RIT bored piles

Electric discharge impulse technology
Construction, testing, design and applications

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SELAR

Electric discharge impulse technology, known as RIT, increases the geotechnical bearing capacity of bored piles. Electrical discharges in fresh concrete form local enlargements beneath the pile toe and along the shaft while compacting the surrounding soil.

RIT piles are used in new construction and reconstruction, including piled raft foundations for high-rise buildings, foundation strengthening and work on sites with restricted access.

The RIT piling method

This technology was introduced to Novosibirsk as a new method of constructing bored piles. Its name, RIT, is derived from the Russian term for electric discharge impulse technology.

Increasing the geotechnical bearing capacity of friction piles is a significant design task. In bored piles, the structural capacity of the shaft material is often underused because the surrounding soil cannot provide sufficient resistance. Local enlargements formed along the pile by compacting the adjacent soil address this limitation.

Many methods form an enlarged pile base. A distinctive feature of our technology is the ability to form enlargements along the full length of the pile as well, increasing both its bearing capacity and the stiffness of the pile foundation.

Formation of enlargements

Compacting an enlarged toe by ramming takes considerable time, produces dynamic effects and provides a lower pile capacity. Explosive methods are hazardous and technically complex, with restrictions in densely built urban areas.

RIT uses numerous low-energy dynamic actions. These are generated by electrical breakdown of the concrete mix under a high-voltage current pulse, producing an electrical explosion. Successive pulses treat the required sections of the pile.

Bearing capacity

RIT piles have high geotechnical bearing capacity, often approaching the structural capacity of the pile material.

Borehole diameter	Geotechnical bearing capacity
180 mm	More than 60 tf
250 mm	100 tf
300 mm	Up to 150–200 tf

Under design loads, settlements measured in tests to GOST 5686-94 remained within permissible limits, with a substantial reserve of geotechnical bearing capacity. Residual movements of only a few millimetres indicate elastic behaviour of the pile–soil system.

Pile construction

A borehole is drilled to the design depth and filled with concrete. The electrode system is then lowered into the mix. Breakdown across the electrode gap occurs in a liquid medium; in this process, the fresh concrete provides that medium.

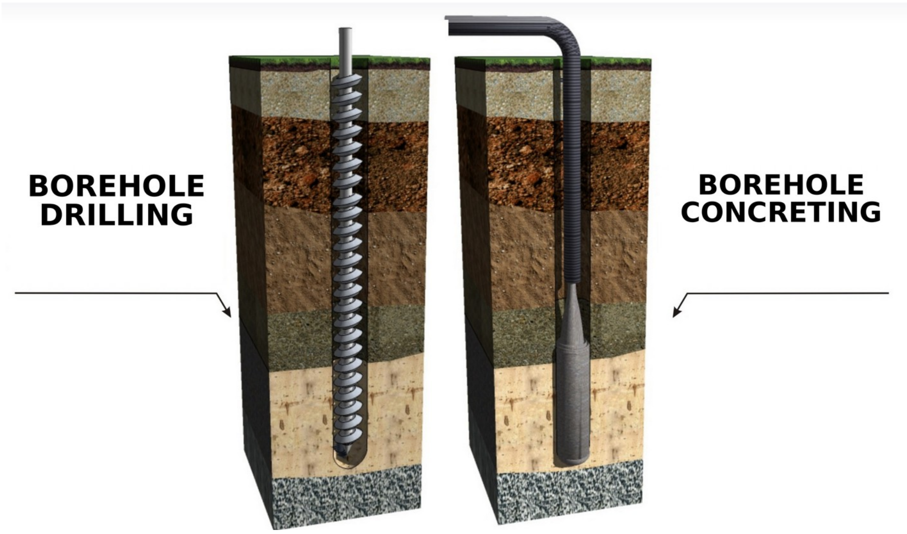


Figure 1. Borehole drilling and concreting.

During an electrical discharge, pressure generated in the concrete acts on the borehole walls. A series of pulses compacts the soil locally and forms a discharge-induced, or camouflet, enlargement.

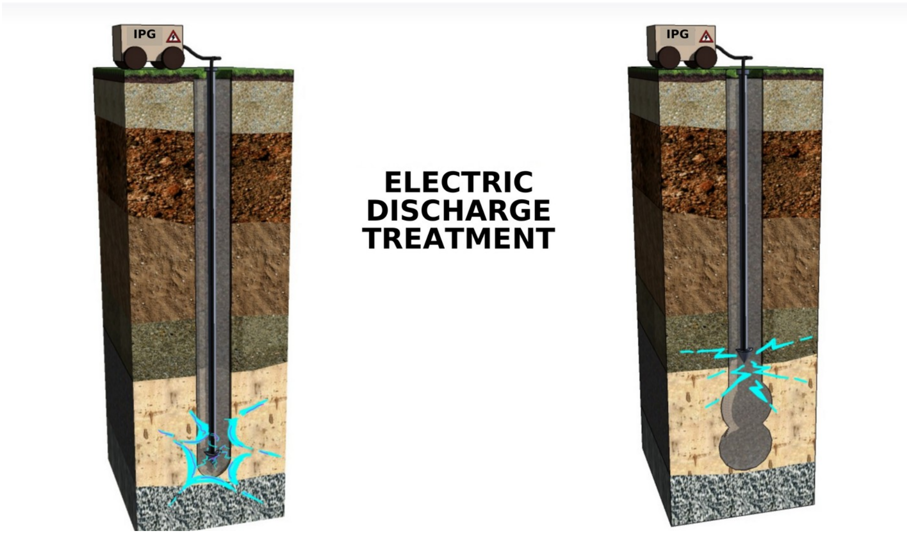


Figure 2. Electric discharge treatment of the pile toe and shaft. IPG: impulse current generator.

Pile formation and soil response

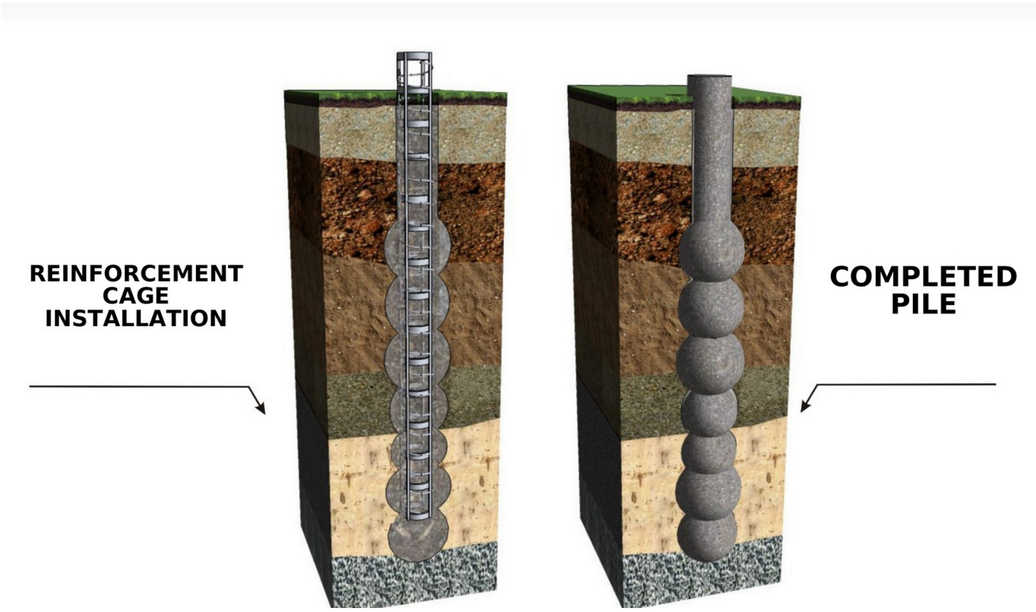


Figure 3. Reinforcement cage installation and the completed pile.

Both the toe and the shaft are treated when a RIT pile is formed. Small shocks can be felt near the borehole. The degree of soil compaction is assessed from the drop in the concrete level at the borehole head.

The adjacent soil deforms and begins to mobilise resistance during pile construction. Experiments show that a conventional pile develops its full shaft resistance only after some movement or settlement. Camouflet enlargements give RIT piles high resistance to alternating loads.

The compacted zone around the discharge location may extend to two or three radii of the equivalent camouflet cavity. The result is a geotechnical mass comprising the pile and the modified surrounding soil, which acts with the pile as a single system. In the immediate vicinity of the pile, soil properties exceed the initial values established by the geotechnical investigation.

