DOI: 10.5585/ExactaEP.v11n3.4562

The use of polymer slurry as an economic and sustainable way to build diaphragm walls – a case study of a construction work in São Paulo/Brazil

Utilização de fluido polimérico como uma forma econômica e sustentável de construção de paredes diafragmas – um estudo de caso de uma obra na cidade de São Paulo/Brasil

João Alexandre Paschoalin Filho
Professor do Programa de mestrado em Gestão Ambiental e Sustentabilidade da Universidade Nove de Julho – Uninove.
São Paulo, SP [Brasil].
jalexandre@uninove.br

Antonio José Guerner Dias
Professor da Faculdade de Ciências da Universidade do Porto – UP.
Porto, Porto [Portugal]
agdias@fc.up.pt

Eric Brum de Lima Duarte
Engenheiro Construtora W.Torre
Programa de Mestrado Profissional em Gestão Ambiental e Sustentabilidade – GeaS/Uninove
ericbrum@uol.com.br

Abstract

The Civil Construction Industry is one of the first economic sectors to react to the stimulus of favorable economic conditions of a country. In such a scenario, new tools for handling and reusing solid waste from construction sites have been extensively discussed in technical conferences. This paper is a case study of a construction work in the city of São Paulo, Brazil where a polymer slurry was used instead of a bentonite-based one as stabilizing fluid for excavation work on diaphragm walls. Based on the evaluation of the data obtained in the cited case study, it was possible to conclude that the use of polymer slurry in the excavation of diaphragm walls is technically and economically feasible, besides presenting several environmental advantages in comparison to the use of bentonite slurry.

Key words: Civil construction industry. Sustainability. Solid waste management.

Resumo

A indústria da construção civil consiste em um dos primeiros setores econômicos a reagir às condições econômicas favoráveis de um país. Neste aspecto, novas ferramentas de manejo e reuso dos resíduos sólidos produzidos nas obras têm sido extensivamente discutidas em encontros técnicos da área. Este artigo apresenta um estudo de caso de uma obra localizada na cidade de São Paulo, Brasil, em que foi utilizado polímero como fluido estabilizante na escavação de paredes diafragma ao invés de lama bentonítica. Por meio dos dados obtidos por esta pesquisa, foi possível concluir que a utilização de fluido polimérico na escavação de paredes diafragma é técnica e economicamente viável, além de apresentar diversas vantagens ambientais em relação à utilização de lama bentonítica.

Palavras-chave: Indústria da construção civil. Sustentabilidade. Gestão de resíduos sólidos.

1 Introduction

According to the Brazilian Institute of Geography and Statistics (IBGE, 2011) the Brazilian Civil Construction sector showed a growth rate in 2010 of 11.6% – the best result for the last 24 years. Furthermore, this sector generated more than 329,000 formal jobs. It is estimated that it accounts for investments surpassing U$ 45 billion a year. The demand for labor has also grown accordingly, generating 62 indirect jobs for every 100 direct jobs.

Nevertheless, although civil construction has an important social role, helping to directly reduce the home construction and infrastructure deficits, which are crucial factors for a country's development, it is also responsible for the high consumption of natural resouces, once most of the raw material used in construction is extracted from natural deposits. According to Dias (2004), around 45% of the resources in Brazil extracted from nature reserves are utilized in construction.

Although not always obvious for ordinary citizens, the quantity of waste generated by construction activities represents a highly significant proportion of urban waste. It is estimated that construction and demolition waste (CDW) may account for 50% of the waste generated by some municipalities in Brazil (ULSEN et al., 2010). In the city of Salvador (Bahia), CDW represents 45% of the total volume of urban waste (UW) generated daily (AZEVEDO et al., 2006), whereas in the cities of São Paulo (SP) and Rio de Janeiro (RJ) it is only 21% (GOMES et al., 2008). Morais (2006) presents data related to a few medium-sized and large cities in Brazil in which the mass of CDW, as a percentage, varies from 41% to 70% of the total mass of urban solid waste.

Currently, it is increasingly common to hear discussions about sustainability in the construction industry and about environmental management tools for this sector. The concept of sustainability extends beyond practices related to the preservation of natural resources; it also comprises several different areas such as sociology, economics, politics, ecology, culture, and environment, to name just a few.

Due to the growth in the construction industry and the recognized value of management tools to reduce its impacts on the environment, sustainable processes are becoming increasingly widespread and gaining more relevance in current construction sites. The fact of choosing sustainable practices to build a facility can affect positively all the other sectors involved in the construction process, resulting in lower costs of services and materials, as well as providing a better quality of life for the labor force and everyone else who benefits from the building itself.

In building construction there are several sustainable technologies and products available in the market that are increasingly being used in Brazil. The use of polymer as a substitute for bentonite to stabilize excavations in the specific task of building diaphragm walls could be cited as an example.

