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SOIL-VEHICLE TERMINOLOGY — SAE J991

SAE Recommended Practice

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PREFACE

The effects of soil on the operation of vehicles and construction equipment is a subject of increasing engineering attention. In recognition of this fact, Subcommittee XX, "Soil Effects," of SAE Construction and Industrial Machinery Technical Committee was established to collect and disseminate related information. One of the first tasks undertaken by this Subcommittee was preparing a list of definitions to aid in communication and to provide a first step in organizing the discipline.

This report contains the first published edition of the list of definitions. The list has been prepared using as a basis similar lists compiled by the American Society of Civil Engineers in cooperation with the American Society for Testing and Materials¹ and by the American Society of Agricultural Engineers.² Only those definitions which are felt to be pertinent enough to the interests of SAE have been included. Many of the definitions have been revised to be more meaningful for application to SAE. The terms have been arranged so that the related ones are together; however, an alphabetical cross-reference has been provided. The definitions pertain to soil mechanics, implements, and soil-vehicle interrelationships.

The definitions are provided as a recommended guide rather than as an approved standard. Therefore, comments including suggested revisions or additions are desired and should be submitted to the Subcommittee.³ Periodic republication of updated lists is planned.

DEFINITIONS

1. Soil Type

Sand (or Sand Size)—Particles of rock ranging in diameter from 0.050 to 2.0 mm (USDA classification).

Silt (Inorganic Silt, Rock Flour)—Fine-grained soil which is non-plastic or very slightly plastic and that exhibits little or no strength when air-dried.

Silt Size—That portion of soil whose particles are finer than 0.05 mm and coarser than 0.002 mm (USDA classification).

Clay (Clay Soil)—Fine-grained soil or the fine-grained portion of soil that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dried.

Clay Size—That portion of soil whose particles are finer than 0.002 mm (USDA classification).

Cohesive Soil—A soil that has considerable strength in the air-dried state when unconfined and that has significant cohesion when submerged. Such a soil may generally be considered as one in which the shearing strength due to cohesion (c) is much greater than that due to internal friction (ϕ), i.e., it has a shearing resistance under no normal load.

Cohesionless Soil—A soil that has little or no strength in the air-dried state when unconfined and that has little or no cohesion when submerged. Such a soil may generally be considered as one in which the shearing strength due to internal friction (ϕ) is much greater than that due to cohesion (c).

2. Soil Structure (See Fig. 1)

Moisture Content (Water Content), $w(D)$ ⁴—The ratio expressed as

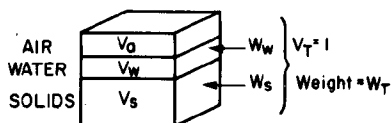


FIG. 1—ARBITRARY UNIT VOLUME OF SOIL DIVIDED INTO COMPONENTS

a percentage of the weight of water in a given soil mass to the weight of solid particles, that is, $w = W_w/W_s \times 100$.

Percent Saturation, $S_r(D)$ —The ratio expressed as a percentage of the volume occupied by water in a given soil mass to the total volume of void space, that is, $S_r = V_w/(V_w + V_a) \times 100$.

Density (Unit Weight), $\gamma(FL^{-3})$ —Weight per unit volume of soil.

Dry Unit Weight (Unit Dry Weight), $\gamma_d(FL^{-3})$ —The weight of soil solids per unit of total volume of soil mass, that is, W_s/V_t .

Porosity, $n(D)$ —The ratio, usually expressed as a percentage, of the volume of voids of a given soil mass to the total volume of the soil mass, that is, $(V_a + V_w)/V_t \times 100$.

Void Ratio, $e(D)$ —The ratio of the volume of void space to the volume of solid particles in a given soil mass, that is, $(V_a + V_w)/V_s$.

Relative Density, $D_r(D)$ —The ratio of the difference between the void ratio of a cohesionless soil in the loosest state and any given void ratio, to the difference between its void ratios in the loosest and in the densest states, that is, $e_{max} - e/e_{max} - e_{min}$.

3. Soil Strength

Normal Stress, $\sigma(FL^{-2})$ —The normal force per unit area acting within the soil mass.

Effective Stress (Intergranular Pressure), $\bar{\sigma}(FL^{-2})$ —The average normal force per unit area of a soil mass transmitted from grain to grain. It is the stress that is effective in mobilizing internal friction.

Neutral Stress (Pore Pressure), $u(FL^{-2})$ —Stress transmitted through the pore water (water filling the voids of the soil).

Shear Stress, $\tau(FL^{-2})$ —The shearing force per unit area acting within the soil mass.

