Prebuilding, necessary for housebuilding on soft areas

Préconstruction, nécessaire à la construction de résidence dans les zones molles

J.HAVUKAINEN, Geotechnical Department of the City of Helsinki, Finland
I.VÄHÄAHO, Geotechnical Department of the City of Helsinki, Finland

SYNOPSIS: The ground conditions picked for building sites in Helsinki are worse than ever, boggy, marshy, muddy, clayey. Building in these areas can no longer be done by the traditional expedient of driving piles into the ground; rather must prebuilding measures be taken in the form of soil improvement. In Helsinki tentative limit values of settlements in different types of areas have been proposed for the purpose of estimating the need for prebuilding. The value of the land reclaimed by prebuilding for the purpose of house building is double in comparison with the cost of prebuilding.

1 INTRODUCTION

By prebuilding is meant the taking of improvement measures prior to actual building operations toward making an area of land or water that is unfit for building suitable for it. Furthermore, it creates conditions economically and environmentally better conductive to building. Prebuilding also includes the increasing of land suitable for building by reclamation from the sea. Among the most typical sites requiring areal soil improvement are muddy and clayey tracts, in which the thickness of soft ground varies between 3 and 30 m. The settlements resulting from construction measures would in such areas amount to 0,5 - 1,5 m in the absence of soil improvement. Owing to the duration of the settlement, maintenance measures would have to be taken in yard and street areas at a nearly annual rate.

Prebuilding measures are also required in areas of peat soil, as municipal technical facilities and yards could not be established on ground consisting on peat. Most typically, the thickness of such peat beds varies from 1 to 4 m. Under typical loadings the peat will usually be compressed 40 - 60 % of the initial thickness of the peat layer. When the groundwater table sinks, furthermore, the peat is liable to molder away.

In Helsinki, land has been acquired previously too by filling shallow shore areas to meet the needs of Harbour Authority. The most valuable building lots in the heart of downtown Helsinki were obtained in the 19th century by filling in the so-called Kluuvi Bay.

It was in the decade of the 1980s that prebuilding technology began to be used as a method of land reclamation. Then the administrative systems required for prebuilding operations were created in the city administration and prebuilding was included in the normal planning practice of the municipality.

Characteristic for prebuilding is that a project area must be large enough, at least 0,5 hectares, and measures must be done early enough, usually 0,5 - 3 years before actual building measures depending on the ground conditions and the used method.

2 THE OBJECTIVES OF PREBUILDING

2.1 Procurement of land for housing production

There are two possibilities to acquire new land to meet the needs of housing production. The primary and most economical way is to make land for house building in areas unsuitable for any building purposes. The secondary but still significant way is to improve the geotechnical quality of the land so that it fulfils the demands of housing production.

Between the years from 1980 to 1987 when prebuilding technology began to be used as a method of land reclamation, approximately 60 hectares of land was prebuilt at a cost of some 13...50 $/m^2 (= 50...200 FIM/m^2).

In the near future prebuilding measures have to be used more than ever and on more difficult sites. According to the prebuilding program made with the 1988 - 1992 housing program the total area of geotechnically very difficult sites is some 25 hectares or annually some 5 hectares. The average costs of prebuilding are about 125 $/m^2, which makes annually the total costs of 6 mill.$. The total area of the sites where the geotechnical quality will be improved to the demanding level is some 50 hectares or annually some 10 hectares. The average costs of prebuilding are about 40 $/m^2 which makes annually the total costs of 4 mill.$.

The worst areas are usually situated nearer from the center of the town than the others available. The value of the former ones is 0 $/m^2 before prebuilding and about 200 $/m^2 after that. The procurement value of the other sites to be reclaimed is about 50 $/m^2 before prebuilding and about 150 $/m^2 after that. So the value of the land reclaimed by prebuilding between the years from 1988 - 1992 will be fourfold in comparison with the initial value of the land and the cost savings will be remarkable (Table 1).

2.2 Reduction in building costs

The geotechnical conditions can be homogenized by prebuilding measures usually including not only residential quarters but also the streets and pipelines connected with them. Therefore any

Table 1. The annual area of the land acquired by prebuilding for house production in Helsinki, the initial and final value of the land, the costs of prebuilding and the average savings.

Initial quality of the land	Initial value $/m^2	Final value $/m^2	Prebuilding costs $/m^2	Cost savings $/m^2
Unsuitable for building (5 ha)	0	200	125	75
Under allowable (10 ha)	50	150	40	60
Average	40	165	60	65
Total (15 ha) mill.$	5	25	10	10

lightweight constructions or transitional slabs are not generally needed in prebuilt areas.

