PAVEMENT MATERIALS

Lecture 8

Sequence

- **SUBGRADE**

- **Investigation**
- **Material Classification/Identification**
- **Material Evaluation**
- **Material Selection**
- **Construction of Subgrade**
- **QA/QC**
- **Post Construction Investigation**

Subgrade Construction

- **Sequence**

- **Construction Principles** } **Lecture 7**
- **Construction Equipment**
- **Construction Processes**

Compaction Equipment

- The kind of compacting equipment or rollers used on a job will depend on
  - Type of soil to be compacted
  - Desired or Targeted Properties

- Equipment is available to apply
- ***Pressure***
- ***Impact***
- ***Vibration***
- ***Kneading***

Compaction Equipment

- *Types*

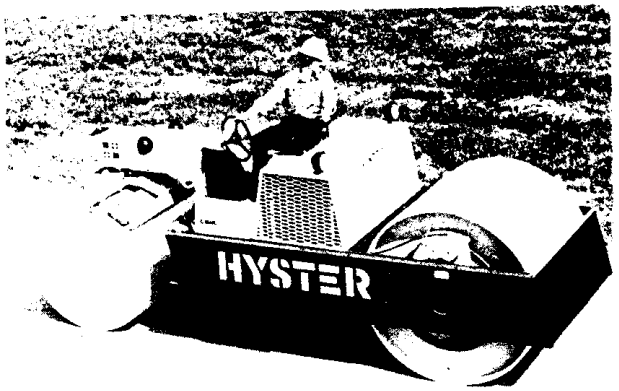
- **Smooth Wheel**
- **Pneumatic Tyred**
- **Sheep Foot**
- **Tamping Foot**
- **Grid Type**

- ***with or without vibrations***

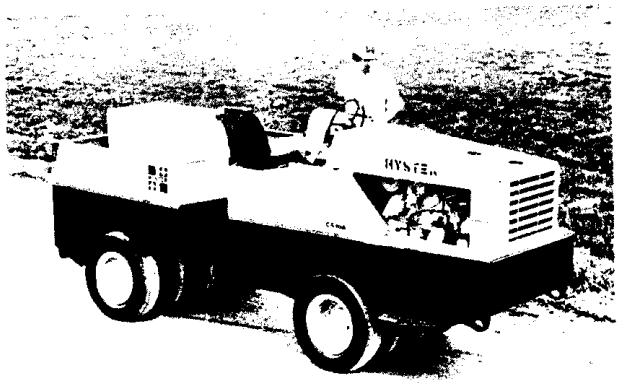
Compaction Equipment

- **A smooth wheel**, or drum, roller supplies 100% coverage under the wheel, with ground contact pressures up to 380 kPa (**55 psi**) and may be used on **all soil types except rocky soils.**

- The most common use for large smooth wheel rollers is for
  - **proof-rolling subgrades and compacting asphalt pavements.**



(a)



(b)

Fig. 5.11 Types of rollers: (a) smooth-wheel roller; (b) rubber-tired roller (self-propelled) (photographs courtesy of Hyster Company, Construction Equipment Division).

Compaction Equipment

- **The pneumatic, or rubber-tired** roller has about 80% coverage (80% of the total area is covered by tires) and tire pressures may be up to about 700 kPa (**100 psi**).

- Like the smooth wheel roller, the rubber-tired roller may be used **for both granular and cohesive highway fills, as well as for earth dam construction.**

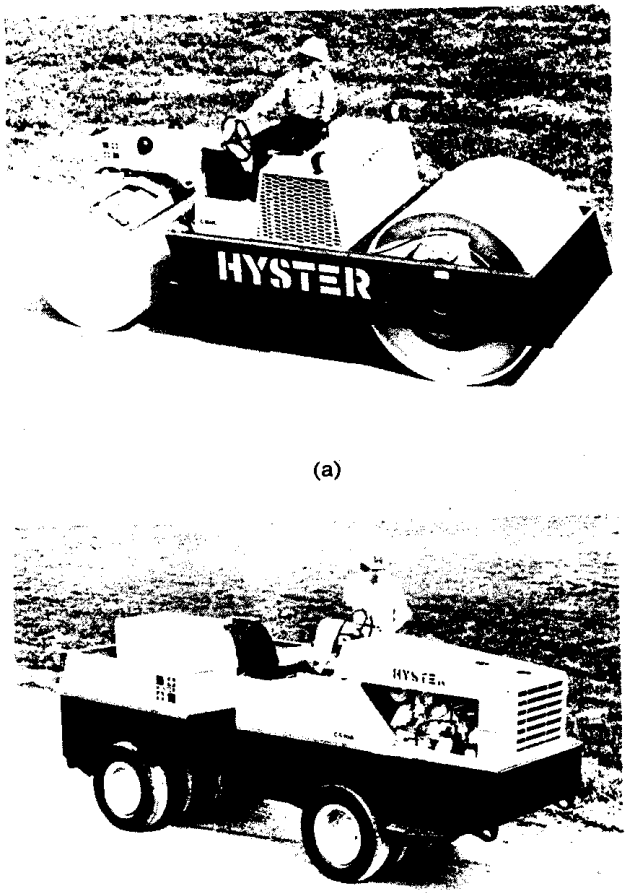
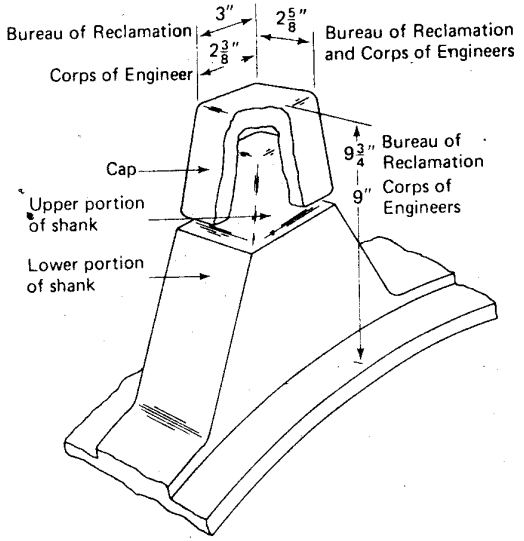


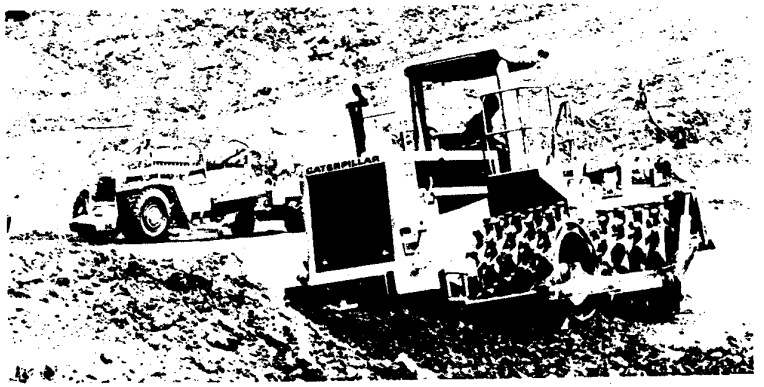
Fig. 5.11 Types of rollers: (a) smooth-wheel roller; (b) rubber-tired roller (self-propelled) (photographs courtesy of Hyster Company, Construction Equipment Division).

