# “ROOT PILES” IN THE USA. FONDEDILE S.P.A. AND FONDEDILE CORP. A CHRONICLE

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ABSTRACT

After the end of the Second World War the reconstruction of the port of Naples creates great opportunities of work for local contractors. One of them, Fondedile S.p.a., enjoys great success under the creative engineering leadership of its chief engineer, Ing. F. Lizzi. He invents and develops the “Root Pile” a type of micropile that can be easily drilled through the obstructions of the harbor and is based on his concept of exploiting the load bearing capacity of the “force” of soil’s “skin friction”. “Root Piles” are applied to underpin structures throughout Europe. Ing. Lizzi’s extends the use of the “force of friction” to the restoration of monumental structures with the “Reticolo Cementato”. In 1952 “Root Piles” are patented. The application of the “force” of soil’s “skin friction” culminates with Ing. Lizzi’s invention of the “Reticulated Root Piles” structures based on a network of “Root Piles” symbiotically working with the soil encompassed by them. By 1958, “Reticulated Root Piles” structures are extensively used as support of excavation, to stop landslides and soil movements and for tunneling underneath buildings. In 1970 Fondedile’s worldwide growth sees the establishment of Fondedile Corp. in the U.S. Market resistance slows Fondedile Corp.’s progress and suggests finding a US partner. In 1974 Warren-Fondedile is formed. In 1976 continuing market resistance results in Warren-Fondedile ceasing operations. Fondedile Corp. continues operations alone and completes the construction of the first “Reticulated Root Piles” structure in the USA. Two more similar projects are completed in 1978 and 1979. The expiration of Fondedile’s “Root Piles” patents, spurs competition by other contractors. In the period 1980-1990 Fondedile Corp. is unable to gain contracts generating sufficient resources for its survival. In 1990 it is shut down. Shortly thereafter Fondedile S.p.A is sold and will quickly disappear from the contracting world.

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# A CHRONICLE

Fioravante A. Bares

## 1944-1952 -The beginning

The Second World War in Southern Italy is over. The town of Naples, and its sea port, one of the major such infrastructures in Italy, lay in ruins upon the heavy aerial and sea bombardments and the destruction performed by the retreating German army.

Italy needs all kinds of supplies and materials to feed its reconstruction effort and the occupying armies need a steady flow of wares to keep them operating. An extensive reconstruction of the harbor and of its infrastructures becomes a high priority project.

Demobilized soldiers, return home and Ing. Ferdinando Lizzi is one of them. Upon fast graduating at the Naples' engineering university he is hired by SACIF (Societa` Anonima Costruzioni Industriali e Fondazioni), a Naples company specializing in general construction and foundation work. SACIF, established before the beginning of the war, is already performing harbor rehabilitation work since 1944.

By 1947, upon the finalization of plans considering future harbor expansion and thanks to financing provided by the Marshall Plan, harbor reconstruction picks-up pace. To compete for larger contracts, SACIF is re-organized as Fondedile S.p.A. Managing the new company is an enterprising man of Rumanian origin (Mr. G. Chitis, the founder of SACIF), who will soon be joined by an equally enterprising man of Lithuanian origin (Ing. S. Newburg, who contributes some needed expansion capital), while Ing. Lizzi is still the one and only civil engineer working for the company.

A major cleaning of the port area has been completed. It required removing tons of twisted metal, unexploded ordnance, the remainders of blasted massive stone wharves and sunken vessels of any shape and dimension resting on the bottom within scattered cargoes remains. Wharves reconstruction includes the increasing of berthing drafts to accommodate larger vessels. Time is of the essence. It becomes expedient to use the old wharves or what is left of them to shorten construction schedules. Berth deepening beside existing stone structures and/or rehabilitating them to bear heavier loads, requires deeper foundations. Driving piles through massive rock blocks and other obstructions is difficult to impossible. Additionally, at this time, the Italian economy offers a lot of cheap labor, but finished products, like steel piles, are unavailable. It is a challenge that Ing. Lizzi suggests resolving by using drilled, cast-in-place, small diameter piles that can more easily penetrate the obstructions and carry load by the "power" of soil's "skin friction".

The “power” of soil’s “skin friction” to carry loads is not a new geotechnical concept. The formula proposed by Dörr to design the load bearing capacity of drilled shafts is available (Reference 1). However, it is not comfortably used because of the subjective assumptions that must be introduced about the effective friction generated by surrounding variable soil. Additionally, it allows the use of coefficients of safety that are too dependent from the experience of the designer.

Young Ing. Lizzi (he is not yet thirty years old), under the incentive of providing clients with piles of unquestionable quality and load bearing capacity, starts working along two directions: improving field construction quality and upgrading geotechnical engineering and design. He specifies the use of continuous drilling casing to support the cavity advanced through the soil, high slump grout to prevent necking, single steel bar reinforcing (or a cage according to pile diameters) installed prior to grout casting and (new at the time) pressurization of the grout by blasts of compressed air from the top of the casing. The pressurization has different aims: forcing grout into the ground to create a gradual transition zone at the pile-soil contact, building an intimate bond between grout and ground and vibrating the grout. Last but not least, he is convinced that the addition of sand to the grout mix, introduces a solid element onto which pressure can effectively act to increase the final shaft’s unevenness and roughness. These procedures and improved quality control of operations in the field, help eliminating the construction problems that, in those days, contribute to the low reputation of drilled cast-in-place piles. On the geotechnical engineering and design side, he systematically analyzes and scientifically uses the results of the many load-bearing tests Fondedile S.p.a. must perform to assuage clients’ uneasiness about using drilled cast-in-place piles and takes advantage of the progress fostered by the work of other engineers (Cliquot and Kerisel and others, Reference 2 and 3). The use of geotechnical data verified by field tests allows Ing. Lizzi to more confidently quantify the “power” of soil’s “skin friction” and convince clients of the reliability of the “Root Piles”. Eventually, the key to developing a pile of superior load bearing capacity is the staged pressurization, a procedure that does not appear to have been used before and the reassuringly and systematic use of the results of many load-tests’. The Fondedile “Palo Radice” (“Root Pile”) is born.

