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SURFACE SOIL CLODDINESS IN RELATION TO SOIL DENSITY AT TIME OF TILLAGE

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A rough, cloddy surface has proved best to prevent soil from drifting and blowing on wind-erosion-susceptible lands lacking an organic residue cover. Except for cohesionless sands, most soils will form clods when stirred by tillage implements. Soil moisture, soil texture, type of tillage implement, and soil density largely determine the size and percentage of clods produced.

Compaction has been considered detrimental from most viewpoints on agricultural soils, and considerable research has been concerned with means of preventing or alleviating compaction (1, 4). However, soil compaction may be desirable for wind erosion control if the size and distribution of clods are increased by timely packing before tillage.

This paper presents the results of a study initiated to determine the possibility of increasing the cloddiness of soils by increasing soil bulk density.

EXPERIMENTAL EQUIPMENT AND PROCEDURE

Laboratory equipment included a power winch rated for a 700-pound load at 100 feet per minute, a tillage box with a 3- by 5-foot test section, a tool carrier with strain link (fig. 1), a 2- by 10-inch narrow-point chisel, a weighted lawn roller, and a strain recorder with amplifier.

Three field soils with clay percentages of 17 (sandy loam), 33 (silty clay loam), and 46 (clay) were selected and sieved through a 0.25-inch sieve. Soil particles less than 0.25 inch in diameter were used to conduct the tests. Standard Proctor tests were performed on each soil to determine the maximum density and the optimum moisture for packing (5). These values were 1.89 g./cc. and 13 per cent for sandy loam; 1.59 g./cc. and 20.2 per cent for silty clay loam; and 1.44 g./cc. and 28.8 per cent for clay.

Soil was brought to optimum moisture content and packed with the water-weighted lawn roller, or combination of roller and hand packer, to provide densities ranging from 1.31 to 1.71 g./cc. on sandy loam, 0.98 to 1.41 g./cc. on silty clay loam, and 0.93 to 1.30 g./cc. on clay; or, expressed in percentages of maximum density: 69 to 90, 61 to 88, and 64 to 90, respectively, for the three soils. Maximum density in this paper refers to the bulk density obtained at the optimum moisture content by dropping a standard 5½-pound Proctor hammer 25 times through 12 inches onto 3 equal layers of soil placed in a cylinder whose volume is 1/30 cubic foot. Three replications each of five densities were used on each soil. Bulk density was determined by core sampling.

Compacted soil was tilled with a full-size, 2- by 10-inch, narrowpoint chisel immediately after packing (figure 1). All soil thrown up on the surface within the 5-foot test length was placed in soil pans. Clods large enough to permit sizing to 1- by 1-inch cross section were selected and used to determine the relative resistance to crushing (fig. 2). One-half the clods sampled were oven-dried and the size distribution determined by rotary sieving (3); the other half were placed outside in trays with bottoms of wire gauze for weathering. After approximately 6 months the samples were brought inside and the sieving operations repeated. Force necessary to pull the chisel through the soil was measured at each density.

RESULTS

Clod size distribution and stability

Effect of density and texture on percentage of clods greater than 6.4 mm. is shown in figure 3. This size was used in lieu of 0.84 mm. (the size

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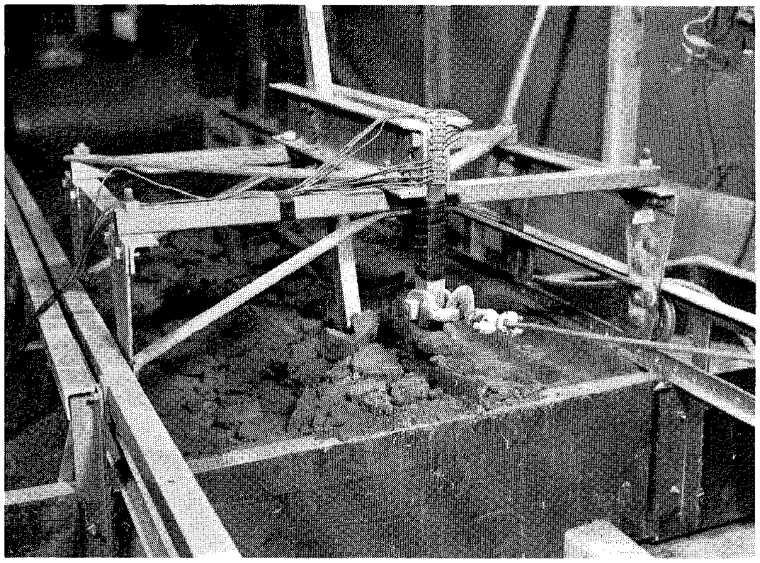

