

## **Application of the Joining Pile for Foundations on Expansive Clays and Rocks**

**Jan Jaremski**

Rzeszów University of Technology  
Rzeszów, Poland

### **Abstract**

*This article presents various methods of estimation soils capacity to expansion. The rage of swelling should be taken into consideration in order to determine the reasons of cracking and failures of existing buildings. The author provides a new idea of piling, where the basic part of the pile is located at the depth of the foundation occurrence. This model of piling is suggested for the objects with great load as well as for those with small load, on expansive soils. This considered solution is very cheap and its realization does not require very heavy equipment at the building site.*

### **1. Introduction**

The expansive clays occupy about 20 per cent of a building area in the United States. Similarly the problem is also significant in Africa, India, Asia, Australia and partly in Europe. Expansive clays are present on many areas of the hot temperate zones, also in many enclaves of soils and rock eluvia containing minerals belonging to the groups of montmorillonite, illite etc. Identification of expansive clays ability and methods of its investigations were described in early papers [9,10,12]. Losses caused by soil swelling in building industry are comparable to losses caused by environment. Usability of the joining pile on the expansive soils gives an important advantage. Joining piles provides a new idea of piling. It is a combined foundation including the base made in the soil, and the post elements (a bundle of piles or micropiles) joining the base with the girt. In the case of swelling soils, capacity of the system of piles or micropiles bundle is making a base joining them to make up the role of the anchoring pile. The joining pile has a relatively small lateral surface.

There are many reasons for which the received results should be compared with the results of research conducted in the other countries as it makes possible to know the geological properties of several kinds of soils. Author compared the properties of many swelling soils and soft rocks. Considering mainly on their origin and mineralogy. The worked-out associations permitted to compare the phenomenon of swelling occurring in different soil media and to analyze also the researches made in various countries and at the same time, to including the exploitation problems of building founded on expansive soils and including the placement moisture-water content and to determine the value of maximum swelling. The process of swelling occurring in soil and rock media brings about the changes in volume which are the reasons for settlement (shrinkage) or displacement of the foundation upwards (swelling). The recognition of the ability of swelling of some cohesive soils is of great importance for the selection of foundation for building objects and for determining the exploitation conditions of objects and for site planning. The range of swelling should be taken into consideration in order to determine the reasons of cracking and failures of the existing buildings.

In the rock media and particularly in their weatherings e.g. in marl eluwium, swelling brings about continuous changes in fissures or in spaces between larger rock fragments, exerting an influence on the strength of a medium, and also leads to the continuous variations of the medium which is debris under extreme humidity conditions and which in proper, changes in moisture content, preceded by the periods of drought, becomes similar to cohesive soil. The phenomena of swelling and shrinkage may bring them to the extremal states. First of all it should be stressed, that the phenomenon of swelling occurs only in the aeration zone identified with zone of fluctuation of the level by underground water and foundation layer. It has been explained that there is maximum swelling or soil shrinkage if near to the outer surface of the ground soils (or rock weathering) have minerals of distinctly high negative charges montmorillonite, illite, baidelite etc. and when the environmental conditions of soil allow moisture to change the essential variations in maximum swelling occurred in the plan area of impended buildings.

According to the present world knowledge much of them has been already done for better understanding of the processes occurring within expansive clays. This problem is, however, considered as an extremely complex one and it seems impossible to forecast and evaluate the subsoil movements (for needs of practical engineering).