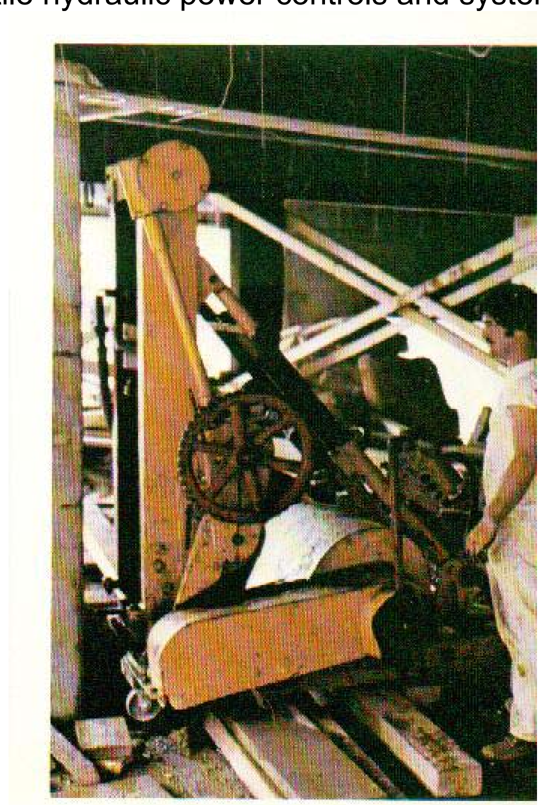
**1952: Patenting of the “Palo Radice” (“Root Pile”).**

The name “Palo Radice” (“Root-Pattern Pile” on the patent) will eventually become a world-wide renowned Trademark. The name derives from the remarkable capacity shown by these slender piles to carry both compression and tension loads by mobilizing the strength of the soil surrounding or encompassed by them and to resist displacement from the soil, like the roots of a tree. Their construction and engineering features make them unique and distinct from other small diameter piles and worth the recognition and award of a patent that gains them entrance into the universe of human discoveries and scientific progress.

In 1952 Fondedile is granted a patent protecting the features and construction specifications of the “Palo Radice” (“Root Pile”). This launches a contest by and between competing contractors to devise and market similar piles, matching or even claiming superiority to the “Palo Radice” (“Root Pile”).

The “Palo Radice” (“Root Pile”), primarily born as a novel underpinning tool would not have encountered the success that it did if it had not been accompanied by Fondedile designing and manufacturing of a simple, but sturdy, small dimensioned drilling rig to construct it.

The rig, manufactured in two base models (the M1 and the M2, a basically identical but larger and more powerful copy of the M1), would appear primitive when evaluated with present-days machinery progress in mind. However, twenty first century rigs performing similar type of work show almost identical dimensions. The main and evident difference is the replacement of mechanical drives with more versatile hydraulic power controls and systems.



Fondedile M1 drilling machine (photo courtesy of Foundation Drilling, Inc.)

As late as 1999 M1 and M2 rigs imported in the USA in the 1970s were still in use. Some, upgraded by the installation of limited hydraulic power systems.

Both the M1 and the M2 will be the standard Fondedile’s rigs for the next 25 years. The original mechanical power transmissions will be left unmodified (“we do not want to lose the powerful ramming jolt that rapid clutch engagement can impart to a jammed casing" was the explanation for it) and only minor rig's components would be updated. M1 rigs would generally be used for the construction of 75 and 100 mm (3 and 4 inch) diameter piles and the M2 for 150 and 200 mm (6 and 8 inch) diameter piles and would prove ideal to work at projects requiring operating in low headroom and space-limited conditions inaccessible to machinery of larger dimensions.

**1952-1957: Growth and expansion.**

By 1952 Fondedile has completed a considerable number of projects for the reconstruction of the port of Naples (where it will have an almost uninterrupted presence until the late 1970s) and has expanded its activity to the underpinning and strengthening of structures in other areas of Italy.

Fondedile's underpinning system, by doing away with any undermining excavation, is a revolutionary approach when compared to typical underpinning procedures in use. Its base concept is to perform underpinning with the goal of, first of all, avoiding additional structural strains and settlements that would result in damages to the underpinned structure. Only a very limited area of soil support (a pile diameter-width at the time) is removed from underneath the structure. The underpinning is "built" into the structure and immediately becomes a monolithical part of it, beginning to work with it, not undermining it.

Underpinning by "Root Piles" becomes the often most suitable, safer and more economic procedure of salvage/restoration of structures that if subjected to conventional underpinning would not survive unscathed. Upon many successful and often extensive applications, "Root Piles" features are publicized by Ing. Lizzi in one of the first Fondedile's technical-promotional publications (Reference 4). The same publication lists a series of projects completed between 1952 and 1958 amounting to $1,840,000 that, for the times, is a significant volume. Considering that Fondedile would have completed other construction projects, it would appear that in that period the company was expanding by doubling its volume of work every other year, till, most probably reaching a yearly volume of over $1.0 million in 1952, a respectable amount of work for an Italian specialized contractor in the 1950s.

The market and the applications of the "Root Piles" gradually expand to multiple and diverse uses other than the original underpinning, with "Root Piles" used for: strengthening and increasing the load bearing capacity of existing industrial building foundations; modernizing industrial structures without interfering with ongoing operations (by constructing new footings where conventional drilling rigs do not fit); increasing the load bearing capacity of existing building foundations and adding stories to them; strengthening and deepening of bridge foundations and retaining walls, restoring war damaged structures that otherwise would have required more expensive and disrupting reconstruction and rehabilitating/reconstructing and expanding more wharves and port terminals.

The use of “sacrificial” “Root Piles” is first implemented for the stabilization and leveling of a tilting and settling multistory building founded on a reinforced concrete slab (References 4 and 6). It will reappear upon Fondedile developing the “Reticulated Root Piles” system, when the integrity and load carrying capacity of an initial set of piles would purposely be “sacrificed” to initially counteract the overwhelming and continuing stress generated by moving soil. The “sacrificial” piles, upon contributing to the slowing and containing of the soil and to the lessening of the stress on newly constructed piles, would eventually be replaced.

In 1956, the “power of friction” leads Ing. Lizzi to conceive and use the “Reticolo Cementato” for the restoration and stabilization of older and monumental structures. In fact, in many instances, what is keeping old, time weathered and/or damaged structures together?: friction amongst component parts. Hence, if an additional friction element is properly inserted and securely fixed within a structure’s body, stability may be reconstituted and assured in time. Italy abounds with such structures and a considerable number of them have gravely suffered the consequences of the Second World War and of many seismic events.

