THE ROLE OF MULTIPLE SHEAR BANDS IN DEFORMATION OF GRANULAR MATERIALS

Danuta Lesniewska
Polish Academy of Science, Institute of Hydro-Engineering, PL 80-953 Gdansk, Poland

Summary The patterning of shear bands in granular materials is one of the fundamental features of their behaviour. To illustrate this statement the results of a number of tests on a dry course sand are presented. The results form a specific data base which can serve to verify theoretical models, describing post-failure behaviour of granular materials. A shear band width is chosen to show that some assumptions of commonly used models are not confirmed by experiments.

Experimental data base

All the data presented here were obtained in Cambridge University, Engineering Department, between 1962 and 1974. During this period a number of researchers (Arthur, 1962, James, 1965, Lucia, 1966, May, 1967, Bransby, 1968, Adeosun, 1968, Lord, 1969, Smith, 1972 and Milligan, 1974) was working on the active and passive failure of a mass of dry sand deforming under plane strain conditions, what belongs to the slow granular flow class of problems. Their work is also presented and discussed by Lesniewska, 2001.

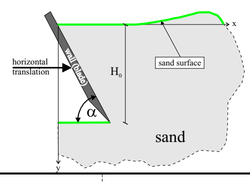
Characteristic examples of slow granular flow

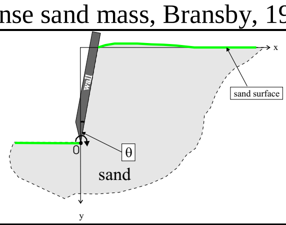
Subsequent stages of slow granular flow caused by:

Fig.1. Cutting blade moving horizontally into a mass of dense sand, May, 1967

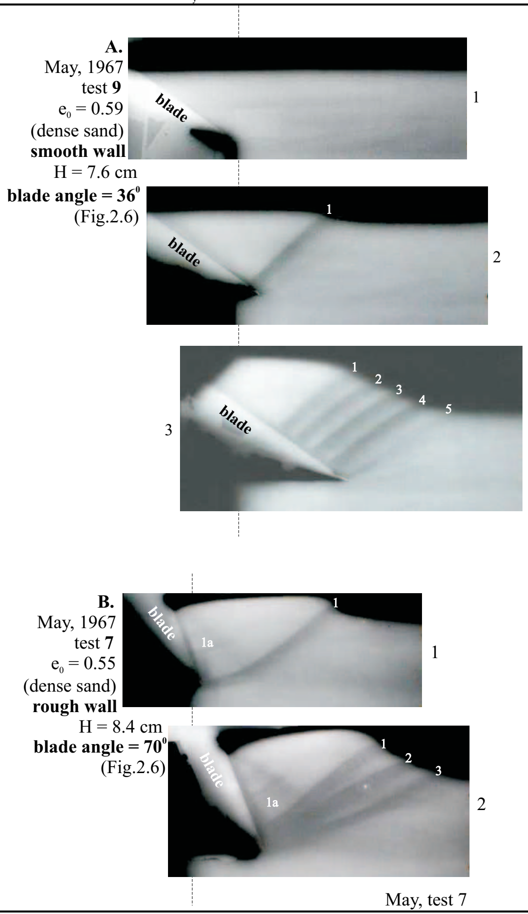
Fig.2. Rigid vertical wall rotated about its toe into a dense sand mass, Bransby, 1968