Factors increasing bearing capacity

- Enlargement of the pile shaft at the treated levels.
- Compaction of soil around the shaft and beneath the toe.
- Partial cementation of soil around the shaft.

Soil resistance beneath the toe increases by a factor of 1.3–2.0, and shaft resistance increases by a factor of 1.2–1.5.

Local pile enlargements

Increasing the geotechnical capacity of friction piles allows more complete use of the strength of the shaft material. RIT makes it possible to form enlargements at the base and at selected levels along the pile.

Figure 4. Exposed pile sections with local enlargements, shown from two viewpoints.

Figure 5. Enlargement profiles and the adjacent soil zone.

The photographs show the actual pile profiles after excavation. The enlargements are formed by successively treating the selected levels.

Pile profile and pile field

Figure 6. An extracted pile with enlargements along its shaft.

Figure 7. A pile field before construction of the superstructure.

High bearing capacity per unit of pile size, practical construction methods and rapid installation in restricted urban sites make RIT piles suitable for piled raft foundations in high-rise construction.

RIT piles compete with segmental driven piles. Their small settlements under high loads also allow them to replace larger bored piles, 600–1200 mm in diameter, as well as drilled screw piles and jacked-in piles.

Load testing and settlement

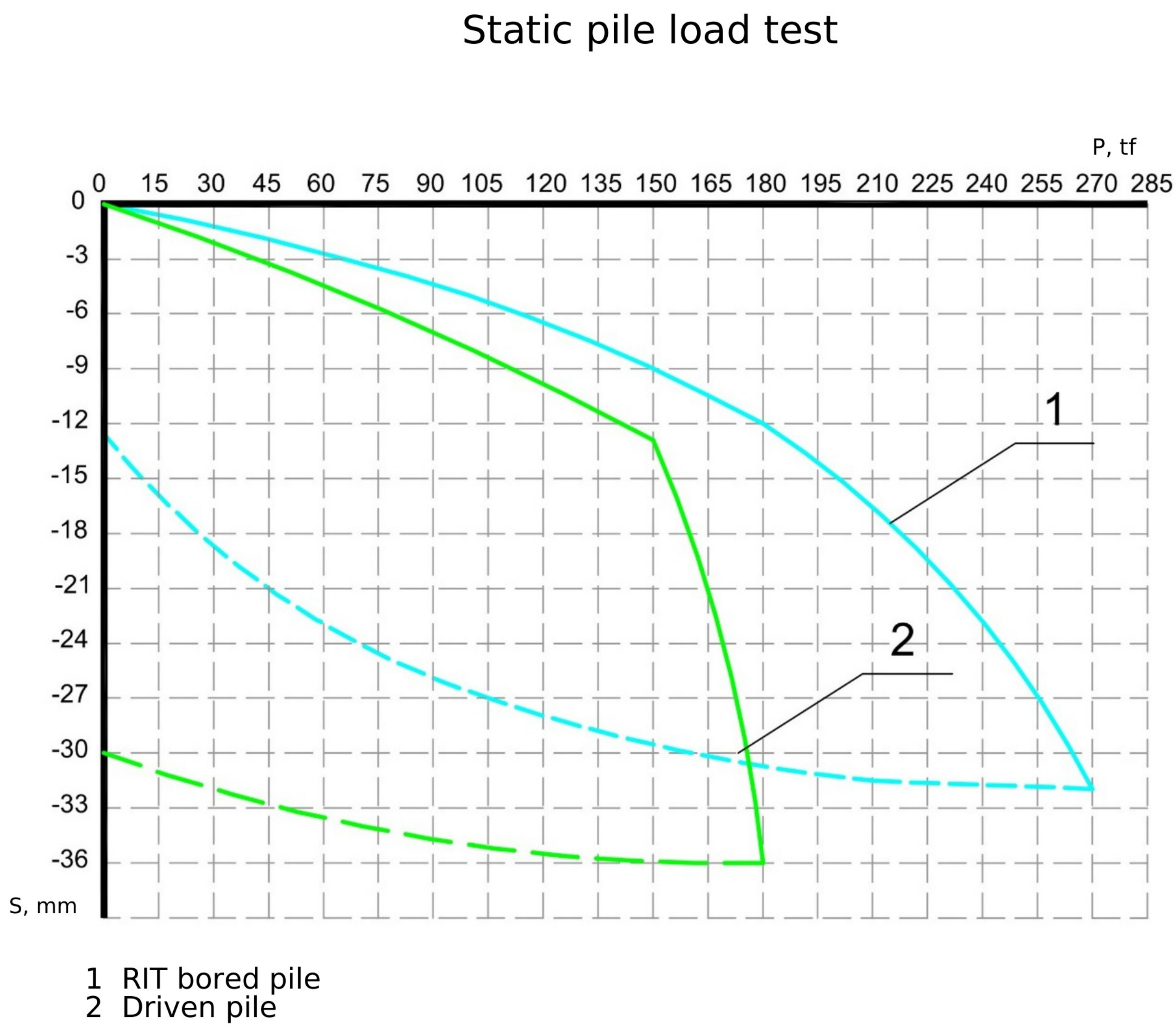


Figure 8. Load–settlement curves for a RIT bored pile and a driven pile. P: load in tonne-force; S: settlement in millimetres.

A conventional bored friction pile may show a sharp change in the slope of its load–settlement curve, indicating loss of shaft resistance. RIT pile test curves are smoother, including at test loads approaching the design structural resistance of the pile material.

Settlement plotted against time at each load increment shows stabilisation of deformation. On unloading, RIT piles return almost to their initial position; residual movements are only a few millimetres. This indicates elastic behaviour of the RIT pile–soil system.

Static load test results

Table 1. RIT pile tests at completed projects in Moscow. Loads are expressed in tonne-force (tf); settlements are in millimetres. Pile dimensions are borehole diameter and length.

1. 1 Arbat Street, entrance hall of the second exit from Arbatskaya metro station

Pile: 250 mm / 8 m. Soil: Dense peaty loam; clay.

Test date	Design load tf	Test load tf	Settlement mm	Residual mm
26 Feb 2002	75	90	8.39	3.21
2 Mar 2002	75	90	7.79	2.50

2. Mitino, district 8B, block 2, section 2; residential building foundation

Pile: 300 mm / 10 m; 11 m. Soil: Dense fine and medium sand; water-saturated at the toe.

Test date	Design load tf	Test load tf	Settlement mm	Residual mm
1 Jul 2002	80	100	4.14	0.90
2 Jul 2002	80	100	4.39	0.88

3. Mitino, district 8B, block 2, section 1; RIT pile test site

Pile: 300 mm / 19 m. Soil: Fill and peat to 12 m, then water-saturated medium sand.

Test date	Design load tf	Test load tf	Settlement mm	Residual mm
7 Jun 2002	70	240	17.30	6.42
9 Jun 2002	80	270	32.04	12.64

Static load test results continued

4. 147 AB GSh VS RF E 00; Series III M residential building, pile foundation

Pile: 250 mm / 5 m. Soil: Fine sand.

Test date	Design load tf	Test load tf	Settlement mm	Residual mm
20 Feb 2002	47	60	5.15	2.94

5. 23 Bolshoy Znamensky Lane; pile foundation for a 10-storey block of the 1st Ministry of Defence building

Pile: 250 mm / 15.2 m. Soil: Medium-dense fine sand with loam interlayers.

Test date	Design load tf	Test load tf	Settlement mm	Residual mm
25 May 2001	92	120	6.40	1.00
20 May 2001	92	120	8.30	1.80
22 May 2001	92	120	8.40	1.70

6. 23 Grishina Street, building 7; pile foundation above a civil defence shelter

Pile: 250 mm / 15 m. Soil: Stiff loam and water-saturated silty sand.

Test date	Design load tf	Test load tf	Settlement mm	Residual mm
20 Nov 2000	85	102	5.20	2.80
23 Nov 2000	85	130.5	8.30	1.60
26 Nov 2000	85	102	7.30	1.30

Static load test results continued

7. 8 Vrachebny Proezd; pile foundation for a 25-storey residential building

Pile: 250 mm / 11.2 m. Soil: Stiff loam and water-saturated medium sand.

Test date	Design load tf	Test load tf	Settlement mm	Residual mm
5 Aug 2002	60	72	3.32	0.52
7 Aug 2002	60	115	10.90	2.80

8. 7 Soymonovsky Lane, building 2; garage pile foundation

Pile: 250 mm / 7 m. Soil: Loose medium sand and medium-dense medium sand.

