Soil Compaction

Densification of the soil by decreasing voids in the soil (entrapped air) to improve the structural stability and related characteristics of the soil. Improved stability of certain characteristics of the soil may be achieved by mechanical or chemical means.

Purposes of compacting soil

- increases soil strength => increased bearing capacity, slope stability, pavement system strength
- decreases amount of settlement =>reduces damage to structure from foundation movement (especially from differential settlement)
- decreases permeability – e.g. dams, levees, lagoon (liner) bottoms
- improve site conditions for the construction process itself (working platform)
- decrease frost susceptibility (decreased voids, less water infiltration)
- control soil expansion (using chemical additive like hydrated lime or cementitious agent plus careful moisture and density control)

Other means of stabilizing and compacting soil can include

- dewatering – lowering groundwater elevation to reduce the availability of free water, also allows the soil to become denser due to higher effective stresses (reduce soil buoyancy)
- preloading – surcharge soil with other soil temporarily to cause the soil to densify under the temporary weight

Field compaction

Field compaction requires applying mechanical forces to compact the soil particles.

Usually done with a roller:

- Smooth-Wheel Roller
- Rubber-Tire Roller
- Sheeps-Foot Roller
- Vibratory Roller =>Acceleration (for coarse-grained and dry soils, especially granular)

Degree of compaction depends on:

1. Characteristics of the compaction equipment
   a) mass, size
   b) area over which the applied compactive force is applied
   c) type of roller (rubber tire, drum, sheepsfoot)
2. Characteristics of the soil
   a) type of soil (cohesive, granular, mix)
   b) moisture-density relationship of the soil
   c) water content
   d) initial density

3. Construction process
    a) number of passes
    b) layer (lift) thickness (applied pressure diminishes with depth)
    c) travel speed
    d) vibration (frequency, intensity)

(table below is from pages 118-119 in Das)

Table 5.2 Requirements to Achieve R = 95 to 100% (based on standard Proctor maximum dry unit-weight)*

Equipment type	Applicability	Requirements for compaction of 95 to 100% standard Proctor maximum dry unit weight: Compacted lift thickness	Passes or coverages	Dimensions and weight of equipment			Possible variations in equipment
Sheepsfoot rollers	For fine-grained soils or dirty coarse-grained soils with more than 20% passing the No. 200 sieve. Not suitable for clean, coarse-grained soils. Particularly appropriate for compaction of impervious zone for earth dam or linings where bonding of lifts is important.	150 mm (6 in.)	4 to 6 passes for fine-grained soil	*Soil type* Fine-grained soil, $PI > 30$	*Foot contact area* 30 to 80 cm² (5 to 12 in²)	*Foot contact pressures* 1700 to 3400 kN/m² (250 to 500 psi)	For earth dam, highway, and airfield work, a drum of 1.5 m (60-in.) diameter, loaded to 45 to 90 kN per linear meter (1.5 to 3 tons per linear ft) of drum is generally utilized. For smaller projects, a 1 m (40-in.) diameter drum, loaded to 22 to 50 kN per linear meter (0.75 to 1.75 tons per linear ft) of drum, is used. Foot contact pressure should be regulated to avoid shearing the soil on the third or fourth pass.
				Fine-grained soil, $PI < 30$	45 to 90 cm² (7 to 14 in²)	1400 to 2800 kN/m² (200 to 400 psi)	
			6 to 8 passes for coarse-grained soil	Coarse-grained soil	65 to 90 cm² (10 to 14 in²)	1000 to 1800 kN/m² (150 to 250 psi)	
				Efficient compaction of soils on the wet side of the optimum requires less contact pressure than that required by the same soils at lower moisture contents.			
Rubber tired rollers	For clean, coarse-grained soils with 4 to 8% passing the No. 200 sieve.	250 mm (10 in)	3 to 5 coverages	Tire inflation pressures of 400 to 550 kN/m² (60 to 80 psi) for clean granular material or base course and subgrade compaction. Wheel load, 80 to 130 kN (18,000 to 25,000 lb.)			A wide variety of rubber-tired compaction equipment is available. For cohesive soils, light-wheel loads, such as provided by wobble-wheel equipment, may be substituted for heavy-wheel loads if lift thickness is decreased. For cohesionless soils, large-size tires are desirable to avoid shear and rutting.
	For fine-grained soils or well-graded, dirty, coarse-grained soils with more than 8% passing the No. 200 sieve.	150 to 200 mm (6 to 8 in)	4 to 6 coverages	Tire inflation pressures in excess of 450 kN/m² (65 psi) for fine-grained soils of high plasticity. For uniform clean sands or silty fine sands, use larger-size tires with pressures of 280 to 350 kN/m² (40 to 50 psi.)			
Smooth-wheel rollers	Appropriate for subgrade or base course compaction of well-graded sand-gravel mixtures.	200 to 300 mm (8 to 12 in.)	4 coverages	Tandem-type rollers for base-course or subgrade compaction, 90 to 135 kN (10 to 15 ton) weight, 53 to 88 kN per linear meter (300 to 500 lb per linear in.) of width of rear roller.			Three-wheel rollers are obtainable in a wide range of sizes. Two-wheel tandem rollers are available in the 9 to 180 kN (1- to 20-ton) weight range. Three-axle tandem rollers are generally used in the 90 to 180 kN (10- to 20-ton) weight range. Very heavy rollers are used for proof rolling of subgrade or base course.
	May be used for fine-grained soils other than in earth dams. Not suitable for clean, well-graded sands or silty, uniform sands.	150 to 200 mm (6 to 8 in.)	6 coverages	Three-wheel roller for compaction of fine-grained soil; weights from 45 to 55 kN (5 to 6 tons) for materials of low plasticity to 90 kN (10 tons) for materials of high plasticity.			
Vibrating baseplate compactors	For coarse-grained soils with less than about 12% passing the No. 200 sieve. Best suited for materials with 4 to 8% passing the No. 200 sieve, placed thoroughly wet.	200 to 250 mm (8 to 10 in.)	3 coverages	Single pads or plates should weigh no less than 0.9 kN (200 lb) May be used in tandem where working space is available. For clean, coarse-grained soil, vibration frequency should be no less than 1600 cycles per minute.			Vibrating pads or plates are available, hand-propelled or self-propelled, single or in gangs, with width of coverage from 0.45 to 4.5 m (1½ to 15 ft). Various types of vibrating-drum equipment should be considered for compaction in large areas.
Crawler tractor	Best suited for coarse-grained soils with less than 4 to 8% passing the No. 200 sieve, placed thoroughly wet.	250 to 300 mm (10 to 12 in.)	3 to 4 coverages	No smaller than D8 tractor with blade, 153 kN (34,500 lb) weight, for high compaction.			Tractor weights up to 265 kN (60,000 lb.)
Power tamper or rammer	For difficult access, trench backfill. Suitable for all inorganic soils.	100 to 150 mm (4 to 6 in.) for silt or clay; 150 mm (6 in.) for coarse-grained soils	2 coverages	130 N (30 lb) minimum weight. Considerable range is tolerable, depending on materials and conditions.			Weights up to 1.1 kN (250 lb); foot diameter, 100 to 250 mm (4 to 10 in.)

* After U.S. Navy (1971). Published by U.S. Government Printing Office