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The Competitive Advantages of RIT Technology

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Abstract: Construction project engineers are faced with the task of ensuring reliability and durability of pile foundations while achieving their cost-efficiency. This paper presents the experimental data on implementation of RIT technology, a Russian know-how in the field of pile foundations that has been successfully used by construction projects in Russia and abroad. Evidence is presented of the advantages that make RIT-piles an undeniably competitive choice over conventional pile designs. This article discusses the use of the RITA pile technique in Russia, Germany and Tunisia. The comparison of the bearing capacity of piles manufactured using Fundex technology and piles-RIT operating under the same initial conditions and almost the same initial dimensions is shown. According to the results of work in Germany, the piles-RIT received product testing by the German institute DIBt. Particular attention is paid to the experience of using piles in the conditions of weak soils of the coastal areas of Tunisia. It is shown that when replacing traditional bored piles with piles-RIT, the cost of pile foundations is reduced. The production time of pile foundations is reduced by 2-3 times.

1 Introduction

In the early 1990s, geophysical engineering received a new type of piles with increased load-bearing capacity in soil – RIT-piles. RIT-piles use recharge impulse technology to achieve dynamic compaction in the soil around them by means of high-power discharge in liquid concrete in the pile shaft (Fig. 1). One of the biggest dreams of geotechnic engineers has come true: with RIT-piles, loose soils can be compacted not only at deeper depths, but also across soil layers. The know-how marks an important step towards achieving an increased load-bearing capacity of piles without having to increase their length.

The recharge impulse technology works as follows. After filling the pile hole with fine-grained concrete or cement mortar, a rigid rod with electrodes is lowered into the shaft to all the way to the bottom. Then, a series of high-voltage electrical discharges is produced to cause electrohydraulic effect, as a result of which the pile body assumes the shape of a sable fin, with the soil surrounding the pile compacted.

Exposed to electrical discharges, the initial pile hope diameter of 200...350 mm can increase 2 to 3-fold, depending on the discharge intensity, physical and mechanical properties of soil, and on-site hydrogeological conditions. The soil surrounding the pile is compacted,

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and the porosity within the zone of impact impulse is reduced (According to MPO RITA LLC Booklet, 2006). In case of loose, water-saturated soils, the consolidation process occurs almost "instantly", as in the case when dynamic consolidation achieved with the use of super-heavy ramming appliances (According to Michel P. Gambin. 1979. Menard Dynamic Consolidation. Sols Soils №29. 27-40).

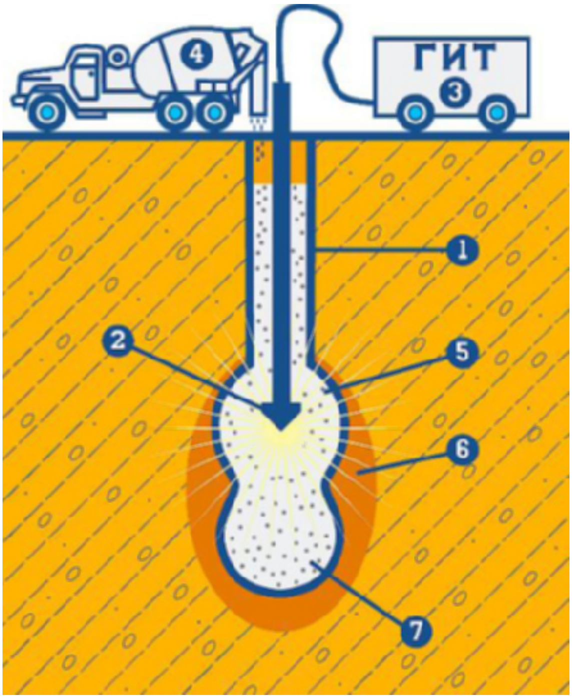

Fig. 1. Recharge impulse technology in RIT-pile:
1 – pile shaft prior to exposure to electric explosions;
2 – rod with electrodes ;
3 – SCG (surge-current generator);
4 – concrete pump;
5 - soil cementation zone;
6 – soil compaction zone;
7 – pile shaft prior after exposure to electric explosions.

The exposure to high-voltage electric discharge occurs within the concrete within small fractions of a second, so the dynamic effect on nearby buildings is negligible. Since the process is adiabatic, liquid concrete does not have time to heat up. At 10 kV voltage pulse, a pressure of more than 108 Pa occurs in the liquid concrete. The piles involving this technology are known under the abbreviated name of RIT-piles.

Among the Russian users of RIT technology is MPO RITA. This development company has used RIT-piles in hundreds of projects in Russia and abroad, including the pile foundations for several dozen buildings of 30 to 45 floors in Moscow.

