SOLEDAD MOUNTAIN ROAD LANDSLIDE REMEDIATION PROJECT

EDITED BY KELLY M. PAGE

On the morning of October 3, 2007, at approximately 8:50 a.m., a large landslide approximately 250 ft (76.2 m) in width occurred in the 5700 block of Soledad Mountain Road. The failure, which represents a partial reactivation of a larger ancient landslide underlying the Soledad Corona Estates subdivision, lasted 45 minutes and resulted in a total lateral eastward translation of approximately 25 ft (7.6 m). Soledad Mountain Road was rendered impassable in both directions, and Upper Desert View Drive was blocked by debris, cutting off access to eight residences. In addition to affecting traffic flow in the area, four homes were destroyed, and three more adjacent to the landslide margins were damaged to varying degrees and tagged as unsafe for occupancy by the city of San Diego. Overhead and underground utilities were also damaged. Thankfully, no injuries occurred.

INVESTIGATION

The initial phases of the subsurface geotechnical investigation began on October 4, 2007, and included both test pits and large diameter borings surrounding the perimeter of the landslide mass. Following clearance by the fire department, small-diameter drilling began on the slide mass on October 5, 2007. Soil samples were retrieved for laboratory analysis and six inclinometers were installed at various points on and adjacent to the landslide mass to monitor any ongoing slope movement. Six piezometers were also installed around the head of the landslide to detect

Soledad Mountain Road landslide, October 3, 2007

groundwater. In the initial phase of investigation, a total of seven large-diameter borings, 13 small-diameter borings, and two test pits were excavated and logged.

Subsequent phases of geotechnical investigation were concurrently performed with construction activities as the project progressed and included a number of additional borings and inclinometer installations. The additional subsurface information was used to further refine the geologic model and improve shear pin design. Many of the shear pin shafts were downhole, logged by project geologists during the course of construction. A total of 10 reinforcement cages were fitted with inclinometer casings prior to placement to provide permanent slope monitoring installations for future monitoring of the completed landslide repair.

TEMPORARY SHORING

During the process of data acquisition and the development of a working geologic model for the landslide, it was concluded that the landslide had significant potential for westerly expansion in the headscarp region. Consequently, due to the significant risk posed to adjacent properties, plans were drawn up for the initial phase of the repair, which included the installation of 37 cast-in-drilled-hole (CIDH) shear pins flanking the headscarp region of the landslide. Twenty-three 42 in. (1067 mm) steel-reinforced shear pins spaced on 8 ft (2.4 m) centers were installed along the west side of Soledad Mountain Road behind the headscarp of the landslide. The 60 ft (18.3 m) long reinforcement cages weighed 10,400 lb (4717 kg) each and consisted of 14 No. 18 vertical reinforcing steel bars (equally spaced) wrapped with a No. 4 reinforcing steel spiral. Due to higher driving forces in the northwest-southeast direction, the remaining 14 shear pins were larger and were installed in a single northeast-southwest-oriented row crossing Soledad Mountain Road. The remaining shear pins were 48 in. (1219 mm) in diameter, 66 ft (20.1 m) in length, and weighed 20,760 lb (9417 kg) each. The larger cages were installed on 7 ft (2.1 m) centers with reinforcing consisting of 18 equally spaced No. 18 vertical reinforcing steel bars wrapped with a No. 4 reinforcing steel spiral. All of the cages were fabricated off site from Grade 60 steel, trucked to the site, fitted with centralizers, and set into predrilled holes by crane at the specified elevation below grade. Concrete was monolithically placed via a tremie to a predetermined elevation below grade to allow for future utility and shoring installation during grading operations to remove landslide debris within Soledad Mountain Road. The design for the temporary shoring was intended to achieve a static factor of safety of 1.3 during planned excavation activities.

EAST-SIDE SHORING

Following completion of the temporary shoring and implementation of winterization measures to prevent infiltration of water into the landslide mass, installation of the east-side shoring began in March 2008. Thirty-eight 54 in. (1372 mm) diameter CIDH shear pins were constructed on 8.5 ft (2.6 m) centers. Reinforcement cages consisted of 26 equally spaced No. 18 vertical reinforcing steel bars wrapped with a No. 4 reinforcing steel spiral weighing 36,000 lb (16,329 kg) each. Cages were prefabricated and delivered by truck to the site, fitted with centralizers, and set by crane working from either side of the landslide. Six thousand psi (41.4 MPa) concrete was pumped in via the tremie method to top pier at 3.5 ft (1.1 m) below the proposed finished grade to allow for the future installation of shallow residential utilities such as

Closeup of reinforcement cage

East-side shoring panel wall construction

Temporary and east-side shoring during excavation

Geogrid reinforced fill in Slot 1 excavation

Aerial view of shoring during repairs

water and gas. Shear pins were monolithically placed with the exception of shear pin Numbers 51 through 69, which required two separate pours per shear pin to construct an exposed length of pier above the ground surface to support new roadway fill. A tube form was cut to the required length and placed over the exposed steel reinforcement for the second pour.

Following installation, shear pin Numbers 49 through 70 were connected by poured-in-place concrete panels. The top of each panel wall was formed to match the flanking piers, whereas the bottom of the panels matched existing grade across the landslide mass at the time of construction to a maximum height of 16 ft (4.9 m). Panels were 12 in. (305 mm) thick, reinforced with No. 5 reinforcing steel bars (vertical) 15 in. (381 mm) on center and No. 5 reinforcing steel bars (horizontal) 12 in. (305 mm) on center. Connections to adjacent pins were made with 3 ft (0.9 m) lengths of No. 5 reinforcing steel bars, vertically spaced 12 in. (305 mm) on center, lap-spliced with the panel wall reinforcement with 18 in. (457 mm) embedment into the adjacent pin. The purpose of the panel wall was to prevent soils from pushing between the shear pins during restoration of the right-of-way and to provide additional lateral support for Soledad Mountain Road until fill could be placed on the east side of the shear pins and eliminate the grade break. Blockouts were formed at predetermined elevations to facilitate the future installation of residential sewer connections for the residences at 5703 and 5715 Soledad Mountain Road.