It should be stressed that the practice of building diaphragm walls is widely used in Brazil, once most buildings feature several floors which are below ground level, and that this kind of walls is needed to resist the thrust of the soil against the structure and to ensure the stability of the underground floors.

Even though it is more frequently used than polymers, bentonite slurry causes severe impacts on the environment, because the waste generated from its use, besides being a contaminant, is very difficult to be disposed of. On the other hand, the polymer has the advantage of being biodegradable, which makes it easier to dispose of and reduces the environmental impact caused by the excavation of the diaphragm wall.

The use of a biodegradable product in the excavation of diaphragm walls presents a profitable cost-benefit ratio because it makes it possible to build according to the technical specifications of certain environmental cerifications, such as Leadership in Energy & Environmental Design (LEED) and AQUA, as well as to lower costs with the transport and disposal of its waste.

This paper presents a comparative study between two kinds of products used to stabilize the excavation of diaphragm walls: bentonite and polymers. This paper will clarify this issue, as well as the advantages, disadvantages, costs, and implementation process, among other relevant information.

Thus, the present paper intends to show that the implementation of sustainable practices (such as the use of polymer slurry), can impact positively its results, provided they are based on a strategic planning aligned to the reality of the work, reducing costs, in addition to lowering its environmental impact.

2 Building diaphragm walls as contention works

A diaphragm wall can be defined as a vertical wall with different depths and thicknesses made of reinforced concrete lamellas that absorb axial loads, water and soil thrust, and kind of solicitant efforts. This type of construction is spreading due to the many advantages that it offers and the variety of instances in which it can be used.

The process of building a diaphragm wall can be considered as a relatively simple one, but to obtain a satisfactory result it is fundamental to use especific material and equipment as specified by the Brazilian Technical Standart ABNT: NBR 6122:2010 "Design and construction of foundations" and ABNT: NBR 6118:2007 "Design of structural concrete - Procedure".

The building process basically comprises four distinct steps: (a) building the guide wall; (b) excavation of the wall; (c) building and placement of the steel frame and the joint plate; (d) concreting the lamella and excavation of the ground to get access to the wall; and (e) whenever it is necessary, placement and perforation of the risers. During the process of building a diaphragm wall some special equipment is needed, such as a cutting auger, an auxiliary crane, slurry reservoirs, and suction and injection pumps.

According to Saes et al. (1998), diaphragm walls present better performance than other kinds of contention for the following reasons:

a) they can be implemented in almost any type of terrain without needing to lower the groundwater table;
b) they form a watertight piece, therefore avoiding the percolation of water into the excavated ground;
c) they adapt better to the perimeter of the containment and can be used without any type of shoring.

As the soil is excavated, the drilling mud is introduced into the trench and pumped to the reservatory. The drilling mud efficiency will depend on its physical and chemical properties, that is, density, viscosity, gel consistency, control of the filter and plaster, and inhibition of the hydrating clays (LUMMUS; AZAR, 1986).

Among the drilling muds used to stabilize excavations, bentonite slurry is the most used. The purpose of this drilling mud is to counter the thrust from soil and water, avoiding the collapse of the faces of the trench during the excavation work. Bentonite slurry has a stabilizing characteristic because it forms a layer similar to a gel, called "cake," that penetrates into the voids of the soil, making the wall more uniform and offering better stability (CARDOSO; SHIMIZU, 2002).

Although the stabilization of perforations using bentonite slurry is the most commonly-used method, currently there are several restrictions to its use by norms from environmental and labor health governmental agencies. In addition to causing environmental impacts, such as soil contamination, bentonite can also affect the health of people working directly with this kind of clay.

According to Brazilian Technical Standard ABNT NBR 10004:2004 "Solid Waste – Classification", bentonite slurry is classified as Class II B Waste – inert and non-hazardous material. When it is mixed with soil from an excavation, it must be disposed of on sanitary and/or industrial landfills where Class II material is accepted. The waste generated by bentonite slurry makes the soil clog and can cause perishment of some fauna and flora specimens, generating a great impact should a large disposal happen in the same region (MOTA, 2010).

The increasing restrictions imposed on the use of bentonite slurry by Brazilian environmental agencies has generated a demand for new technologies related to the stabilization of excavations. The use of polymers as substitutes for bentonite is closely associated to the fact that the polymer is a biodegradable material, thereby facilitating the disposal of materials coming from perforations (MOTA, 2010).

Polymers are classified by Brazilian Technical Standard ABNT: NBR 10004:2004 as a Class II B Waste – inert and non-hazardous material, and when they are mixed with the soil from the excavation, they must be disposed of on sanitary or industrial landfills where Class II material is accepted. The treatment applied to enable the final disposal of the polymer slurry remaining in the storage tanks is based on the application of calcium hypochlorite to destroy the molecular chain of the polymer and of hydrochloric acid and/or sodium hydroxide which have the function of neutralizing the alkalinity of the slurry, transforming the fluid into residual water. After this treatment is applied, the polymer slurry can be disposed of without harming the environment (MOTA, 2010).