2 Load-bearing capacity: RIT technology vs. Fundex technology

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Fundex technology uses flattening appliances to install cast piles. As the pile is driven, the soil is compacted along depth in horizontal direction. In this case it can be assumed that compaction occurs under static load.

Fig. 2. The 350 mm diameter Fundex pile installation process.

In Khimki, Moscow Region, a 16-storey housing project in 5 Rodionov Street used Fundex piles with a diameter of 350 mm and a length of 15 m as a foundation for one block of flats, and RIT-piles with a diameter of 300 mm and a length of 13.5 m as a foundation for another block of flats. For comparison purposes, static pile load tests were performed (Yeremin, V.Ya. 2003).

The static pile load tests have clearly shown a significant increase in the rigidity of foundation soil around the RIT-pile, compared to displacement technology. While the Fundex pile "sank" under the load of 100 tons, the RIT-pile and the soil around it continued to remain in almost elastic stage. After removing the load, the residual settlement of the RIT-pile was 3 times less than that of the displacement piles. RIT-piles show undeniably better performance.

Fig. 3. The pile foundation installation process: 300 mm diameter RIT-piles in the foreground, Fundex piles in the background.

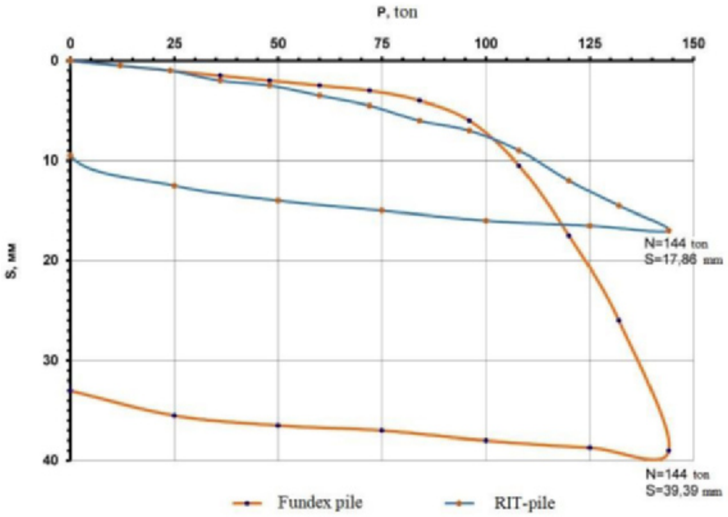

Fig. 4. The static pile load tests: Combined diagram. Fundex piles (diameter 350 mm, length 15 m) vs. RIT-piles (diameter 300 mm, length 13.5 m). Standard GOST 5686-94.

3 RIT-pile performance in loose soils of the coastal areas of tunisia

Geologically, the coastal areas of Tunisia are characterized by common occurrence of loose, water-saturated soils as thick as 30 to 60 m., with high porosity and compressibility and low strength. Geotechnical cross-sections show water-saturated clays, loams, silty deposits and sands of parallel (horizontal) stratification. Highly loose, medium-density clay, silty and sandy soils occur in the upper layer to depths of 25 to 30 m. The interlayers of sandy soils have an average thickness of 1.5 m [1].

When using the conventional cast piles with a diameter of D=800÷1200 mm, the said strata and interlayers have no supporting effect on the load-bearing capacity under the pile toe and along its lateral surface, causing the pile to sink within a thickness H (Geuze rule 3D < H). In such soils in Tunisia, piles are driven to the depth of 40-50 m or more.

In case of RIT-piles, the layers of sandy soils serve as a fairly reliable foundation.

According to Fascicule No. 62.-Titre V (Règles technique de calcul et de conception des fondations des ouvrages de génie civil. Eyrolles. P 183), the mobilized force beneath the pile toe is determined as follows:

$$Q_{pu} = A * q_u \tag{1}$$

where A = cross-sectional area of the pile;

q_u i= ultimate breaking stress under the pile toe;

$$q_u = k_p * P_{le}^* \tag{2}$$

k_p = load-bearing capacity coefficient depending on the category of soil and pile manufacturing method; and

P_{le}^* = equivalent limit pressure determined after processing the pressuremeter tests.

In case of conventional cast piles, k_p =1 for loose sand (Type A soil) and k_p =1.1 for medium-density sand (Type B soil) [2].

RIT-piles are considered as piles whose installation involves soil displacement, and in this case k_p = 4.2 for loose sand and k_p = 3.7 for medium-density sand. The advantages of using RIT-piles in geologically complex conditions are reflected in the national standards of France and Russia.