A description of the “Reticolo Cementato” and of its many applications is found in the Fondedile brochure entitled “Fondedile Group” (Reference 5). Here it is sufficient to remember that it is fundamentally based on Ing.Lizzi’s leading principle:

*“when intervening on a damaged structure, first of all, do not disturb its current stability and gradually work to improve it”. “The problem is that most often the conditions of stability of a structure that, in time, has been affected by many and diverse disturbing agents, are extremely difficult to quantify and generally escape the application of conventional remedial and stability measures”. “Any restoration work must be performed assuring the persistence of the current stability without generating vibrations, cuts or removal of portions of structure and introducing new stress. Restorative work must be based on removals of minor portions of structure and limit it, for example, to small diameter holes filled by steel rods grouted using low pressure and drilled along well studied directions with the final goal of realizing a sort of reinforced conglomerate within the body of the structure. This is easier said than done, because the work must be completed without minimally altering the exterior appearance of the structure and requires that the engineer or the architect possesses a sensitivity matured beyond any formal technical education, upon the suggestions of a keen investigative mind, a somewhat artistic imagination and lot of repeated experience”.*

(By 1973 Fondedile will have dealt with over 2,000 such structures). (Reference 5)

**1958: The Reticulated Structures**

Until 1958 Fondedile's growth does mainly involve projects around Naples and in Southern Italy, with some ventures into Northern Italy. By then, Ing. Lizzi's goal of exploiting the "power" of soil's "skin friction" has fully matured and expanded to the visionary concept of the "Reticulated Root Piles" structures. These structures are first idealized and then designed by him as the reactive combination of soil and of a network of Root Piles "working intimately" and encompassing it to form almost a cellular system. By Ing. Lizzi's own admission, this is not the first time that man considers utilizing a form of "reinforced earth" for the construction of structures (Reference 11). His fundamental achievement is progressing from empiric and random earth reinforcing to a scientific rationalization of the effects of introducing a pre-designed (patterned) reinforcing structure into a mass of soil and devising a way of quantifying its effects by a design methodology allowing controllable replications or alterations to suite differing geotechnical and stability conditions. "*As it is done for reinforced concrete*", he says (Reference 11).

By now, his theoretical approach has been proven successful in a few projects and is ready for a major test at one of the construction sites of the first line of the Milan subway. The subway is under construction, using slurry walls as main support of excavation. It must cross the historic center of the town and fit within narrow streets flanked by antique and fragile structures. One of these, the "Broletto Nuovo" ("the New Town Hall"), built in 1233 with large arches and a floor added in 1771, shows the wear of time and of the intense vibrations caused by Second World War bombing. Its conditions raise the fear that soil relaxation caused by the slurry wall excavations (scraping against its shallow foundations) may cause additional instability and damages. The 5 km of slurry walls constructed up to this site has caused neither stability nor structural problems. However, these are the very first 5 km of slurry wall constructed in the world. The technique is still in its infancy and the mode by which it secures the stability of the excavations is neither fully understood nor trusted, notwithstanding the completion of a full scale lateral load test during which no soil relaxation was measured[(2)]. Eventually, the importance and the fragility of the "Broletto Nuovo" suggest performing a delicate operation of consolidation and underpinning of its foundations prior to any subway excavation. This consists in the old brick and stone foundations being "stitched together" by the grout-embedded ("cemented") reinforcing steel rods constituting the upper portions of the 100 mm (4 inch) Root Piles of the "Reticulated" structure that extend the old foundations to a depth beyond the bottom of the forthcoming subway, while acting as a massive gravity wall preventing soil relaxation behind it (Reference 6).

**1960: Expansion to foreign markets**

By 1960 Ing. Lizzi is no longer the "one and only" Company engineer (many more have been hired) and Fondedile's substantial success in Italy makes an equally successful expansion to other European markets a natural transition. Subsidiaries are opened in quick succession in France, Benelux, Greece, England, Israel and, later, Spain (For reasons having to do with construction codes (DIN 1054) that do not allow the design of piles' load bearing capacity based on available geotechnical formulae, Fondedile will never enter the German market) (Reference 2).

(2) The success of the lateral load test along an open, slurry supported excavation was fundamental to convince the Milan subway engineers to adopt slurry walls as support of excavation. The use of slurry walls in similar conditions and for more important depths will later prove that, once slurry wall construction operations are carried out with due care and skill no soil relaxation occurs.

Fondedile's contracting now covers the full spectrum of geotechnical specialties including: soil exploration, drilled shafts, waterproofing, grouting, guniting, watertight cutoff walls (slurry walls), waterfront works, piers and tunneling.

**1962: Tackling soil failures and landslides**

A large and very lucrative portion of Fondedile's activity concentrates on the more challenging, more sophisticated and larger applications of Ing. Lizzi's use of the "power" of soil's "skin friction", namely "Reticulated Root Piles" structures for soil stabilization, land slides corrections, tunneling and structural restorations.

It is interesting to note that without the exploitation of the "power" of soil's "skin friction" with the "Reticulated Root Piles" structures, Fondedile's use of small diameter piles would probably have been confined to underpinning and increasing the load bearing capacity of existing foundations.