Compaction Equipment

- **Sheepsfoot Roller**, as its name implies, has many round or rectangular shaped protrusions or "feet" attached to a steel drum. The area of these protrusions ranges from 30 to 80 cm2 (5 to 12 in.3).
- Because of the **8% to 12% coverage,** very high contact pressures are possible, ranging from 1400 to 7000 kPa (**200 to 1000 psi**) depending on the drum size and whether the drum is filled with water.



(a)



(b)

Fig. 5.12 Sheepsfoot rollers: (a) detail of a rectangular sheepsfoot (drawing provided by Hyster Company, Construction Equipment Division); (b) self-propelled sheepsfoot roller in foreground ("pan" in background) (photograph courtesy of Caterpillar Tractor Co.).

Compaction Equipment

- Sheepsfoot rollers are usually towed in tandem by crawler tractors or are self-propelled, as shown in Fig.
- The sheepsfoot roller starts compacting the soil below the bottom of the foot (projecting about 150 to 250 mm from the drum) and works its way up the lift as the number of passes increases.
- **Eventually the roller "walks out" of the fill as the upper part of the lift is compacted.**
- ***The sheepsfoot roller is best suited for <u>Cohesive Soils.</u>***

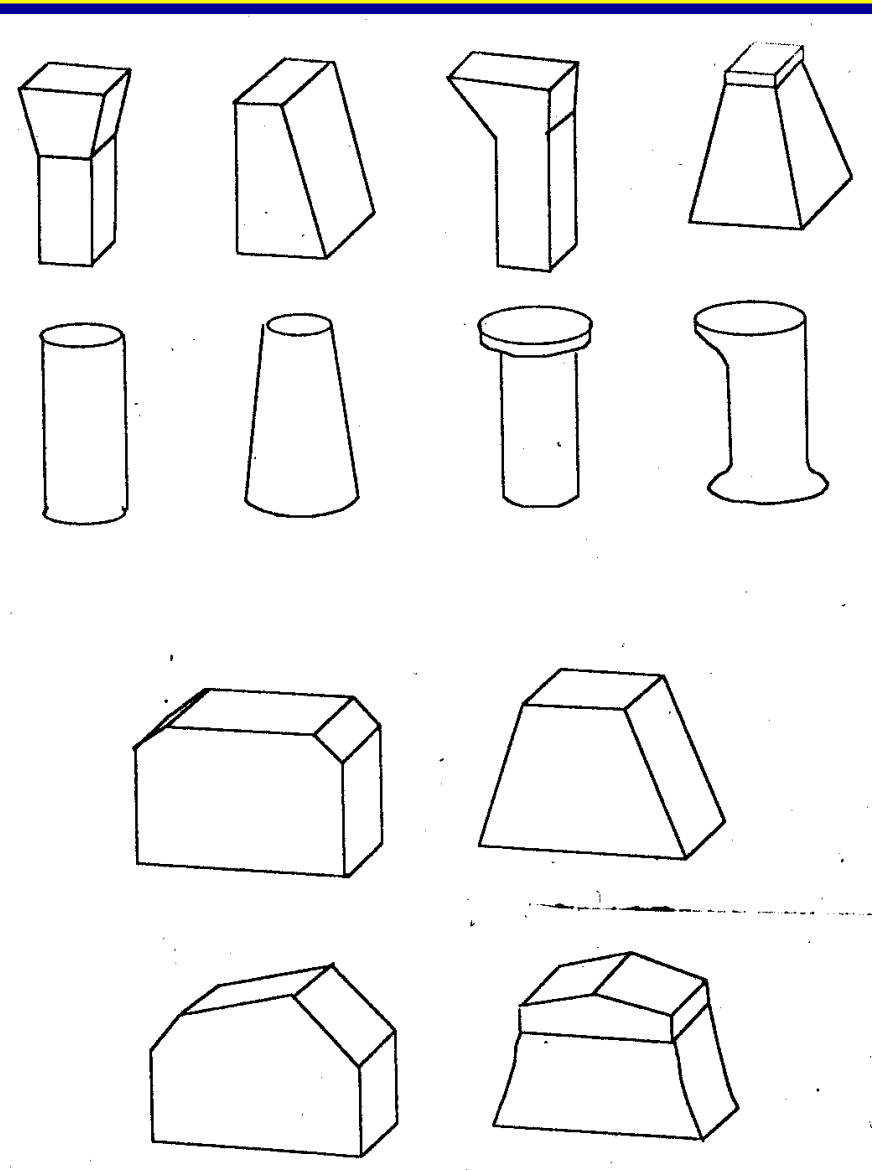


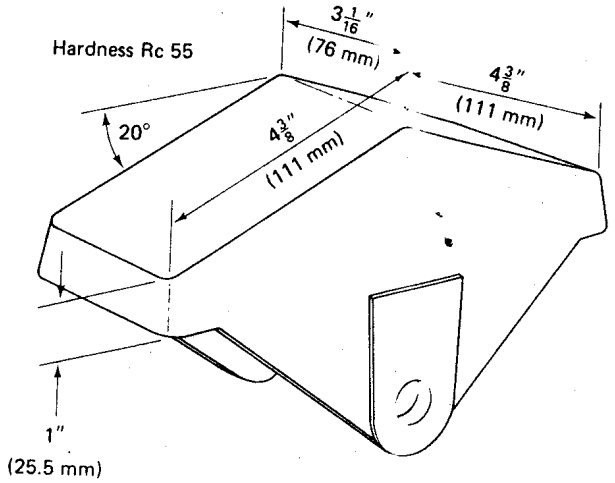
FIGURE 2.4
Sheepsfoot and padfoot shapes. [*After Poesch and Ikes (1975).*]

