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Landslides

LANDSLIDES IN THE FRANCISCAN GROUP

By

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Synopsis

On the many miles of highway that have been constructed in the Franciscan group in the North Coastal regions of California, landslides have been frequent and difficult to correct. The chief causes of these landslides have been the weakness of the weathered and faulted Franciscan group and subsurface water resulting from the heavy rainfall in the area. Many of the landslides are old and are not a result of construction operations.

Means of detection or exploration for these landslides have included geologic mapping and field reconnaissance by competent engineering geologists and foundation engineers, studies of all available geologic and soils information from the area, geophysical studies and drilling operations.

It is frequently possible to avoid or minimize the effects of active or potential landslides by proper location of line and grade, but it would be impossible or at least impractical

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to construct a highway through much of the coastal area without crossing an active or potential landslide.

Corrective or preventive measures have been based on (1) effecting a favorable load or weight distribution and (2) adequate subsurface drainage. These two functions have been accomplished by (1) grade changes, line changes, struts or buttresses, and slope flattening; and (2) by stabilization trenches, horizontal drains, pervious blankets, and drain wells. Corrective or preventive measures are usually a combination of some of the above steps rather than a single means.

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Landslides in the Franciscan Group

Introduction

Most of U.S. Highway 101 from near San Francisco to the Oregon line and State Highway 1 from San Francisco to its northern terminous as well as many other State Highways in the north coastal part of California are in the Franciscan. Landslides are rather common throughout most of this area. In fact there are many miles of highways in this region where it would be virtually impossible to locate the highways without crossing landslides. Many of these landslides were in existence prior to the construction of the highways. Also the construction of the highways has been the immediate cause of additional landslides. Landslides that have taken place as a result of construction have been in fills as well as in cuts.

The Franciscan is in general structurally weak or at least contains many zones that are weak. There has been considerable crushing and distortion of the Franciscan as a result of uplift, folding and faulting. This diastrophism and the heterogeneous composition of the Franciscan has exposed the formation to the weathering processes. The heavy rainfall in the region where the Franciscan is prevalent has played a major roll in landslides in the area. Many portions of the formation are susceptible to water and hence break down into clays and silts with relatively low strength and poor structural characteristics.

Presented at the 3rd Annual Meeting of the California Association of Engineering Geologists, October 15, 1960 by T. W. Smith, Senior Materials and Research Engr., Materials and Research Dept., California Div. of Highways, Sacramento, Calif.

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Investigation

In determining the existence of active or potential landslides the use of competent engineering geologists and foundation engineers can not be overemphasized. Methods of investigation usually include field reconnaissance, the use of airphotos, geologic mapping, drilling, testing and analysis of data from many available sources. The specific geologic methods often include studies of aerial photos, strip mapping, seismic surveys, resistivity studies and many hours of tramping the hills, and the review of all available data to obtain the best possible concept of the conditions as they exist. It should be emphasized that many embankment foundations in the Franciscan are potential landslides and they require extensive and adequate investigation. There is no substitute for experience and basic knowledge that is necessary in the process of evaluating the geologic conditions involved in cut slope and foundation treatment design.

The actual drilling operation usually consists of coring and ground water studies made on the various borings. The general practice of the California Division of Highways is to electrolog the borings made in connection with such a study. These logs are used to correlate between borings and they also make it possible to reduce the quantity of coring on some of the borings. Tests and visual inspection provide much valuable information in evaluating the strength and drainage characteristics of the cores and hence the materials that they represent.

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Frequently no one phase in the investigation will provide the answer to a landslide problem but rather the proper evaluation of the data that can be obtained from many of these phases will point to possible solutions. Close cooperation and exchange of information between engineering geologists, soils engineers, and design, construction and maintenance personnel is important.

Corrective and Preventive Measures

In the correction or prevention of a landslide the basic approach is to increase the forces that will reduce the possibilities of failure and decrease the forces that are causing failure. Some of the conditions or features that will contribute toward preventing failure are (1) struts or buttresses to prevent movement, (2) strength of foundation soils that may be increased by reducing the moisture content and pore pressures, and (3) replacing soil of low strength with soil of higher strength. The forces that tend to cause failure are (1) the weight of soil mass tending to move, and (2) pore pressure that reduces the strength of the soil.