FIG. 1. View of tillage box, tool carrier, and strain link; lawn roller in background was used for packing.

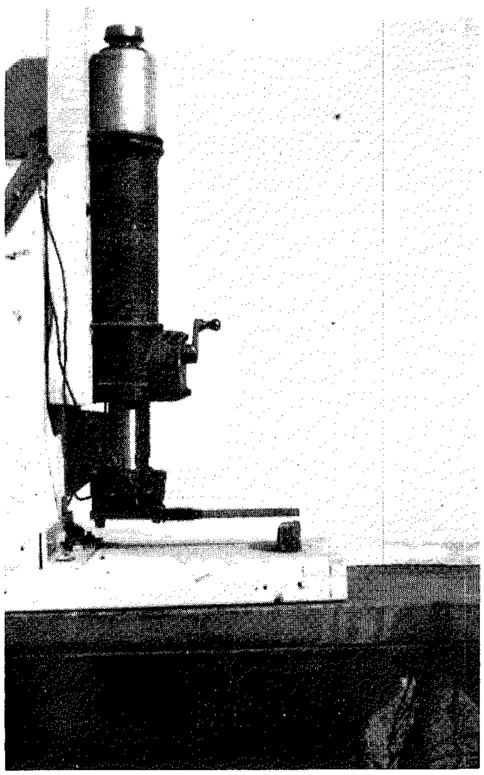

FIG. 2. Apparatus used to measure relative crushing strength of clods. Force was applied to clod through a 3/16-inch square, 5-inch long cantilever beam, and was measured by determining strain in beam with strain gages and appropriate amplifying and recording equipment.

usually considered to be resistant to movement by wind) because of soil-sieving procedures used before compaction. Clods greater than 6.4 mm. must have been formed by the tillage action and could not have occurred as natural aggregates. The percentage of clods greater than 6.4 mm. in diameter increased decidedly with increasing bulk density both before and after weathering in all three soils. Clay contained the largest percentage of clods among the three soils. Silty clay loam contained more clods than sandy loam. Rate of increase in percentage of clods greater than 6.4 mm., as determined immediately after tillage, was more rapid for the silty clay loam and sandy loam than for clay. For example, increasing the density from 70 to 80 per cent of maximum raised the number of clods greater than 6.4 mm. 25 per cent for silty clay loam and sandy loam in comparison with about 14 per cent for clay. Such differences, however, were not marked after weathering. Degree of breakdown was least for clay and greatest for sandy loam. At low densities most of the clods had disappeared after weathering in the silty clay loam and sandy loam.

Resistance to breakdown due to mechanical action of resieving is shown in figure 4 (2).

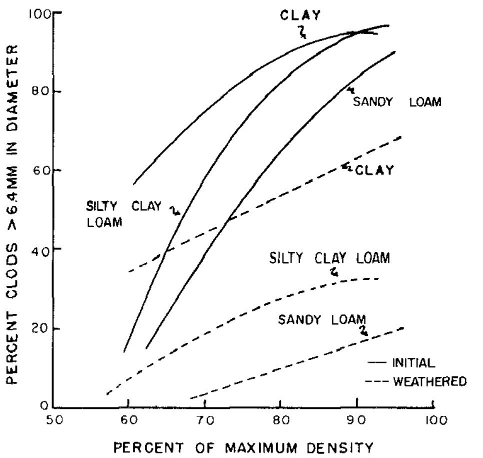

FIG. 3. Soil cloddiness immediately after chiseling and after 6 months of natural weathering in relation to soil density.