However, more remarkable savings in building costs can be achieved if cheaper methods may be used when laying foundations for streets, pipelines etc. They can be established on prebuilt ground by the layer of gravel or crushed stone without expensive piling (Figure 1). Generally, buildings have to be based on piles also in prebuilt areas. However, sometimes one-story and even two-story houses have been succesfully based on prebuilt soft clay ground without piles.

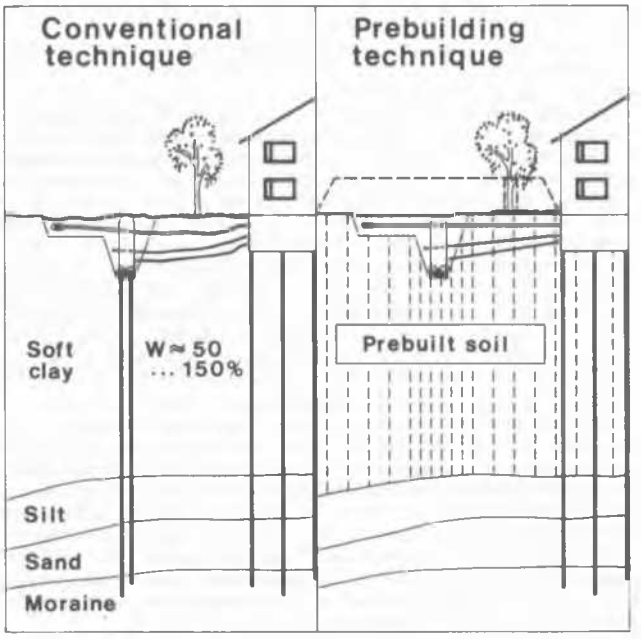

Figure 1. The advantages of the prebuilt land in comparison with the land built by the conventional technique on soft areas.

Big amounts of soil materials are used for prebuilding measures. By using surplus materials significant economies can be achieved. The price of material accumulating in excess during construction is only 20...50 % of the price of the material being purchased. Moreover, peat from the projects involving the exchange of soil material can be put to benifical use.

2.3 Improvement of quality and decrement of maintenance measures

Besides the functional safety of technical facilities also the conditions of general quality have to be fulfilled on built areas. The traditional building technique often leads on soft areas to a situation where the areal drainage of surface waters does not function as expected causing the formation of pools.Expensive maintenance measures would have to be taken in yard and street areas at a nearly annual rate. These and other kind of technical, visual and environmental disadvantages caused by settlements will decrease the commercial value of the land. All of these harms can be avoided or at least decreased by prebuilding.

In Helsinki, tentative values have been arrived at for allowable settlements in areas set aside for building sites. The values of allowable settlemets also give a point of departure in deciding when an area should be prebuilt. The curves have been used in Helsinki for a period of three years.

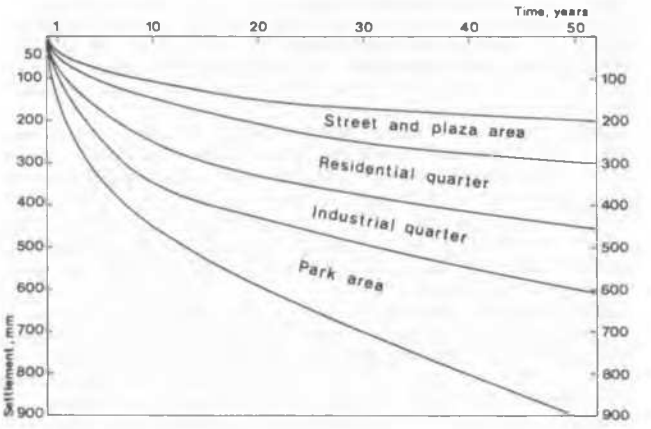

Figure 2. Proposal regarding the limit values of settlements in an area (not structures) for the purpose of estimating the need for prebuilding. The settlement values of areas connected with unsettled structures and structures based on the ground are calculated separately in each given case in connection with their ground construction planning. Piping, pavements etc. might require considerably stricter limits.

3 PREBUILDING METHODS

The most suitable method for application on an areal scale depends on the geotechnical conditions the thickness of the soft soil layers, the expected quality of the site after prebuilding and the time allowed for prebuilding measures.

Prebuilding measures in clayey areas include preliminary loading with or without vertical drainage, deep stabilization with lime or other binding agents, use of reinforcing fabrics or nets, reduction in permanent loads and, in some cases, exchanging of soil.

