EXPERIMENTAL STUDIES OF CAVING A SOIL
BENCH UNDERCUT AT THE BASE

É. G. Chaikovskii

The creation of generally acceptable methods for designing undercutting machines requires a study of the features of caving a soil bench. Parameters for the bench before and after caving and also the production rate for the cut affect machine linear dimensions, driving power and energy capacity for working soils with caving, and also the safety of using undercutting machines.

Previous theoretical studies are inadequate for solving the problem of creating hydraulicking for soils which are difficult to work using undercutting machines since they do not embrace a whole series of questions [1]. In particular no study has been made of the picture of mechanical undercutting of heavy soils of considerable moisture content and stickiness which are difficult to wash out, there has been no consideration of the effect of the geometric and kinematic parameters of the working head and also the cutting rate during caving, and the action of the caved soil mass on the undercutting device has not been studied. Parameters have not been determined for the caved bench in relation to soil physicomechanical properties, preparation of the required lump size after caving, energy content of the caving process, operating safety, etc.

Results are given in this article for studying undercutting of dense clay soils of categories I–III which are difficult to wash out and which are mainly worked by hydromechanization in open-cast mines of the Kuzbass. In carrying out the studies the problem was posed of determining parameters which characterize caving of these soils, the effect of production rate for the cut slot on the caving process, and the size limits for lumps of soil after caving.

It is well known with bench height not exceeding the limiting height for a stable vertical slope the caving picture may be represented as follows. Caving commences on reaching a minimum or 'critical' area of bench undercutting. This area changes in relation to the height of the undercut layer. The area of the undercut is characterized by two parameters, i.e., cutting depth and length of the undercut or caving increment. There is a minimum cutting depth with which caving commences [2].

Experimental determinations provided a study of the overall picture and features of the soil caving process in a face of crescent (in plan) shape undercut with a horizontal cut. Undercutting of the bench was carried out by a special unit which simultaneously also served for studying the working heads of the worm-cutter type.

Factors which affect the caving process for a soil bench undercut at the base by a cut slope may be conditionally separated into three main groups:

caused by physicomechanical properties of the soil being worked;
connected with the geometric shape of the working head, dimensions and production rate for the cut slot;
determined by the type of working head producing the cut slot and the nature of its effect on the soil mass.

The main effect on development of the caving process is caused by factors which relate to the first and second groups, and therefore in these studies they were considered first.

The following parameters were measured (Fig. 1): 1) the minimum cut depth required for developing caving, \( l_{ca,\text{min}} \); 2) the caving increment \( l_{ca} \) in relation to cut depth \( l_{cu} \) and the height of the undercut layer \( H_{1a} \); 3) collapse parameters for the caved soil: length \( a \), width, \( b \), caving angle \( \alpha \).

All of the processes were photographed and recorded on cine film.
A study of caving for a bench composed of light soils of category I (according to GOST 1734-83) was carried out in a quarry of the Chernorechensk cement factory in an experimental unit (Fig. 2). It consisted of a self-propelled single-caterpillar trolley 1 with an automatic electric drive 2 and a hinged joint with its skid frame 3 supporting the working head in the form of a screw cutter 5 with a drive. A boom 6 of length 15 m was hinged with the caterpillar frame 8. The other end of the boom was fastened to an immobile support. In order to increase the support area on the soil there was a support roller 7. The unit made it possible to undercut a bench with a single cut at the base. The cutting radius was 18.5 m and the length of the undercut front was up to 40 m.

The face was composed of light loams with a DorNII densimeter impact number of 4-5 and a moisture content of 16-18%. The soft caved after undercutting was collected by a bulldozer.

The main aim of studying caving for light soils was checking the theoretical assumptions obtained previously and also checking and improving the unit construction. The height of the undercut layer in tests was taken as 2.0 m, and the cut depth was taken as 0.5-1.0 m; the undercutting rate was varied from 2.3 to 12.7 m/min. The height of the cut determined by the diameter of the working head was 0.5 m.

In all 25 tests were performed for undercutting and bench caving. The number of observations in each test was three to five. The overall length of the undercut bench was 510 m.

The main parameters obtained in tests which characterize caving for a bench composed of soils category I are provided in Table 1.

From the test data dependences for cutting depth on caving increment and caving increment on undercutting rate were obtained. It is established that with a constant height of the layer and cutting depth with a change in undercutting rate from 2.3 to 12.7 m/min, i.e. by about a factor of six, the caving increment, and consequently also the critical area, increased a little, i.e. by 20% (Fig. 3). It is also established that the minimum cutting depth required for developing caving is 0.3 m. Caving commenced in the form of individual small falls above the cut slot, and on reaching an undercut length of 1.9-2.0 m there was separation of the undercut mass over the whole height. The size of individual lumps after caving did not exceed 0.4-0.5 m.

Testing of the unit showed the efficiency and reliability of this construction, which made it possible to outline a program for further studies in heavy soils directly in mines of the Kuzbass.

A study of caving for a bench composed of heavy soils of categories II and III was carried out in the Novosergeev coal mine of the Chemerovougl Combine. The thickness of loose formations of the Novosergeev deposit varies from 2.5 m in interstream areas up to 28-35 m in river valleys and ravines.

In interstream areas and the slopes of covering formations there are mainly loams of light-brown and light-yellow color of hard, semihard, and high-plasticity constitution of average density with a thickness of 2-10 m. In ravines and river valleys they are covered by formations of peat and green-gray soils or clays (grasses). The loams and clays are uliginous, strongly compressed, and with an increase in pressure they are capable of bulging, but with dynamic action they liquefy. These soils relate to the category which are difficult to wash out and whose thickness reaches 20 m.