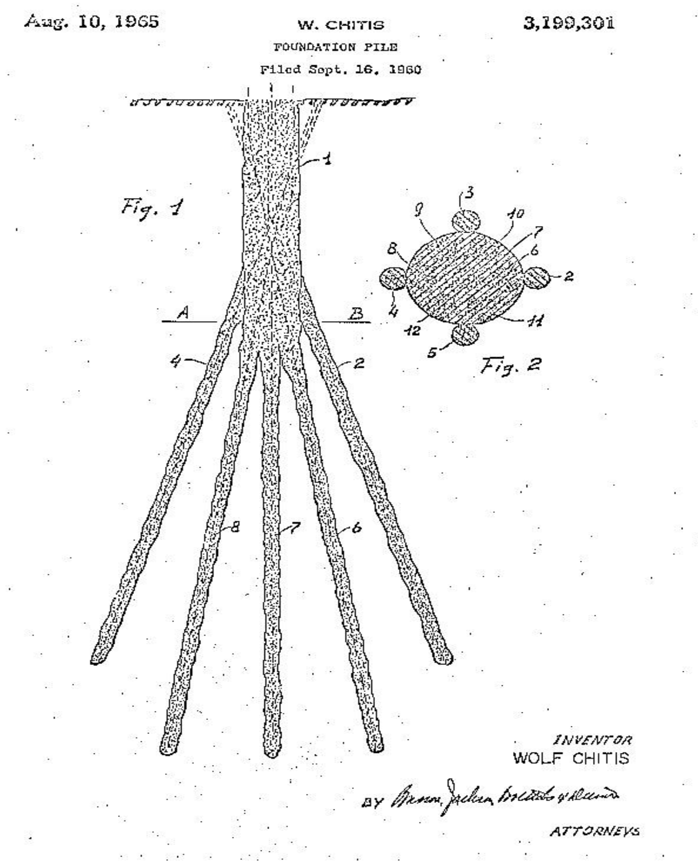
Now, the fact that a number of engineers in different countries design "Root Piles" and "Reticulated Root Piles" structures has deprived Ing. Lizzi of the immediate control and knowledge that he used to exert on all design performed at Naples' headquarters. Hence, he mandates a Company-wide policy by which Fondedile's engineers limit the allowable load bearing capacity of each "Root Pile" to 50% of its <u>*safe*</u> design capacity (a capacity already made *safe* by a congruous coefficient of safety). Namely, for instance, a 100 mm diameter pile may not be sold with a load bearing capacity higher than 10 t. Most of the results of load tests carried out on "Root Piles" and published, reflect such limitation. Clearly, this policy is not simply dictated by prudence and by trying to limit the risks involved with subjective interpretations of soil conditions and parameters: it is intended to maximize sales and profits while competition is still harnessed by patents. Overall a wise (and profitable!) policy, when considering the increasing design and engineering challenges raised by "Reticulated Root Piles" structures destined to support high rise buildings underpassed by subway and railway tunnels across dense city centers and to remedy ever larger soil movements threatening nearby structures.

**1965: Renewing patents**

Fondedile obtains a number of additional and "improved" patents worldwide as a further attempt at hindering aggressively copying competition.

One of the patents (The "Palo Pilone" or "Pillar Pile") addresses and makes proprietary an underpinning scheme used in 1960 for the restoration of a historical church built in 1460 (the Duomo of Pienza, near Siena in Tuscany, Italy). The monumental structure, founded on fissured rock has undergone centuries of settlements and structural damages. Fondedile's restoration project, based on encompassing the old foundations within a spiraling "Reticulated Root Pile" structure", extends the original foundations to depths beyond the fractured rock and away from concrete attacking aggressive waters (Reference 6). The success of the application, suggests patenting the use of similar micropiles' patterns to replace large diameter shafts where large diameter shaft drilling is difficult and uneconomical due to the presence of obstructions or for lack of space to operate large machines. The patent covers the construction of "A foundation pile comprising an upper stalk extending downwardly into the ground to a relatively shallow depth with a group of branch members which are integral with said stalk at their upper ends and extend downwardly and outwardly there from to a greater depth so as to define an approximately conical shape".

Efforts and suggestions to replace large diameter shafts with micropiles, will constantly (and obviously) guide Fondedile's engineering and marketing philosophy throughout its many years of successful world expansion. An example of replacing large diameter shafts with micropiles will be implemented in the late 1970s for the construction of the foundations for the last viaduct completing the "Blue Ridge" highway in North Carolina. The replacement, instigated by Fondedile Corp.'s promotional work, substituted extremely difficult drilling of large diameter shafts through a boulder strewn hillside with a less expensive drilling of small diameter shafts and satisfied stringent environmental concerns that excluded the use of large machinery.




The “Palo Pilone” or “Pillar Pile”

**1967: Large tunneling projects**
Fondedile micropile projects become ever larger and bolder. The use of massive “Reticulated Root Piles” structures allows driving railways and subway tunnels through cities’ hearts instead of traditionally following street paths. The “Reticulated Root Piles” structures create the equivalent of supporting arches deflecting the loads from existing, often massive, building foundations away from or deeper than the tunneling zones. One advantage of the technique is that most of the work is performed from basements or from temporary shallow tunnels avoiding traffic closures, construction noises and interference with people’s normal life. Subways in Rome, Barcelona, Liege, Paris and Milan (just to mention a few) adopt the system. One application worth mentioning for what happened during construction is the Galleria Santa Lucia in Salerno, Italy, a railway tunnel driven straight under the center of the city to eliminate a circuitous hilly path constantly under the threat of rock slides. A portion of the tunnel (in granular soil) crossing under a city street between two high rise buildings (previously underpinned by “Reticulated Root Piles” structures) collapses causing the formation of a large “glory hole” that consumes the street (not supported by a “Reticulated Root Piles” structure) and the plunging in it of a number of vehicles.

While intense and worrying moments are lived at Fondedile's headquarters, none of the buildings (note: fully inhabited) is affected by the sudden soil relaxation occurring beside each of the "Reticulated Root Piles" structures standing on opposite sides of the street. This test, while unexpected, unpublicized (for obvious reasons) and above all, unwelcome, confirms the correctness and safety of the engineering design concepts and the effective load bearing capacity of the "Reticulated Root Piles" structures (Reference 7).

**1969: Patenting the "Reticulated Root Piles" and expiration of the "Root Piles'" patent.**

Patenting of the "Reticulated Root Piles" structures is granted as "A soil retaining structure including a plurality of spaced apart slender pile elements arranged in a three-dimensional network for use in preventing lateral sliding of a ground formation".

Now, if a "Reticulated Root Pile" structure" is so effective in carrying foundation loads imposed on it and in diverting it away from stress-sensitive areas, what about using it to radially counter and contain lateral stress threatening to squash tunnels constructed through expansive soils? Hence, "Reticulated Root Piles" structures" begin to be used to construct cylindrical shield zones of reinforced soil around tunnels. A solution that effectively attenuate stresses during construction as well as reduce them on finished tunnel shells (Reference 8).

1969 is also the last of the 17 years of validity of the "Root Piles" patent. Now anybody may construct micropiles with similar characteristics as the "Root Piles" but may not use the "Root Piles" name: it has been registered as a "Trade Mark".

**1970: the M2 micropile. Fondedile Corp. is established in New York**

Trying to further protect its proprietary construction techniques, Fondedile patents and begins promoting the M2 micropile featuring the formation of an "upper shaft expansion", a "bottom bulb" (pile pre-stressing), resin-coated reinforcing steel (single bars and pipes) and, upon request, pre-tensioning to increase overall load bearing capacity (Reference 9). Meanwhile, the conventional "Root Piles" remain the bread-and-butter item of the Company.