Compaction Equipment

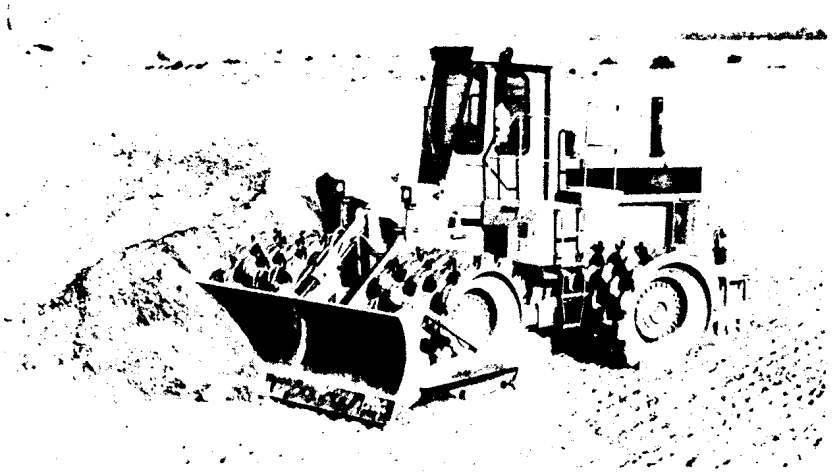
- **Tamping foot Roller**

- have approximately 40% coverage and generate high contact pressures from 1400 to 8400 kPa (**200 to 1200 psi**), depending on the size of the roller and whether the drum is filled for added weight. The special hinged feet of the tamping foot roller apply a kneading action to the soil.
- These rollers compact similarly to the sheepsfoot in that the roller eventually "walks out" of a well-compacted lift.

- **Tamping fool rollers are best for compacting fine-grained soils.**



(a)



(b)

Fig. 5.13 Tamping foot roller: (a) details of a tamping foot; (b) self-propelled tamping foot compactor. Note how the blade is used to spread the material before compaction by the rollers (drawing and photograph courtesy of Caterpillar Tractor Co.).

Compaction Equipment

- Another kind of roller is the **mesh, or grid pattern,** roller with about 50% coverage and pressures from 1400 to 6200 kPa (**200 to 900 psi**)
- ***The mesh roller is ideally suited for compacting Rocky Soils, Gravels, and Sands.***
- ***With high towing speed, the material is vibrated, crushed, and impacted.***

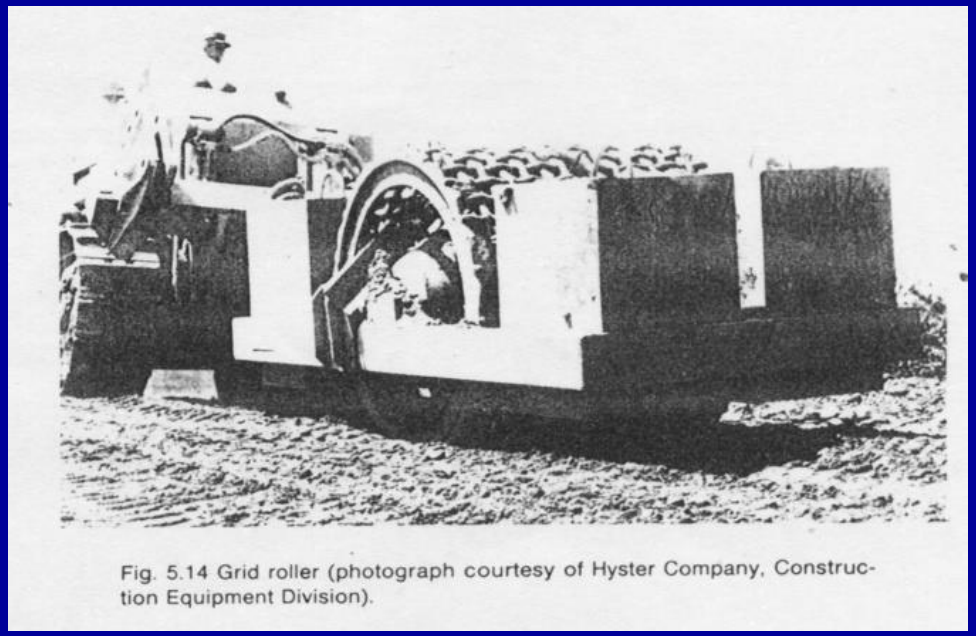


Fig. 5.14 Grid roller (photograph courtesy of Hyster Company, Construction Equipment Division).

Compaction Equipment

- **Several compaction equipment manufacturers have attached vertical vibrators to the smooth wheel and tamping foot rollers so as to more efficiently densify granular soils.**

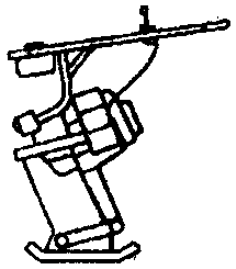
- Vibrating Drum
- Vibrating Plates and Rammers

- Compaction depth for even the larger plates is less than 1 meter.

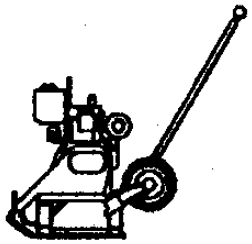
- These devices are used in ???

Fig. 5.15 Vibrating drum on smooth-wheel roller (photograph courtesy of the Hyster Company, Construction Equipment Division).

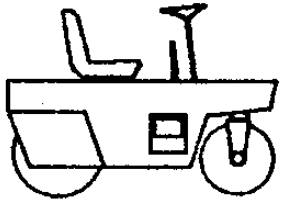
Compaction Equipment



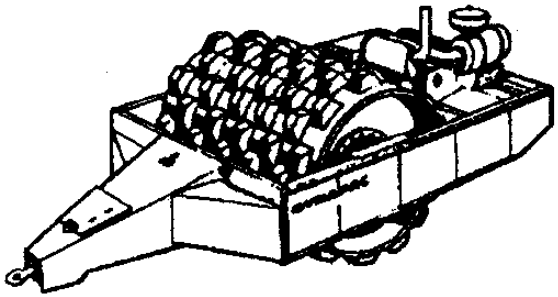
Type 1



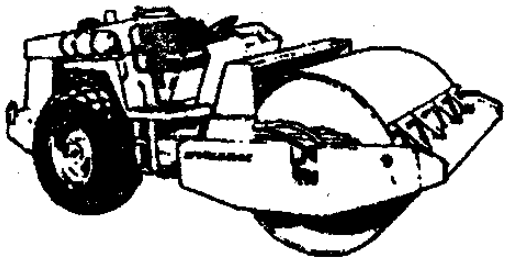
Type 2



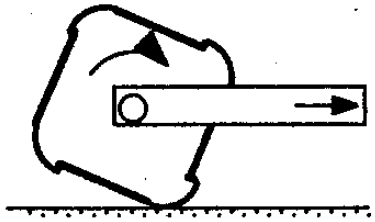
Type 3



Type 4



Type 5



Type 6

FIGURE 2.3
Vibratory and impact compactors for shallow compaction (refers to Table 2.2).

