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Review Article

Evaluation of the Containment Curtain Staking Influence on Underground Water Flow through the Seep/W Software Utilization

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Abstract

With the increasing urbanization and land use, engineers are forced to seek solutions in underground works. In order to enable the implementation of this methodology, it is often used a solo containment system, being it through retaining walls, diaphragm walls, or as usual as it is in Brazil, concrete pile walls. When there is the necessity to achieve greater depths, a common problem occurs while reaching the water level: the outcrop of the water table. Therefore, it is necessary to use, in addition to a containment system, a groundwater lowering system; being it temporary or permanent - or both. The combination of these two systems, containment and groundwater drawdown, then becomes necessary for the execution of underground works in these exceptional cases. The study of the underground water flow behavior and their permanent or temporary drawdown, as well as the influence promoted by concrete pile walls, are topics with low academic production in Brazilian bibliographies. This article aims to deepen the knowledge about the greater efficiency and economy provided by the use of these two systems together by analyzing and producing information in the construction field.

Keywords: Containment; Water; Software

Introduction

The objective of this paper is to analyze the influence of the containment curtain staking on underground water flow (juxtaposed stakes) using the Seep/W calculation software of the Canadian company Geo-Slope International Ltd.

It will be shown a real case work in a building of 17000 square meters, located in Olímpia, Sao Paulo, Brazil.

In this case, the water table was, at certain points, 0,60 meters deep (Figures 1-6), being necessary to dig an underground pavement to a depth of 3,50 meters. Additional block foundations, underground reservoirs and lifts shafts were also built; totalling 5.50 meters depth.

Figure 1: Situation before lowering system.

Figure 2: Situation before lowering system.

Figure 3: Comparison situation before lowering system.

Figure 4: Comparison situation after lowering system.

Figure 5: Situation after lowering system.

Figure 6: Situation after lowering system.

Therefore, a temporary water table lowering system was designed through drainage wells.

After the complete execution of the system and the excavation in accordance with the project quota, it was noticed that the few wells located near the containment curtain of the project were not as necessary for the effective lowering of the water table as other wells in the project.

The purpose of this project is to understand, with the help of a software called Seep/W, how the containment curtain line influenced the flow of underground water by naturally lowering it only through its execution.

By understanding how the containment curtain affected the water table, it will be possible to develop a more succinct project with the same efficiency but with reduced costs, thus improving the cost-benefit rate – the main goal of an engineering project.

Development

Methodology

All the basic and theoretical concepts used in this study were extracted from research sources, such as books and technical journals. For additional information in the general development of this research, specialized websites were also consulted.

The lowering of the water table is an issue rarely studied in Brazil, therefore, few sources of national bibliographic information were found. The work that was taken into account the most was the calculation system and downgrade proposed by Alonso, U. R. (2007) Rebaixamento Temporário de Aquíferos, São Paulo, Oficina de Textos.

Materials

The methodology of this article consists in analyzing, through the use of the Seep/W software, the influence of the containment curtain stacking on the underground water flow.

This consideration became known after the execution service of a groundwater lowering system project in a hotel company in Olímpia, São Paulo, Brazil.

This project was made by means of drainage wells specifically calculated with the local soil data obtained.

After the project was fully implemented by the business owner, a peculiarity was noticed: some drainage wells, located near the containment structure, were not useful.

Then, the main question that gave purpose to the writing of this article emerged: how and how much do the containment curtain structures impact on underground water flow?

All materials and procedures used in the investigation of such problems will be listed in the following topics.

Building Data

The project to be studied is a hotel and water park complex, in the city of Olímpia, in the state of São Paulo, Brazil.

The hotel and water park complex have 04 towers, each with 17 floors, an underground pavement completely buried, and a ground floor half buried.

Local soil data

The soil survey report was made by means of a Standard Penetration Test (SPT) in November 2012.

A total of 16 SPT holes were made in an area of 17000 square meters in order to obtain a report which characterized the soil and observed the water level in the corresponding month of its execution.

Based on the values found in the SPT report, two 3D modeling pictures with the coordinates XY of each SPT hole were made, one for the water lever (Figure 7) and other for the impenetrable level (Figure 8).

Figure 7: Water Level Digital Modeling.

Figure 8: Impenetrable level digital modelling.