In August 1970, Fondedile Corp. is established in New York as the US subsidiary of Fondedile S.p.A. Performing construction in the US has long been a dream of Ing. Newburg who sees a great potential for further expansion of Fondedile's operations into such a vast market. He expects that the dynamics of the US economy will quickly pick-up and appropriate the innovative, safer and more economic construction procedures promoted by Fondedile. Time will show how remote from reality are his expectations when confronting an extremely conservative, risk eschewing US construction market.

Initial reactions from US engineers when approached and suggested to consider using 3, perhaps 4 inch-diameter “Root Piles” to solve underpinning problems, are hilarious. They are startled by the idea and explode in friendly laughing while asking: “Do you actually suggest that we use such flimsy piles to safely and effectively carry tons of “***real***” foundation loads?” A 3 inch diameter drilled shaft, working by the “force” of soil’s “skin friction” only, is an unheard and unreal concept for them. They cannot envisage any pile with a diameter of less than 8 inch. “And it must be made of steel!” Last but not least, they are tied on to the concept of traditional underpinning done by transferring foundation loads onto separate elements through a process of separation, insertion and “packing”. They cannot figure out how a pile drilled through a structure to be underpinned may become an immediate and monolithical part of it. There is no code, book, school or authority in the country that ever mentioned such piles, let alone allowing their construction! “No way!” thunders the top engineer of one of New York consulting firms, “Piles of these dimensions and your system of underpinning will never work in this Country”!

Efforts and negotiations to include micropiles in different States’ and local construction codes become an arduous and time consuming task, requiring contacts at high levels and being beaten by the constant refrain of: “Once you complete the construction of a “Root Pile” in the US, come back and we will consider including it in our construction code”.

**1971: The Fondedile Group**

Fondedile S.p.a. becomes the “Fondedile Group”, with operations and offices all over Europe (except Germany as mentioned), Israel, South America and the US. The years between 1970 and 1976 are the years of maximum expansion and profit of the Company. By 1976, the total yearly volume of work performed by the Group hits the $250 million mark.

For the Group’s US operations, it is a year of promotion and preparation including qualifying and obtaining Contractor’s Licenses in many States. It eventually sees a somewhat reluctant Ing. Lizzi, touring the US and Canada to help promoting Fondedile’s budding operations. The summary of his lectures and presentations about “Root Piles” and about projects completed using them are collected in a widely distributed Fondedile promotional brochure (Reference 8). Ing. Lizzi’s uneasiness is motivated by his wondering why in such an outwardly modern and vibrant economy, US engineers and contractors are so reluctant to consider (let aside adopt!) the geotechnical concepts and construction procedures that he is enthusiastically promoting, upon wide and successful implementation in Europe. And, like the rest of the Fondedile people, he has difficulty comprehending how the US bidding system is geared to accept the cheapest competitive solution (even if often inadequate according to his engineering judgment) instead of a better (even if non competitive!) one. He keeps mentioning Fondedile’s success and acceptance *on merit alone* of its geotechnical construction procedures by the rest of the world to a skeptic audience that keeps asking: “Where in the US did you construct “Root Piles”?” “Do that, then we will consider them!”

Eventually, his visit, followed by additional and intense promotional work by Fondedile Corp.’s personnel has an effect. The Federal Highway Administration and a few contractors involved in the construction of the Washington, D.C. subway begin showing interest in “Root Piles” and their many applications.

**1972: First use of “Root Piles” in the US.**

The spring of 1972 (April 26$^{th}$) sees the first use of “Root Piles” to underpin residential buildings in the US, at Elgin and Rockford (IL). At Elgin, the underpinning of one and two family houses and of a recreation building is “indirect”. Namely, “belt” beams constructed around and tightly keyed to the houses’ thin foundation walls transfer loads from settling ground onto micropiles drilled through and under them. Loads are minimal and the micropiles are designed to mobilize sufficient load bearing skin friction upon traversing layers of frozen fill left under the homes. The thawing of the fill is the cause of widespread and random differential settlements.

At Rockford the underpinning of a settling portion of a nursing home is performed by the traditional “Root Pile” trestle pattern, by drilling through existing footings, without disturbing the home’s operations or the residents.

These first jobs bring to light the operational problems that will continuously plague the growth of the Company in the US. The M1 rigs sent to the US require a crew larger than more modern rigs would in a country where labor is 4 times more expensive than in Italy. They are powered by electric motors, a common feature in Italy (where fuel cost is four times higher than in the US) thus requiring generators and additional labor.

Non-English speaking rig operators (the “Specialisti”) sent from Italy cannot communicate with local labor. At Naples Headquarters, only a few engineers have knowledge, but limited, of the English language. Correspondence between Naples and the US office must be exchanged in Italian. “Root Pile” project documents are prepared in metric units with descriptions in Italian. They need translation prior to submittal to potential clients or going to a job site. Specifications or descriptions of projects worth considering or bidding in the US must be translated in Italian prior to transmission to Naples. No engineer at headquarters has notion of US codes and, most of the times, questions the application of them when compared to codes in force in Europe which they consider more advanced. The consequences are delays and missing bidding dates with last minute interventions and modifications that disrupt bidding proceedings and schedules. Meeting deadlines set by US contractors to examine Fondedile Corp.’s proposals is difficult.

Fondedile Corp. has only one engineer promoting and taking care of the business in the assigned, but large territory of US, Canada and Mexico and no permanent, English speaking, project manager or field superintendent. Only in 1975 the Company finances will allow hiring a permanent project manager. Still, most of the projects' design will need Naples' approval and eventual changing from metric to English units and from Italian to English language.

And It will also be 1975 when Fondedile Corp. is eventually equipped with modern drilling rigs of the type that are presently manufactured in Fondedile's newly built, large manufacturing and maintenance plant near Naples. A plant that takes also care of providing tools and of servicing the vast fleet of rigs of other Fondedile's divisions: slurry walls, large diameter shafts, grouting and other specialized construction operations.

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**1973: "Root Piles" constructed in Canada and for the Washington, D.C. subway system**

The first **"**Root Piles" constructed in Montreal, Que. Canada take care of the logistically complicated underpinning (no interferences with passengers and train traffic allowed) of a wing of the Longoeuil subway station that is undergoing alterations and widening. The project's design is made in New York and performed using locally available machinery. Operating in the intense cold is not easy, but the project is very successful.