Test date	Design load tf	Test load tf	Settlement mm	Residual mm
20 Feb 2002	50	60	3.05	1.48
5 Mar 2002	50	60	4.98	2.99

9. 37 Vernadsky Avenue; pile foundation for a 19-storey block

Pile: 300 mm / 18 m. Soil: Man-made ground, loam and water-saturated medium sand.

Test date	Design load tf	Test load tf	Settlement mm	Residual mm
12 Mar 2003	150	180*	15.11	5.73
1 Apr 2003	150	180	8.93	1.88
17 May 2003	150	234**	18.46	5.47

* The 180 tf compression test was carried out 15 days after concreting. The concrete cured in the ground at +8 °C.

** At a control load of 180 tf, the RIT pile settlement was 10.71 mm.

Development of the technology

Early research

The first construction experiments using electric discharge impulse technology date to 1963, when the Moscow Institute of Civil Engineering investigated compaction of water-saturated sandy soils. In 1977, the Leningrad Institute of Civil Engineering studied a method of constructing bored piles.

In the 1960s and 1970s, equipment operated at 30–60 kV and, in some cases, as high as 300 kV, because output increased with the square of the voltage. Electrical components had a short service life. Early capacitors contained polychlorinated biphenyls, which are highly toxic.

The equipment weighed 8–9 tonnes and was moved by a tracked tractor. These factors constrained the development of RIT.

Transition to construction practice

In the late 1980s, instructors at a military construction school near Leningrad installed piles for a number of projects. The technology was subsequently adopted in Moscow, while the equipment and working methods continued to improve.

Operating voltage was reduced to 10 kV. Our equipment weighs no more than two tonnes. Mean time between failures increased, transformers became more compact, and toxic substances were eliminated from the relevant electrical components. Design guidance for RIT piles was also developed.

Additional work and resulting capacity

Applying electric discharge impulse treatment to a conventional bored injection pile increases construction labour and cost by 10–15%, while increasing bearing capacity by a factor of 1.7–1.9.

Bearing capacity calculation

Like any friction pile, a RIT pile transfers compressive load to the ground through its toe and shaft. The calculation includes both components:

$$F_d = \gamma_c \left(\gamma_{cR} R \;\; A \; + \; u \;\; \sum \gamma_{cf} f_i h_i \right)$$

Fd is pile bearing capacity; γc is the pile working-condition factor; γcR and γcf are soil working-condition factors for the toe and shaft; R is toe resistance; A is base area; u is shaft perimeter; and fi and hi are the resistance and thickness of the relevant soil layer.

The first term makes a substantial contribution to bearing capacity. For camouflet enlargements, the soil working-condition factor γcR may be increased to 1.3. The area A is the cross-sectional area of the enlargement, determined from the volume of concrete used to fill it.

The design resistance R beneath a RIT pile toe is taken as that beneath a driven pile with a diameter equal to the equivalent camouflet cavity formed by successive electrical discharges at the borehole bottom.

Equivalent enlargement diameter

The volume filling the cavity corresponds to the volume between the upper and lower concrete levels at the borehole head during toe treatment. The equivalent diameter is calculated as:

$$d_c = \sqrt[3]{\frac{3}{2} {d_b}^2 \Delta h}$$

db is the borehole diameter, m; Δh is the drop in concrete level during electric discharge treatment of the pile toe, m.

The design method accounts for the specific geotechnical conditions at the site. Five years of practical application showed close agreement between calculated RIT pile capacities and compression control tests to GOST 5686-94.

Technical recommendations

Additional research, including work in Germany and South Korea, enabled the State Unitary Enterprise NIIMosstroy to develop TR 50-180-06, Technical Recommendations for the Design and Construction of RIT Piles for High-Rise Buildings and Structures of Responsibility Level I. The recommendations were approved by the Moscow Government on 6 May 2006.

Reinforcement joints

14.9.3. When designing unwelded lap joints in compression reinforcement with bar diameters not exceeding 32 mm, the requirements of SP 52-101-2003, clause 8.3.27, must be followed.

Joints between reinforcement cage sections in RIT piles supporting high-rise buildings are always in compression. Their lap length must be at least ln:

$$l_n = \alpha R_s A_s / (\eta_1 \eta_2 R_{bt} u_s) \times A_{s,cal} / A_{s,ef}$$

$$= 0.36 R_s A_s / (R_{bt} u_s) \times A_{s,cal} / A_{s,ef}$$

$$= 0.36 R_s / (R_{bt} u_s) \times A_{s,cal} / n \qquad (14.23)$$

Here α = 0.9 accounts for the stress state of the compression reinforcement, the structural arrangement in the lap zone, the proportion of reinforcement spliced at one section, and the spacing between pairs of lapped bars. That spacing must not exceed 2ds or 30 mm. Rbt is the design axial tensile resistance of the pile concrete; n is the number of bars being spliced. Other symbols are as in equation (14.22).

14.9.4. For lap joints, the distance between the lapped bars must not exceed 2ds, where ds is the longitudinal bar diameter. The spacing between adjacent pairs of lapped bars must be at least the equivalent diameter dred.

For cage sections with six working bars of class A500C reinforcement, Rs = 435 MPa, in class B30 concrete with Rbt = 1.2 MPa, equation (14.23) becomes:

$$l_n = 0.06 R_s A_{s,cal} / (R_{bt} u_s) = 21.75 d_{s,cal}^2 / d_{s,ef}^2 (14.24)$$

ds,cal and ds,ef are the calculated reinforcement bar diameter and the diameter actually installed, respectively.

Design factors in TR 50 180 06

14.10 Geotechnical bearing capacity of RIT piles

14.10.1. Shaft resistance may be disregarded over the upper 2 m below the underside of the pile cap, where no electric discharge treatment is performed.

14.10.2. Taking account of SNiP 2.02.03-85 and SP 50-102-2003, the geotechnical bearing capacity Fd of a friction RIT pile, in kN (tf), is determined by:

$$F_d = \gamma_{kk} \gamma_{crit} \left(\gamma_{cR} R_{rit} A_{rit} + \gamma_{cf} \sum u_{irit} f_i h_i \right) \qquad (14.25)$$

γkk is the pile foundation reliability factor associated with the responsibility class of the building or structure: 0.7 for high-rise buildings and Class I structures; 0.85 for Class II buildings; and 1.0 for other buildings.

γcrit is the RIT pile working-condition factor, equal to 1.0 in all cases.

γcR is the soil working-condition factor beneath the pile toe, taken as 1.3 for all soils, as for piles with a camouflet base enlargement.

γcf is the soil working-condition factor along the shaft. For all soils it is taken as 1.3, as for piles with enlargements along the shaft, except in the upper section. If resistance in the untreated section is included, use γcf = 0.4 down to the bottom of the guide casing and γcf = 0.5 below the casing down to the start of the treated section.

Rrit is the design soil resistance beneath the RIT pile toe, kPa (tf/m²), determined from the dimensions of the compacted zone beneath the pile.

Arit is the pile base area, m², taken as the cross-sectional area of the camouflet enlargement at its maximum diameter.

uirit is the pile perimeter at level i, m. It is recommended to use the borehole perimeter, uirit = πdc. An increase in perimeter caused by discharge treatment at that level may be included.

fi is the design shaft resistance of soil layer i, kPa (tf/m²), taken from Tables 6.3 and 6.4 of Appendix 6, compiled from Table 7.2 of SP 50-102-2003 and Table 2 of SNiP 2.02.03-85. hi is the thickness of soil layer i in contact with the pile shaft, m.

14.10.3. The dimensions of the compacted zone beneath a RIT pile are assessed using the diameter of the equivalent cavity.

Enlargement ratios in sand

Table 2. Ratio of camouflet enlargement diameter Dkul to borehole diameter dc. The borehole diameter is taken as the drilling-tool diameter.