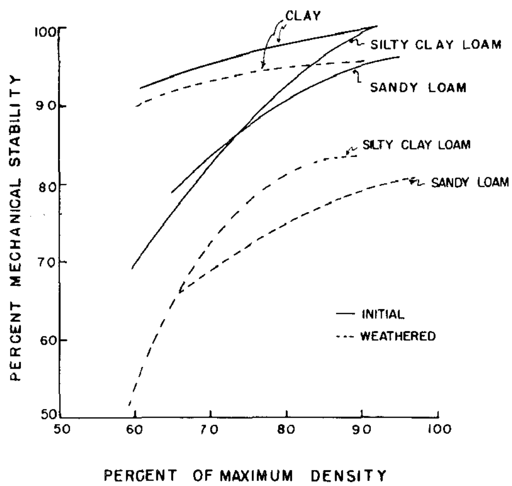

FIG. 4. Relationship between mechanical stability and soil density immediately after chiseling and after 6 months of natural weathering.

Clay produced clods that were highly stable at all density levels used in the study and remained quite stable after exposure to weathering. Silty clay loam and sandy loam responded rather well to packing, forming more stable clods with increasing density. These two soils, however, were more susceptible to weathering. The clods remaining were fragile, as indicated by lower mechanical stability.

Clod strength

Figure 5 shows the influence of texture and moisture on the relative strength of clods formed by chiseling at a fairly high density. Figure 6 contains the same information for clods produced at a low bulk density. Crushing resistance of clods increased rapidly with drying on all three soils after they were packed to a high bulk density. Clod strength is related also to the amount of clay; stronger clods were produced as

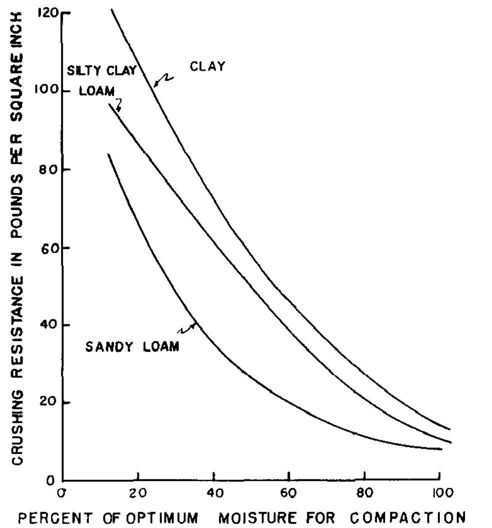

FIG. 5. Relationship between crushing resistance and clod moisture for soils packed to high bulk densities (87 per cent of maximum).

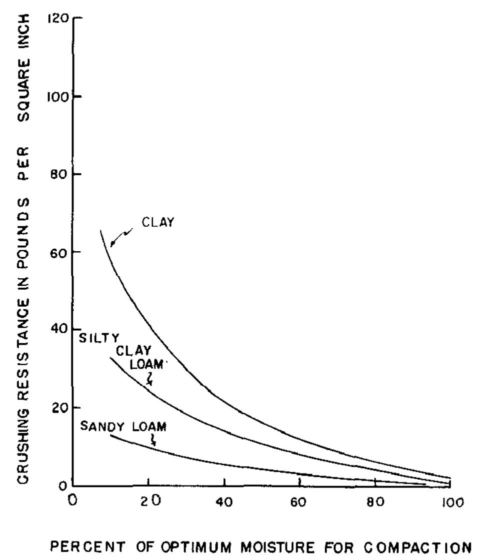

FIG. 6. Relationship between crushing resistance and clod moisture for soils packed to low bulk densities (69 per cent of maximum).

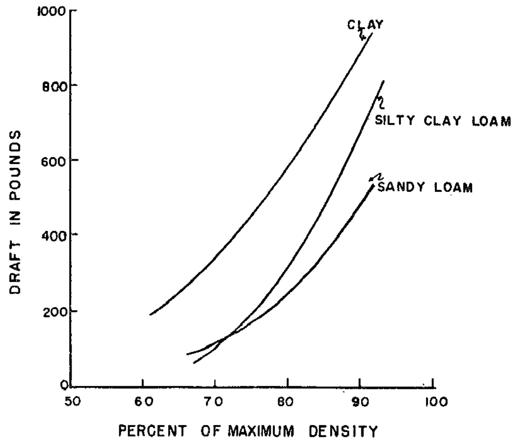

FIG. 7. Draft requirements of a single narrow point chisel in relation to soil density and texture.

the clay content was increased. Clod strength increased slowly with drying at low-density levels.