## ***2. Some Example Foundations in Expansive Soils***

Misfortunes connected with foundation situated on illite clays with hidden parameter of swelling. For this type of clays I propose to include illite clays and other soils and rock eluvium with considerable content of illite minerals and expansive housing estates in the town I worked in, was built up in the years 1930-1959. The area of the housing estate is built over by detached houses. They have cellars, wooden floors and rafter framing. The houses are founded at the depth of 1.20 + 2.5m below the ground. There are gardens around the houses. About 20 years ago cracks appeared in some houses and they were several centimeters wide. These damages have occurred, first and foremost, in the quoins of houses and in the walls between window openings and door-ways. Around several houses there were organized test grounds on which exploratory bore – holes and cuts were made from which samples were taken for laboratory tests. After testing with traditional methods the swelling was not recorded. Instead of expected expanding only settlement in consolidometer was registered under the influence of moisture. Then samples were taken from the same soil in order to test swelling according to the proposed method of the author [10] of examination of the maximum swelling. The degrees of swelling from 10 to 18 per cent were registered for samples taken from various places. The tests were repeated several times in several periods of time for samples taken from places around the houses which had new damages.

Finding the best foundation level and the choice of the most suitable foundation method remain also troublesome. With the change in the natural moisture content these soils expand or shrink intensively. Considerable changes of volume, which accompany these processes, result in serious damages of various construction such as foundations of buildings aerodromes, roads, underground installations and systems. Generally speaking the phenomenon of expansion is noted in many countries of the world with a specific geologic structure of the subsoil in accompanied by climatic conditions that favour significant periodical variations of the water contents soils. It has been found that expansion or shrinkage of soils depend on possibility of contain in the minerals which a distinctly high negative charge (montmorillonite, illite) close to the land surface. Significant changes of potential expansion occurred in the plan areas of most highly expansion were noted after 10 years since the construction works began but already after 2 years culminating impendency could also occur [1]. The damages due to expansion of clays start to be more and more carefully recorded as use on these clays for construction works becomes more popular. A foundation in expansive clays results the milliards dollars damage in the world every year. In the United States the costs more can be than the whole damage caused by earthquakes, hurricanes, floods, etc. I know the examples from literature in which 40 per cent of buildings in a town were considerably destroyed [1].

The ideal solution would be if the conditions of moisture were, for the whole period of exploitation at its initial point i.e. moisture - content “ found ” in the substrate at the beginning of construction. Therefore I postulate, first of all, to accept as necessary the registration of soil moisture in several places of built - over area. In case of cracking which may occur even after 60 years of service as it took place in case of the National Gallery in Sydney where numerous cracks appeared when the trees in the vicinity of the Gallery had been cut down[13]. The recognition of the basic humidity is an important piece of information which helps to establish the reason and the choice of solution if the accepted and evaluated swelling parameter in a geotechnical design could be incorrect. Considering that the effective activity, aiming at the mechanism of their origin. A variation expansion properties occurs as already mentioned, even within a building projection resulting in various expansions under individual elements of a construction. In fact, it leads to destruction and so easily suggests the influence of trees as the latter do not occur symmetrically around a building. I wish to underline that I do not intend to eliminate the influence of trees as I know that a single tree in our climate can use up to 1000 litres of water a day. I only intend the proper to find the proper influence of the trees. I think that the British problem is a good example as the British mild and wet climate makes the seasonal variation of volume of expansive soils smaller. On the other hand the droughts of 1975 and 1976 in Northern Europe, resulted also in the United Kingdom, under such bad conditions, the deficiency of water content, in soils so that the largest damage was noted in south eastern England. The drought effect in the densely populated suburbs of London caused a serious increase in damage and therefore, the payment by insurance company.

About 34 per cent damage was considered to be done by the trees. I expect that even and or the climatic conditions of the United Kingdom cannot be sure that the drought will not repeat[14]. I think that one should not trust so much to the influence of trees on expansibility although it seems comfortable, especially for the courts that solve the disputes on the influence of trees in the neighbourhood. I think that the proposed method of stating maximum swelling may be helpful not only for the planned objects, but also for existing buildings on this account that the cost of research is minimal and easy to do. I think that the so-called service consciousness of the user is based on an unquestionable statement that the used object is founded on expansive clays and this may, as a consequence, lead to keeping stabilized soil moisture by proper site planning in the vicinity of the object by cultivation of adequate plants and by planting trees of proper species and placing them at the safe distances. The advantages of the coins of simple solutions owning the possibility of fast stating of the reason of failure is very well illustrated by the example of the procedure in suppressing the crack which appeared between the nave and the tower of St Barbara's Church in Chicago - where humidifying of soil around the tower was applied.