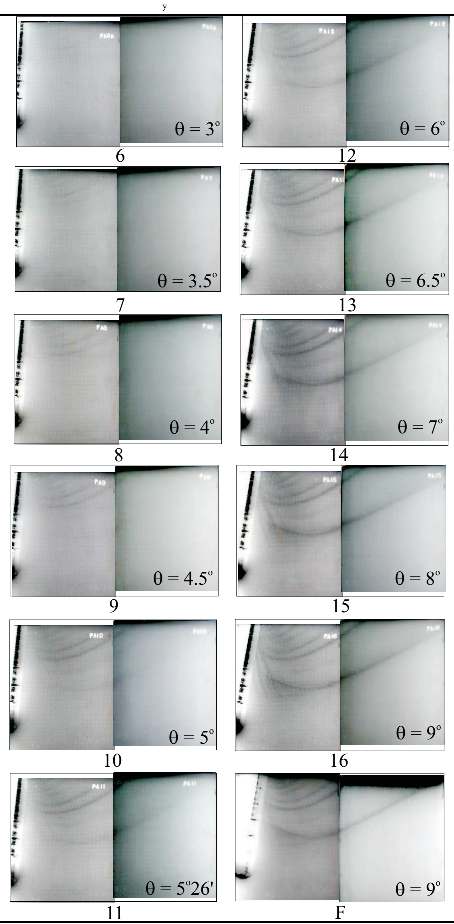
Outline of the test





Radiographs taken





Dark bands on the radiographs represent shear bands (or rupture surfaces), since the high shear strains in them cause dilation and hence a reduction in density in comparison with that of the surrounding sand. Reduction in density in turn results in decrease in its capacity to absorb X-rays.

Discussion and conclusions

General conclusion coming from Cambridge tests on walls is that the actual post-failure behaviour of granular materials is much more complex then it is regarded in any of the established methods of analysis. On the other hand this complex behaviour seems to be based on multiplication of some simple failure mechanisms. As a result actual failure mechanisms show striking regularity, characterising almost all types of tests (Lesniewska 2001). This regularity consist in creating sets of geometrically similar and clearly separate shear bands, forming the whole failure patterns, specific for any particular type of tests.

Another important conclusion is that in plane strain condition only two distinct families of shear bands were observed in sand. These two families split up the soil mass into a number of quasi-rigid domains, which deform very little during movement. The flow of the whole sand mass is realised by the relative movement of the domains, thus making the strains within a sand highly localised. The dimensions characteristic for such a soil partition are quite big in comparison with wall height and seem to depend very much on test conditions.

A few characteristic patterns of shear bands were observed in Cambridge tests on walls. The simplest one consist of single main shear band cutting off the moving soil block of different shape (Lesniewska, 2001). Such a case is well known from classic approach, but as most of the Cambridge tests suggest, it is only a special case, belonging to the much wider class of possible shear band patterns. In a little more complicated situation the sand mass can be divided up into a few domains by a set of shear bands belonging to the same family (like for example in Fig.1A). The most developed pattern of shear bands is built from shear bands belonging to both families. Such a meshlike pattern resembles very much stress characteristics. Slow granular flow caused by wall movements has apparently progressive character (Fig.2).

The role of two families of shear bands seems to be different - one of them (α) is responsible for a basic soil movement, and the other (β) not always appears and seems to be responsible for adjusting failure mechanism to changing boundary conditions (so called „adjusting shear bands"). The presence of second family of shear bands was observed both in passive and active tests. In passive tests it appeared whenever rough wall had been used (e.g. Fig.1B) - the only exception were Arthur's and James' tests on walls rotated about its top (Lesniewska 2001). There is no such a rule in case of active tests. Comparing two dredged tests on walls with different flexibility one can say that more flexible wall is responsible for activating the second family of shear bands. Looking some other results however, one could understand, that in case of rigid rotating wall the smooth wall makes activating the second family of shear bands easier then the rough wall, in contrast to passive tests on rigid walls. The conclusion resulting from these observations is that the particular test conditions are responsible for activating some of potential shear bands, whilst the others remain non-active. In this way the existence of some unknown mechanism of selection is confirmed. Whenever multiple shear bands appear, the distance between two neighbouring bands is of the same range of magnitude, suggesting that some material characteristics of sand may have the influence on it.

Clearly the type of shear band pattern, activated in any particular test, depends strongly on type of constraints put on the sand by the test conditions. This fact should be included into theoretical analysis. Less constrained tests enabled dilation along the mesh-like shear bands pattern. It was not possible for example in case of similar tests, during which only one curvilinear shear band developed. The only difference between both types of tests was that during the second one the top of the wall was fixed and thus the dilation in the vicinity of the wall suppressed.

All mentioned above observations are of great importance for any attempts to model post-critical behaviour of granular materials and should be taken into account to achieve more realistic approach to it. Especially the following phenomena should be studied:

- Existence of internal structure, defined by initial conditions put on a soil sample, expressed in terms of soil division into finite quasi-rigid domains
- Influence of soil-wall interaction, expressed in terms of soil-wall contact parameters
- Mechanisms of selection of certain shear bands to become active.

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