EXAMPLES OF LANDSLIDES ASSOCIATED WITH THE NATAL GROUP AND PIETERMARITZBURG FORMATION IN THE GREATER DURBAN AREA OF NATAL, SOUTH AFRICA

EXEMPLES DE GLISSEMENTS DE TERRAIN ASSOCIÉS AU « GROUPE DU NATAL » ET À LA « FORMATION DE PIETERMARITZBURG » DANS LA RÉGION DU GRAND DURBAN, NATAL, AFRIQUE DU SUD

BELL F.G.* and MAUD R.R.**

Abstract

If the incidence of landslides in the greater Durban area is related to geological formation, then most landslides have been associated with the shales of the Pietermaritzburg Formation. However, in the last eight years, most landslides have been associated with the Natal Group Sandstone and occurred during the very heavy rains of September, 1987, and March, 1988. In fact, prior to 1987 the Natal Group Sandstone was considered relatively stable. On the other hand, many areas in the greater Durban area underlain by shale have long been regarded as unsuitable for development as they were considered potentially unstable.

Two types of instability occur on these formations, that is, sliding blocks of rock along bedding planes, and sliding of the weathered and colluvial soil material on top of bedrock. Illustrations of both types of slides on both formations are presented.

Résumé

Si l'on veut relier les glissements de terrain du Grand Durban à une formation géologique, alors on peut dire que la plupart ont été associés aux schistes argileux de la Formation de Pietermaritzburg. Cependant, au cours des huit dernières années, la plupart des glissements ont été associés au grès du groupe du Natal et se sont produits au cours des très fortes pluies de Septembre 1987 et Mars 1988. En fait, avant 1987, ce grès était considéré comme relativement stable. D'autre part, de nombreuses zones du Grand Durban reposant sur des schistes argileux ont été longtemps considérées comme impropre au développement, en raison de leur instabilité potentielle. Deux types d'instabilité se produisent dans ces formations, le premier correspondant au glissement de blocs rocheux le long de plans de stratification, le second au glissement des sols colluviaux et d'alteration situés au sommet du substratum. Des exemples des deux types de glissements dans les deux formations sont présentés dans l'article.

Introduction

Landslides frequently are mobilized during periods of prolonged rainfall and so the frequency of landslides can often be correlated with rainfall events. Of course, other factors influence the occurrence of landslides including rock and soil type, drainage and the type of vegetation present. In particular, excess groundwater is one of the major causes of slope instability. This is especially the case in soils which are subjected to the development of excess pore water pressures which reduce the strength of the soil and hence its resistance to motivating forces. Olivier et al. (1994) showed that in the greater Durban during the period 1970 to 1991, if the incidence of landslides is related to geological formation, then most of the landslides occurred on the sandstones of the Natal Group. However, 60% of the recorded landslides occurred during heavy rains associated with the floods of September 25th to 29th, 1987, and March 2nd and 3rd, 1988. Prior to the 1987 floods, when some 600 mm of rain fell over a four day period, the Natal Group had been considered a relatively stable formation. The other geological formation on which a significant number of landslides occurred was the Pietermaritzburg Shales, 51 being recorded in the greater Durban area in the two decades mentioned. Olivier et al. also showed that there was a reasonable relationship between the amount of rainfall that fell and the number of landslides which occurred during this period. For example, they concluded that there appears to be two thresholds for the sandstones of the Natal Group which need to be exceeded if landslides are to occur. These are, firstly, 100 to 150 mm of rainfall in 2 hours or, secondly, around 450 mm of rain over a 15 day period. In the case of the shales of the Pietermaritzburg Formation there appears to be a 100% probability that landslides will be initiated when rainfall exceeds 150 mm in 24 hours.

The Natal Group

The Natal Group is of Ordovician-Silurian age and rests unconformably on the Basement granites. It consists primarily of sandstones. These sandstones occur in the coastal and subcoastal areas of Natal and they are overlain, again unconformably, by rocks of the Karoo Supergroup. The
sequence is over 500 m thick in places and thins in a westerly direction.

The sediments of the Natal Group were deposited in a foreland graben, parallel to the present coastline of Natal, in a fluviatile environment. They consist of medium to coarse grained sandstones, quartz arenites, subarkoses and arkoses. Micaceous shale horizons do occur but rarely exceed 0.5 m. Generally the sandstones are well bedded, with typical thickness of around 0.3 to 3 m. Frequent jointing means that the sandstones tend to be blocky.

These sandstones tend to resist erosion and therefore tend to cap hills, frequently giving rise to extensive plateaux. In the coastal area the sequence was faulted by the break-up of Gondwanaland so producing a series of variously tilted faulted blocks. In fact, the regional dip in the greater Durban area frequently is controlled by large fault blocks dipping towards the east or southeast at angles up to 15°, although a few inland dipping blocks do occur.