It is frequently possible by changes in anticipated grades and alignments to cross landslides in the most favorable position. This is particularly true in the Franciscan where most landslides are of the rotary or slump type. One rule of thumb in taking advantage of better load distribution would be, if a landslide must be crossed with a road, it should be in fill near the bottom of the slide, or in cut near the top of the slide. A fill near the bottom of the slide would generally serve as a buttress or strut to support the slide and a cut in the upper portion of the slide

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may tend to reduce the load or driving force producing sliding if the load is removed at the proper place within the slide mass. Each situation must be analyzed carefully in order to take best advantage of the load distribution factors. Care must be exercised in using struts or buttresses that the load from this filling does not add to the overall driving force and cause rather than prevent sliding. Also in making cuts at the head of a slide care is necessary that this does not induce further sliding above the cut or head of the slide. Steps that will reduce the possibility of such sliding are making the cut on flat slopes or by improving the subsurface drainage in or above the cut. If the bedding planes are favorable with respect to the cut slopes the possibilities of a stable cut are better than if the bedding is unfavorable. It is usually difficult to take advantage of the bedding planes with reference to cut slopes since both the alignment of the roadway and the strike of the material may vary within very short distances. It should also be pointed out that in many instances where the materials have weathered severely the material may be very little stronger across the bedding planes than it is along the bedding planes. In these cases, and they are typical of many of the landslides in the Franciscan little or nothing is to be gained by favorable bedding since the inherent strength and ground water conditions will largely control slope stability or foundation stability.

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In the vast majority of landslides in the Franciscan groundwater is a major contributing factor. We have used various means to remove groundwater and thereby improve the strength and stability of active or potential landslides. The most common methods for removing groundwater that we have made use of have been stripping, stabilization trenches, horizontal drains and drain wells.

Stripping has consisted of removing overburden or mantle soil, frequently of poor quality, in order to expose a water-bearing strata underneath. The area is then blanketed with pervious material in order to drain the subsurface water. A fill can then be constructed in the usual manner over such an area. This procedure not only removes the water with its detrimental effects, it results in replacing the wet weak soil with well compacted fill material. Stabilization trenches might be considered a modification of the stripping procedure. A V-shaped trench is excavated through overburden or mantle soil in order to expose a water bearing strata underneath. The side and end slopes are excavated as steep as foundation conditions permit. These trenches might be longitudinal or at an angle with reference to the highway. The bottom of this trench, and the sides where applicable, are blanketed with pervious material, and a perforated pipe is then placed in the pervious material and extended through an outlet trench to remove the groundwater from the area. These trenches are most commonly used underneath embankments but have upon occasion been used to stabilize cut slopes. Vertical

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drain wells have been used to provide a means of egress for ground water where depths are such that it is not practical to strip or provide stabilization trenches. Outlets must be provided from these wells. Horizontal drains, siphons, and pumps have been used as outlets. Horizontal drains have been used in many areas to remove ground water and improve the stability of cuts or foundations for embankments. In cuts the drains are usually installed from roadway and from benches on the cut slope. In fill foundations the drains are usually installed from below the roadway but are sometimes installed above the road in order to intercept water before it reaches the embankment foundation. Grades may vary from 2% or 3% to as steep as 15% or 20%. Spacing may vary from 10 or 15 feet to as much as 100 feet. Depths have varied from as short as 100 feet to more than 300 feet.

It is important in the prevention or correction of landslides to provide adequate facilities for the removal of surface water. In general, surface water and subsurface water should be handled by separate facilities. To combine them usually decreases the efficiency of one or both.

Summary

In summary, we, in the Division of Highways, have had to construct many miles of road in the Franciscan where landslides have been very prevalent. We make extensive use of geologic methods, soil mechanics, and other means in the investigation of active and potential landslides.

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Methods of correction or prevention have been aimed largely at improving conditions by realignment, use of more favorable slopes and subsurface drainage procedures. Correction or prevention of landslides in most instances has entailed a use of a combination of methods of correction.

It should be noted that we have not always been able to correct these numerous landslides. In many instances it has been necessary to use whatever corrective methods were deemed advisable and merely "live with" the landslide. The cost of correction may be prohibitive, and it may be advisable to anticipate a high maintenance cost rather than attempt correction. Thus, there is an extensive field for future work in connection with investigation and correction of landslides. In fact, the design of cut slopes and foundation treatment should challenge the best efforts of engineering geologists and soils engineers. It is a field in which they have mutual interests and mutual benefits can be attained.

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