Analyzing the SPT report, it was observed that the water level had a peak of outcropping in the upper right corner of the building, influenced also by the geological characteristics of the place. In this point, the impenetrable level is very close to the surface, about 7 meters deep. In some points near this critical region there were water levels very close to 0,60 meters from the terrain surface.

In general, the NA had an average value of 3,40 meters deep.

The soils characterized in the SPT report were: sandy clay in the first 3 meters; clay silt from the third to the sixth meter; silt sand from the sixth until the fourteenth meter, in this case, the end of the SPT.

Temporary water table lowering system data

Initially, the method proposed to lowering system calculation consisted in dividing the business area into 4 parts of 50 x 50 meters.

After calculations, as recommended by Alonso's formulas (2007), there was a need for each part to place 08 drainage wells with a diameter of 0,50 meters and a depth of 12 meters (Table 1). It was 4 parts, and then the total number of drainage wells was 32 units.

Well Diameter (meters)	0,50
Well Radius (meters)	0,25
Soil Permeability Average (meters/second)	0,00001
Pit Width (meters)	50
Pit Length (meters)	50
Limited area (square meters)	2500
Well Equivalent Radius (meters)	28,20
Water Level Height as of the rock (meters)	12
Height of Water Table Lowered to rock (meters)	7
Influence Ray of Drainage Well (meters)	106,1
Total System Flow (cubic meters/second)	0,011
Number of Drainage Wells (units)	8
Distance Between Drainage Wells (meters)	25
Flow of Each Drainage Well (square meters/second)	0,0015
Drainage Well Filtration Length (meters)	2,10
Flow Rate in the Filter (meters/second)	0,00047
Groundwater Reduction (meters)	3,60
Water Height Inside the Drainage Well to the rock (meters)	3,40
Drainage Well Length (meters)	10,70
Extra Safe Additions (meters)	1,50
Total Drainage Well Length (meters)	12,20

Table 1: Original Temporary Water Table Lowering System for Each Quarter.

To assure the correct work of the system, an executive methodology was adopted. This methodology was carried out as described below:

I. Implementation of provisional wells, with a diameter of 1 meter and depth of 2,50 meters strategically positioned to help draining some water found in excess on the surface, enabling the ground to start next steps.

II. Implementation of trenches with width of 0,60 meter and depth of 1 meter in all of internal perimeter of the building land;

III. Implementation of drainage wells after steps I and II, which could take from 10 to 20 days depending on the conditions presented in the work environment.

Seep/W software application

With the software Seep/W a computational analysis about the influence of stacking of the containment curtain on the underground water flow was made.

A graphic based on CAD (Computer Assisted Design) was used in the analysis. It was drawn from the software Seep/W to create a digital model of the case.

The software worked with the building real dimensions. Data regarding the soil, hydrology and water levels variation found in the SPT report were also used.

In addition, the containment curtain stacking line location has also been carefully added to the software.

After organizing all data properly, it was added to the contour conditions of the software, trying to keep the digital model as close as possible to the real situation experienced.

Inserting data and parameters into the seep/W Software

The digital model started in Seep/W software by inserting some project data as size, width and length of the building and so, an initial analysis plan was created (Figure 9).

Figure 9: Analysis plant set up and configured. the ticker line represents the containment curtain.

On average, from the 6 meters depth, only silt sand was found until the impenetrable surface. Since the analysis was made using a flat view perspective (a view from the top), it was not possible to define different layers of materials on top of each other, so only the silt sand was adopted, presenting permeability $k = 1 \times 10^{-6}$ cm/sec. As the software only accepts input in meters, it was set as $k = 1 \times 10^{-8}$ m/s.

After that, a fictitious region of 1 meter wide was created to simulate the line of containment curtain. In the real situation, the containment curtain line is arranged by concrete piles of 0,40 meter spaced every 0,70 meter.

A weighted average was calculated and the permeability k = 1 x 10^{-8} cm/s (for software k = 1 x 10^{-10} m/s) in the region signalled by the containment curtain.

After the materials were defined, the limit parameters of the thickness of the soil layer were added, which means the boundary of the impenetrable level was defined. From the data obtained in the SPT report, 20 meters were adopted as average thickness.

Then, the hydrological parameters were inserted into the software. The results of the groundwater level curves in digital model were in accordance with the results and graphs obtained by the SPT report (Figure 10).

Figure 10: Hydrologic parameters and impenetrable boundary added to the software so that they match the actual SPT survey data.