Author in the previous papers studied the zone of the swelling and that this zone is determined by the migration of the water level and the foundation surface of structure buildings. In – the way of an analysis of numerous cases occurring in our geographic region he elaborated the method of determination of soil a swelling or an extreme swelling for the media with moderate expanding. By the observation of the weathered marls and illite clays with the limited contents of the media with cache swelling. This method allows for the investigations such minerals as illite monmorillonite, gypsum, vermiculite, baidelite. Swelling media (soils and rocks) are the mixture of various (heterogeneous) minerals which can expand at the presence of a water. This elaborated method take an advantage of the existing endothermic it allows to determine the swelling minerals to determine the swelling process. The author worked in Opole city the south Poland, where the waste of the marls which was not qualified as building basis steps out already under the layer of humus. This waste in exceptional years (precipitation preceded long-lasting dry) have changed from typical rocks debris into the coherent soil out of which the samples were cut out with about the intact structure [5]. The author had the possibility to observe swelling and shrinkage in natural conditions. The marls and marl eluvium have been studied since many years. Numerous analyses have led to recognition from debris to cohesive soils, the process occurring in the waste.

Many years' of the investigations utilization of SEM, derivatogram method, fluorescence, diffraction method, allowed to establish that theillite is responsible for the phenomena of swelling and cramp. Simultaneously the investigations of stamina parameters in laboratory conditions and in the sieve were led. These investigations allowed to classify the wastes of marls as building foundation and eliminated the need of expensive exchange of the soil, sometimes even to 7m. These investigations were also led on the enclaves of clays containing illite. The author used the fact of the existence of endothermic maxima (temperature near which minerals lose water connected - the temperature points at which the minerals loses contents of bound water) then noticed that practically minerals calling out swelling and cramp such as montmorillonite, illite, baidelite, some of sulfate, plaster and holzollite have these temperatures up to the 200 Celsius deg. In the elaborated method a simple way used in the engineering practice has been shown. The method is much simpler than ones shown in earlier works and it gives similar effects[6][9][10]. This way consist in formation a sample similarly to the traditional methods ( in the case of rocks and their wastes on previous grinding, humidity and formation of the sample). Then the prepared samples are put into the dryer and they are being dried to the temperature 200 Celsius deg.. We place the sample in the apparatus for the investigation of swelling after cooling. In this way the soils which are the mixture of many minerals show accumulative ability to swelling, and it allows to choose proper foundation. Soils in the part of Poland where the author works at present are multilayered with organics and swelling minerals showing sometimes destructive swelling.

### ***3. The Proposed Solution Foundations on Expansive Soils***

Expansive soils are present throughout the world and known in each state of USA. Every year they cause billions dollars of damage. The American Society of Civil Engineers estimates that 1/4 of all homes in the United States have some damage caused expansive soils. In the typical year in the United States they cause and greater financial loss this property owners than earthquakes, floods, hurricanes and tornadoes combined[3,12]. One proposes the applying joining pile after executing the analysis of solutions foundations on expansive soils introduced in the literature and numerous internet sources.

Usability of the joining pile on the expansive soils is its important advantage. Conventional piles located in swelling soils transfer loadings to non-swelling layers, but they do not protect the structure against effects of swelling because of an action of forces from swelling on lateral surfaces of piles. The joining pile has a relatively small lateral surface. So-called joining piles represent a new idea of piling where the basic part of the pile (the base of the high-diameter pile) is located at the depth of the foundation occurrence. Depending on the ground conditions, in many pile structures the basic part of loading is carried by the pile base. The joining pile is an example of such piles[7]. It is a combined foundation including the base made in the soil, and the post elements (a bundle of piles or micropiles) joining the base with the girt (see Fig.1,2,3).

