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## **EXCAVATION FOR UNDERGROUND PARKING IN SEVILLE (SPAIN). TREATMENT WITH REINFORCED INJECTIONS.**

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### **ABSTRACT**

For the accomplishment of a excavation of several levels, it is necessary the containment decision-making of the ground, and more in work situations under the phreatic level. The possible existing techniques in the market, they are various, each one of them with different applications. One of them is the technique of the treatment of the soil through the Technique of the reinforced injections. With this technique it is considered to accomplish a treatment of the perimeter of the zone to dig, in such a way that modifying the geotechnical characteristics of the soil, they could be obtained the required and cited conditions previously. For power to observe the great validity of this system, is presented a real case executed in the year 2002, in the city of Seville, in the south of Spain, together to the river Guadalquivir, the accomplishment of an underground parking of two plants, in a decrease soil quality, with next buildings of importance.

### **THE PARKING**

Seville, it is a city with a great evolution in its dimension, in its population, and with a historical transcendence of great importance.

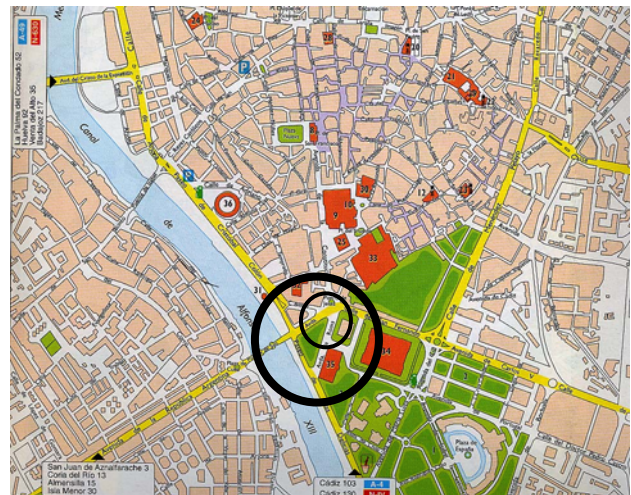
The current situation of the rolled traffic is made incompatible with the urban tracing of the historical centre of the city. And this is translated in the impossibility of finding parking between a great numbers of vehicles that regulation.

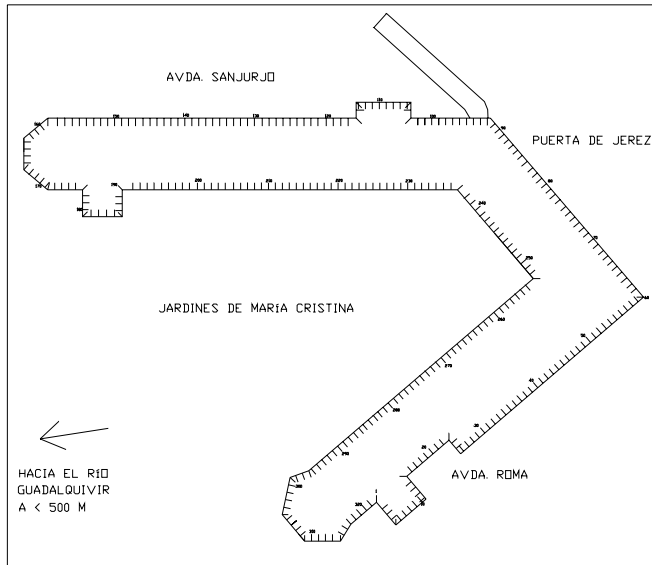
Before this situation the town hall of Seville has promoted the creation of a series of underground parking that ease this need. Even though the execution of this type of constructions bump into many problems outside of the merely administrative, on the one hand the need of be executed in a way rapid, to avoid and it extended traffic courts, additionally I give it the archaeological remains existence of various importance, need of be dated, and by third place the need of executing them through technical that minimize the impacts and damages that any performance of lands movement produces.

One of the parking in the one which attend all these circumstances, it is awarded it to the company MARTIN CASILLAS, of two plants, and certifying a V, in one of the greater conflict zones, in the one which for the solution of the containment technique more adequate was counted on the collaboration of the company CIMTRA.

### Location of the performance.

The parking is located in the avenues of Rome and Sanjurjo, occupying respectively each one of the arms of the V certified by the parking, being the vertex located in the Sherry Door, and remaining between them the gardens of María Cristina. In the lateral of the Avenue of Rome, we find singular buildings as are the Alfonso XIII Hotel, and the Headquarters of the Government of the Board of Andalusia.