Compaction Equipment

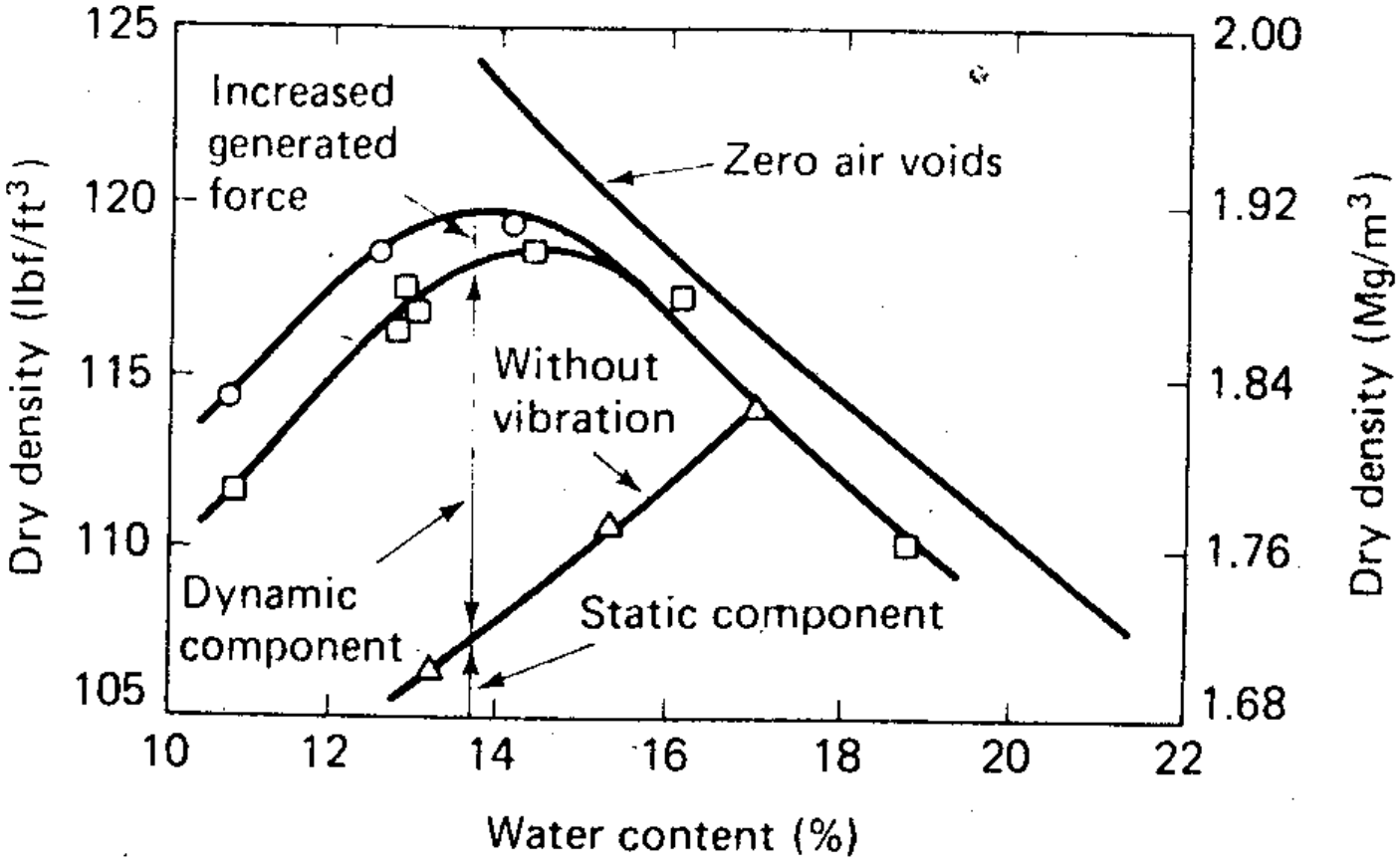


Fig. 5.16 Compaction results on 30 cm (12 in.) layers of silty sand, with and without vibration, using a 7700 kg (17,000 lb) towed vibratory roller (after Parsons, et al., 1962, as cited by Selig and Yoo, 1977).

Compaction Equipment

TABLE 5-2 Different Types of Vibratory Soil Compactors*

Surface Vibrators			Internal Vibrators		
Type of Machine	Mass	Frequency	Type of Machine	Diameter	Frequency
Vibrating tampers (rammers):			*Concrete vibrators*:		
Hand-guidedd	50–150 kg (100–300 lb)	About 10 Hz	Manually operated or tractor-mounted	5–15 cm (2–6 in.)	100–200 Hz
Vibrating plate compactors:			*Vibroflotation equip.*:		
Self-propelled, hand-guided	50–3000 kg (100–6000 lb)	12–80 Hz	Crane-mounted	23–38 cm (9–15 in.)	About 30 Hz
Multiple-type, mounted on tractors, etc.	200–300 kg (400–600 lb)	30–70 Hz			
Crane-mounted†	Up to 20 tons	10–15 Hz			
Vibrating rollers:					
Self-propelled, hand-guided (one or two drums)	250–1500 kg (500–3000 lb)	40–80 Hz			
Self-propelled, tandem-type	0.7–10 tons	30–80 Hz			
Self-propelled, rubber tires	4–25 tons	20–40 Hz			
Tractor-drawn	1.5–15 tons	20–50 Hz			

*After Broms and Forssblad (1969).
†Used on a limited scale.

TABLE 5-3 Applications of Vibratory Soil Compaction*

Type of Machine	Applications
Vibrating tampers (rammers):	Street repair. Fills behind bridge abutments, retaining and basement walls, etc. Trench fills.
Vibrating plate compactors:	
Self-propelled, hand-guided	Base and subbase compaction for streets, sidewalks, etc. Street repair. Fills behind bridge abutments, retaining and basement walls, etc. Fills below floors. Trench fills.
Multiple-type	Base and subbase compaction for highways.
Vibrating rollers:	
Self-propelled, hand-guided	Base, subbase, and asphalt compaction for streets, sidewalks, parking areas, garage driveways, etc. Fills behind bridge abutments and retaining walls. Fills below floors. Trench fills.
Self-propelled, tandem type	Base, subbase, and asphalt compaction for highways, streets, sidewalks, parking areas, garage driveways, etc. Fills below floors.
Self-propelled, rubber tires	Base, subbase, and embankment compaction for highways, streets, parking areas, airfields, etc. Rock-fill dams. Fills (soil or rock) used as foundations for residential and industrial buildings.
Tractor-drawn	Base, subbase, and embankment compaction on highways, streets, parking areas, airfields, etc. Earth- and rock-fill dams. Fills (soil or rock) used as foundations for residential and industrial buildings. Deep compaction of natural deposits of sand.