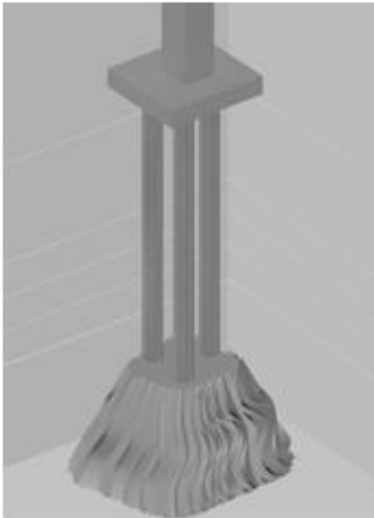


Fig.1



Fig.2

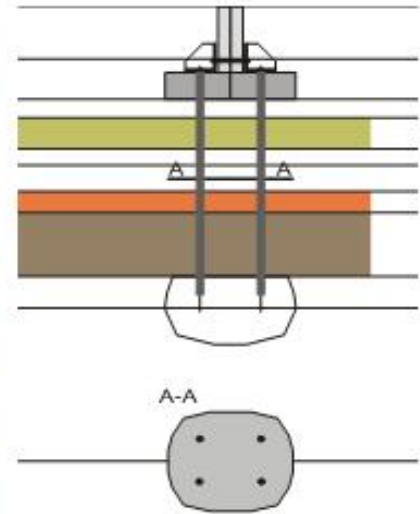


Fig.3

Fig. 1 The computer simulation of the pale. Fig.2, 3 A scheme of foundation reinforced with a bundle of piles joined by concrete base.

In the case of swelling soils, capacity of the system of piles or micropiles bundle with base joining them has playing the role of the anchoring pile. Additionally, after the injection, the anchors made of steel ribbed bars are introduced through the holes at the depth providing a proper anchorage. Loading conveyance from the building object to the carrying ground zone takes a place through the bundle of piles (posts) joined at the base with the solid of a big projection zone and volume. The solid is formed of the hardened soil-concrete generated from the deposited aggregate or the degraded rock with injections cement grout. Such a pile allows to distribute loading on a large surface; and in a consequence to reduced load intensity. It also allows to make a base increasing load capacity of the bundle of piles for improvement of soil capacity under existing foundations located on the grounds of low load capacity and on swelling ground. In many cases, direct capacity of the considered pile can be compared with high-diameter piles because of their base surfaces. The considered solution is very cheap and its realization does not require heavy equipment at the building site. In case of many pile solutions (high-diameter piles) the fundamental part of loadings is transferred by the pile base. The base manufactured requires high-diameter bore-holes made by means of heavy equipment. Such piles are rather expensive. In such cases, the joining pile can be an alternate solution. In case of such a pile, at least three prefabricated piles are introduced in a traditional way at the depth of occurrence of the bearing layer containing coarse sands and gravel on the surface. Next, injection is performed by the axial holes in piles, at least 40 mm in diameter; where the binding medium (for example cement grout) is introduced under pressure 3 – 150 bars.

Application of the joining piles under several conditions has been considered. Namely, it concerns the conditions where there is no layer of non-cohesive soil, and at the level of pile foundation where there are shale clays, shales, sandstones, fine sands, silts, clays etc., being a base for the element joining the pile heads. It seems to be possible to make an empty space necessary for generation of the pile base by explosion of an explosive material.

