TERRANOTES
A Ground Improvement Update from TerraSystems

RAPID IMPACT COMPACTION

Another Form of Dynamic Compaction?

Rapid impact compaction (RIC) is a technique that was developed in the United Kingdom in the 1990's for rapid densification of soils to repair bomb craters on runways. The primary usage in the U.K. is for shallow compaction of floor slab and roadway subgrades. RIC has recently been introduced in the United States and some engineers in the U.S. are mistakenly equating RIC and conventional dynamic compaction. While RIC performs well for the shallow applications for which it was intended, it is categorically not suited for deep compaction of soils. The purpose of this paper is to provide a technical comparison of the two techniques.

RIC consists of an excavator-mounted hydraulic pile-driving hammer striking a circular plate that rests on the ground. The 7.5-ton hammer is hydraulically raised to a maximum height of 4 feet and then allowed to free-fall, resulting in a maximum energy per blow delivered to the plate of 30 ton-feet. The tamper typically strikes the plate at a rate of 30 to 40 blows per minute and generally 10 to 30 blows are applied per compaction location

Dynamic compaction, also called dynamic deep compaction (DDC) and impact densification, is a ground improvement technique that has been used for over 40 years, and has been used on several thousand projects in the United States alone. Dynamic compaction involves the systematic dropping of a 6 to 20-ton tamper from heights of 40 to 80 feet. The tamper is dropped multiple times at each impact point, typically 5 to 15 drops per impact location.

Dynamic compaction and RIC are similar in that both utilize a falling weight to compact the ground. They differ, however, in several respects. First, with RIC, the energy is delivered to a circular plate that remains in contact with the ground, whereas with dynamic compaction, the weight does not remain in contact with the ground. The only difference in energy delivery between the two systems is that a portion of the energy applied with RIC is lost before it reaches the ground, due to having to overcome the inertia of the plate resting on the ground.

The second difference between the two techniques is in the rate of application of energy. With dynamic compaction, the typical rate of application is one to three drops per minute, whereas with RIC, the rate can be as high as 30 to 40 drops per minute; however the total number of drops per drop location is generally limited to 10 to 30. The effects of this difference will be examined on the following page.

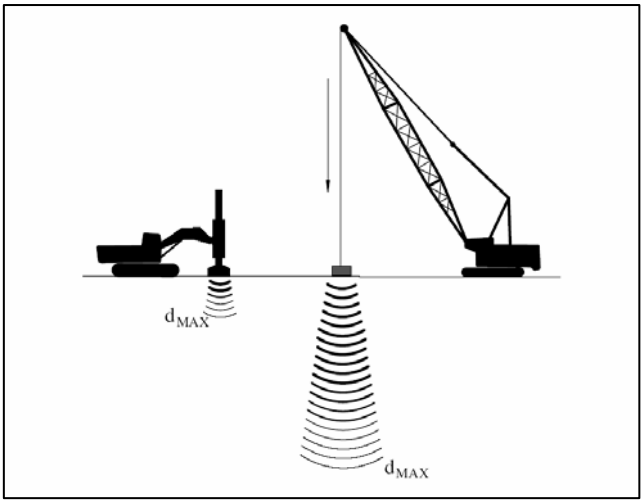
The third and major difference is the amount of energy applied per blow. The maximum impact energy with RIC is 28 ton-feet per drop. With dynamic compaction, typical energies per drop are 300 to over 1,000 ton-feet. This last difference is the defining difference between the two techniques, as explained below.

	RIC	DDC
Tamper	7.5 tons	20 tons
Max Drop Height	4 feet	80 feet
Max Energy Per Impact	60,000 ft-lbs	3.2 million ft-lbs
Max Impact Rate	Rate 30-40 bpm	2 bpm
Max Energy Per Minute	2.4 million ft-lbs	6.4 million ft-lbs

With either DDC or RIC, the maximum depth of compaction d_{MAX} is a function of the impact energy per weight drop. Numerous researchers over the past 40 plus years have demonstrated that the depth of compaction d_{MAX} (in meters) can be approximated by:

$$d_{MAX} = N\sqrt{WH}$$

where W = weight of tamper in tons, H = drop height in meters, and N is typically 0.5.
N can be as high as 0.9 for clean sands.



Using an N of 0.5 for normal soils and typical DDC drop parameters demonstrates that:

$$d_{MAX} = 0.5\sqrt{7.5tons \times 1.2m} = 1.5m \quad \textbf{for RIC}$$

$$d_{MAX} = 0.5\sqrt{20tons \times 24.4m} = 11m \quad \textbf{for DDC}$$

Using an N of 0.9 for very clean sands results in the following compaction depths:

$$d_{MAX} = 0.9\sqrt{7.5tons \times 1.2m} = 2.7m \quad \textbf{for RIC}$$

$$d_{MAX} = 0.9\sqrt{20tons \times 24.4m} = 19.9m \quad \textbf{for DDC}$$

This difference in the achievable compaction depth is the defining difference between RIC and DDC is the depth of compaction.

Research funded by the Federal Highway Administration has shown that after about 3 to 4 drops, the depth of improvement does not increase with the number of drops per impact point. Therefore 6 dropping the weight up to 30 or 40 times does not increase the compaction depth.

The calculated maximum compaction depths by RIC are consistent with the published literature by the manufacturer of the RIC equipment in the United Kingdom, who claims that improvement depths of up to 10 feet can be achieved. Increasing silt and clay content in the soil dramatically reduces the maximum compaction depths.

The primary factor affecting the degree of improvement ***(not depth)*** is the amount of total energy input into the ground. The greater the total energy used, the greater the level of improvement will be, ***but only within the zone of maximum influence***. Applying approximately one minute of RIC per imprint is identical to one to two drops of dynamic compaction in terms of equivalent total applied energy. For the same amount of total energy applied, the depth of improvement with RIC is much less than with dynamic compaction.

While RIC works well for its intended purpose, i.e., very shallow compaction, it is not suitable for moderate or deep compaction of soils, no matter how rapidly or how many times the tamper is dropped. The RIC literally falls well short of DDC, and for this reason, the technology cannot compare to the high energy, deep impacting characteristics of dynamic compaction.

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