Compressive Strength (Unconfined Compressive Strength), $q_u(FL^{-2})$ —The load per unit area at which an unconfined prismatic or cylindrical specimen of soil will fail in a simple compression test.

Shear Strength, $s(FL^{-2})$ —The maximum resistance of a soil to shearing stresses. (See Coulomb equation, cohesion, angle of internal friction.)

Coulomb's Equation—The relationship between the shearing strength (s) of soil and the effective stress ($\bar{\sigma}$) on an internal surface. The equation is written $s = c + \bar{\sigma} \tan \phi$, where c is cohesion and ϕ is angle of internal friction.

Contact Pressure, $p(FL^{-2})$ —The unit of pressure that acts at the surface of contact between a vehicle component and the underlying soil mass.

4. Components of Soil Strength

Cohesion, $c(FL^{-2})$ —The shearing strength of soil on an internal surface which is independent of the normal pressure.

Angle of Internal Friction, ϕ (degrees)—A measure of the shearing strength of soil on an internal surface which is proportional to the normal pressure, for example, the angle of inclination from the normal direction of the resultant of the normal and frictional forces (over an area) on the internal surface.

Coefficient of Internal Friction (D)— $\tan \phi$.

Angle of Repose, α (degrees)—Angle between the horizontal and the maximum slope which a pile of soil can assume, due primarily to internal friction or interlocking of the particles.

Shearing Adhesion, $a_s(FL^{-2})$ —The portion of shearing resistance between soil and another material which is independent of the normal pressure.

¹ASTM D 653-64, "Terms and Symbols Relating to Soil Mechanics."

²ASAE R291, "Terminology and Definitions for Soil Tillage and Soil-Tool Relationships."

³Chairman, Subcommittee XX, CIMTC, Society of Automotive Engineers, Inc., 185 Lexington Ave., New York, New York 10017.

⁴Dimensional units for terms: D = dimensionless, FL = force/length, time.



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Tensile Adhesion, $a_t(FL^{-2})$ —The tensile resistance of the bond between soil and another material to forces which tend to separate the two in the normal direction.

External Frictional Resistance, $a_e(FL^{-2})$ —The portion of shearing resistance between soil and another material which is proportional to the normal pressure. This resistance is generally expressed in terms of a coefficient of friction or angle of external friction.

Coefficient of External Friction, $\mu(D)$ —Ratio between the shearing resistance due to friction and the normal pressure acting on the contact area between the soil and another material.

Angle of External Friction, $\delta(\text{degrees})$ —Angle of inclination from the normal direction of the resultant of the normal and frictional forces acting on the surface between soil and another material, that is, $\tan \delta = \mu$.

5. Strength Tests—Generally accepted standard tests to determine the shear strength of soil include: unconfined compression test, triaxial compression test, direct shear test, torsional shear test, and vane shear test.

Penetrometer—A device used for measuring the resistance to penetration into soil of a flat or cone-tipped rod. It is used as an indication or empirical index of the shear strength of soil.

6. Soil Consistency

Consistency—The relative ease with which a soil can be deformed.

Plasticity—The property of a soil which allows it to be deformed irreversibly without cracking or appreciable volume change.

Atterberg Limits—Moisture content limits proposed by Atterberg for separating the semisolid, plastic, and liquid phases of soil. These limits are determined by special soil tests and are empirical in nature because there is no clear demarcation between phases in soil (see Liquid Limit and Plastic Limit).

Liquid Limit, $w_L(D)$ —(a) The water content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil; or (b) the water content at which a pat of soil, cut by a groove of standard dimensions, will flow together for a distance of $\frac{1}{2}$ in. under the impact of 25 blows in a standard liquid limit apparatus.

Plastic Limit, $w_p(D)$ —(a) The water content corresponding to an arbitrary limit between the plastic and the semi-solid states of consistency of a soil; or (b) water content at which a soil will just begin to crumble when rolled into a thread approximately $\frac{1}{8}$ in. in diameter.

Plasticity Index, $I_p(D)$ —Numerical difference between the liquid limit and the plastic limit.

Shrinkage Limit, $w_s(D)$ —The water content of soil at which, upon drying, the soil ceases to decrease further in volume.

Sticky Limit, $T_w(D)$ —The lowest water content at which a soil will stick to a metal blade drawn across the surface of the soil mass.

7. Soil Characteristics

Remolded Soil—Soil that has had its in situ structure modified by manipulation.

Remolding Sensitivity, $S_r(D)$ —The effect of remolding on the consistency of a cohesive soil. The degree of sensitivity is expressed as the ratio of the unconfined compressive strength of an undisturbed specimen of soil to the unconfined compressive strength of a specimen of the same soil after remolding at unaltered water content.