### Geotechnical particularities

For the study of this performance are accomplished two geotechnical studies for the companies GEOPRIN and CIMTRA, in the one which are determined four geotechnical levels:

- 1º level: Artificial landfills of various origin and heterogeneous grain, with thickness middle of some 6 m. In them the results of the trials S.P.T. provide a  $N < 10$ .
- 2º level: Sands, clays and alluvial slimes of the river Guadalquivir, with lateral continuity and lateral changes of facies. Variable coloration of brown to grey or white. Thickness middle of 9 m and with a soundness of very brandish to brandish.
- 3º level: Alluvial gravel, with size songs until 10 cm and mainly sandy counterfoil with something of brown slime. The roof of the gravel is found environment 15 m, and has a mean power of some 11 m. It is detected a high degree of permeability in this cap, with the lost water total in the accomplished tests.
- 4º level: Blue marls, firm and of high soundness, unless in the contact with the gravel, in a thickness middle of 1.5 m of altered cap. They are detected as of 26 m.

The phreatic level is located from different levels in the accomplished campaigns, between 5.20 m and 7.50 m.

Could concluded initially, that the geotechnical particularities of the excavation, understood until the level of - 7,50, they are definable as very wrong, to be the practical whole the same, in a landfill area, or of character very soft, submitted to the movements of the phreatic level, therefore is made indispensable to accomplish it a containment system of the you push lateral.

### THE SOLUTION FOR THE EXCAVATION

The various technical of application should fulfil missions between other, as the following:

- Of containment of the ground, to avoid falls of material blocks during the operations of the excavation
- Of impermeability, to avoid the water entry during the execution as well as in the useful life of the parking to accomplish.
- Of consolidation of the perimeter ground, to avoid possible pathology problems in the next constructions.

Before the possibilities of selection, between the traditional containment systems, is opted for adopting a novel solution, the accomplishment of a treatment of the ground, of reinforcement of the subsoil, by means of the injections technique navies, to consolidate the area in the perimeter court of emptied anticipated, so that result stable to slide upon effecting to excavation of the emptied, without additional elements aid of containment.

In the field of the injections there are multiple technical and systems of application, and that it is not convenient to confuse, since this can carry to very serious mistakes of concept. Because of this below it will be made a short reference to the system of the reinforced injections and to its execution particularities.

#### Short presentation of the technique of the reinforced Grouting.

It is considered to create a discussed area zone, through the adequate modification of its geotechnical characteristic, in such a way that is to him ability of the characteristics required for its correct operation.

Through the application of a series of fracturation injections, with the introduction of the material adequate, is procured to endow to the ground of a great homogeneity, with a degree of cohesion, and with an internal structure, that permits ground a better respect behaviour corresponding natural area, increasing the adhesion capacity with the existing foundation, being able to arrive to be join with her, and increasing the capacity of support.

In essence, this treatment consists of the transformation of the initial mechanical state of the ground through three simultaneous processes that are described below:

A. - hydraulic Break of the ground in controlled form, so that the deformations are phased. This process permits the treatment with stable mixtures base of soils cement whose texture would prevent the impregnation even by mixtures decrease chemistries viscosity. The referred hydraulic break is produced with grout volumes applied through injection points, protected by glue muffs, disposed in steel pipes, with separation not superior to 0,5 meters between consecutive injection points of a same pipe. These injection points permit the repetition of the treatment, how much times is wished, after have forged the previously industrious mixtures, as well as the dosing in each injection phase of the volume and personnel wealth, what favors a control very accurate of the deformations induced in the subsoil.

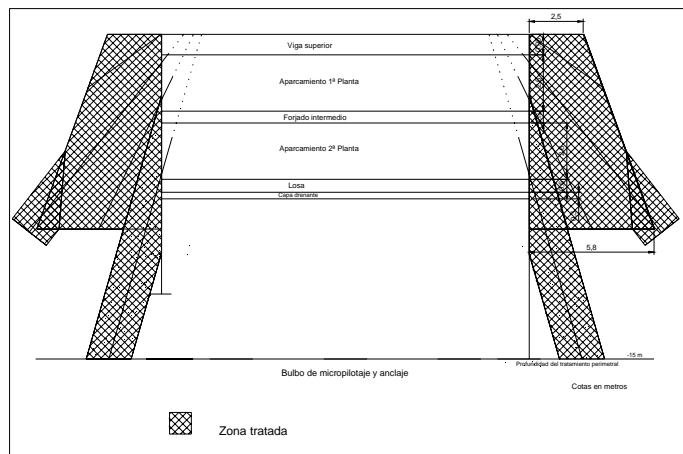
B. - Consolidation of the ground by pressure and setup. The regulation of the injection wealth forced by break of the ground, permits the application of pressures "staticss" growing, until the pressure last of close of each muff that is preset according to depth. These pressures produce the consolidation of the small area dominances (of centimeter dimension) understood between grout languages. In clayey soils can be appreciated this consolidation effect, since in perforations of pressures relief interstitials intermediate to those of injection is registered during the treatment a labeled abundance of water that ceases when is produced the forged of the injected mixture. The result of this process consists of the incorporation of the area of a form of cement languages toughened (resistance of more than 20 kg/cm<sup>2</sup> to 28 days of equal density manometers to the initial of the grout; logically very superior in the incorporation densificy of the ground) between those which is imprisoned a consolidated soil that, if is tried to consolidated clay for example to so alone 5 kg/cm<sup>2</sup> would have, according to the relationship of Skempton, a nearby apparent cohesion to 1 kg/cm<sup>2</sup>.

