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34. Report on landslips affecting the railway near Rhyndaston.

D.E. Leaman

Landslips along about 300 metres of the permanent way near mile peg 43½ have been a feature of some concern for at least 30 years. They have been the subject of two previous geological reports (Carey, 1952; Keid, 1954).

As a result of the wet weather of 1971 all slips have been active and the permanent way is now endangered at one point and at increasing risk in two other places. The slips were inspected on 17 November, in company with permanent way engineers of the Railways Department. Acknowledgment is made for the assistance they provided in describing and discussing the history and nature of the problem and many of the comments presented below were initiated by these on-site discussions.

There are three distinct slip areas. The first, some 20 m wide, occurs at the 43½ mile peg. This slip is currently undercutting the permanent way. The second area is some 100 m north of the first and is the most extensive (about 50 m wide). The slip appears to be partly stabilised but the fringe areas are currently quite active. The third slip area is about 100 m further north and is new: only one slip about 8-10 m wide has occurred recently.

The railway line is located about 10-15 m below the Colebrook-Rhyndaston Road on a narrow bench cutting. The general hill slope is quite steep, in places more than 30-40°. In this position the permanent way loads the upper part of the slip zones. All slips are located on hill spurs truncated by the railway cuttings.

SLIP MATERIAL

A major fault cuts across the hill spurs at this locality. More than one fault is present. The faults trend approximately N-S. A quartz sandstone sequence occurs to the east of the fault and an alternating sequence of sandstone and shale with a high content of feldspar on the western side. The principal fault is at about road level with subsidiary failures downslope.

The faulting and associated fracturing has resulted in the deep weathering of the rocks. This has resulted in an accumulation of sand and sandy clay containing rock fragments. Part of the deposit is collapse material and wash from the steep slopes above the line, and some small slips are visible above the line.

NATURE OF FAILURE

The material described above has several characteristic features: a heterogeneous texture, a generally high porosity, variable permeability and weakness under load and water transfer.

The deposit whilst primarily of sand grade material contains localised bands of clay. The texture is thus variable. The porosity of all materials may exceed 30%. The variability of composition gives rise to zones of high and low permeability.

Should such a deposit become water saturated the total weight is greatly increased and if the slope is steep the whole may be unstable. Water transfer may enhance collapse by inducing piping of the contained silts. Only rarely does collapse occur where the land remains in its original vegetated state. However, once cleared and grazed water access is increased and transpiration reduced. The overall result of land development is more active

hydrological transfer with alternating period of drying and shrinkage.

The original slip in each case is about 10 m wide with a drop of about one metre. There is a distinct 'slip circle', a distinct heave zone and a pattern of tension fractures. Once a slip has occurred many further failures are inevitable. One set of failures will occur within the old slip due to improved water access, consequent piping and rapid saturation. A second set of failures will occur around and above the old slip due to unloading lower on the slope with consequent relaxation producing tension higher on the slope. Following further shrinkage and tension, heavy or persistent rainfall initiates subsidiary slips - generally up slope. It is as a result of this process that the line is being undercut in area 1.

Subsidiary slips within a failure zone often occur as soil creeps or 'mud' flows. The process appears to be caused by the rapid ingress of water into tension and shrinkage cracks followed by piping and saturation. As a result of piping the failure is usually little more than a flow of dirty water. Most secondary failures occur in the heave zone where the crack frequency is greatest and there is a high permeability horizon - at the base of the heave material and at the top of the old soil horizon.

It must also be noted that pounding of the soil and weathered rock by stock increases the volume of stored water until the whole is in a quick state. Vibration of passing trains may also induce a similar result by cracking the dried upper layers allowing water ingress and distribution. External impulsive loading of the slip material is also a key factor in failures. Permanent way misalignment has occurred following night passage of heavy freight trains.

WATER PROBLEMS

Previous reports have dwelt at length with the problem of water ingress and drainage. However inspection of all drains above the line shows that little water can be seeping into the slip zones from up slope. The impervious drains installed are excellent and transfer all water clear of the failed areas. However, there is an instance north of slip area 3 where the drainage water should be transferred further downslope clear of the railway property boundary. A further slip might be triggered if this is not done.