Loose sand

Sand type / borehole diameter	≤150 mm	151–250	251–320	321–450
Gravelly, coarse and medium sand	3.3	2.4	2.1	1.8
Fine sand, low or medium saturation	2.8	2.1	1.8	1.6
Fine sand, water-saturated	2.9	2.2	1.9	1.6
Silty sand, low saturation	2.3	1.7	1.6	1.4
Silty sand, medium saturation	2.4	1.8	1.7	1.5
Silty sand, water-saturated	2.5	1.9	1.8	1.5

Medium-dense sand

Sand type / borehole diameter	≤150 mm	151–250	251–320	321–450
Gravelly, coarse and medium sand	2.8	2.1	1.8	1.6
Fine sand, low or medium saturation	2.5	1.8	1.6	1.3
Fine sand, water-saturated	2.6	1.9	1.7	1.4
Silty sand, low saturation	2.0	1.6	1.4	1.3
Silty sand, medium saturation	2.1	1.7	1.5	1.3
Silty sand, water-saturated	2.2	1.8	1.6	1.4

Dense sand

Sand type / borehole diameter	≤150 mm	151–250	251–320	321–450
Gravelly, coarse and medium sand	2.5	1.8	1.6	1.4
Fine sand, low or medium saturation	2.0	1.6	1.3	1.1
Fine sand, water-saturated	2.2	1.7	1.4	1.2
Silty sand, low saturation	1.8	1.4	1.3	1.2
Silty sand, medium saturation	1.9	1.5	1.3	1.1
Silty sand, water-saturated	2.0	1.6	1.4	1.2

Saturation and cohesive soils

Sand is classified by degree of saturation Sr in accordance with GOST 25100-95, Table B.16.

Degree of saturation	Sr
Low saturation	0–0.50
Medium saturation	0.50–0.80
Water-saturated	0.80–1.00

$$S_r = w \rho_s / \left(e \rho_w \right)$$

w is the natural water content of the sand, expressed as a fraction; e is the void ratio; ρs is the density of sand particles, g/cm³; and ρw is the density of water, taken as 1 g/cm³.

Enlargement ratios in silty and clayey soils

Table 3. Ratio of enlargement diameter to borehole diameter. Soil type and liquidity index IL determine the ratio. Borehole diameter is taken as the drilling-tool diameter.

Soil and liquidity index	≤150 mm	151–250	251–320	321–450
Sandy loam: IL < 0	1.2	1.1	1.05	1.02
Sandy loam: 0 ≤ IL ≤ 1	1.5	1.3	1.2	1.1
Sandy loam: IL > 1	1.8	1.6	1.5	1.4
Loam and clay: IL < 0	1.15	1.1	1.05	1.03
Loam and clay: 0 ≤ IL ≤ 0.25	1.25	1.15	1.1	1.05
Loam and clay: 0.25 < IL ≤ 0.50	1.3	1.2	1.15	1.1
Loam and clay: 0.50 < IL ≤ 0.75	1.4	1.3	1.2	1.5
Loam and clay: 0.75 < IL ≤ 1.0	1.5	1.4	1.3	1.2
Loam and clay: IL > 1	1.6	1.5	1.4	1.3

Project application in Novosibirsk

Expert review report No 412 10

Administration of Novosibirsk Region
State Budgetary Institution of Novosibirsk Region
State Non-Departmental Expert Review of Novosibirsk Region

Design documentation: Public building with an underground car park on Vatutina Street in the Leninsky District of Novosibirsk. Foundations.
Project reference: 221-09.08.10-KZh0.
Novosibirsk.

Original foundation design

The design documentation by ARiST LLC specified an 800 mm thick monolithic reinforced concrete raft supported by 168 bored piles, each 400 mm in diameter and 9.55 m long. The piles used class B15 concrete with frost resistance F75, class AIII reinforcement of 12 mm diameter and class Vr1 wire of 4 mm diameter.

The calculated pile load was 41.8 tf. Pile spacing in plan was 1.5 × 1.5 m. Before construction of the pile foundation, the design required static testing of three full-scale piles and determination of their geotechnical bearing capacity with allowance for wetting of the ground.

The raft was supported on a 100 mm layer of class B7.5 blinding concrete. The raft itself was designed in class B15 concrete, with class AIII reinforcement of 16–28 mm diameter at spacings of 100 and 200 mm.

Revised foundation design

The 2010 design by SELAR Scientific and Production Centre LLC changed the bored pile construction, bearing capacity and spacing in plan, and substantially reduced the number of piles in the pile field.

The revised foundation comprised an 800 mm thick monolithic reinforced concrete raft supported by bored piles of 250 mm diameter and 8.95 m length, constructed using electric discharge impulse technology (RIT).

Parameter	Original design	RIT design
Pile diameter	400 mm	250 mm
Pile length	9.55 m	8.95 m
Raft thickness	800 mm	800 mm

Benefits and construction materials

Buildings founded on RIT piles have shown settlements substantially below calculated values. Construction time and cost are reduced, as are the quantities of excavated soil removed and concrete delivered. These reductions are particularly valuable where site logistics are difficult, as in Moscow.

The behaviour of RIT friction piles, particularly their stiffness, approaches that of end-bearing piles.

Advantages over conventional bored and injection piles

- The borehole diameter is increased at the required levels by compacting adjacent soil with a series of electrical discharges. Enlargement is monitored by measuring the concrete volume used to fill the expanded section.
- Loose soil that is difficult to remove from the borehole bottom is compacted. A compacted zone forms beneath the pile toe and may exceed the size of the zone beneath a driven pile.
- The engineering properties of the soil that govern foundation capacity are improved.
- The bearing capacity of the soil mass is increased and used more fully.
- The load-bearing capacity of the pile material is used as fully as possible.

Materials and organisation of work

RIT piles use conventional materials: concrete, cement, sand, crushed stone, reinforcing steel and admixtures.

- Earthworks and dewatering during below-ground construction can be minimised.
- Lightweight, compact drilling rigs can be used.
- High pile and anchor capacities can be achieved with small volumes of drilled spoil and short pile shafts or anchor bond lengths.

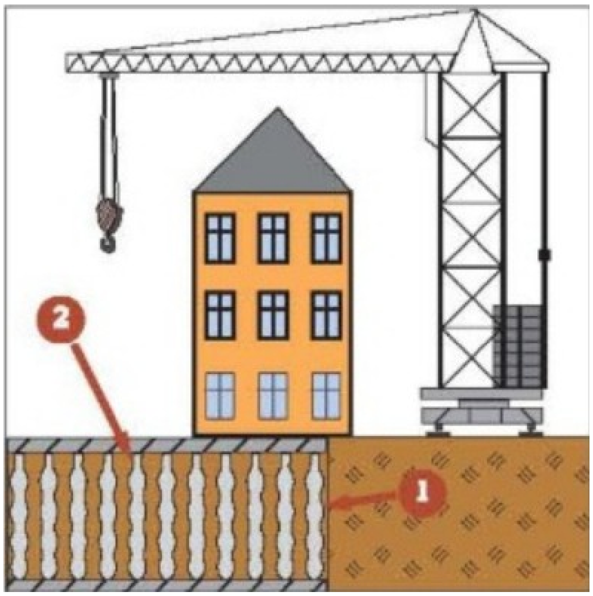
Magnetic impulse treatment of the hardening mix, one component of the electrical discharge process, significantly increases the strength and uniformity of fine-grained concrete and improves pile quality and reliability.

Fields of application

Electric discharge impulse technology is used in geotechnical construction for bored piles, permanent and temporary ground anchors, soil nailing of slopes, grouting of walls and foundations, soil grouting and deep compaction of sandy soils.

Construction and reconstruction

- Changes to the architectural and structural layout of existing buildings: additional storeys, increased spans and loads, increased basement height and other alterations.
- Underground car parks beneath existing buildings and construction in restricted spaces.
- Retaining walls, pits, support and strengthening of underpasses and service tunnels, quay structures and other civil engineering works.