Generating analysis in Seep/W software

After obtaining the necessary data, the software started running the calculation process. The results obtained can be seen in figure 11.

Figure 11: Groundwater contours recessed after insertion of the retaining curtain element.

From these software results, 4 sections in plain view were chosen (Figure 12) and then charts were drawn up to analyze the water level variation as it moved away from the containment curtain line (Figures 13 and 14).

Figure 12: Plan of Analysis Sections.

Figure 13: Variation of underground water level without staking.

Figure 14: Variation of underground water level with staking.

Analysis of results

It could be possible to infer from Figure 14 that, after inserting the containment curtain element, there was a general lowering of the water level.

When observing the points of the lower face of the hotel, where the curtain makes a curve and seems to "embrace" the building, before the insertion of the staking representative element, the water was being maintained at 1,20 meter and, after insertion of the representative element, the water table was lowered to 2,20 meters, thus representing 1 meter of effective lowering in this area.

However, as it progressed northward, becoming more distant from the containment curtain, this difference gradually decreased until it stabilized at the groundwater level before the insertion of the representative containment element, being it in about 80 meters away from the curtain.

From the results obtained, it was possible to recalculate the water table lowering system previously designed.

System recalculating and analytical comparisons

Based on the results obtained through the software, the height value of the water table was modified, and the system was recalculated. No other modifications, rather than this new water table level analysis, was made, and so it was possible to compare the new system sizing based only in the correct theoretical containment curtain influence in the water level.

By the same means, the new dimensioning was executed, dividing the business into 4 parts of 50x50 meters adopting wells with the same diameter of about 0,50 meter.

The interaction of the formulas resulted in wells with a slightly lower depth than initially calculated.

The new total depth of the wells resulted in 11,50 meters. The previous system was 12,20 meters.

The simple fact that the reduction in the height of the water level led to a diminution in the depth of the drainage wells at 0,70 meter shows that this real interpretation about the containment curtain influence can generate huge savings in materials, time and workers to the business constructor.

The resizing results may be followed in Table 2.

Well Diameter (meters)	0,50
Well Radius (meters)	0,25
Soil Permeability Average (meters/second)	0,00001
Pit Width (meters)	50
Pit Length (meters)	50
Limited area (square meters)	2500
Well Equivalent Radius (meters)	28,20
Water Level Height as of the rock (meters)	11,50
Height of Water Table Lowered to rock (meters)	7
Influence Ray of Drainage Well (meters)	95,50
Total System Flow (cubic meters/second)	0,011
Number of Drainage Wells (units)	8
Distance Between Drainage Wells (meters)	25
Flow of Each Drainage Well (square meters/second)	0,0015
Drainage Well Filtration Length (meters)	2
Flow Rate in the Filter (meters/second)	0,00047
Groundwater Reduction (meters)	3,50
Water Height Inside the Drainage Well to the rock (meters)	3,50
Drainage Well Length (meters)	10
Extra Safe Additions (meters)	1,50
Total drainage well length (meters)	11,50

Table 2: Recalculated Water Table Lowering System for Each Quarter.

Conclusion

According to the facts presented in this work, it was concluded that the stacking of the containment curtain only contributed to the groundwater lowering, close to the staking process and not throughout the construction, as imagined at the beginning of this study.

However, it could be perceived that in regions where the staking "embraced" the building, creating a kind of region that we can call "protected" by the stacking line, the water table had a considerably large drawdown from 0,8 to 1,0 meter approximately regarding its original level. But as the staking ceased to "embrace" the building, its influence on the effective lowering of the water table was very small, being it around 0,40 to 0,60 meter.

The limit of containment curtain staking influence was seen up to 80 meters from the stacking line, since there was no effect on the water flow.

It is necessary to point out that this limit distance is not an universal parameter, but it is possible for similar cases to be based on it. Other very important observation is that each case will require a new analysis in the Seep/W software – that means adding new parameters of the soil, water level, containment curtain density and, mainly, its geometry and layout settings.

It can also be concluded that the fact that some drainage wells were not useful could have occurred for other reasons rather than the containment curtain stacking line influence. For example: the bad execution of the well *in situ*; or perhaps because the well has been located in a region surrounded by a soil with lower permeability; the influence of the adjacent wells can also be considered and, finally; the water may simply have infiltrated towards regions of higher hydraulic gradient where the percolation was easier, thus not reaching to be captured by these tested wells..

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