In areas of peat soil, the peat, as organic matter, usually has to be removed completely, and the exchange of soil material comes into the question. Stabilization methods for peat are also under development.

Moreover, besides the surplus materials from construction sites the City of Helsinki has the valuable prebuilding material of its own, coal ash, which is produced by three power plants. The ash is an economical substitute for uncrushed natural aggregates in projects involving filling operations.

4 PROCEDURE OF PREBUILDING ACTIVITY

4.1 Selection of sites and financial adjustments

Prebuilding in Helsinki is guided along the lines of a prebuilding program drawn up with a housing program five years in advance. The present program has been made for the years from 1988 to 1992. The lines of financing are drawn up for the same period.

Annually, the program and the financial situation are checked within the budgetary estimates of the City. Geotechnical Department determines the areas to be prebuilt with Building Program Bureau, City Planning Bureau and Land Policy Department and submits an estimate of the costs for inclusion in the municipal budget. The expences are collected totally or partially from the builders.

The need for prebuilding on soft areas is determined on the basis of the allowable settlements (Figure 2). The principal scheme of the decision procedure for selection of the sites to be prebuilt is seen in Figure 3.

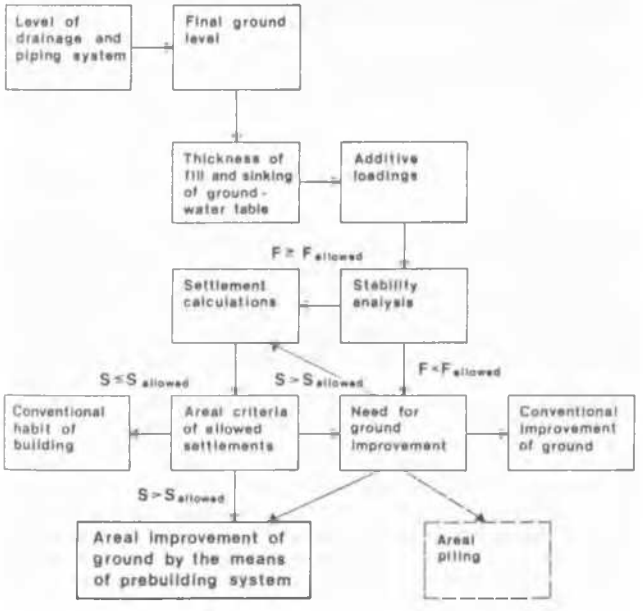

Figure 3. The principal scheme of the decision procedure for selection of the sites to be prebuilt. The decision will be made on the basis of economy, expected quality and the time available.

4.2 Planning, implementation and follow-up observation

The course of planning proceeds on the same principles as in the planning of ground improvement in general. The selection of the prebuilding method and the actual design will be made on the basis of the results of ground investigations and the aspects shown in figure 3. The objective in prebuilding is a settlement of at most 100 mm following prebuilding. On very soft areas the corresponding value may be 100...300 mm because it can be impossible to achieve a better value at a fair price. Additive measures of soil improvement, if needed, are planned in connection with the detailed planning of ground constructions for actual building.

The city plan covering the area should be ready or at very least sketched out before the prebuilding operations are started. Furthermore, the land should be owned by the city or its transfer to municipal ownership should be ensured. Prebuilding should be started as soon as possible, or at least between 0,5 and 3 years before housing construction.

The City Public Works Department carries out the prebuilding work on funds appropriated separately for the purpose by the municipal government.

Control of working procedure and follow-up observations connected with prebuilding are carried out by the Geotechnical Department. The typical measurements are settlement gauging and observation of hardening in stabilized zone or columns. On the basis of observation the design can be adjusted if permitted by the time table and prebuilding situation.

4.3 Actual building after prebuilding

The results of observation during prebuilding give a point of departure in starting the detailed planning of ground constructions for actual building. Each case is different and the detailed guidelines cannot be given how to plan and build on prebuilt land. However, the fact is that the solutions connected with actual building will be much more economical and technically significantly better than those without prebuilding.

5 EXAMPLES

5.1 The peat area of Tattarisuo

The area of 50 hectares is an example of a soft area where prebuilding measures have not been made although the land is practically unfit for building. The area has been covered with 2 - 4 m thick peat layer underlain by 10 - 12 m thick soft muddy clay layer. The peat has not been removed and the filling layer of about 2 m has been laid on it. From the late fifties nearly 300 halls for small industry and storing were based on the filling layer. The settlements of the buildings and streets are now on the order of magditude of 0,5...1,5 meters. The buildings have sustained settlement damage and the sewage system and drainage function very poorly. Consequently, exceptional measures are now required to renovate the area, for prebuilding can no longer be done on an areal basis.