*After Broms and Forssblad (1969).

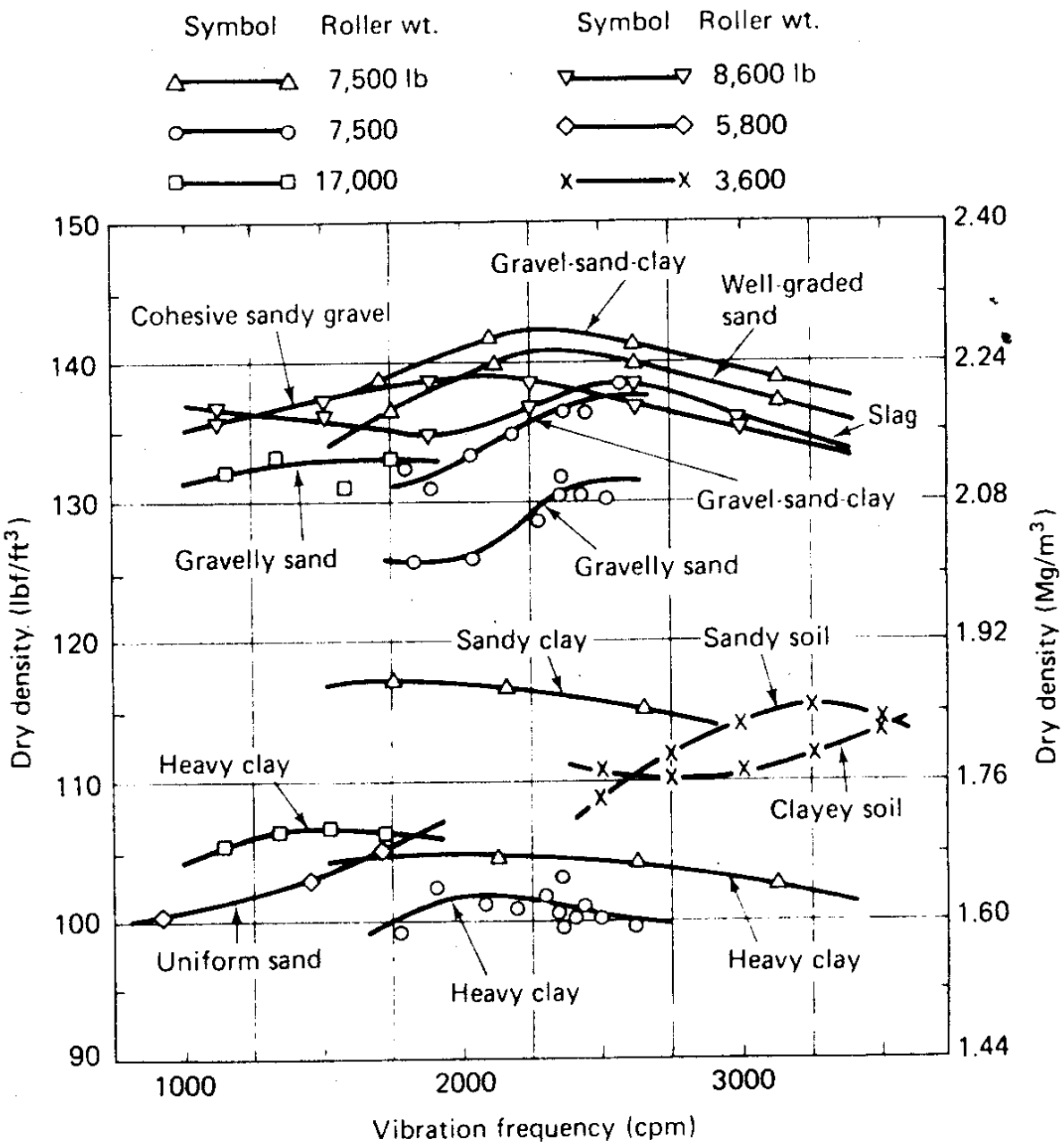


Fig. 5.17 Variation with frequency of compaction by smooth-drum vibratory rollers (after several sources as cited by Selig and Yoo, 1977).

CONTRACTOR's JOB

- Choice of Compactor
- Minimum Effort Versus Maximum Compaction
- How to Quantify Compaction ?

- *Number of Passes*
- *Speed of Roller*
- *Frequency (Vibratory Roller)*
- *Sequence of Rolling*

CONTRACTOR's JOB

- **Choice of Compactor**

- **Depends on ?**
- ***Type of Soil***
- ***Target Density (and/or other Properties)***
- ***Depth of Compaction (lift thickness)***