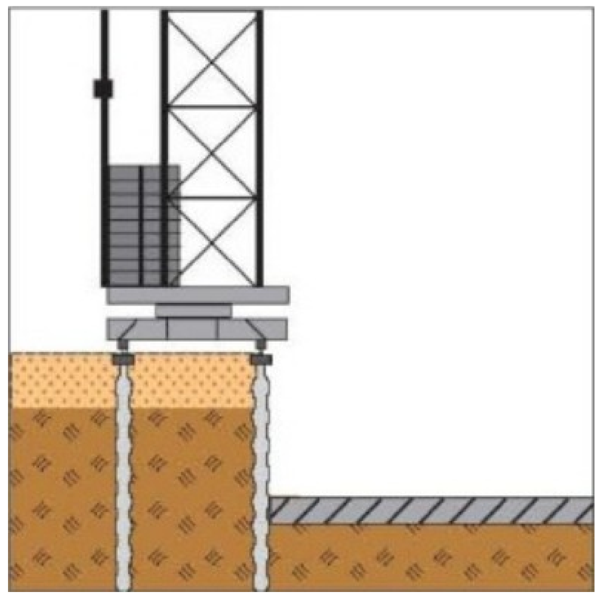
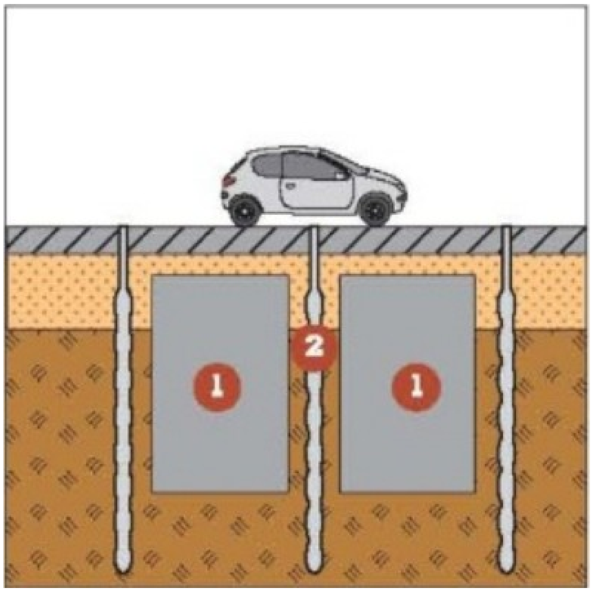


Figure 9. Retaining wall of RIT piles. 1: RIT pile; 2: capping beam.
Figure 10. Retaining wall supporting a crane at the edge of an excavation.

Piles and anchors can be combined to carry vertical loads, support excavation walls and stabilise ground. The following diagrams show applications in transport, structures and ground improvement.

Roads railways and airfields



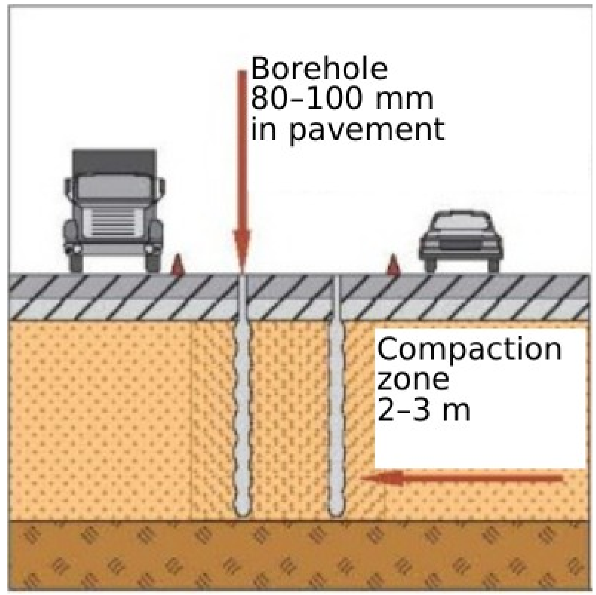
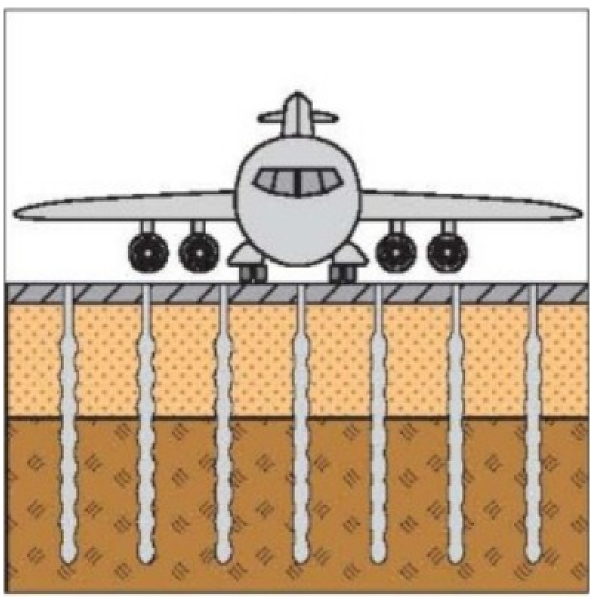


Figure 11. Roadway supported on RIT piles acting as columns and retaining walls. 1: underpass; 2: RIT pile.
Figure 12. Compaction of road subgrades through 80–100 mm pavement boreholes. Compaction zone: 2–3 m. Seasonal traffic restrictions are unnecessary.



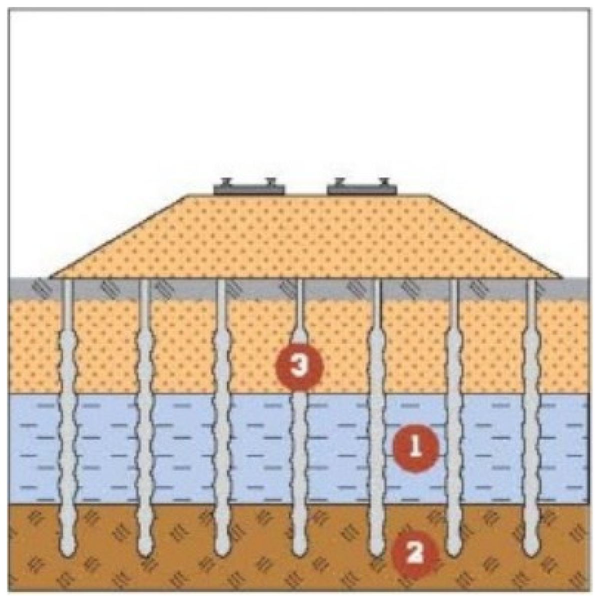
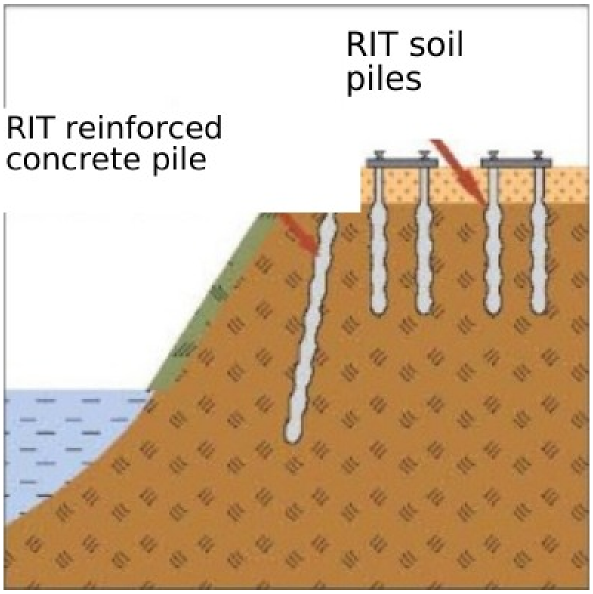


Figure 13. Compaction beneath runways and taxiways to accommodate heavier aircraft.
Figure 14. High-speed railway construction. 1: quicksand, peat and similar weak soils; 2: aquitard; 3: RIT soil pile.

Transport structures and slopes



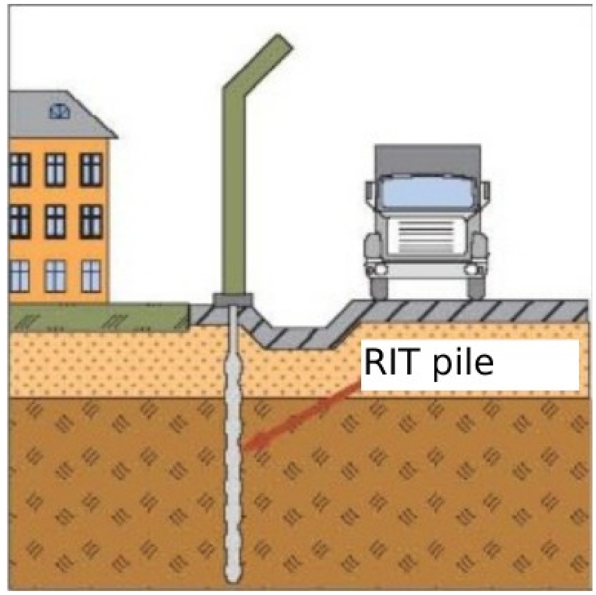
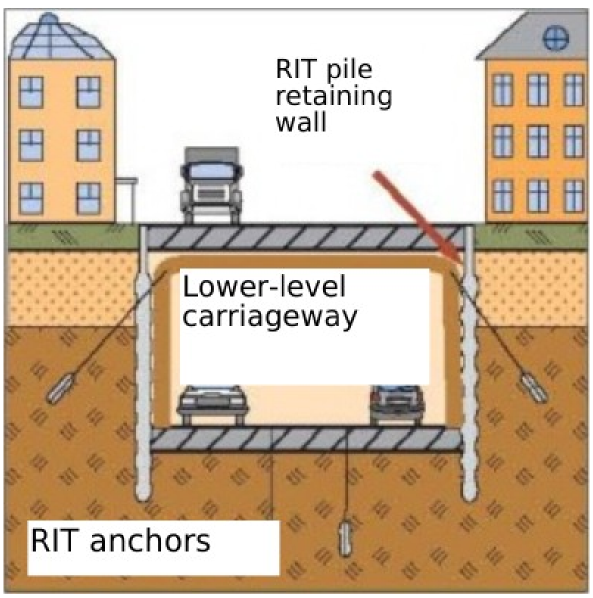


Figure 15. Railway embankment strengthening with RIT reinforced concrete piles and RIT soil piles.
Figure 16. Foundations for noise barriers.



