Energy Piles Contribution on a Green Building Context

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Abstract

The mutation of our practices in the field of construction to sustainable construction makes us win on different levels. The construction of a structure requires a foundation in the soil capable of maintaining it. The choice of a type of foundation depends directly on the terrain, rock or soil resistance, the size of the structure and the level of the water table. The piles are a kind of foundation. The latter can be superficial when the terrain is good and / or distributed loads. But we use piles when the good soil is deep and the loads concentrated. Geo-structures in contact with the ground can be used to exchange heat with the ground, which is the case of piles. Therefore, in this work, we will focus on energy piles contribution on green building. Eco-construction requires the mastery of techniques to significantly reduce energy consumption for energy self-sufficiency, financial savings and reduction of greenhouse gas emissions.

Keywords — *Energy piles, green building , geo-structure.*

I. INTRODUCTION

Promoting Green building is a challenge to preserve our environment. It is now known that geo-structures in contact with the ground (tunnels anchors, foundation slabs, deep foundations, retaining walls, etc.) can be used to exchange heat with the ground [1], which is the case of piles. The energy pile can be a part of the green building solution. It is equipped with individual or several pipe circuits composed by plastic in order to exchange heat with the neighbouring soil. The concept of energy piles is not new. The approach was pioneered in Austria in the 1980s [2] and taken up in a number of other northern European Countries.We will present in the following a state of the art of classic piles afterward energy piles are introduced.

II. CLASSIC PILES

A. *Prefabricated piles*

They can be piles made of metal, wood, reinforced concrete or pre-stressed concrete. They are driven into the ground in various ways: by threshing, screwing, vibrating, etc.

1) Wood piles

The use of piles in construction work dates back many centuries. Herodotus, the Fourth Century B.C. Greek writer and traveler, also known as “the father of history”, provided the first documented historical reference to piles. Ancient Egyptians, Greeks, Phoenicians, Romans, Chinese, Mesopotamians, and others all used piles. In Lake Constance, located between Switzerland and Germany, archeologists found well preserved remains of wood piles, which are estimated to be 2000 to 4000 years old [3]. They are trees cut in length. The tip can be protected by a metal shoe and the head by a helmet. This type of structure tolerates without deviation the deviations, during threshing, or the long-term movements. These piles must always be beaten below the piezometric level to avoid rapid destruction. This condition involves important preparatory work such as excavations to keep the stake head accessible. The elements are light, handling and installation are simple.

Fig 1: Wood pile shape

2) Driven Metal piles

Metal piles became available in the mid-1830s [4]. They consist of metal beams made of E24-1 steel or similar, possibly with added copper, H-shaped, ring-shaped or of any shape obtained by welding sheet piles, for example. Implementation by threshing or vibration requires no additional equipment. These piles are lightweight, easy to beat and are resistant to bending stresses caused by angled thrust. The shape of the sections increases the lift of the structures because the ground is compressed between the wings of the H or inside the tube. This process easily passes through the hard layers. On the other hand, the chemical study of the soil and water flowing around the piles must be sufficiently complete to determine the risk of corrosion. For example, the active physicochemical elements of the soil can lead to corrosion of the steel. The means of protection are various:

- Use of special alloys,
- Galvanizing or zinc painting
- Coatings based on bituminous products, resins, cement

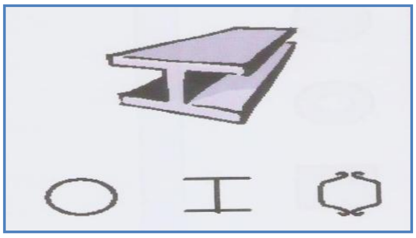

Fig2: Driven Metal piles shape

3) Prefabricated piles

They are constructed of reinforced concrete, their preferred use being in water-saturated or water-filled terrains with compressible intermediate layers. This system is favorable to the use of negative friction. In the case of prefabricated piles, only a small amount of equipment is necessary on site. Basically, only the pile driver is indispensable, after the piles have been unloaded with the help of travelling crane [5]. The piles are reinforced at the head and terminated by a sharp hoof. For threshing, they are equipped with an elastic protective helmet. The execution of the threshing must follow a precise logic. It is considered that the stake is in place when it has reached its final boundary, verifying that the refusal obtained corresponds to the forecast. When the denial occurs before the pile has reached the desired depth, special arrangements should be made. The section is generally circular, but some prefabricated piles may have a square section with slanted angles or octagonal to provide better resistance to local bending forces.

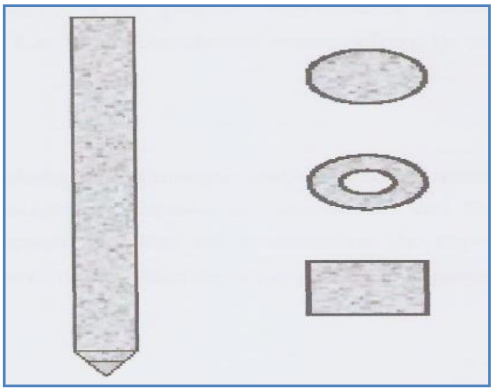

Fig 3: Prefabricated piles shape

B. Piles executed in-situ

When pile driving is difficult or economically unprofitable, piles cast in place are essential [6]. In the case where dimensioning leads to long piles, it is difficult to use prefabricated piles that are too heavy and very difficult to handle. It is essential to use molded piles. Once the drilling is done at the desired depth, the hole is filled with concrete or reinforced concrete.