"Root Piles" are then used for the construction of the first tangent micropiles-anchored retaining wall in the US at Glen Burnie, MD. The retaining wall replaces a planned steel-sheeting wall that, if constructed, would most probably have caused damages to the buildings along the site perimeter. Vibrationless and noiseless construction is the selling feature convincing both the engineer and the contractor to adopt the "Root Piles" structure.

In June, WMATA consents to a first use of "Root Piles" for the underpinning of a sensitive government building standing along the cut-and-cover excavation for the Washington, DC subway, a major infrastructure project in the US. A value engineering proposal submitted by Fondedile Corp. to a General Contractor ready to cash-in on the savings offered by the "Root Pile" system is accepted. This is right in the territory of the New Yorkk consulting firm previously mentioned. Its distrust of the "Root Piles" is synthesized in a final dire prophecy: "Soil relaxation during tunnel excavation will weaken the load bearing capacity of the piles".

The project begins with the performance of the first load test of a "Root Pile" in the US. Upon it successfully demonstrating the construction reliability and the high load bearing capacity of the tested 4 inch micropile, "Root Piles" are officially included in the construction code of the City of Washington and in WMATA's construction specifications.

The underpinning is completed on schedule and during the subsequent cut-and-cover operations it performs as anticipated. Measured structural settlements are minimal, well below allowable limits and monumentally below the magnitudes of settlements caused to other structures by different underpinning systems. No damages to the underpinned building are noticed or recorded.

A report on results obtained in Washington, D.C. using different underpinning systems presented in 1975 by Mr. K. Ware of Bechtel Associates at the ASCE Rapid Transit Convention mentions "Root Piles" as a successful solution (Reference 10). This notwithstanding, and the fact that conventional underpinning of structures along the subway route keeps causing large building settlements and widespread structural damages, it will be the one and only time that "Root Piles" are used by WMATA. Methods like pit-pier underpinning, often having to fight large water inflows and potentially disastrous soil losses from around the pits, continue being used. Somebody does evidently not share Ing. Lizzi's credo that "*Any restoration work must be performed assuring the persistence of the current stability without generating vibrations, cuts or removal of portions of structure and introducing new stress."*

On this subject and as a contraposition of systems and results, I can't refrain from remembering the large cracks that appeared throughout the Washington National Gallery edifice during the construction of the subway. The massive edifice was denied the "tender loving care" it should have received and was subjected to a brutal underpinning treatment that, upon cutting off its foundations, transferred its weight onto needle-beams on jacked piles. The consequences: 90 mm of measured settlements (Reference 10). At the time, as a (relatively) young engineer coming from a culture of respect and delicate treatment of historic buildings, I was deeply saddened by the carelessness I was witnessing. I had difficulty understanding how, when faced by such a disaster, a change of underpinning methodology would not even be remotely considered. Foundations kept being cut off and transferred onto temporary supports while (and often vainly) attempting at maintaining stability and structural integrity through cycles of repeated packing and jacking operations that induced new structural damaging tensions and stresses (This was also a big blow to Ing. Newburg's expectations: "*the Americans are so keen on progress that they will promptly adopt our damage-preventing, conservation-oriented technology!*")

**1974: Fondedile Corp.'s slow growth. The formation of Warren-Fondedile Inc.**

This is a year of pause in the growth of Fondedile Corp. and a worrisome and glaring contrast with the profitable growth of the Fondedile Group in the rest of the world.

The profit generated by the volume of work completed by Fondedile Corp. in the past three years is insufficient to continue financing the cost of the promotional work still needed to penetrate what has proven to be a very conservative market. This fact and the fact that the Fondedile Group is very profitable everywhere else it operates, leads the Chitis' shareholders group to consider terminating the US venture to end what they perceive as misdirected efforts to penetrate an unresponsive and hostile market. At Naples' headquarters they are in the habit of making money! Hence, who needs struggling and bleeding in a difficult market when the Group is welcomed with open-arms and is very profitable anywhere else? The Newburg's group is shaken but still looking forward to succeed in a market so promising for its large size. A compromise is reached by which Fondedile Corp. will seek a way out of its penurious situation, namely by finding *in the US* the help needed to finance its survival and expansion.

By the fall of 1974 a new company by the name of Warren-Fondedile Corp. is organized. Warren Brothers Construction Corp., a subsidiary of Ashland Oil, holds 51% of the new Corporation's shares and the Fondedile Group the remaining 49%. Warren Brothers Construction Corp.'s main business lies in road construction and paving, namely, in selling one of Ashland products: bitumen. Warren Brothers looks with favor to the business diversification offered by entering and expanding in the field of underground and foundation work and likes the association with a company of the size and dynamic success as the Fondedile Group.

Warren-Fondedile offices are set up at the Warren Brothers Construction Corp.'s headquarters, in Cambridge, MA. Fondedile Corp. becomes a dormant corporation.

**1975: A year of struggle**

Warren-Fondedile completes a number of projects where "Root Piles" are used as safe and economical means of providing new foundations in tight spaces for the modernization of industrial complexes (refineries, heavy industrial plants, paper mills, hospitals and silos). At the same time it builds up its volume of work by expanding operations to other fields like slurry walls, continuous flight auger piles, tiebacks and grouting. However, it continues failing to secure the profitable and large projects that the Fondedile Group is so successfully acquiring elsewhere using "Reticulated Root Piles" structures, namely remediation or prevention of landslides and of large soil movements and restoration of monuments and old buildings.

The main factors that continue hindering the acceptance of "Reticulated Root Piles" structures in the US are:

- The technique is proprietary (patented). It cannot be included as "sole system" in most public agencies' bids, the ones dealing with the desired large projects unless a qualification allowing bids on an "equivalent" system is introduced. A qualification that both Warren-Fondedile and the public agencies do not like to introduce.

- US engineers cannot rationally confirm that the system will work in all and any circumstance. It is impractical and too expensive to field test it. On this subject, the Fondedile Group does, obviously, have no interest in fully disclosing the ultimate design concepts. They are part of its know-how. The summary information released is insufficient and incomplete to allow a full check of the design. Additionally, while basically it is a simple design, it incorporates the use of often subjective geotechnical parameters derived from experience as per Ing. Lizzi's assertion that: "*In the field of foundation piling the direct experience precedes the design. The latter follows as a summary of proven data obtained in advance by load tests*" (Reference 11). A re-statement of his technical and design base principles he so effectively used in the 1960s to conceive and engineer the "Root Piles" and the "Reticulated Root Piles" structures.