The Figures 1 and 2 show soil from excavations using bentonite and polymer slurries as drilling muds. The physical aspect of the construction site and the process of moving and disposing the excavated soil are very important issues to be considered for making the best choice.

Figure 1: View of the excavated soil using bentonite slurry
Source: The authors.

Figure 2: View of the excavated soil using polymeric slurry
Source: The authors.

Observing the above-shown figures, it is possible to note that the soil coming from the excavation using bentonite slurry retains a high level of moisture and is contaminated. This physical state makes it very difficult to move, transport, and dispose of the material and impacts negatively on other services performed at the site. As to the excavation using the polymer slurry, it is possible to note that the soil is drier and much easier to move and does not contain any contaminating agents.

3 Results and discussions

3.1 Characteristics of the studied construction site

The studied construction site is a commercial building with 16 floors located at President Juscelino Kubistchek Av. in the city of São Paulo, Brazil. To create the contention with a diaphragm wall, it was necessary to excavate 3,344.27 m^3 of soil, equivalent to approximately 4,682.98 tons. The diaphragm wall has thickness of 0.4 m, depth of 15 m deep, and surface area of 8,360 m^2. Figure 3 shows a view of the construction site.

3.2 Achieved results

Before building the diaphragm wall, a study was performed to identify the best alternative to attain the stabilization of the excavation that had to be done. For this purpose, two alternatives of drilling muds were considered: bentonite and polymer slurries. The costs were obtained based on market tenders in São Paulo in 2011 during the construction process.

Figure 3: General view of the construction site
Source: The authors.

The Tables 1 and 2 show the comparison between the two alternatives that were evaluated for the present study.

Table 1: Disposal cost of soil using bentonite slurry

Total volume of excavated soil (m^3)	3,344.27
Total volume of contaminated soil to be disposed of (m^3)	836,07
Total volume of non contaminated soil to be disposed of (m^3)	2,508.20
Total cost of non contaminated soil to be disposed of (US$)	53,675.50
Total cost of contaminated soil to be disposed of (US$)	45,983.80
Total cost of the total generated soil to be disposed of (US$)	99,659.35

Source: The authors.

Table 2: Disposal cost of soil using polymer slurry

Total volume of excavated soil (m^3)	3,344.27
Total volume of contaminated soil to be disposed of (m^3)	0.00
Total volume of non contaminated soil to be disposed of (m^3)	3,344.27
Total cost of the total generated soil to be disposed of (US$)	71,567.38

Source: The authors.

According to Table 1, it can be noticed that considering the total volume of the soil to be disposed of, approximately 25% is contaminated material, whose total cost for disposal (including transportation) is 1,17 times superior to the value of the disposal cost for the non-contaminated soil. That said, it can be noticed that the cost for the disposal of the contaminated material is 46% of the total cost. Compared to the alternative using the polymeric slurry, where the disposed soil is not considered as contaminated material, the costs with transportation to the final disposal site are lower, as can be seen on Table 2 that follows.

Comparing Tables 1 and 2, it is noticeable that the disposal of the soil waste generated by the excavation using polymer slurry is 28% lower than the cost calculated for the disposal of the soil when the bentonite slurry is used. This is due to the fact that the soil resulting from the excavation using polymer slurry is not considered as contaminated material; therefore, it does not require a special landfill to be disposed of.

Figure 4 shows the comparison of costs, per cubic meter, for both alternatives.

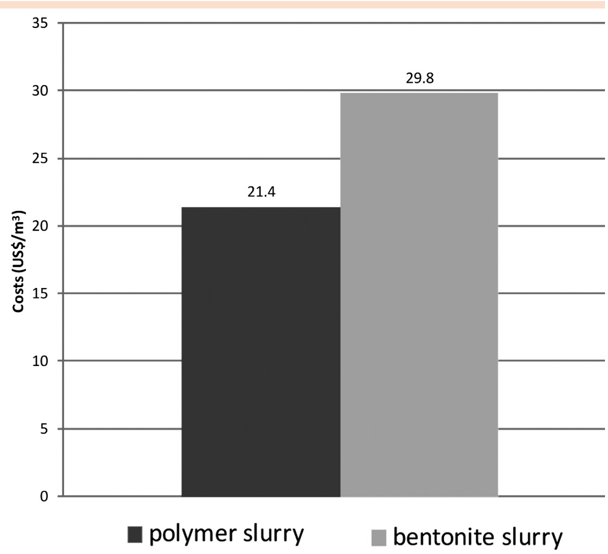

Figure 4: Comparison of the cost for disposal (US$/m³)
Source: The authors.