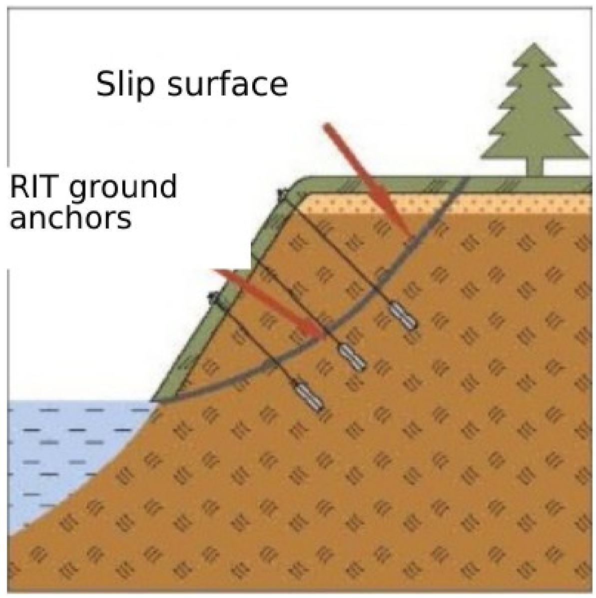
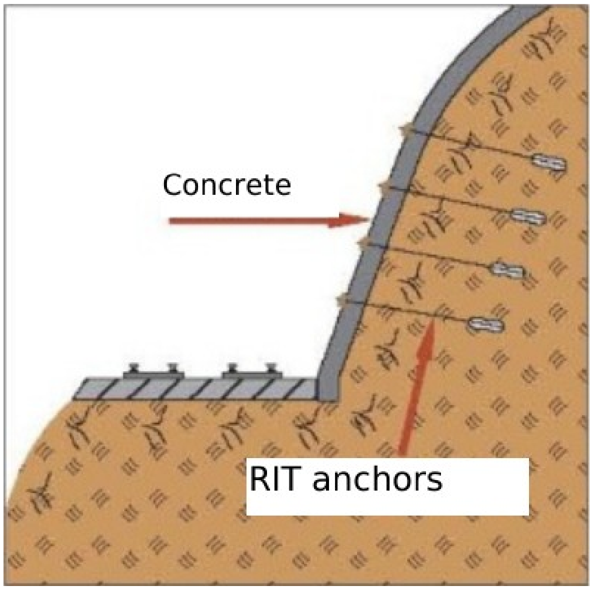


Figure 17. Two-level road interchanges. A RIT pile retaining wall supports the lower-level carriageway; RIT anchors restrain the wall.
Figure 18. Shoreline slope stabilisation with RIT ground anchors crossing the slip surface.

Anchored and mast structures



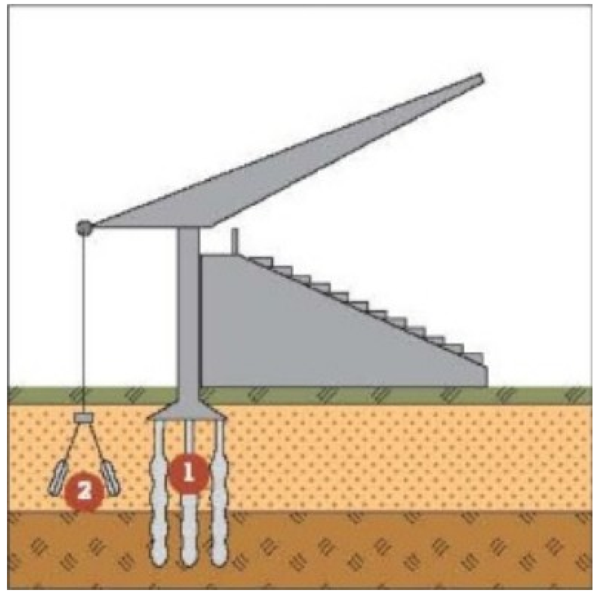
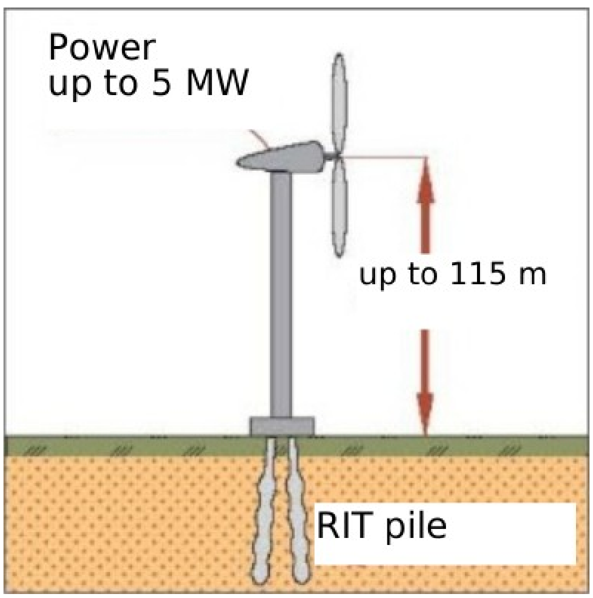


Figure 19. Stabilisation of fractured rock slopes with concrete facing and RIT anchors.
Figure 20. Roofs of sports facilities. 1: RIT piles; 2: RIT anchors.



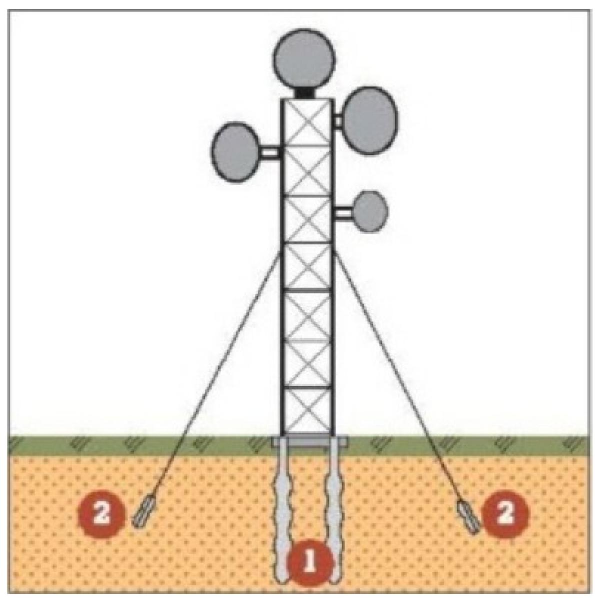
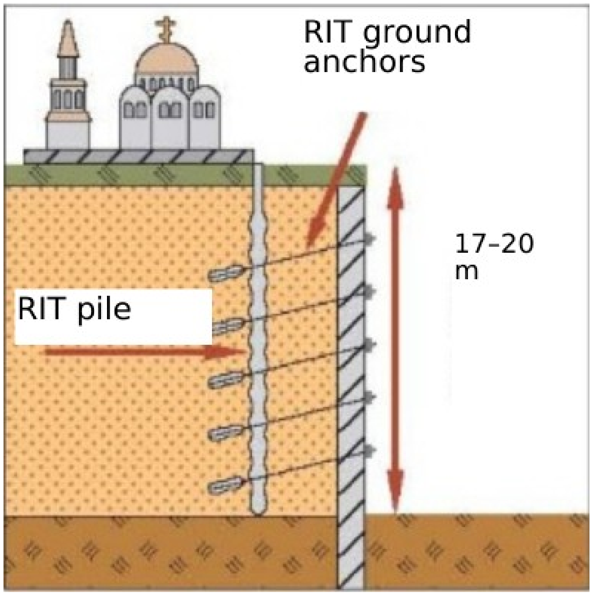


Figure 21. Foundations under alternating loads. Wind turbine power: up to 5 MW; height: up to 115 m.
Figure 22. Antenna and mast structures. 1: RIT pile supporting the antenna; 2: RIT ground anchor.