Since 2010, Tunisian-Russian venture RITA Foundations installed piled foundations for eleven projects. A total of more than 4,000 continuous flight auger (*CFA)* piles were installed in those projects. The 320 mm diameter wells were drilled in one run to a depth of 22 m, followed by pouring of fine-grained concrete through the continuous flight auger using an HP compressor. There is no need to use bentonite in this case. With such a workflow, the projects were installing 12 to 18 piles per shift. It was obligatory (according to French standards) to perform vertical static pile load test at each construction site.

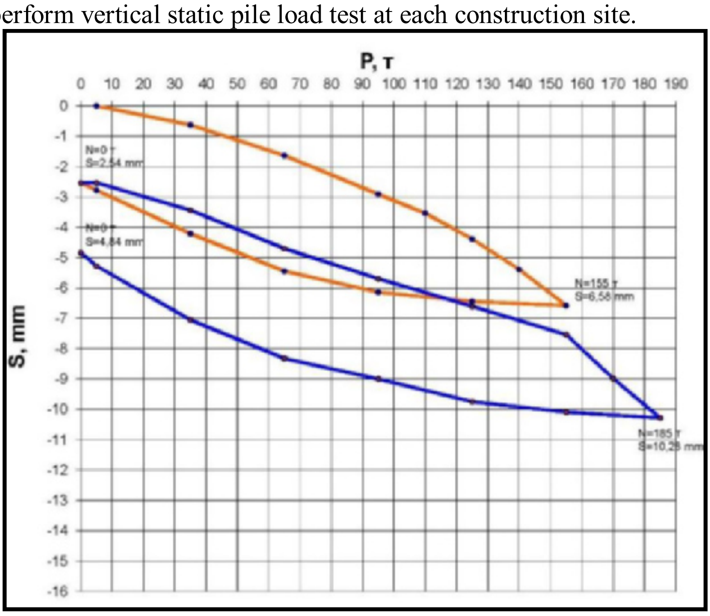

Fig. 5. RIT-pile E1 static tests.

The graphs above show the testing results for "faulty" RIT-pile E1, installed for SODAPRIM Company's 10-storey housing project in coastal district Luk II, Tunisia. The surveyors found the pile defective, since due to an error in the dosage of the BV40 plasticizer, the concrete began to harden only on the second day. The works took place in August at a temperature of 36^{0}-40^{0}.

It should be noted that the above coastal district was Tunisia's first to pioneer the RIT technology in loose soils. The local inspection authorities were governed by maximum design load Q_{max} = 100.0 t (in terms of load-bearing capacity) [3].

The defective pile E1 was first tested under N = 155 t, with settlement stabilizing at all stages of the loading. The maximum settlement equaled S = 6.56 mm. The residual settlement after unloading equaled S = 2.5 mm.

Since this defective pile was excluded from works under the building, it was decided to perform a second loading cycle under the load maximum for the jack in use (200 t). Similarly, during the second cycle, the settlement stabilized under 185 t. The maximum settlement measured S = 10.23 mm. After unloading, the residual settlement measured S = 4.84 mm.

The RIT-piles have shown high load-bearing capacity in all construction projects in Tunisia. Even under loads almost twice as high the design ones, the proportionality limit was not reached, which indicates the high reliability of RIT-piles in thick loose soils.

More than 10 years have passed since RIT-piles were first installed in coastal areas of Tunisia. The recent monitoring of their buildings has found no signs of yielding.

In some areas of the recently developed areas of Tunisia, there occur horizontal layers of very strong crusts with a thickness of 20-40 cm. These layers form crusts that often have an area larger than the construction site itself and are of biogenic nature, consisting of carbonate residues of marine organisms and a small proportion of carbonate cement. The strength of such crusts is comparable to that of concrete. Figure 6 shows some of their fractions.

Fig. 6. Thin (thickness 20 cm) stone crust. Sample taken from the depth of 19 m.

For conventional cast pile driving process, the occurrences of these crusts causes nothing but trouble, having no positive effect on the load-bearing capacity, whereas with RIT technology it becomes possible to benefit from them. At some of the construction sites in Tunisia, where such crusts occurred, soon after the pile shaft was exposed to electrical discharges, there formed widenings (coves) underneath the crust and within the soil above them.