CHOICE OF COMPACTOR

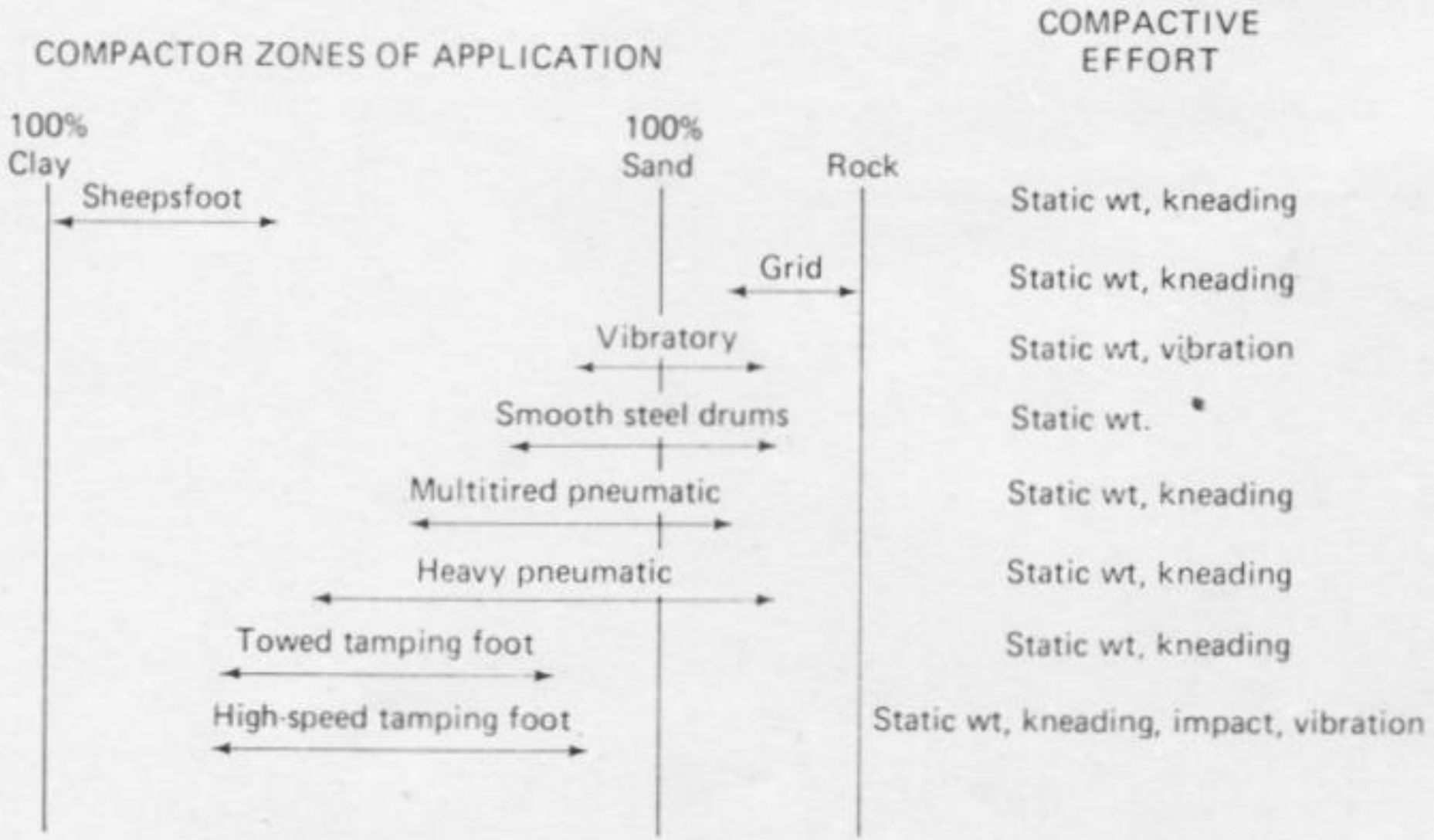


Fig. 5.20 Applicability of various types of compaction equipment for a given soil type (modified after Caterpillar Tractor Co., 1977).

CHOICE OF COMPACTOR

TABLE 2.3
Applicability of compaction equipment

Equipment	Most-suitable soils	Typical applications	Least-suitable soils
Smooth wheel rollers, static or vibrating	Well-graded sand-gravel mixtures, crushed rock, asphalt	Running surface, base courses, subgrades for roads and runways	Uniform sands
Rubber-tired rollers	Coarse-grained soils with some fines	Road and airfield subgrade and base course proof-rolling	Coarse uniform cohesionless soils, and rock
Grid rollers	Weathered rock, well-graded coarse soils	Subgrade, subbase	Clays, silty clays, uniformly graded materials
Sheepsfoot rollers:			
Static	Fine-grained soils with more than 20% fines	Dams, embankments, subgrades for airfields, highways	Clean coarse-grained soils, soils with cobbles, stones
Vibrating	As above, but also sand-gravel mixtures	Subgrade layers	
Vibrating plate (light)	Coarse-grained soils, 4 to 8% fines	Small patches	Cohesive soils
Tampers, rammers	All types	Difficult-access areas	
Impact rollers	Wide range of moist and saturated soils	Subgrade earthworks (except surface)	Dry, cohesionless soils

CHOICE OF COMPACTOR

Type no. and name	Typical characteristics				
	Mass, t	Max. working speed, km/h	Vibrating frequency, Hz	Depth of lift, m	Number of passes
1. Vibrating rammer	0.3–0.1	—	7–10	0.2–0.4	2–4
2. Light vibrating plate	0.06–0.8	1	10–80	0.15–0.5	2–4
3. Light vibrating roller	0.6–2	2–4	25–70	0.3–0.5	4–6
4. Heavy towed vibrating roller	6–15	8–10	25–30	0.3–1.5	4–6
5. Heavy self-propelled vibrating roller	6–15	6–13	25–40	0.3–1.5	4–6
6. Impact roller	7	10–14	—	0.5–3	Up to 30

*See Fig. 2.3 for illustrations.

SUBGRADE Compaction

- **Natural Subgrade**

- Compact at Grade Level to a depth of **???**
- Compact from the surface (cohesionless soils except silts) .
- Remove, process to desired water content, replace in lifts, and compact .

- **Embankment**

- Once borrow material has been transported to the fill area, bull-dozers, front loaders, and motor graders, called blades, spread the material to the desired layer or lift thickness.
- Lift thickness may range from 150 to 500 mm (6 to 18 in.) or so, depending on the size and type of compaction equipment and on the maximum grain size of the fill.

Compaction Achievement

- **Most Efficient Water Content**
- ??