The east-side shoring was designed to achieve a static safety factor of 1.5. Two specific cases were considered for the design. For Case 1, the load from the shoring-retained soils on the east side of the shear pins was considered during open excavation conditions in Soledad Mountain Road during removal of landslide debris. The shoring-supported roadway fill on the west side of the shear pins during removal of landslide debris on the residential lots to the east for future private property repairs was considered for Case 2.

SOLEDAD MOUNTAIN ROAD EXCAVATION

Following completion of the temporary and east-side shoring, slot-cut excavations were undertaken to remove compressible landslide debris and restore the roadway using geogrid reinforced engineered fill. Temporary lagging was placed between adjacent shear pins. Cut lagging ends were angled to match the approximate curvature of adjacent shear pins. Lagging was braced behind angle iron that was anchored to adjacent shear pins using epoxy-anchored bolts. Shoring was grouted at vertical intervals not exceeding 4 ft (1.2 m). Excavation and backfill

was completed in three slots, and Soledad Mountain Road was restored and reopened to restricted traffic flow on October 16, 2008. Due to the grade break across the east-side shoring, the east side of Soledad Mountain Road could not be completed until final slope regrading was performed at the end of the project on the private residential lots to the east.

UPPER DESERT VIEW DRIVE SHORING

During the repair of the Soledad Mountain Road right-of-way, plans were drawn up for the final phase of construction to repair the Upper Desert View Drive right-of-way. The repair included installation of 44 72 in. (1829 mm) diameter CIDH shear pins installed in two phases. The shear pins were installed west of Upper Desert View Drive in a single row across the majority of the landslide mass, with a staggered, double row at the north side of the landslide. Reinforcing consisted of 30 No. 18 reinforcing steel bars (vertical) wrapped with a No. 4 reinforcing steel spiral. Cages were prefabricated and trucked to an off-loading point below the site and lifted using a 500 ton (453.6 metric ton) hydraulic crane located on a specially constructed crane pad at the toe of the landslide. Temporary CIDH footings were also constructed at several locations to provide additional crane outrigger support. Each cage weighed more than 42,000 lb (10,050 kg). The initial phase of shoring installation occurred across the central portion landslide mass and included the installation of 18 of the shear pins. The second phase included the remainder of the shear pins to the north and south, which could not be reached by the crane during the initial phase of installation. A 6000 psi (41.4 MPa) concrete mixture design was used for all the shear pins installed along Upper Desert View Drive. Concrete was delivered to the shafts via a concrete pump, positioned as needed above the work area along the recently repaired Soledad Mountain Road.

Following the installation of the shear pins, landslide debris was removed and replaced at the toe of the landslide area in three slots. Upper Desert View Drive was re-established on a line and grade matching the original construction plans dated January 10, 1967. A 1.5 to 1 (horizontal to vertical) geogrid reinforced slope was then constructed along the west side of Upper Desert View Drive to a slope hinge point above the recently installed shear pins. From that point, the slope was regraded to a 3 to 1 (horizontal to vertical) slope, matching the top of the east-side shoring. At this point, Soledad Mountain Road underwent final repairs so final traffic flow and speed limit restrictions could be lifted, marking the completion of the repair.

Setting of reinforcement cage using 500 ton (453.6 metric ton) crane

Pumping concrete using 170.6 ft (52 m) boom truck

MATERIAL TESTING, CONSTRUCTION OBSERVATION, AND TESTING

Materials testing was continually performed throughout the project to check compliance with project specifications and drawings. Concrete sampling was performed during concrete placement for every shear pin and during panel wall and temporary crane support construction. Twenty-eight-day compressive strengths routinely exceeded 8000 psi (55.2 MPa). Tensile testing of No. 18 reinforcing steel bars was also performed.

In addition to materials testing, all construction and grading activities were fully documented by the project geotechnical engineer, including limits of grading, compaction testing, verification of proper geogrid installation, and index testing for import soils. Construction activities were also closely monitored using portable vibration monitoring equipment to verify any potential impacts to surrounding private residences.

A total of 119 CIDH shear pins were installed to stabilize and reconstruct the slide-damaged area. Shear pin construction included the installation of more than 3.6 million lb (1.6 million kg) of reinforcing steel, pumping over 6500 yd^3 (4970 m^3) of structural concrete, and the removal and recompaction of over 43,000 yd^3 (32,875 m^3) of earthen material. Innovative design and construction techniques were required due to access restrictions and limited work space. The use of CIDH shear pins and panel walls within city-maintained right-of-ways and general utility easements allowed stabilization of the roadways without impeding future stabilization and redevelopment efforts on private properties. The cost of repairs (not including private property) was approximately $24.5 million, and the remediation was accomplished in less than 2 years.

Soledad Mountain Road

OWNER
City of San Diego Department of Engineering
San Diego, CA

PROJECT ENGINEER
Helenschmidt Geotechnical, Inc.
Carlsbad, CA

REPAIR CONTRACTOR
Hazard Construction Company
San Diego, CA

MATERIAL SUPPLIERS
CMC Fontana Steel
Etiwanda, CA

Vulcan Materials Company
San Diego, CA

Completed landslide remediation repair of Soledad Mountain Road and Upper Desert View Drive