Ammonium saltpetre and potassic saltpetre were applied as explosive materials, and suitable detonators were used –and application of professional procedures could eliminate accidents[2]. The formed volumes could be filled with cement ground. Loading conveyance from the building object to the carrying ground zone takes a place through the bundle by piles (posts) joined at the base with the solid of a big projection zone and volume. The solid is formed by the hardened soil-concrete generated from the deposited aggregate or the degraded rock with cement ground. Joining piles can be manufactured to increase a load and a capacity of the existing foundations. Loading conveyance from the building object to the carrying ground zone takes place through the bundle of piles (posts) joined at the base with the solid of a big projection zone and volume. The solid is formed by the hardened soil-concrete generated from the deposited aggregate or the degraded rock with cement ground. The joining pile in the foundations stabilize the engineering objects from the burdens of (the settlement), and dislocation from swelling. One of the proposes of foundations solutions is the joining pile application after executing the analysis of on expansive soils was introduced in literature and numerous internet sources. For example: waffelmat foundation, mat raft foundation, adjustable foundation piercing system, at reinforced slab-on-grade foundation basement, vertical horizontal moisture barriers stiffened slab foundation, drilled shaft foundation, wall with footing and void space, post tensioned slab, type of reinforcing, slab and footing stiffness, and another[4]. Usability of the pile joining on the expansive soils gives an important advantage. On the made joining piles it is based on strip foundations (continuous footing) or raft on which one can put the plate prefabricated or to execute the plate pours out, laid over the swelling soil. An empty space can be filled with the isolating material, or can be left empty.

#### ***4. Analysis of Possibilities Foundations Situated on Expansive Soils of Objects with Comparatively Small Burden with Utilization of Joining Pile***

The foundations was analysed within the work over the subject on a few meters pales joining, in which post elements were done with the steel pipes, crossing through soils about doubtful carrying capacity to the layer soils in which basis joining the heads of pales has to be mounted. The comparatively easy for the realization of way foundations which one consists in the realization in the point of the slit central continuous footing, the joining pale was proposed (which is composed of three or two tubular) from tubular pales in the corners of the building (for longer buildings indirect pales e.g. what 6 m).The pipe moves to the soil by the means of hydraulic servo - motor, or by the usage of the light ram. The cement leaven moves in dependence on the porosity of the soil of the bearing layer, by the portions fills up the pipes and pressing or also cement injection. One can reach similar effects by the use of the hole in the centre (to cement injection ) sorcerer prefabricated serialized pale (the sorcerer pile) united on points of contact the sections of pipes - the connection sealed up epoxy resins e.g. the attitude of the pale joint is executed by the means of the injection of the cement leaven.

The realization of injections to the basis, is particularly easy for the pervormance in the soils which are below the layers of soils expansive the layer of soils steps out or sand can similarly execute the basis of the pale by the means of the injection of the cement leaven in demoted non-cohesive rocky wastes, alternatively after utilization of the explosive material, is to create the basis in the zone of the level of land water in the expansive soils well. Poles (prefabricated serialized piles with the opening in the centre) pressed by hydraulic servo - motor , we perform in this way that the resistance from hydraulic servo - motor, is balanced by the weight placed on the semitrailer. Piles in tubular casing by the means of light derricks in pipes about small diameters, it sealed up inside the line near higher pressures injections Sometimes the pipe also sealed up outside by the means of pneumatic gasket (the tube of the ball ) .On the made joining piles is bases where continuous footing or raft on which one can put plate prefabricated or to execute the plate pours out, laid over the swelling soil. The joining pile in moreover opens large possibilities cheap and stable foundation of wooden buildings.

#### ***5. Joining Piles Manufactured For Building in the Existing Foundations Were Considerably Destroyed***

As an example cracks occurred on the walls and floor cellars at the final phase of the major overhaul process at the building (see Fig 2). Also non-uniform deformations caused by ground settlement under a part of the building, on the ground swelling were registered. It is caused by vertical cracks on the walls in the cellar in eighteen reinforced concrete cores. The supporting structure of the higher storeys included reinforced concrete frames, combined as a monolith in reinforced concrete finials of the ceilings of channel plates. After 25 years later of operating, the internal walls were damaged. During adaptation, works the walls were replaced by new ones.