5.2 The clay area of Torpparinmäki

The area of 1,2 hectares is located in a clay area where a humus layer c. 0,4 m thick is underlain by a soft clay bed 5...8 m. The clay water content was 60...85 % and the shear strength of undisturbed clay varied from 10 to 16 kN/m^2. The parameters of compressibility were m = 9,6...10,1, β = 0,14...-0.21 and the coefficient of consolidation was c_v = 0,2...0,6 m^2/a. Underneath the clay bed is a layer of silt 2...3 m thick which is underlain by glacial till layer.

The area was prebuilt by vertical drainage and preloading. The drain distance varied from 1,4 to 1,8 m and the thickness of the preloading embankment was 1,5 m. After 2,5 years the preloading was taken off and the total settlements measured during the time varied from 300 to 350 mm. In 1985 - 1986 twelve two-storey houses were built on the site. Five of them and a house of one story were based on the prebuilt ground without piles. The others were established by supporting piles of 10...12 meters. The residual settlements of the houses without piles were calculated to be 10...35 mm. Furthermore, the pipes and yards could safely be based on the prebuilt ground. An example of the settlements observed in six points of a house during 2,5 years after building is shown in figure 4.

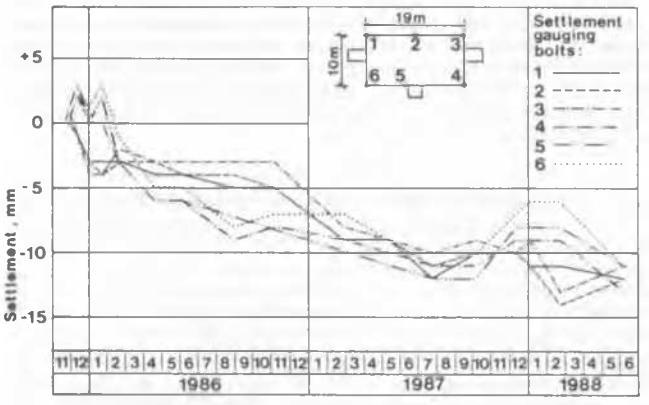

Figure 4. The settlements gauged from six points of a two-storey house during 2,5 years after building. The house was based on prebuilt soft clay.

The site was not geotechnically the worst but it functioned as a suitable experimental prebuilding site for coming projects. Furthermore, the careful design made possible to build two-storey houses on prebuilt soft clay area without piles. The costs of prebuilding were some 17 \$/m^2 of land on lot or about 50 \$/m^2 of floor space.

5.3 Other sites

In Helsinki, about 10 different soft soil sites purposed for house production have been prebuilt. The most remarkable of them are the muddy clay area of Pikku Huopalahti (c. 25 hectares), the peat area of Mellunmäki underlain by muddy clay (c. 6 hectares), the peat area of Kurkimäki (c. 10 hectares) and the clay area of Pukinmäki covered by the old fill (c. 4,5 hectares).

All types of the prebuilding methods have been used. However, the most general methods have been vertical drainage with preloading and deep stabilization by lime columns.

In the near future, some three sites will be prebuilt every year so that annually about 15 hectares will be improved.

6 CONCLUSIONS

Prebuilding has been found to be an advantageous soil improvement method in Helsinki. The land for the housing production has reclaimed between the years from 1980 to 1987 approximately 60 hectares. In the near future about 50 % of the land needed for the housing production will be acquired by prebuilding. The method has led to the laying of better foundations in soft ground. The value of the land reclaimed by prebuilding is fourfold in comparison with the initial value of the land and the cost savings are remarkable in comparison with the traditional building system.

Prebuilding can be considered as a better and cheaper alternative for the conventional method "building and postbuilding".

REFERENCES

Anttikoski, U. 1988. When prebuilding is necessary in Helsinki. II Baltic Conference on soil mechanics and foundation engineering, Tallin May 12, 1988, Comment speech.

Havukainen, J. 1985. The development of prebuilding. The Report of the Geotechnical Department of the City of Helsinki, Bulletin 43, Helsinki (In Finnish Only).

Geotechnical Department of the City of Helsinki 1983. Prebuilding, necessary on soft areas. Leaflet by the work team.