acceleration

Seismic stability analyses for the proposed rockeries were completed using the peak ground acceleration (PGA) resulting from the maximum considered earthquake (MCE) corresponding to a 10% probability of exceedance within a 50-year period (return interval of approximately 475 years). The corresponding horizontal ground acceleration was obtained using the United States Geological Survey's (USGS) Java Application *Ground Motion Parameter Calculator* (USGS, 2008). The calculator database includes correlations with the USGS 2002 Probabilistic Seismic Hazard Maps. Probabilistic spectral accelerations corresponding to MCE seismic hazard level for rock-like conditions were calculated based on the latitude and longitude of the site.

To account for site soil effects, site coefficients (F_a and F_v) were used to attenuate the rock-based spectral acceleration values. Based on our field investigation, we believe the soils at this site are representative of a "very dense soil and soft rock" profile, best described by International Building Code (IBC) Site Class C with F_a and F_v values of 1.20 and 1.68, respectively (International Code Council, Inc., 2006). From these procedures the MCE peak ground acceleration (PGA) was established as 0.17 g. The MCE and Design Response Spectra are presented in Appendix D at the end of this report.

Internal and External Stability Analysis

Engineering analysis to determine minimum rock sizes was performed based on *Rockery Design and Construction Guidelines*, FHWA Publication No. FHWA-CFL/TD-06-006 (Mack et al., 2006). The analysis included external and internal sliding, internal and external overturning, and bearing capacity under static and pseudo-static conditions. Design calculations are presented in Appendix C.

Global Stability Analysis

The global stability analysis included both static and pseudo-static (seismic) analysis of the maximum rockery sections for both the rockery against the rock cut (Rockery No. 1) and the rockeries against the soil cuts (Rockery Nos. 2 and 3). The stability analyses were completed using the geometric conditions, soil strengths and assumed rockery construction as observed on site and described in previous paragraphs. The boulders were considered to be an anisotropic material with a boulder-to-boulder lateral shear resistance characterized by a friction angle of 45° and a cohesion value of 0 psf. A cohesion value of 2,000 psf was assumed to characterize the internal rock strength. Minimum factors of safety of 1.5 and 1.1 for static and seismic conditions, respectively, were considered acceptable. The results of the global stability analyses are presented in Appendix B.

Rockery Construction Specifications

Based on the analysis and the constraints presented in this report and in accordance with the Associated Rockery Contractors (ARC) *Rock Wall Construction Guidelines*, the attached drawings and specifications presented in Appendix A (Plates A-2 through A-7) were developed. The following paragraphs further describe design elements that should be incorporated into the rockery construction.

Section drawings of the proposed rockeries are included in Appendix A as Plates A-2 through A-5. Based on our design analyses, the rock facing should not be placed steeper than 0.5 to 1 (horizontal to vertical). The bottom rocks along each rockery should be keyed into the ground a minimum of 12 inches for sections less than 10 feet tall. Sections exceeding 10 feet in height should be buried a minimum of 1.5 feet.

Rock facing should be placed in general accordance with the ARC *Rockery Construction Guidelines* as shown in Plate A-6 and as summarized in the attached Construction Specifications, Plate A-7. The guidelines state “rocks should be placed so that there are no continuous joint planes in either the vertical or lateral direction and wherever possible, each rock should bear on at least two rocks below it.” In addition, the guidelines state “the upper plane of each rock between courses (the top surface of rock), should slope back towards the protected soil face and away from the face of the rock wall.”

The Northstar Subdivision Road is located at the toe of each rockery and due to the cut nature of the rockeries, all back slopes should be graded at a maximum slope of 3H:1V until catching the existing site grade. A channel lined with a minimum of 6 inches of low permeability soil should be constructed above the top course of rock to prevent surface water such as precipitation or irrigation from flowing over the top of the rockery or infiltrating the soil above and behind the rockery.

Conclusions and Limitations

The results of the analyses indicate that the proposed rockery met adequate factors of safety. A section drawing of the rockery and General Construction Guidelines are provided in Appendix A. The rockeries should be constructed as shown in the drawings. Boulders should be set with the largest dimension perpendicular to the rockery facing. To increase facing stability, voids between boulders should be chinked with smaller rocks.

The design drawings and specifications have been completed to reduce the potential for erosion and scour at the toe of the rockery and saturation of the slope behind the rockery. A channel lined with a minimum of 6 inches of low permeability soil should be constructed above the top course of rock and efforts should be made to quickly vegetate/landscape the area above the rockery to reduce erosion and infiltration.

A perforated drainage pipe and a 1.0-foot partition of gravel wrapped in geotextile fabric or alternatively a continuously placed prefabricated drainage composite has been included in the section drawing to provide some drainage behind the rockeries. However, this system may not be adequate to draw water away from the rockeries if increased moisture conditions occur due to groundwater, seeps or springs. These conditions were not identified during the site investigation conducted by IGES as part of this rockery design, However, if these conditions are encountered during the construction of the rockeries, IGES should be immediately notified so that recommendations may be revised.

Conditions such as leaky or broken irrigation lines and ponding of precipitation or runoff can lead to saturation of the soil behind the rockery, which can lead to slope failure. Erosion and scouring of soils at the toe of the rockery can undermine the rockery which may also eventually lead to slope failure. The Owner/Client should be aware of the risks if these or other conditions occur that could jeopardize the stability of the rockery.

Inspection Scheduling

In order to facilitate inspection of the rockery construction, we propose the following schedule:

1. Inspect the first course of rocks for size, embedment, and back drain construction.
2. Inspect the second or third course of rocks for size, position and placement, and drainage.
3. Inspect finished rockeries for conformance to design requirements such as maximum heights, batter, front and back slope geometries, and rock sizing, positioning and placement.

The contractor, owner or developer is responsible for informing IGES of the construction schedule to facilitate the inspections. The reviewing engineer also reserves

the right to increase the frequency of inspections if conditions warrant. We appreciate the opportunity to provide you with our services. If you have any questions please don't hesitate to contact us at your convenience.

Respectfully submitted,
IGES, Inc.

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John F. Wallace, P.E.
Principal

PROFESSIONAL ENGINEER
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Appendices: A) Rockery Design Drawings and Construction Specifications
B) Global Stability Output Plots, Input and Output Files
C) Internal Stability Analysis
D) Seismic Response Spectra, Laboratory Test Results

References:

Alpentech, Inc., *Revised Proposal for Road and Storm Drain Improvements, Northstar Subdivision Road*, Project Plans, dated September 20, 2008.

Associated Rockery Contractors (ARC), *Rock Wall Construction Guidelines*, www.ceogeo.com, 1999

Gary H. Gregory, P.E., *GSTABL7,* Version 2.002, Gregory Geotechnical Software, Copyright 1996-2001

International Code Council, Inc., *International Building Code* (IBC), 2006

Mack et al., *Rockery Design and Construction Guidelines*, Federal Highway Administration, Central Federal Lands Highway Division, Publication No. FHWA-CFL/TD-06-006, November 2006

United States Geological Survey (USGS), *USGS Ground Motion Parameter Calculator*, Version 5.0.9, Java Application, dated October, 6, 2008