1) Single drilled piles

This method does not use wall support. It therefore applies only in sufficiently cohesive soils above ground water tables. A drilling is carried out in the ground by mechanical means and is then filled with concrete and reinforcements. The drilling section is circular. Thanks to special tools, it is possible to drill wells from 1.5 to 2 meters in diameter to a depth of 30 meters. These piles are reserved for exceptional loads.

2) Mud drilled piles

The drilling is similar to the previous ones but under protection of a drilling mud. The vertical piles may be provided with an enlarged base by boring the borehole. The section of the widened base must not exceed 3 times the section of the pile.

3) Piles drilled mud

The drilling is carried out mechanically under the protection of a casing whose base is always located below the bottom of the borehole. This casing is driven by vibration or sinking as the advancement progresses. The filling takes place with concrete of similar composition as for the simple drilled piles.

III. ENERGY PILES

There are many examples of energy structures: the Lainzer Tunnel in Vienna, the Main Tower in Frankfurt and the One New Change Building in London.

An energy pile is an equipped pile small geothermal probes on any the height of the pile: these are pipes, for example of double U type, identical to those used in the technique of geothermal probes from 80 m to 150 m depth. They are inserted manually in piles by a company specialized in probes or boreholes; the void of the pile is then filled with a material conductor (wet sand, sand quartz). Other types of piles may be equipped with energy piles, by example of molded piles (insertion of reinforcement cages equipped with tubes in boreholes, concreted thereafter) or bars (rectangular piles of large dimensions).

In the cold season, geothermal probes integrated into the piles constitute the "cold source" of a heat pump which ensures the heating of the building. The emission of heat takes place by radiation from ceiling to very low temperature (tubes embedded in the slabs of the building), which presents many advantages in terms of comfort, the performance of the heat pump and energy consumption through the use of a large mass thermal accumulation. In the hot season, the cycle is reversed, that is to say that the frigories of the field are used to refresh the premises by the same radiation device ceiling. Excess thermal loads premises are transported in the piles via a heat exchanger (heat pump tripped), which allows to heat-charge the field for the next season Cold. The same facilities are used to fulfill both functions (heating and cooling).

The following image illustrates implementation of collecting tubes:

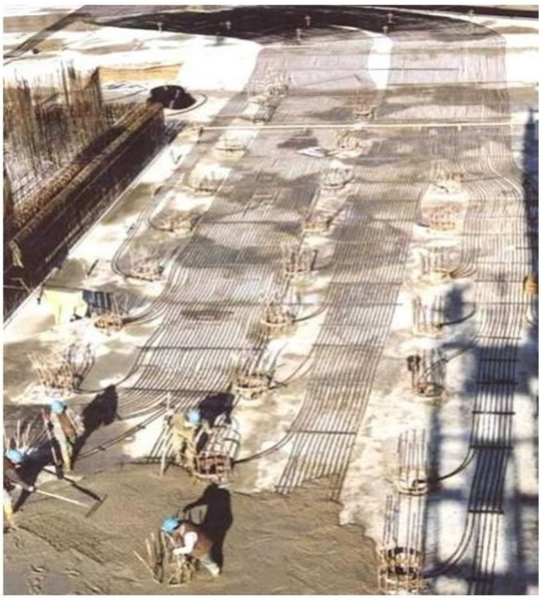

Fig4: Tube implementation for energy piles

This solution is interesting to promote green building. Multiple advantages are obtained:

- No CO2 emissions,
- No waste or use of fossil fuels,
- Greenhouse,
- No sound or visual pollution due to cooling towers,
- No risk of legionellosis,
- Reduction of energy consumption by the effect multiplier obtained (COP).

IV. LIMITS

Despite the growing number of energy geo-structures already operational, their design remains mainly based on recommendations. There are still no standards for true geotechnical design; this deficiency is mainly due to the still limited knowledge of the thermo-mechanical behavior of this type of structures [7].

The use of foundations to ensure the exchange of heat with the soil causes a change in soil temperature and structure, a phenomenon that is not without consequences on the overall operation of the system. The energy piles are thus subjected to thermo-mechanical loading which results in additional deformations. By partially opposing these deformations, the foundation soil then generates additional stresses in the piles.

In addition, the cyclical temperature variations imposed by the piles on the ground also have an effect on the thermo-mechanical behavior of the soil, in terms of deformation and shear strength.

Finally, it is important to note the important role played by group effects in the design of energy foundations. If we imagine for example to heat a single pile within a group, its thermal expansion will be thwarted by the presence of other piles which, because of their constant temperature, will not expand with him; a phenomenon that will cause even higher thermal stresses in the pile in question.

REFERENCES

[1] D. Adam and R. Markiewicz, Energy from earth-coupled structures, foundations, tunnels and sewers. Géotechnique, vol 59 (3), 2009, pp. 229-236.

[2] H. Brandl, Energy foundations and other thermo active ground structures, Geotechnique, vol 56 (2), pp 81 – 122, 2006.

[3] H. Goble "A brief history of the application of stress-wave theory to piles." Current Practices and Future Trends in Deep Foundations vol 125, pp186-201, 2004.

[4] R.W. Peterson and L.T Lee, Underwater Geotechnical Foundations: Ports 2001 Conference: America's Ports-Gateway to the Global Economy, 2001.

[5] J. Rybak,Time dependent factors in pile quality and capacity control.The International Scientific Conference Innovative Materials, Structures and Technologies". 2014.

[6] M.K. Khan, M.H.E. Naggar and M. Elkasabgy. “Compression testing and analysis of drilled concrete tapered piles in cohesive-frictional soil”. Revue Canadienne de Géotechnique, vol 45(3), pp 377–392, 2008.

[7] L. Laloui and A. Di Donna- Energy geostructures: innovation in underground engineering, John Wiley & Sons, 2013.