Deep excavations and buildings



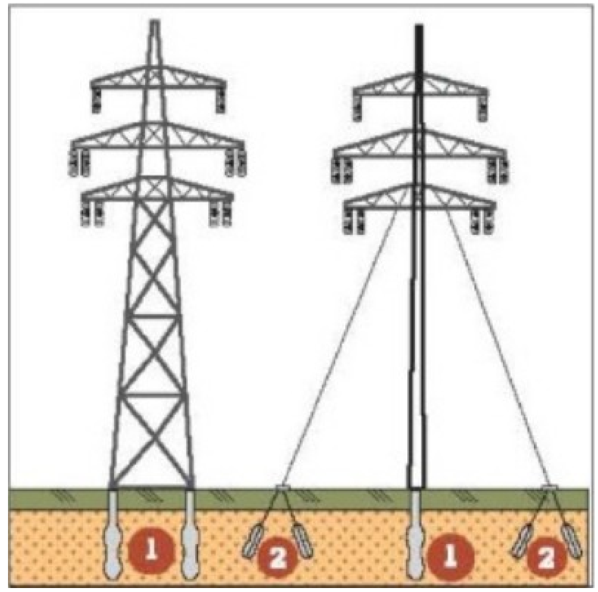
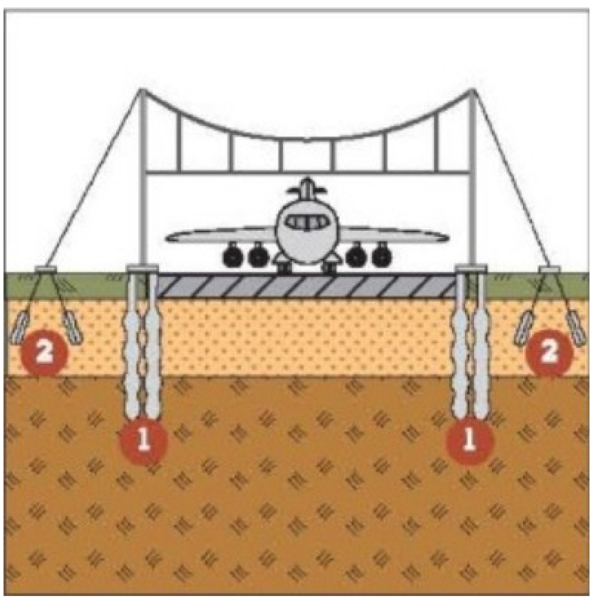


Figure 23. Excavation wall support using RIT piles and ground anchors at depths of 17–20 m.
Figure 24. Mast and power-line structures. 1: RIT piles; 2: RIT ground anchors.



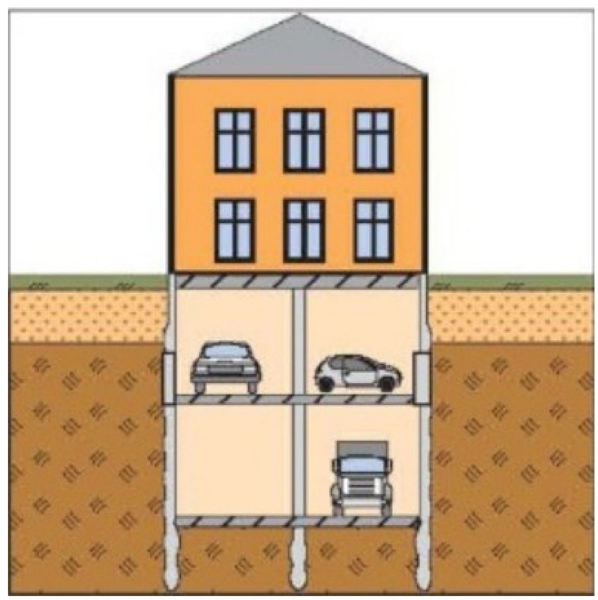
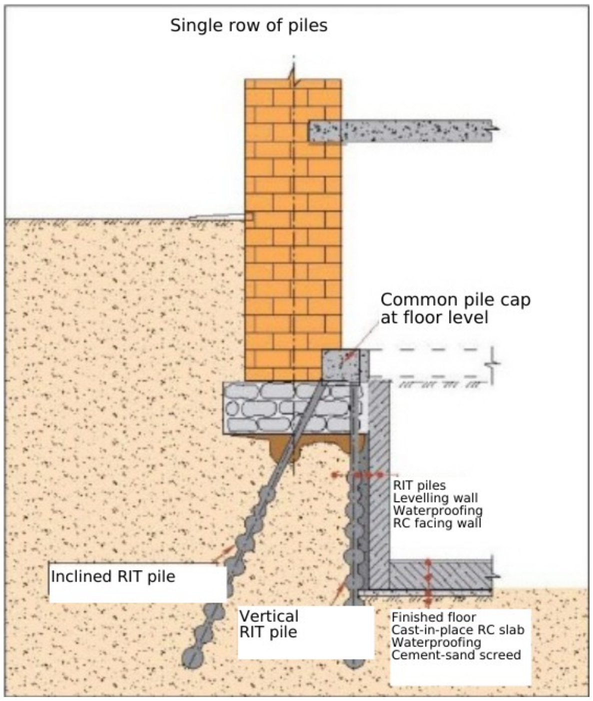


Figure 25. Hangar structures. 1: RIT piles; 2: RIT ground anchors.
Figure 26. Underground car parks beneath buildings that remain in use.

Foundation strengthening



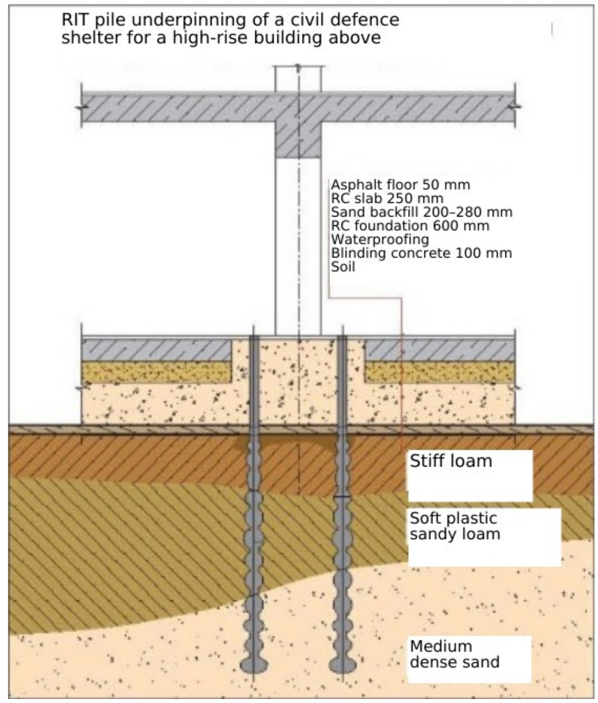


Figure 27. Basement deepening by 3 m using RIT injection piles, with a common pile cap at floor level.
Figure 28. Underpinning a civil defence shelter for construction of a high-rise building above it.

Small-diameter boreholes are drilled through the slab or its ribs, minimising the need to cut reinforcement. The bearing capacity of these RIT piles is at least 70 tf.

Vertical and inclined piles transfer load from the existing foundation to deeper soil layers. At the same time, discharge treatment compacts the soil in the foundation contact zone.