- There are no monumental structures in need of restoration in the US.

In reality, any US experienced engineer willing to follow the lines of design traced by Ing. Lizzi and to accept his theoretical approach, concepts and parameters, would have no difficulty checking the design. However, the fact that the design is geared to generate a factor of safety based on individual experience and not on hard numbers makes less experienced US engineers wary. How can they take responsibility for a design that is based on somebody else's experience and is not "rational", i.e., not based on well defined parameters leading to firm mathematical conclusions? If they cannot do that, they will hardly recommend using it. When Ing. Lizzi in his design explanations, talks of "*The principle of soil "homogenization*" what does he mean?" "Who ever heard of that?"

**1976: Warren-Fondedile Inc. ceases operations.**

In 1976 Warren-Fondedile finally succeeds securing a contract with the Mississippi Department of Transportation for stabilizing the sliding buttresses of a major State highway bridge in Jackson, MS using "Reticulated Root Piles". It is a successful project and a breakthrough, but it is soon followed by the disappointment of being unable to secure another, larger contract that has been under negotiation for a long period with the same DOT. What is happening is that Warren Brothers' hoped-for rapid and substantial build up of Warren-Fondedile Inc. on the foot-path of the Fondedile Group's success, is not materializing due to market resistance. The continuing inability of the Company to generate substantial revenue to pay for its overheads, leads management to overplay the "uniqueness" of the "Reticulated Root Piles" structures. Bids get inflated by attempts at recovering overhead costs to the point that competitors succeed in “stealing” long yearned-for projects using “equivalent” (and in these cases, cheaper) solutions. Eventually, Warren Brothers’ lack of familiarity and late realization that performing geotechnical and underground work involves risks not normally associated with its traditional operations (road paving) and the difficulty of having to deal with a partner reluctant to upgrade its base organization and to supply dedicated, English speaking support to its US subsidiary, raises doubts about a profitable Warren-Fondedile’s future. This is compounded by Fondedile’s unrelenting belief that if “Root Piles” work successfully all over the world they must also work in the US and must be accepted as a superior product everywhere. In November 1976, a series of culture-clashes and misunderstandings (Wolf Chitis, a son of one of the founders has taken over the management of the whole Group but barely speaks and understand English) leads to the dissolution of Warren-Fondedile and to the resurrection of Fondedile Corp.

**1977: Construction of the first “Reticulated Root Pile Structure” in the US**

As an answer to the pressing requests of the US market for more design disclosure, Ing. Lizzi elaborates a description of the design philosophy and methodology of the “Reticulated Root Piles” structures and returns to the soil laboratory to provide support to his design with the results of (small scale) tests.

He believes that every US geotechnical engineer with some experience may understand the concepts on which the design of the “Reticulated Root Piles” structures is based. He presents them in a document by the title: “The Fondedile Reticulated “Pali Radice” (Root Piles) structure: Intuition, Practical applications, Tests and Design” (Reference 11). The explanations are simple and straightforward. Basically he says: to stop a soil movement, perform the necessary investigative work to identify the slip surface and determine the increase of shear resistance needed to arrest soil movements along such surface. Fondedile does it by inserting an adequate number of shear resisting elements (i.e. “Root Piles”) across the surface according to a “soil amplification coefficient” $m=E_p/E_t$ where $E_p$ is the modulus of elasticity of the elements (i.e. the “Root Piles”) and $E_t$ is the modulus of elasticity of the soil. The “soil amplification coefficient” is the equivalent of the similar coefficient used when designing reinforced concrete. It addresses the fact that when dealing with “Reticulated Root Piles” structures” one is dealing with a composite matter made of soil and micropiles as reinforced concrete is made of steel and concrete. The coefficient m is the “homogenizing” factor that allows considering the composite matter as a single matter.

Ing. Lizzi’s work and the persistent promotion (still by a lone engineer) of the “Reticulated Root Piles” at the Federal Highway Administration (FHWA) and State Transportation Departments, at the U.S. Army Corps of Engineers and at their Waterways Experimental Station and at other large public agencies does eventually result in the FHWA awarding Fondedile Corp. a "demonstration project" using a "Reticulated Root Piles" structure for the correction of a landslide threatening the stability of Forest Highway 7 (State route 162) in the Mendocino National Forest, California. Personnel of the Waterways Experimental Station are designated to perform instrumentation of piles to determine actual working stresses acting within the structure. Resulting information will hopefully help "rationalizing" Fondedile's design process.

Engineering-wise, the project is very successful ("*the roadway was prevented from failing by the "Reticulated Root Piles" structure during the disastrous storms of 1982-3"*), but the final FHWA report (Reference 12) emphasizes the "*non-competitive form of the concept*", while encouragingly conceding that "*this type of earth reinforcement system will definitely find its place in the US market, once US engineers are satisfied that each "Reticulated Root Piles" structure is based on a rational design*".

It is a fact that the NY State Department of Transportation, Caltrans, the FHWA, the USACE and other State Departments of Transportation while interested, still do not understand how the "Reticulated Root Piles" structures work. And while Caltrans announces the introduction of computerized design calculations of the structures (Slope9 and Slope92), still limited design data are available. US engineers do not like designing according to Ing. Lizzi's statement that: "*In the field of foundation piling direct experience precedes design*". Experience is personal and difficult to quantify. This remains, at least for what concerns rationalizing the design of "Reticulated Root Piles" structures, an insurmountable axiom. Finally, the statement included in FHWA's report (Reference 12): "*The Reticulated Root Piles" structures are too conservatively designed and too expensive*" adds to Public Agencies' skepticism about the system viability in the US market. Privately, Ing. Lizzi will concede that "*in some instances we designed "Reticulated Root Piles" structure with positive exuberance*"….