The soils developed above the sandstones are generally thin, often less than 1 m thick on the upper and middle slopes of escarpments, increasing to between 2 and 4 m on the lower slopes. They are characteristically sandy. An eluvial layer of fine to medium grained sand with silt normally occurs beneath the topsoil. It is usually less than 1 m in thickness and is underlain by sandy clay of low permeability. This is an illuvial horizon in which clay leached from the eluvial layer above has been deposited, on the lower slopes it may be up to 0.3 m in thickness. The residual soil beneath tends to be a clayey sand in which fragments of sandstone occur. The clay-silt content of the residual layer varies appreciably, from less than 10 % to 50 %. These soils tend to have a low plasticity with liquid limits frequently below 35 % and plasticity indices usually in the range 5 to 20 %. Linear shrinkage normally is less than 10 %.

Because of their permeability, these soils are relatively well drained under normal infiltration rates. Under rapid infiltration, however, the small silt and clay content may inhibit drainage, facilitating rapid saturation with a corresponding rise in the water table. After heavy rainfall the illuvial layer can develop high excess pore water pressures which can give rise to virtual quick conditions and so has been referred to as running sand. Problems generally occur on the middle and lower slopes and in valley bottoms.

Slope instability on the Natal Group tends to be associated with the soils resting on the sandstones, although planar and wedge failures occur where blocks bounded by bedding planes and joints, are mobilized. The soils on dip slopes in which high water tables are present are most prone to landsliding. The slides are commonly associated with periods of heavy rainfall and frequently take the form of earthflows.

The Hammersdale Landslide

An example of movement in the sandstones of the Natal Group is provided by the landslide which occurred at Hammersdale. Movements occurred during construction operations in the Mpumalanga Township at Hammersdale west of Durban. The slide occurred on an east-facing slope inclined at about 10°, with sandstones dipping in the same direction at about 9 to 10°. The area of ground movement was contained within a depressed area on the general slope, this area being bounded on the south and west by a low curved scarp some 10 m in height. The sandstones concerned range from very hard quartz arenites to micaceous shaley sandstone with thin beds of shale. A thick cover of grey sandy soil about a metre in thickness rests upon the sandstone. In places a layer of ferricrete is developed in the soil overlying the sandstone. Sandy clay colluvium which contains cobbles and boulders occurs in the depressed area of the landslide where it rests on sandstone. It varies between 2 and 5 m in thickness. A discordant sill of Karoo dolerite, averaging about 10 m in thickness, was intruded into the sandstone (Figure 1). An extensive area of a previous landslide in sandstones of the Natal Group was revealed during construction. The low scarp, referred to above, marks the position of the arcuate boundary crack of the former major landslide.

Groundwater seepage occurred at the surface over virtually all the upper part of the depressed area of colluvial soil. However, in the lower part of the depressed area the water table occurred at about 1.5 to 2 m below the ground surface, that is, at the contact between the colluvium and the underlying sandstone. The presence of dongas (steep-sided erosion gullies) in this area probably helped lower the water table.

The slide was investigated by sinking a series of exploratory diamond drill boreholes on and around the slide to determine whether further movement would pose a risk to areas of the township surrounding the slide (Figure 2). Shear box tests carried out on the sandy clay colluvium showed it to have an internal angle of friction averaging 25° and zero cohesion. Using these values in a back-analysis showed that an artesian head varying from 0.7 to 1.9 m above the water table would give rise to sliding. However, such an artesian head did not appear to exist. Nevertheless the investigation showed that the ground movements involved the saturated colluvium sliding downslope within the scar of the former landslide, the area of movement being located in the central lower part of the former slide. The movements took place because of the excessive ingress of water into the area via the outcrop of sandstone underlying the colluvium, saturating the colluvium. Movements occurred at the colluvium-sandstone contact. The investigation also showed that the original slide occurred in the relatively recent geological past and that the primary cause of movement had been the build-up of pore water pressure along the contact between the sandstone and the overlying dolerite sill.

The use of effective stabilizing measures was uneconomic because of the large area involved. The area within about 20 m of the slide therefore was changed from one dedicated to housing to one of open space. A sewer which was being constructed across the toe of the former slide, and was in part responsible for the movements, was rerouted to avoid the disturbed area. A main road across the head of the slide could not be relocated as it involved a fill of up to 6 m in height. It therefore was bench'd on to sandstone and provided with an adequate drainage system. Eucalyptus trees were planted over the slide to assist in absorbing excess groundwater and to improve its stability.