Most water is transferred at the base of the soil zone and above rock and weathered rock. Seepages are thus 200-300 mm below the surface. Groundwater flow through the rock is too slow and not sufficiently impulsive to be of importance if other sources of water can be removed. No run-off or near surface flow passes the permanent way into the slip areas. This means that only water from direct precipitation is of any consequence.

Some treatment of the slips has attempted to drain contained water. This is probably of limited success due to restricted permeability on parts of the slips. Slip area 1 was probably being drained at a rate of 400-600 litres per hour from all drains. Whether this rate is sustained and for how long, is unknown. It is estimated that the volume of water which could be stored in slip area 1 is 150,000 litres of which one inch of rain could introduce 7,000 litres. Thus a wet year and periods of intensive rainfall can effectively create a saturation position.

Slip area 1 also contains a rock filled drain some 2 m deep. Infiltration into this drain must be nearly 100%. Disruption of the drain has increased the danger to the slip. This drain is currently acting as a collector of water and by being across the slip is weakening the whole.

POSSIBLE SOLUTIONS

As the source of the problem is the infiltration of rain-water into slip zones or potential slip zones, the ultimate solution therefore involves reduction of infiltration, increased evaporation or increased rate of drainage.

Evaporation may be increased by planting water-wasting plants with a good root system, e.g. poplars or willows. Infiltration can only be reduced by covering the slip slopes with an impermeable material.

Alternatively piling or bridging as suggested by Carey (1952) should be considered. Such a solution may only be of temporary value unless piles or piers can be well founded and as the problem areas occupy a fault zone this may be difficult.

Slip areas 1 and 2 are now rather large and compound and are unsuited to simple treatments. However counterforts could be a solution, especially to slip area 1. Slip area 3 which is small and new could be adequately stabilised at this time by excavation of the failed material and support of the embankment by a concave crib-wall founded on rock. Such a solution depends on the thickness of soft material present.

RECOMMENDATIONS

- (1) The detailed composition and thickness of slip material must be determined by drilling. At least one hole in each of the three slip areas is recommended. This information will enable judgments to be made as to whether pile, pier or wall treatments are feasible. Drilling specifications are as follows: 100% core, diamond NX to a maximum depth of 30 m or such depth as to include 6 m of continuous rock core. A minimum amount of water to be used.
- (2) Keep stock clear of slip toes.
- (3) Weld rail joints near the failure area and thereby reduce vibration effects. It might be useful to examine the effect of vibration around the slip area by making dynamic amplitude tests. Any susceptible zones should be located in this way.
- (4) Plant slip areas with appropriate vegetation.
- (5) Shield the slip areas from precipitation and improve run-off. In order to do this a terrace system composed of light concrete walls with clay coated or sheet plastic covered steps. A surface coating of bitumen is an alternative. The overall slope should not exceed 15-20° as this appears to be the stable slope for old slips (see slip area 2, beneath old flume). Counterforts could be a definite aid to run-off.
- (6) The present rock-filled drain and the surrounding fractured region in slip area 1 should be covered immediately in order to help stabilise the present critical situation. Alternatively effective effluent drains are needed.

It is noted that in order to facilitate items 2, 4 and 5 the land forming the steep slope below the railway property would have to be acquired. As this land is of limited use to the present owner but crucial to the long

term stability of the railway it should be considered. If 5 is constructed a large drain would be needed at the foot of the terraces to protect the construction and to transfer water to nearby surface drainage channels and dams of use to the landowner.

Landslips of areas 1 and 2 are complex and can only be stabilised by reduction of all natural or applied stress factors (items 2, 3, 4, 5, 6). No single treatment will resolve the problem.

Alternatively piling or bridging as suggested by Gary (1953) should be considered. Such a solution may only be of temporary value unless piles or piers can be well founded and as the problem areas occupy a limit zone this may be difficult.

Slip areas 1 and 2 are now rather large and compound and are unsuitable for simple treatments. However counterforts could be a solution, especially to slip area 1 which is small and new could be adequately sized at this time by excavation of the failed material and support of the embankment by a concrete crib-wall founded on rock. Such a solution depends on the thickness of soft material present.

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It is noted that in order to facilitate items 3, 4 and 5 the land form on the steep slope below the railway property would have to be modified. As this land is of limited use to the present owner but crucial to the long