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Underground Garage at 220 Morningside Drive, Corte Madera, California

Project Concept

30’ long horizontal axis, a diameter (width) of 26’ and a radius (height) of 13’. This is an inherently stable geometry for tunneling and would accommodate a 20’ to 22’ wide by 8’ high “garage envelope” with space for tunnel supports, final lining and final floor. The final design would likely be a modification of this basic shape and feature a flatter roof area and perhaps short vertical side walls. The final shape will depend on consideration of construction efficiency and stability, as well as architectural requirements.

For purposes of this evaluation, the elevator shaft is assumed to have an ecavated size of 10’ x 10’ in plan view. Depending on the required location of the elevator in plan, there may be a short connecting tunnel between the base of the shaft and the garage. The shaft could be excavated either before or after the garage excavation, although there may be construction advantages in removing muck/spoil through a previously excavated garage.

Site Geotechnical Conditions

Site geotechnical conditions are described in the Geotechnical Report (Geoengineering, Inc, August 29,2005) which addresses foundation engineering for the house. In general, residual soil up to about 4 feet thick, including an overlying “soil mantle”, overlies very highly weathered Franciscan Complex sandstone and shale. The very highly weathered Franciscan rocks are about a foot thick and grade downward to moderately to highly weathered rock that is “variably fractured”. In test pits extending to about 5 feet deep, refusal at the base of the 1 foot thick very highly weathered rock was described as “very hard sounding”. Rocking conditions below a depth of 5 feel were not investigated.

No ground or surface water was encountered, although perched water was said to occur at the top of the rock during periods of high rainfall.

Portal Development

Before the actual tunnel excavation is started, a portal cut with approximately vertical walls would be excavated into the hillside from the edge of the road. The cut would be deep enough to provide adequate vertical cover at the brow of the tunnel and allow installation of initial shoring, drainage and slope protection. The size and geometry of

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the portal cut would also depend on the project architectural requirements. It is expected that the back face of the portal cut would be about 15 feet high.

It is expected that the portal cut can be excavated and supported using soil nailing methods. This is a “top-down” method with an initial bench being excavated at the location of the top of the proposed tunnel face. The back wall of the bench is about 6 feet high and nearly vertical. Shotcrete is applied to the exposed ground and holes are drilled about 4 inches in diameter on 5 foot centers horizontally around the entire benched cut. Steel reinforcing bars, typically 8 to 12 feet long depending on structural requirements, are centered in each hold and backfilled with cementious grout. Additional shotcrete is applied to the exposed wall, bearing plates are installed to the bars, and the benched cut is excavated down another 6 feet and another row of holes are drilled. The shotcrete will be reinforced with welded wire fabric. Drainage materials are installed prior to shotcreting.

Garage Excavation and Support

It is recommended to excavate and support the garage and shaft for the elevator before the house is constructed. This sequence of construction will avoid potentially damaging differential structural settlement of the house due to excavation beneath the house. The final design of the underground openings would include any anticipated structural loads due to the house.

Based on the available geotechnical information, a roadheader is expected to be capable of excavating the tunnel. Such machines very between backhoe-type excavators with boom mounted roadheader heads and purpose-built hard-rock roadheaders. The selection of the appropriate machine depends on having accurate data on the ground conditions. Although the geotechnical investigation, which included 5 foot deep test pits, is adequate for building foundation purposes, a boring to a depth of about 35 fee would enable sampling and logging of the rock/ground at the back of the garage and/ or the base of the elevator shaft.

For the proposed diameter and expected weak rock, the tunnel is not expected to be self-supporting upon excavation. Therefore, pre-excavation support will likely be required in order to advance the entire face in one operation, that is, “full-face”. Typical pre-excavation support would use spiling methods. At the portal face before excavation, a set of holes are bored about 12 inches on center, parallel to and above the location of the tunnel crown. The holes extend across the width of the tunnel, curing down at the sides and extending several feet beyond the full tunnel width. The holes typically are 15 to 20 eet long. In a manner similar to that used for the soil nails at the portal, steel reinforcing bars are installed in each hold and grouted in place. The grout permeates the ground surrounding the each hole and provides a bond between the spile and the ground and increases the cohesion of the ground. In effect the spiles reinforce the roof of the garage and allow the ground below to be sequentially removed and additional supports to be installed.