Compaction—The densification of soil by means of mechanical manipulation.

Consolidation—The gradual reduction in volume of a cohesive soil mass due to the expulsion of water at constant load. (This phenomenon is a consequence of the low permeability of such soils, so that when load is applied excess pressures build up in the water occupying the voids of the soil.)

Thixotropy—The property of a soil that enables it to stiffen in a relatively short time on standing, but upon agitation or manipulation to change to a soft consistency, the process being reversible.

Bulking—The increase in volume of a material due to manipulation.

Heave—Upward movement of soil caused by expansion or displacement resulting from phenomena such as: moisture absorption, removal of overburden, and frost action.

8. Implement Terms

Soil Tool—An individual soil working element.

Simple Tools—Tools which present a reasonably constant boundary and contact area with the soil, that is, dozer blade, router, ripper.

Complex Tools—Free-wheeling tools which rotate or move so that they present a varying boundary and contact area with soil, that is, rotary hoe, disc.

Dynamic Tools—Tools which are powered so that portions of their movements are in directions other than along the main line of travel of the tool, that is, vibratory tool, rotatiller.

Implement—A functional assembly of a soil tool or tools.

Soil Working Surfaces—Portions of tools which are designed to be in contact with soil in order to effect proper manipulation.

Tool Orientation—The position of the tool in a framework of Cartesian coordinates which is normally oriented with respect to the soil surface and the direction of travel. Orientation is specified using such terms as side, tilt, and lift angles.

Sliding Clearance Angle (Heel Clearance Angle)—The angle at the edge of a soil working surface of a tool which is found between the back or nonworking side of the tool and the direction of travel of tool.

Lift Angle—With the tool at ground level, pass a plane parallel to the direction of travel and perpendicular to the soil surface through the point in question on the leading edge of the tool. The soil cutting angle is the angle between the soil surface and a tangent through the point in question on the curve formed by the intersection of the tool surface and the above-mentioned plane. (See Fig. 2.)

Side Angle—The acute angle between a plane perpendicular to the direction of travel and the leading edge of the tool, with the leading edge on the soil surface. (See Fig. 3.)

Tilt Angle—With the lowest point of the tool on the soil surface, project the tool's leading edge on a plane perpendicular to the di-

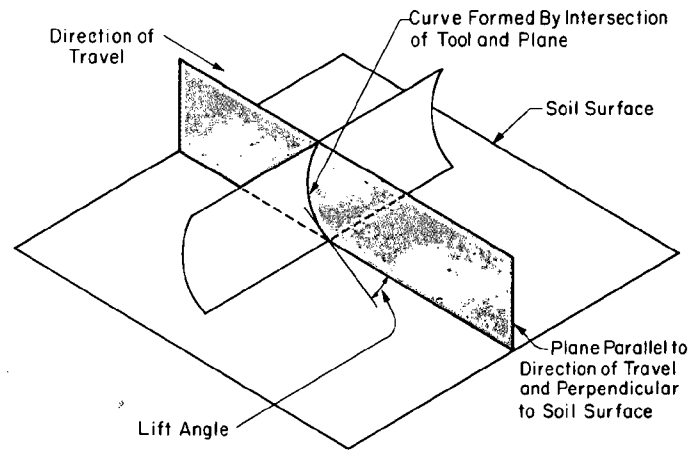


FIG. 2—ILLUSTRATION OF LIFT ANGLE

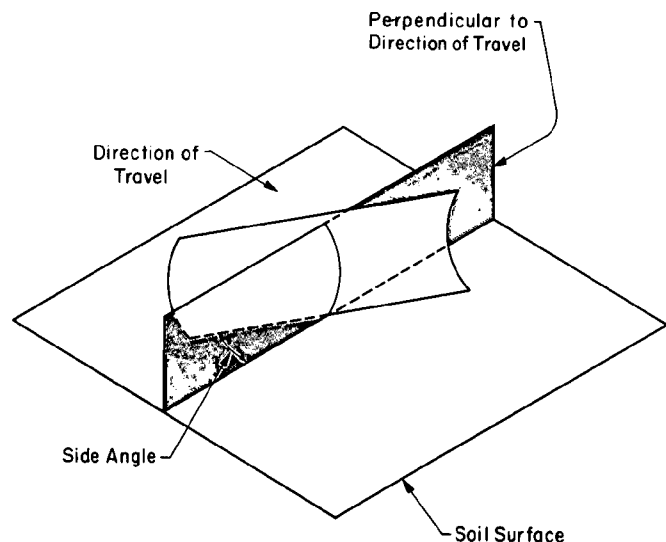


FIG. 3—ILLUSTRATION OF SIDE ANGLE