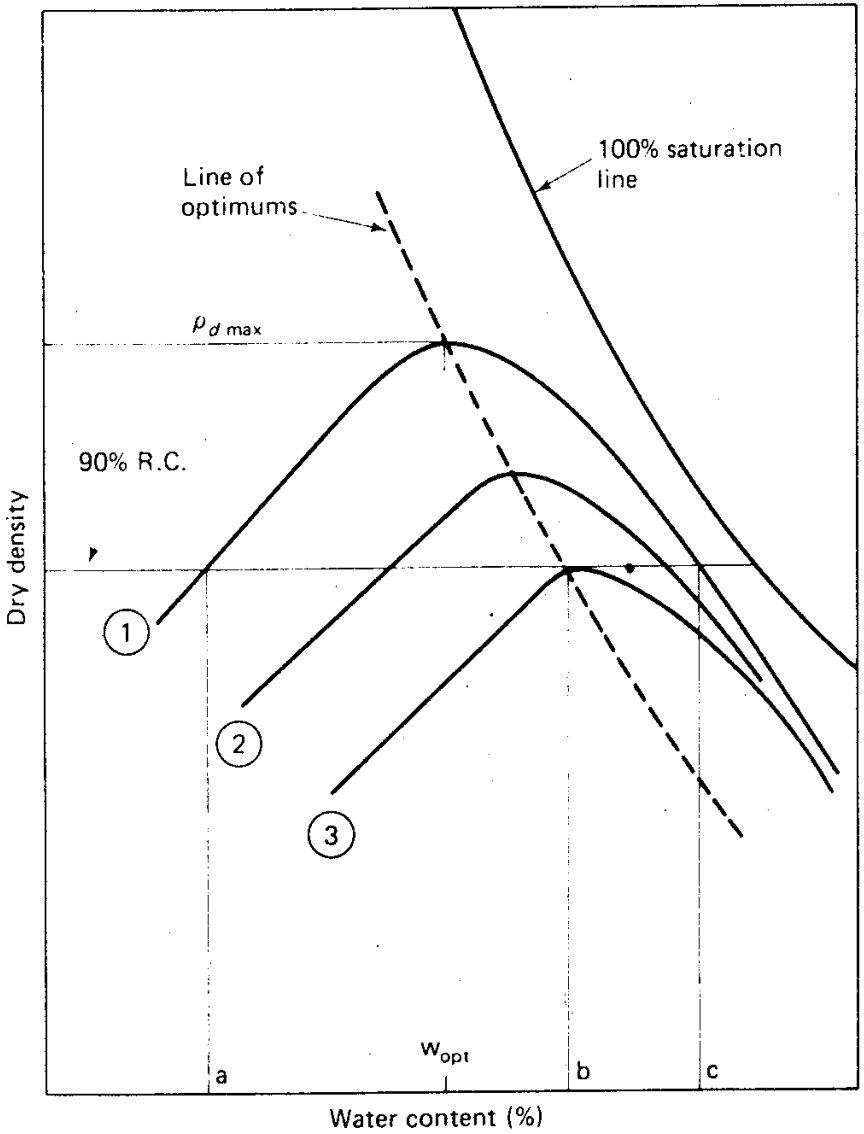


Fig. 5.23 Dry density versus water content, illustrating the most efficient conditions for field compaction (after Seed, 1964).

Compaction Achievement

- NUMBER OF PASSES
- ?
- SPEED
- ?
- Curvature Concept?

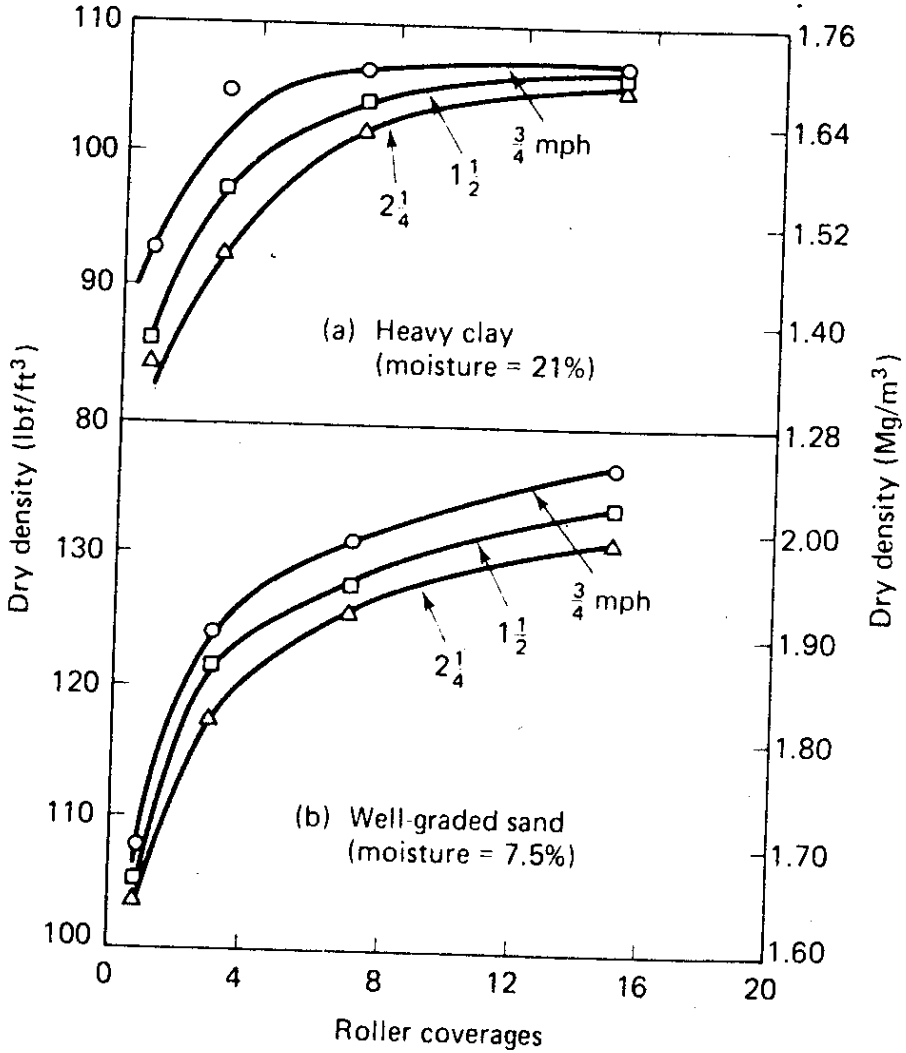
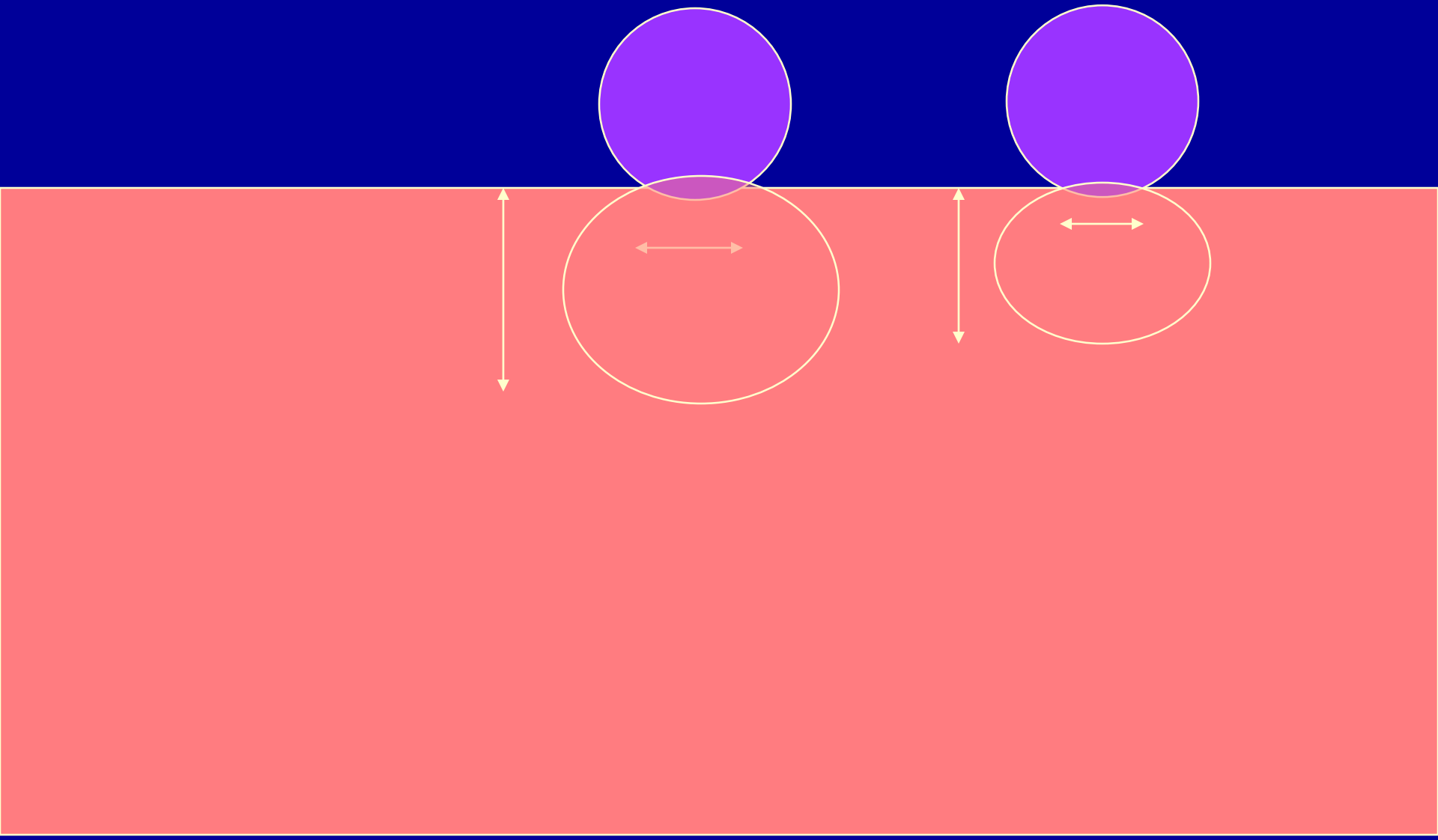