C. - Armed of the ground treated by the injection pipes. The steel pipes of the treatment remain finally of the same, intimately associated with volume of discussed area. The arrangement of the pipes is preset in fan, so that the maximum distance between pipes, within volume of the soil to try, it will be inferior always to two times the action radio of the injection. This last has been contrasted repetitively in nature soils very various (gravel, sands, clays) through the direct examination in quarries of the discussed soil, being verified that the distance of the shaft of the treatment drill to the edge of the zone in which the distribution of grout languages is massive, results always superior to the provisions, in form much more dependent from the resistance of the ground and from the injection pressures that from the texture most or less fine of the soil, circumstance this foreseeable by be tried, as already it has been indicated, of a break and consolidation treatment, not of impregnation of the soil.

The distribution in fan of the drills complementary pursues the one which the nails, that in fact constitute the injection pipes, and whose mechanical capacity can be reinforced in the accurate cases by final introduction of a round of steel in the interior of the pipe, serve of elements of sewn of the potential surfaces to slide of the ground under the charges that request it, what assures the mechanical behavior of the discussed soil.

Design of the applied system

Taking into account all the referred factors, including the structural requirements, of execution time, and of type of area to try is designed a system of reinforced injections treatment, with



equidistant fans, that have part of blind elements, and part of elements with muff, to the effect of minimizing the costs and to avoid the treatment in not anticipated zones.

The design of the different fans is adjusted to the geotechnical reality of each one of the zones to try, even though continue the plan type of section that is accompanied

The geotechnical parameters in the plan

For the purpose of to study the stability to slide of the court of emptied has been opted for a geotechnical profile conservative, to have account of the variability of the alluvial and of the fact that in the proximity of the gravel training, in the maximum depth levels of the alluvial, where the highest values of the internal rubbing angle would be more favourable to the stability, prevails the clayey slime.

The parameters in this way considered as of application in ground exist currently they would be:

- Of 0.00 to 6.50 m ( artificial landfills)  
 $\gamma = 1.8 \text{ T/m}^3$ ;  $c' = 0 \text{ T/m}^2$ ;  $\Phi' = 25^\circ$
- Of 6.50 to 11.40 m ( slimy clay)  
 $\gamma = 1.9 \text{ T/m}^3$ ;  $c' = 2 \text{ T/m}^2$ ;  $\Phi' = 24^\circ$
- Of 11.40 to 13.50 m ( sandy slime)  
 $\gamma = 1.8 \text{ T/m}^3$ ;  $c' = 0.5 \text{ T/m}^2$ ;  $\Phi' = 26^\circ$
- Of 13.50 to 16.00 m ( clayey slime)  
 $\gamma = 2.0 \text{ T/m}^3$ ;  $c' = 1 \text{ T/m}^2$ ;  $\Phi' = 15^\circ$
- Of 16.00 to 23.60 m (gravel)  
 $\gamma = 1.9 \text{ T/m}^3$ ;  $c' = 0 \text{ T/m}^2$ ;  $\Phi' = 40^\circ$
- As of 23.60 (marls)  
 $\gamma = 2.1 \text{ T/m}^3$ ;  $c' = 9 \text{ T/m}^2$ ;  $\Phi' = 28^\circ$

The phreatic level is considered in their/its/your/his position more unfavourable, this is to some 5.00 m of depth.