Draft

As expected, the force necessary to pull the chisel point through the soil increased rapidly with bulk density (fig. 7). As clay content increased, draft requirements also increased. Draft requirements were about the same for silty clay loam and sandy loam at low density. At high density the draft was about 190 pounds greater for silty clay loam than sandy loam.

The relationship between draft and percentage of clods greater than 6.4 mm. is shown in figure 8. All three soils produced about an equal amount of clods at the same draft requirements. An economical point to consider is the increase in yield of clods as draft increases. It appears that a point of diminishing returns might be reached at about 500 pounds draft for the clay and silty clay loam. An additional draft of 300 pounds above this amount showed only a 9 per cent increase in cloddiness for clay and a 5 per cent increase for an additional draft of 240 pounds for silty clay loam. Sandy loam responded well throughout the range of draft necessary for the study. Using 500 pounds pull as a point beyond which it is unprofitable to pack soil for increasing the cloddiness potential, clay soil would not need to be packed beyond 77 per cent of maximum density, silty clay loam beyond 86 per cent, or sandy loam beyond 91 per cent.

Interpretation of results

More investigation is necessary before results obtained can be applied directly to field conditions. Important information is needed on the range and limit of bulk densities obtainable with commercial field packers, the effect of packing at moisture conditions other than optimum, and the effect of drying on soils packed at various moisture contents before tillage is accomplished.

This study clearly indicates that cloddiness of disturbed natural soils can be increased by packing under optimum moisture conditions for compaction. Contingent on future application to field conditions, it appears that packing before emergency tillage operations might prove to be a practical way to obtain clods on soils that otherwise would produce few, if any, by tillage methods.

SUMMARY

Possibility of increasing the cloddiness potential of soils by compaction was investigated by chiseling three soils containing 17, 33, and 46 per cent clay at several bulk density levels. Tillage was accomplished with laboratory equipment.

Percentage of clods produced by the chisel was increased on all three soils by increasing soil bulk density. Total cloddiness after tillage was greatest on clay, but rate of increase was more rapid for silty clay loam and sandy loam.

Breakdown by weathering was evident on all soils, but to a greater degree on silty clay loam

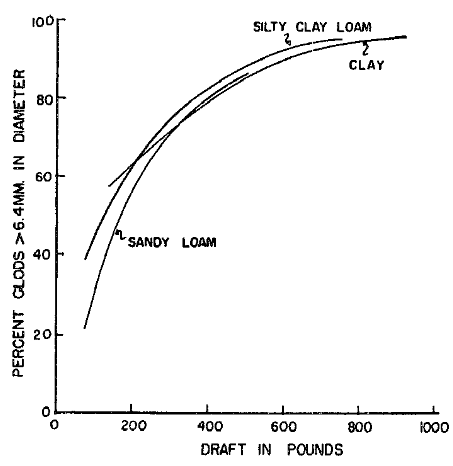

FIG. 8. Relationship between amount of clods producing by chiseling and draft.

and sandy loam. More high-density than low-density clods were still present after weathering.

Mechanical stability, as determined by re-sieving, was also increased on all soils by packing. Clay was highly stable throughout the range of densities studied. Silty clay loam and sandy loam clods remaining after weathering were less stable than clay.

Crushing resistance of clods increased rapidly with drying if the soil had been packed to high bulk densities, but rather slowly if it had been packed to lower levels. Clay produced the strongest clods and sandy loam the weakest.

Both increases in bulk density and clay content caused the draft requirements to go up rapidly. A point of diminishing returns on clod yield was reached at about 77 and 86 per cent maximum density, respectively, for clay and silty clay loam, i.e., draft requirements become so large compared to the increase in percentage of clods that further packing probably would be unprofitable.

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