Fig. 5.18 Effect of roller travel speed on amount of compaction with 7700 kg (17,000 lb) towed vibratory roller (after Parsons, et al., 1962, as cited by Selig and Yoo, 1977).

Compaction Achievement

- COMPACTION DEPTH (Lift Thickness)
- Cohesive Soils
  - Compacted By Pressure, Kneading,....
- Cohesionless Soils
  - Compacted by Vibrations

Compaction Achievement



Compaction Achievement

- Compaction Depth (Lift Thickness)

- Cohesive Soils
- Depends on
  - Pressure
  - Impact
  - Vibration (if any)
  - Initial Density of Soil

Compaction Achievement

- **Cohesionless Soils**

- Difference Between Compaction Characteristics ??
- Compaction Pressure
- Vibration Frequency

Compaction Achievement

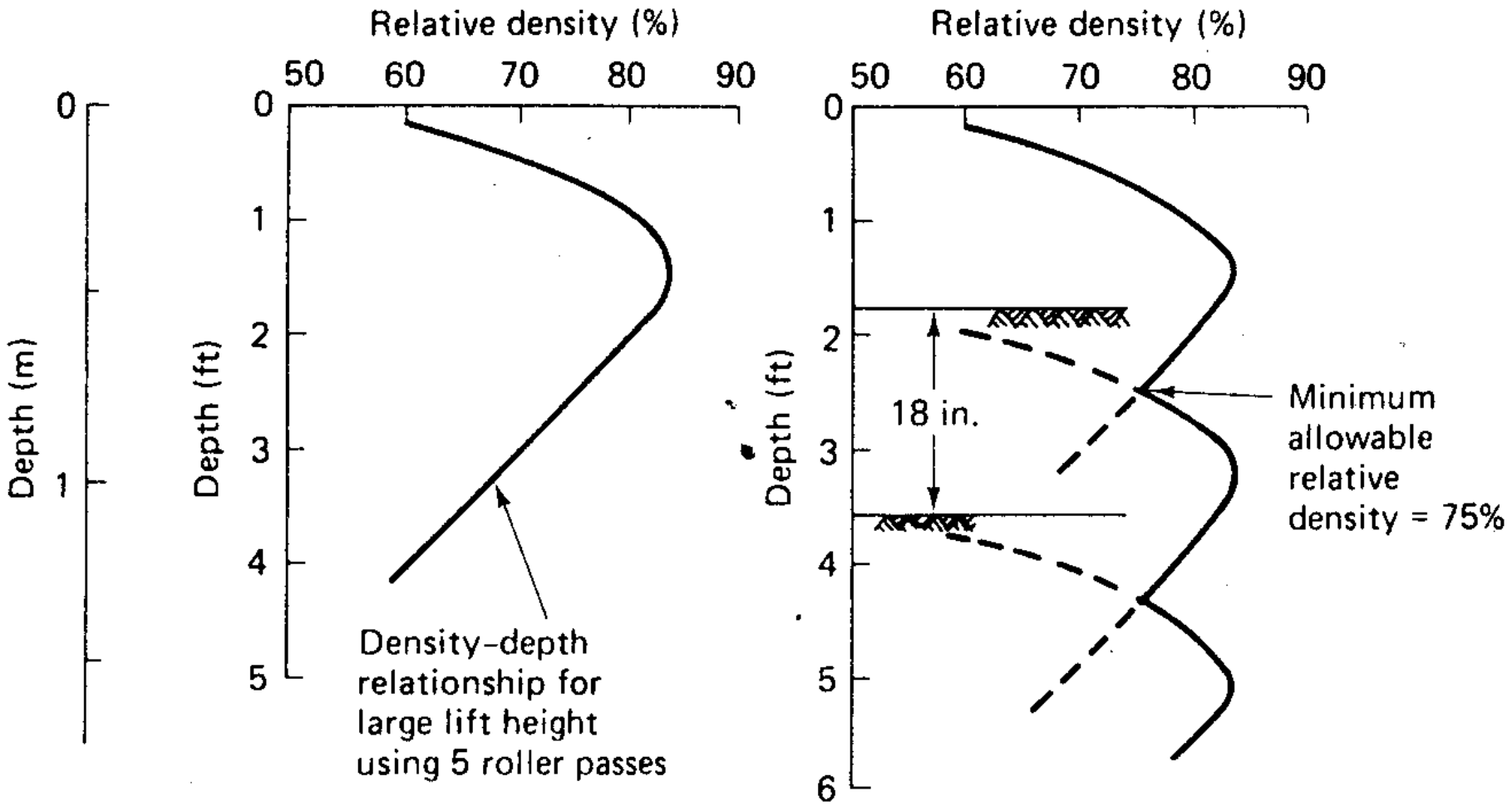


Fig. Ex. 5.2 Approximate method for determining lift height required to achieve a minimum compacted relative density of 75% with five roller passes, using data for a large lift height (after D'Appolonia, et al., 1969).

THANK YOU