The parameters considered for the discussed area, and using conservative parameters, they would be:

$$\gamma = 2.0 \text{ T/m}^3; \quad c' = 15 \text{ T/m}^2; \quad \Phi' = 28^\circ$$

The previous stability checking

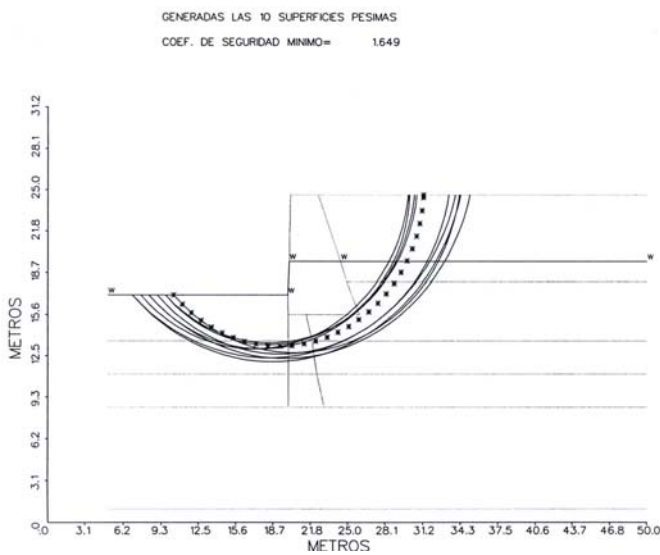
They were effected with previous character, two stability analysis of the joint.

On the one hand the stability calculation to turn and sliding of the treatment prism considered as wall of gravity containment, of the that are obtained safety margins totally adequate. To turn provides a safety coefficient of 2.60, while to slide is obtained a value from 1.85.

On the other hand it was effected the stability analysis of the geotechnical profile typical of the ground, including in the court of emptied, the injected solid, with the indicated parameters. The calculations were effected with the program STABL that uses the method of Spencer for the numerical stability calculation of the slices of the sliding volume.

An advantage of this program is their/its/your/his capacity of generating a considerable number of cylindrical surfaces of circular directress, of movement hypothesis, and to select the worse ten emphasizing, for the one which is determined the coefficient is safety to slide.

It is attached the figure where are referred these last, for the studied case, in the one which with the indicated data is obtained that for the situation from worse character the safety coefficient ascends to a value of 1.65, value very acceptable for the type of performance that it is being studying..



## THE EXCAVATION WORKS

To the effect of proving the efficiency of the used system, it is in the moment of the accomplishment of the quarry when these are shown in all intensity, and of this manner can be cited the following situations of work that imply the advantage of the used system:

- Vertical courts: stable in all its length, without creating you push horizontal, therefore it can be executed the whole the trench of an only occasion.



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- Independence of the interior construction of the dug environment, there is no external solicitations, because of this is outlined the elements pre-manufactured execution separate at least 50 cm of the accomplished court.
- Selective treatment, the area in worse conditions is the one which receives a most extensive treatment, while the zones with a better behaviour are seen affected in smaller degree
- Not alone stability to the you push horizontal, but also to load efforts in treatment edge, as can be observed of the image where the machinery is located in the limit of the court..



- Before the recommendation of a superficial protection of the court before the atmospherically agents, is adopted the placement of a drainage plate, of whose placement is deduced its void functionality as waterproof you, to indicate that was not put any perimeter drainage of the joint.

## THE DATA OF THE WORK

The execute company of the solution of the reinforced grouting was CIMTRA S.A., that executed the treatment during the year 2002.

The number of industrious fans was of 321, with a total installation of 10.953 meter of muff pipe, and 2.728,5 meters of blind pipe. The amount of the operations was in connection with 1,45 million of Euros.

The corresponding section to the Avda. Sanjurjo it is in operation from beginnings of 2003, being in phase of ending the corresponding section to the Avda. of Rome, due to the archaeological findings, that they have provoked a notable lag in its execution.

## CONCLUSIONS



For so much, and as conclusion, the solution of the reinforced grouting with muff pipe, is presented as an alternative to the traditional techniques, with some efficiency results and evident application, as has been shown in the case presented in this motion.

Even though it is fundamental to indicate that due to the complexity of the technique, it is of great importance to know the technique on the part of the technical personnel that apply it, but at the same time is of great importance the specialization of the Company that execute it, such and as has demonstrated the Company CIMTRA, in the execution of the emphasize presented.

One must take into account to a mistake by a wrong execution, by inexperience, or by not to apply the methods or adequate parameters, not alone would provoke a serious prejudice for the promoter of the performance, but also would put in judgement fabric the own system. Because of this to insist on the need of specialization and experience demonstrated in the application of the concrete system of application.

#### ACKNOWLEDGEMENTS

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The authors of paper are members of the Investigation Groups of the University of Alcalá (CCTE2006/F34), with title: "Intervention in the Patrimony And Sustainable Architecture". (Contact us in: [fernando.casa@uah.es](mailto:fernando.casa@uah.es) or, Edificio Multidepartamental. Universidad Alcalá. C/ Cifuentes nº 28. Guadalajara 19003. Spain

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