The substrate below the building should be consolidated after long time, and according to the geodetic measurements results a part of the object was settling, and another part was period rising. Particular layers of the substrate were tested very precisely. All the tested proved a complicated structure of the ground below the building. The soil cooperating with the foundations below the house is and it will remain the active substrate with variable geotechnical parameters because of swelling, or mineralization of organic parts of the soils occurring above the variable level of the underground water. Under the foundation of the reconstructed considered building, the heads were made by an application the pile bases done by injection in the gravel layer (see Fig 3). Injection of cement ground was done by the holes occurring in the bundle of four posts (prefabricated interval piles  $\phi 150$  mm and with the internal holes  $\phi 42$  mm and length 140 cm). The prefabricated piles are introduced at the established depth. The prefabricated piles are introduced at the established depth. Assembly was realized according to the requirement for the adapted building. The prefabricated piles are interval piles of  $\phi 150$  mm - it is the maximum diameter of the drill applied for hole drilling. The ready holes were checked at the building site. Introduction of the prefabricated element is preceded by making a hole  $\phi 150$  mm in the soil by means of the tapered point chisel. In this order, the assembly girt is mounted on the foundation masonry at the height dependent on the servo-motor and the element length. Next, the point chisel was forced into the hole. The reinforced concrete post elements were introduced into the hole by means of the same hydraulic servo-motor post elements were introduced into the hole by means of the same hydraulic servo-motor Assembly was realized according to requirement the typical for the adapted building.

## 6. References

- Burov, E.s., E.A. Sorocan , V.G. Cunichin 1996. Isseledovanie nabuchajuscich usadocnych glin rajone g. Kerchi. Osnovanija , Fundamenty , nr 4.
- Guanzhou Z. Zhiming X.( 2004): The application of blown tip pile used in the saturated soft soil land single stake economic analysis. Proc. Int. Conf. on Soil Nailing, Nanjing,.
- Holtz, W. G. 1983. The influence of swelling and shrinking of clays in the United States of America. Geotechnique , No. 2. Internet sources, Foundations solutions on expansive soils.
- Jaremski J.: (1991) Characteristic of weathering as foundation strata for pile construction on the basis of the researches of the Opole marls eluvium. Proc. 4<sup>th</sup> Int. Conf. Piletalk International, Kuala Lumpur,.
- Jaremski J.:(2005), The influence of physical and chemical processes occurring in the weathered Opole marls on the geotechnical parameters, Publishing House of Rzeszów University of Technology,
- Jaremski J.,(2006) Possibilities of application of rzeszowski pales In cohesive soils and the soft rocks. O możliwościach zastosowania pali rzeszowskich w gruntach spoistych i skałach miękkich.(in Polish),. Zeszyty Naukowe Politechniki Białostockiej, Budownictwo z. 28
- Jaremski J.: Creep property of Opole marls weathering on the base of the model laboratory research on the research in situ. Proc. 7th Int. Cong. on Rocks Mech. Aachen, A.A.Balkema, 1991.
- Jaremski J.:(1994) Influence of physical and chemical processes occurring in eluvium of the Opole marls and their influence on the geotechnical parameters, Proceedings of the 7<sup>th</sup> International Congress IAEG, Lisboa , A.A Balkema,
- Jaremski J.:(1995) Proposal for a method determining value of the maximum swelling of soil by example of the Opole marls eluvium and illite clays. Proc. of 8th Int. Cong. on Rock Mechanics, Tokyo, A.A.Balkema.
- Jaremski J.:(2010), Influence of moisture changes on physico - chemical processes and geotechnical parameters in soft rocks , Studia Geotechnica et Mechanica, Vol. XXXII, No. 1, 2010
- O'Neill, M.W., N. Poormoayed 19980. Methodology for foundations on expansive clays , Metodyka fundamentowania na gruntach ekspansywnych. J. of Geot. Eng .Div. No. 12.
- Richards, B.G., R. Peter , W.W Emerson 1983. The effects of vegetation on the swelling and shrinking of soils in Australia, Geotechnique, No.2.
- Wyles, R. 1983. The legal aspects of the influence of vegetation on the swelling and shrinking of clays. Geotechnique, No.2