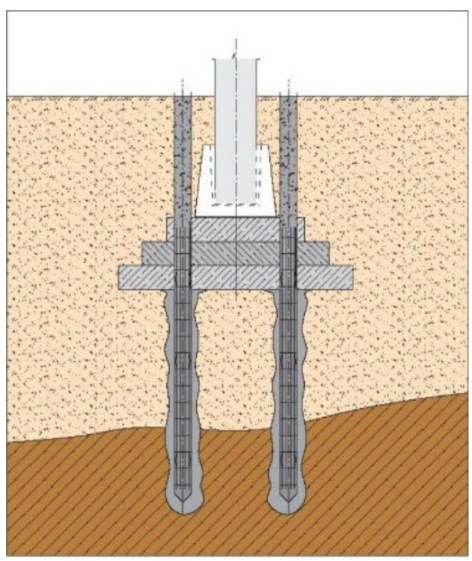
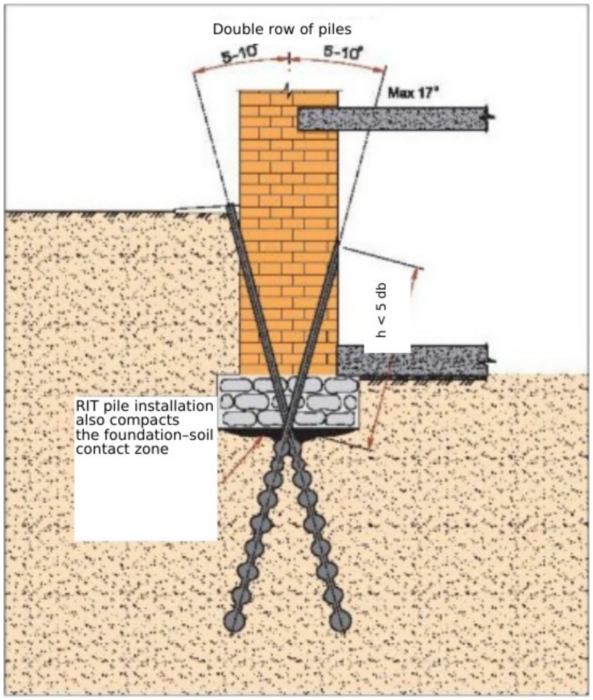


Figure 29. Strengthening an isolated column foundation.

Pile arrangements for underpinning



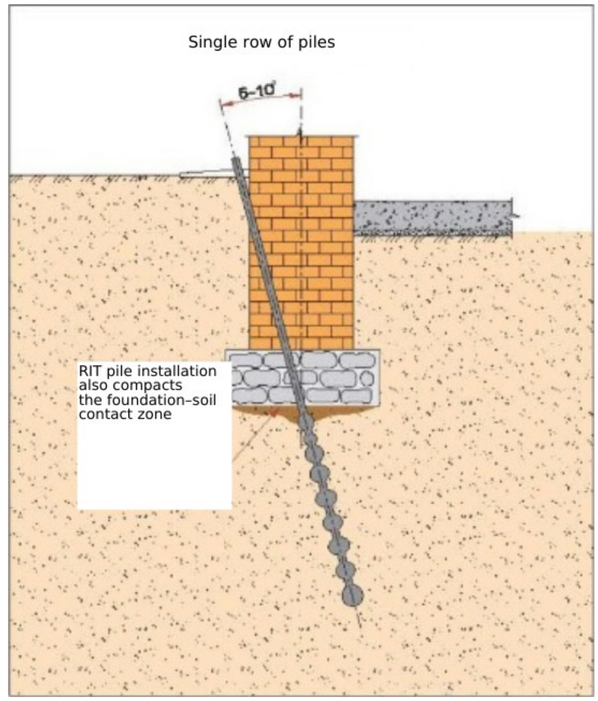
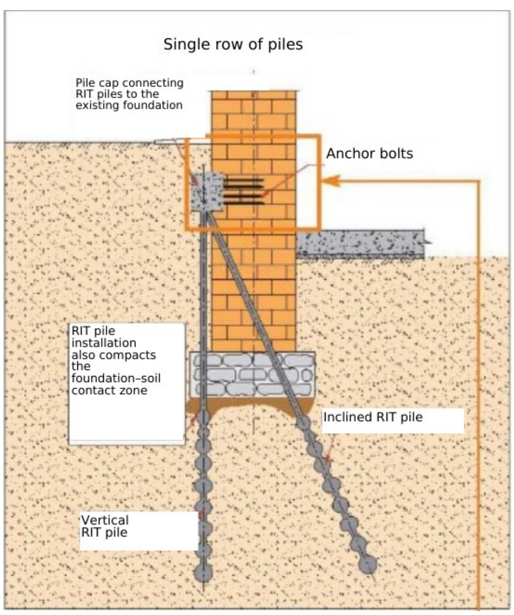


Figure 30. A common arrangement uses paired inclined piles on both sides of the foundation.
Figure 31. A single row is used for smaller loads when access from the basement is unavailable.

RIT pile installation also compacts the foundation–soil contact zone. The diagrams show pile inclinations of 5–10° and 6–10°, with a maximum of 17° in the paired arrangement.



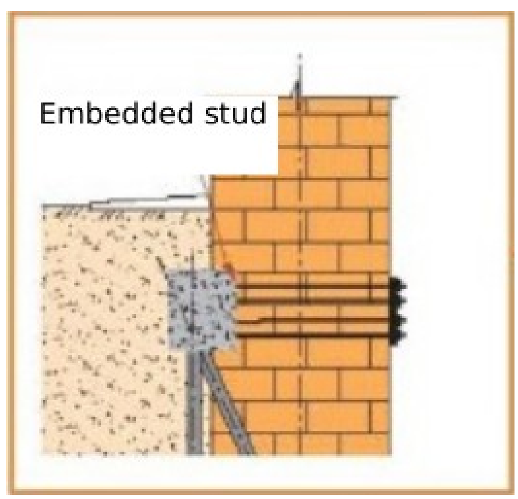
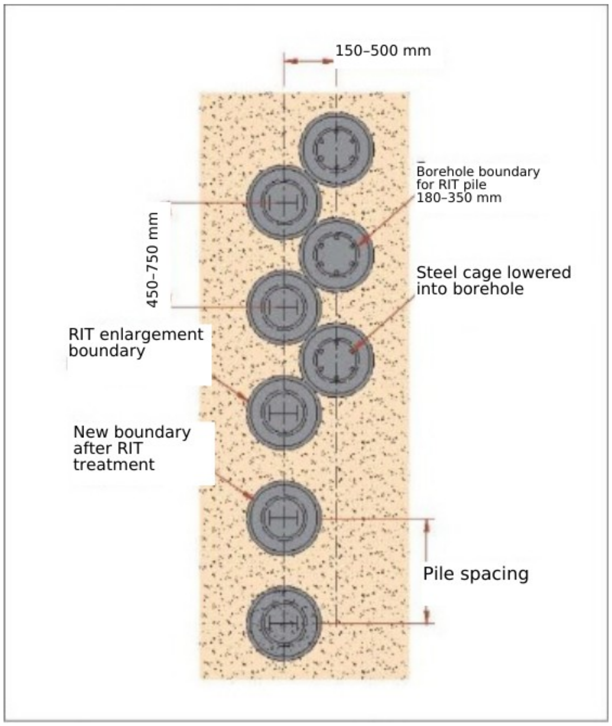


Figure 32. With access from one side and high vertical loads, vertical and inclined piles are connected by a pile cap tied to the building wall.
Figure 33. Pile cap connection to the wall using an embedded stud.

Excavation support and anchors



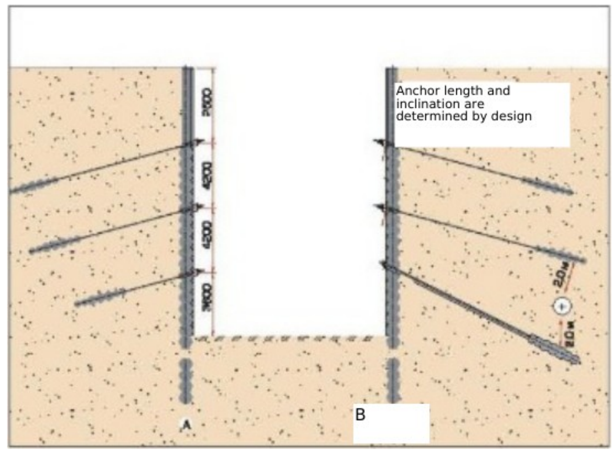


Figure 34. Excavation enclosure using contiguous bored piles or piles spaced up to 1 m apart.
Figure 35. Ground anchor arrangement. The right-hand detail shows anchorage near a service tunnel.

In the pile-wall plan, the labels identify the borehole boundary, the steel reinforcement cage, the RIT enlargement boundary and the new boundary after treatment. The borehole diameter is 180–350 mm; the illustrated arrangement includes dimensions of 150–500 mm and 450–750 mm.

Ground anchors restrain excavation walls. Anchor length and inclination are determined by the design.