Following the completion of the Mendocino National Forest project, Fondedile Corp. begins performing drilling tests in Providence, RI, for the underpinning and rehabilitating of the local Municipal Wharf. The $3.5 million project appears to be finally crowning the intense promotional work performed to date and seems to be the harbinger of that longed-for sequence of "substantial contracts" Fondedile Corp. has been relentlessly seeking in all these years. It includes extending the wharf foundation to deeper soil strata to allow increased berthing depths for larger vessels. The project is also awakening Fondedile's competition to the potential and profitability of "Reticulated Root Piles" structures. In fact, a major US geotechnical contractor is offering to perform the wharf rehabilitation based on an "equivalent" solution. Fondedile's better design, its reputation, its experience and the fact that it has just completed a "Reticulated Root Piles" structure in the US, leads it to secure the project.

**1978: New micropiles and the underpinning of the Municipal Wharf in Providence, RI**

The “Root Piles” promotional work done by Fondedile Corp., the undeniable success and geniality of the projects it completed and the expiration of its protective patents generate interest in the technique and the appearance on the US market of similar piles: “Pin Piles”, Mini Piles, Micro Piles and others become market buzzwords. They are promoted as novel tools for a more efficient and safer resolution of familiar stability problems. However, both promotional descriptions and hype do only re-propose the advantages promised by the “Root Piles” even if some construction procedures are modified to adapt to US engineering and contracting preferences. Left-in-place casings become an alternate way of providing pile reinforcement; grout is pressurized by pumping instead of blasting it with compressed air and cement-only grout replaces mortar to simplify and speed up grout preparation, mixing and pumping.

This is not an isolated occurrence and is not limited to the US market. In fact, by now, Fondedile’s proprietary hold on the micropiles’ market has been broken worldwide. It can no longer impose its prices and must fiercely compete on the base of innovation, quality and productivity provided at the lowest cost. This is a change that requires new and different management approaches and philosophy that, unfortunately, Naples’ headquarters will fail to implement.

Efforts by Ing. Lizzi to improve on Fondedile’s products will however lead to his perfecting (and patenting in 1978) of a system for pre-loading and easily testing the effective load bearing capacity of a pile, a system anticipating the appearance of the very similar Osterberg cell (Reference 14).

Now everybody is in a race to improve on the “Root Piles”, alas, without the support of the considerable experience accumulated by Fondedile. A few disasters ensue. The highly engineering conscious and experienced US highway authorities generate specifications by which the very high grout slump used for micropiles is replaced by grout and mortar with a lesser slump. Why? Because, based on their experience in the construction of large diameter shafts (but without knowing much about micropiles), they “feel” that the use of flowing, high slump grouts will negatively affect the final strength of the concrete. The production of what will be defined as “unworkable micropile specifications” leading to “unfeasible” construction conditions is the result. Project work stops and may be re-started only upon allowing the use of high slump, flowing grout and upon being hit by claims.

Meanwhile, Fondedile Corp. is involved in its Providence project where past organizational and management problems reappear. Specialized personnel do not speak English, cooperation with local specialized foundation contractors is antagonistic at best and the project is run as a “one time only” project. Little preparation of personnel and machinery is performed in anticipation of future projects. Keeping production on schedule and the resolution of construction problems become significant time and energy consuming items. The project falls behind schedule and the client is unhappy.

**1979: The last "Reticulated Root Piles" structure constructed in the US**
1979 sees the successful completion of a "Reticulated Root Piles" structure at Monessen, PA, constructed for the Pennsylvania Department of Transportation (PennDOT) (Reference 14). The project aims at preventing the collapse of a city street by stopping and stabilizing a soil slide that occurred during the construction of a four lane highway along the Monongahela River, North of Interstate 70. The "Reticulated Root Piles" structure is chosen *"because it causes the least amount of disturbance with the minimum construction time at a comparable cost of all other systems (tied back walls, reinforced earth and concrete gravity walls)*" (Reference 14).

This will be the last "Reticulated Root Piles" structure constructed by Fondedile in the US.

**1980-1990: The last years**
This period witnesses the continuation of the management changes, budget cuts and office relocations that, begun in 1977, significantly sapped Fondedile Corp.'s ability to continue as a profitable corporation. The effects of increasing and aggressive competition require ever more competitive bidding of projects, leaving little space for profits and for paying for Company's overheads. The Corporation survives through this period by performing a few underpinning jobs, but never of the magnitude and of the profitability that would justify a continuing presence in the US and is finally shut down in 1990.

Contemporaneously, the Fondedile Group's overall profitability is also gradually declining, the combined result (as mentioned) of the expiration of the patents, the increasing difficulty of generating new products (i.e. the maturing of the micropile market) and the aggressiveness of competitors now free to fully invade specialized construction areas previously Fondedile's sole domain. Add to that the changes occurred in the tunneling and in the soil retaining industries (Tunnel Boring Machines and "Reinforced Earth", just to mention a few) that are gradually eliminating a large portion of the fields of application of the "Reticulated Root Piles" structures. This convinces Mr. W. Chitis to sell what remains of the Company (mainly reputation and "good will" relationships), prior to losing it all. In 1991, the Group is disbanded and separate portions of it sold to investors in different countries.

In Naples Fondedile will briefly survive under a different name and finally disappear into the remembrances of our past.

The chronicle about the Fondedile Company may end here, but the influences of its innovations on geotechnical science and on pile construction techniques, persist and continue. This thanks to the epochal changes that, under the fervent engineering guidance of Ing. F. Lizzi, were brought to a construction field that, by nature, rarely comes to light to enjoy fame or recognition for its brilliance. They revolutionized the thinking and the principles to adhere to when transferring structures onto new foundations or intervening on them ("*Any restoration work must be performed assuring the persistence of the current stability without generating vibrations, cuts or removal of portions of structure and introducing new stress"*).

It is the chronicler's opinion that Fondedile brought to the geotechnical world the "right ideas at the right time". Some of them took strong "roots", continue being used and will undoubtedly be improved in time. Others, while certainly not ephemeral, followed the normal progress of exploitation and gradual obsolescence. They were replaced by improved engineering concepts and now rest within the large pile of discarded ideas that we, as some-time protagonists, occasionally and sentimentally contemplate accumulating behind us as a sign of our progress.

The compilation of this chronicle is based on reminiscing of facts and episodes as they were lived through personal experience and on a subjective recollection of Fondedile's business history. Reporting imprecision or the missing of facts was involuntary and the chronicler hereby apologizes for it.

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   where: $\gamma_n$ is the $n^{th}$ soil layer specific gravity
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   $\varphi_n$ is the soil friction angle
   $f_n$ is the coefficient of friction between soil and concrete
   p is the pile perimeter
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