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Excavation proceeds in rounds, a few feet at a time. For example, following a round of 2 to 4 feet, a layer of shotcrete from 1 to 2 inches is applied to the walls and crown. This "flash coat" will provide temporary support, prevent loosening of the ground and allow placement of a steel arch or set (for example, an 8 inch deep steel beam) across the full width of the tunnel. Alternatively, lattice girders may be installed. The use of steel sets or lattice griders will depend on the specific contractor's means and methods. Either approach is considered appropriate. The ground, with the pre-installed steel spiles already in place, will relax somewhat and load the steel sets. Excavation continues, with additional layers of shotcrete and a layer of welded wire fabric applied to fully encapsulate the steel sets to form a composite reinforced shotcrete lining.

Spiling also continues in advance of the excavation. However, in this case steel rebar spiles are driven into pre-drilled holes that are angled upward between the sets, with the spile insterted from below one set and supported by lying above and on the next set. The spile becomes a cantilever to pre-support the ground before the next round excavates the ground beneath the end of that spile.

Should the face of the tunnel exhibit instability, such as raveling or loosening of rock blocks, a shotcrete flash coat can be applied. When the crown and walls are stabilized, the next round can be excavated along with the temporary flash coat.

As was done for the portal cut, drainage materials (geotextiles) are installed at intervals along the crown and walls and subsequently tied into gravel drains installed below the final floor. The tunnel is excavated to appropriate grades to provide for drainage.

Garage Final Lining

The final lining for the garage is expected to be shotcrete, which can be reinforced using steel mesh and/or steel bars. Analysis includes evaluation of any loads on the final lining due to the influence of the house and the elevator. Depending on the type of initial lining that was installed during the excavation, initial lining elements can be incorporated into the design of the final lining. A combined lining would allow an increase in capacity and more efficiency in construction.

Shaft Excavation and Support

Prior to shaft excavation, a level bench is required to be excavated to construct the shaft collar and provide space for necessary equipment, including a crane. The bench/collar could be excavated in an open cut with sloped sides unless space restrictions require vertical shoring. The dimensions and shape of the final elevator structure are unknown. (10'x10' or 10' circumference). The following discussion presents methods suitable either for a circular or a rectangular elevator plan.

It is expected that the shaft could be excavated using mechanical means, that is with pneumatic and or hydraulic equipment suitable for excavation by hand or by small

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backhoe type excavators. Should sufficiently strong rock be encountered, hoe-ram type excavation could be required. Maximum rock strength and hardness are not known.

It is expected that a circular shaft can be constructed and shored with liner plates. Ring beams may be required to reinforce the liner plates, particularly at the tope of the shaft depending on the shaft diameter and depth of soil like ground. Should sufficiently firm and self supporting rock be encountered, shotcrete reinforced with steel fibers and or steel mesh could be used instead of the liner plates. Rock bolts may be required should loosened rock blocks or sufficient size be encountered. If the bench excavation for the shaft collar is carried down through the very highly weathered rock then except foa few liner plate rings to build the collar, the shaft could be entirely supported with shotcrete/rock bolt methods.

Alternatively, soldier piles and wood or shotcrete lagging could be used to construct the shaft. In this case a rectangular shaft would be built. Lateral support would be provided by internal bracing with wales and struts. This method is probably most appropriate for the support of weak rock or soil like conditions, buy may also better suit the rectangular shape of the final elevator and allow the initial shaft support to be incorporated into the final elevator wall construction.

Construction Considerations (see Construction Plan)

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