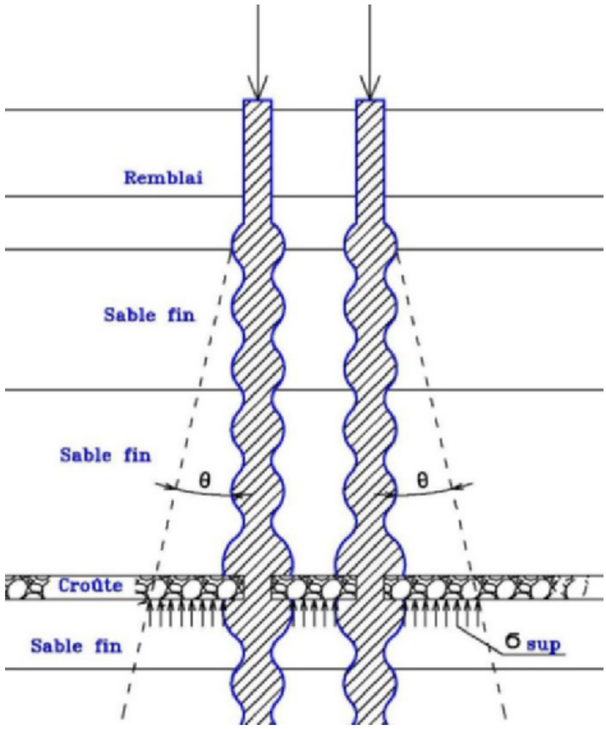

Fig. 7. The rigid stone crusts form part of installation design.

The unique performance of the RIT technology creates within the foundation soil an additional load distribution structure.

Notably, the soils of similar geological composition – with inclusions of hard stone crusts – occur not only in Tunisia, but also in some regions of Russia. One example is Dzerzhinsk District of Volgograd. The surveys for the local school construction project (2018) have discovered similar hard stone crusts with a thickness of approximately 30 cm at depths of 10-15m.

If we compare the ratio of the piles' load-bearing capacity with their dimensions (volume of concrete per pile), we can state [4-7] that for the RIT-piles the specific load-bearing capacity per cubic meter of poured concrete equals $P_{sp} \approx 100$ t/m^3. For the conventional cast piles used in Tunisia, with diameters between 800 mm and 1,200 mm and length of 40 m, $P_{sp} \approx 13.5$ t/m^3. For similar piles in Vietnam, with a diameter of 1,000 mm, $P_{sp} \approx 6.5$ t/m^3. In any case, the competitive advantage of RIT-piles over the conventional piles are obvious.

4 German experience of using RIT-piles

RIT-piles were first installed in Germany in Straussberg in 2002. The German party chose them for a construction project deployed near an old, heavily dilapidated building (Fig. 8.).

Fig. 8. The dilapidated building adjacent to the construction site.

In that dilapidated building, the German engineers installed seismic sensors on the foundation and ceiling above the top floor in order to record the amplitudes of the velocity in structural elements (velocigrams). The expert conclusion reads: The measured amplitude is indicative of the RIT technology having no impact on adjacent buildings, nor does it produce vibrational load on humans, which makes this technology fully corresponding to DIN 4150-2. The report further recognizes the RIT technology as friendly to dilapidated buildings and surrounding environment.

The static pile load tests have been successful and indicative of the piles' high reliability.

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Allgemeine bauaufsichtliche Zulassung für Entladungs-Impuls-Verfahren zur Herstellung von Mikropfählen (E-I-T-Pfähle)

Stellungnahme zur Herstellung von Pfählen mittels dem E-I-T-Verfahren und der damit verbundenen Aufweitung des Pfahlschaftes bzw. Pfahlfußes

Sehr geehrte Damen und Herren,

erfolgt die Herstellung von Mikropfählen und Bohrpfählen mittels dem E-I-T-Verfahren entsprechend den bauaufsichtlich eingeführten Technischen Baubestimmungen:

- DIN EN 14199 Ausführung von besonderen geotechnischen Arbeiten (Spezialtiefbau) – Pfähle mit kleinen Durchmessern (Mikropfähle) in Verbindung mit DIN SPEC 18539 Ergänzende Festlegungen zu DIN EN 14199 bzw.
- DIN EN 1536 Ausführung von Arbeiten im Spezialtiefbau – Bohrpfähle in Verbindung mit DIN SPEC 18140 Ergänzende Festlegungen zu DIN EN 1536,

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Mit freundlichen Grüßen

Hemme

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Fig. 9. Conformance Certificate issued by German Institute of Construction Engineering.

Subsequently, the RIT technology underwent testing by The Deutsches Institut für Bautechnik (DIBt), a technical authority for Germany's construction sector operating under the agreement between the federal government and the states. Headquartered in Berlin, DIBt has as its core task testing of unregulated construction products and technologies. It is an issuer of European Technical Approvals (ETA) to the construction products found corresponding to Construction Products Regulation (Regulation (EC) No 305/2011).

5 Conclusions

In estimating the cost efficiency of RIT-piles, it is necessary to consider that their installation involves extra power costs and increased consumption of cement for the concrete mixture .

In any case, and given the successful experience of using RIT-piles in Russia and abroad, the cost-efficiency varies between 15% and 45%, depending on the diameter of piles being replaced with RIT-piles. With RIT-piles, the piled foundation installation process is 2 to 3 times shorter. Despite the use of impulse impact, the RIT technology does not produce any negative effect on the surrounding buildings.

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