assumed that these shocks were most probably caused by local fracturing of rock in over-stressed zones, which is characteristic of a process of progressive failure.

It should also be mentioned that since the appearance of the perimetral fissure along the upper boundary of the disturbed area of the slide in the autumn of 1960 to the day of collapse in 1963, more than 400 cm (13 ft) of displacement were recorded on the observation monuments. It is therefore not acceptable to classify this motion as creep because the average speed of motion was more than 40 times greater than that assumed by Terzaghi as the maximum speed of creep deformation. Besides, in a region of creep no definite boundary of the area in motion can be detected, whereas the distinct perimetral crack clearly limited the zone already in motion from the autumn of 1960.

During an inspection of the site at Vaiont, the Writer has found a rather significant quantity of lumps of a bentonitic clay of very low shearing resistance ($\phi = 5°–7°$) within the debris material from the sliding surface (see Fig. 2). Geological evidence shows signs of a prehistoric slide on the western part of the recent slide. The low values of the shearing resistance of the rock masses, established in all available stability computations of the Vaiont slide, could be explained if the following three points are duly considered:

(*a*) in the zone of the previous prehistoric slide in the western part of the slide, the strength of the rock mass was reduced to its residual value due to large strains;

(*b*) the average shearing strength of the nonhomogeneous bedded and jointed rock mass was gradually reduced to a residual value of $\phi_r = 17°–30°$ by a process of progressive failure;

(*c*) the variety of clay of very high plasticity and low shearing strength existing in some bedding planes and/or rock zones further reduced the strength on some portions of slip surface to only 5°–7°.

It can be concluded that the study of slides in rock masses needs comprehensive exploration of the weakest constituents in the first place. The rupture phenomena in minutely fractured rock masses seem to be of the same nature as in granular and cohesive materials and the stability of rock slopes can be analysed in the same way.

Zagreb, Kačičeva 26,
30 January, 1967.

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INCREMENTAL STRAIN RATE RATIOS AND THE STRENGTH OF SAND IN THE TRIAXIAL TEST
(Barden, L. and A. J. Khayatt, *Géotechnique*, 16:338–357)

The Writer has followed with interest the development of stress-dilatancy concepts in recent years and the paper by Barden and Khayatt is a further addition to the literature on this subject.

The Writer would like to add some comments relating to the section on failure criteria for soils, a topic of rapidly expanding interest in connexion with granular soils. It is now accepted that none of the three classical criteria of failure, which have been inherited from the discipline of metal physics, are adequate to fit the observed behaviour of sands and, indeed, it would appear that there is not even a unique criterion that is independent of porosity. Only in the

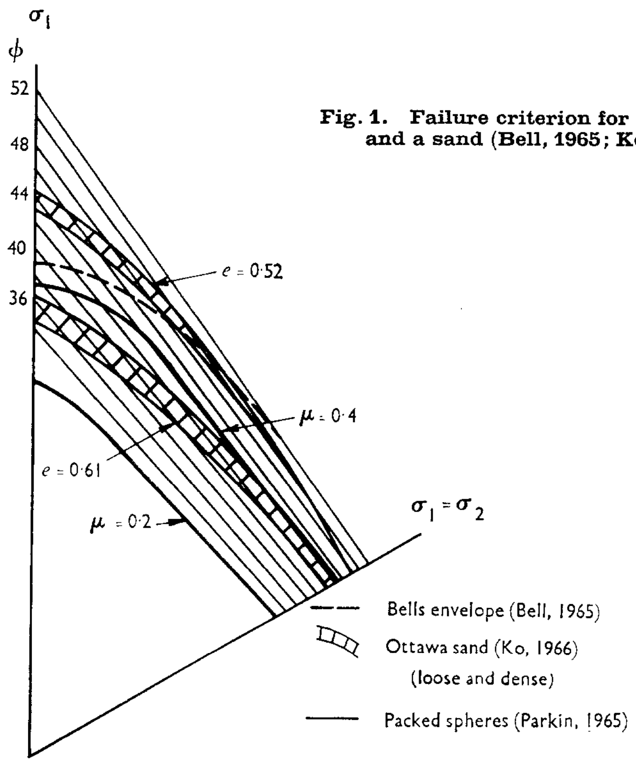


**Fig. 1. Failure criterion for an ideal packing (Parkin, 1965) and a sand (Bell, 1965; Ko, 1966)**

case of the higher porosities can it be established that behaviour approaches that of Mohr–Coulomb.

In fact, it becomes more evident that the failure criterion pertaining to any given condition of sand is a complex one contained between two limiting types of behaviour, relevant to uniformly loose or uniformly dense packings.

The Writer has investigated a criterion of failure applicable to a dense assembly of equal rigid spheres (Parkin, 1965), typifying the more pertinent properties of a granular soil near the upper limit of density. This solution is reproduced in Fig. 1 for values of $\mu$, the coefficient of friction, of 0·2 and 0·4.

Recent results by Bell (1965) and Ko (1966), testing sands in a new type of direct triaxial compression cell, have been superimposed, and while much work yet remains to be done, it is evident that the character of the above failure criterion is being reflected in these results.

Although there is much experimental evidence to indicate identical strength in compression and extension, there is a theoretical case to suggest that this may not be universally true, and the Writer would heartily endorse all efforts to clarify the nature of extension in granular soils.

65 Old Church Street, S.W.3.,
10 February, 1967.

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