Figure 3 shows that the cost for the disposal per volume of material corresponds to US$29.80 for the bentonite slurry option and to US$ 21.4 for the polymer slurry. The mass of studied drilling muds needed for the excavation of the studied diaphragm wall has also been estimated. The quantity was obtained through the information provided by the manufacturers of the used drilling muds and by the ratio of utilization verified at the construction site. The estimated values are presented in Table 3.

Table 3: Estimated consumption for bentonite and polymer slurries

Volume of the excavation (m³)	3,344.27
Mass of polymer to be used (kg)	2,006.50
Mass of bentonite clay to be used (kg)	35,783.70

Source: The authors.

On Table 3, it can be seen that, considering the volume of excavation needed for the construction work, the consumption of bentonite clay was 18 times higher than the consumption of polymer. The study also contemplated the costs comprised in the construction of the diaphragm wall using bentonite and polymer slurries. The calculation included the values related to the use of the studied drilling muds, the total cost of the mechanized excavation of the wall, and the transportation and disposal cost of the waste generated by the excavation work. The costs related to the diaphragm wall steel frame were not included. The values are presented on Tables 4 and 5.

Considering Tables 4 and 5, it is possible to point out that the estimated costs present a difference of approximately 6%, when the values for the bentonite and polymer slurries are compared,

Table 4: Cost estimated to build diaphragm wall using bentonite slurry

Volume of the excavation (m³)	3,344.27
Total cost for excavation works (US$)	309,345
Transportation and disposal cost (US$)	99,659.40
Total cost of applying bentonite slurry (US$)	14,923.30
Total estimated cost (US$)	423,986.70

Source: The authors.

Table 5: Cost estimated to build diaphragm wall using polymer slurry

Volume of the excavation (m³)	3,344.27
Total cost for excavation works (US$)	309,345
Transportation and disposal cost (US$)	71,561.40
Total cost of applying polymer slurry (US$)	74,978.50
Total estimated cost (US$)	455,890.90

Source: The authors.

amounting to US$ 31,904.42. It should also be pointed out that even presenting a cost five times lower than that of the bentonite slurry, the cost of the transportation and disposal of its waste is much higher than for the polymer slurry. Figure 5 presents a comparison between the costs for both alternatives presented per area of diaphragm wall to be built.

Figure 5 shows the difference in the cost per area to build the studied diaphragm wall; the comparison reveals a difference of approximately U$4.00/m² between the two solutions analyzed so far.

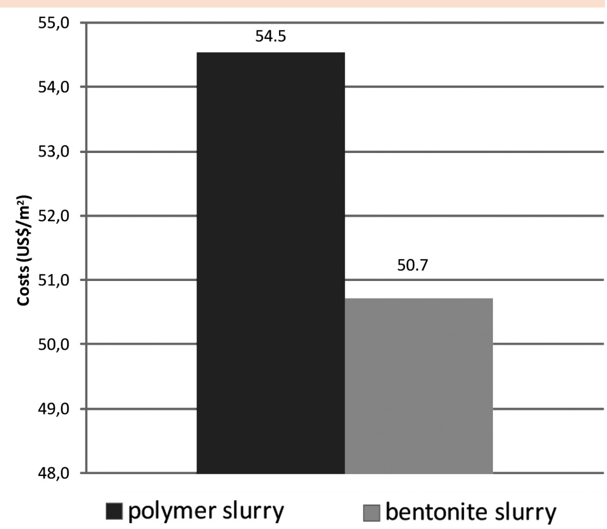

Figure 5: Comparison of the costs per area for both drilling muds
Source: The authors.

4 Conclusions

Based on the parameters obtained by the present research, the following conclusions can be presented:

a) Civil construction is a very important economic sector in Brazil, being responsible for generating jobs and income and for reducing the country's housing and infrastructure deficits. Nevertheless, civil construction is also responsible for the generation of a great volume of solid waste. Therefore, it is very important to adopt systems of environmental management at construction sites, with the main goal of reducing the quantity of solid waste, as well as lowering both losses during the construction process and the need for natural raw material.

b) The data that were obtained indicated that the use of polymer slurry as a drilling mud provided an economical alternative, even though it is a little more expensive (6%) than bentonite slurry, due to the environmental advantages it offers. Being a biodegradable product is a relevant aspect due to the environmental issues that are increasingly being faced by the construction industry; and in the case of the use of the polymer slurry, it was possible to reduce the quantity of excavated soil that needed to be disposed of and transported. In addition to this, for the same volume of soil to be excavated, the amount of material consumed was lower compared to what was needed if using bentonite slurry. It is important to highlight that the implementation of practices and the use of products that cause a low environmental impact, such as the use of polymer slurry, is one of the requirements to be met for a construction site to get Green Building certifications, such as LEED and AQUA.

References

ABNT – Associação Brasileira de Normas Técnicas. *NBR 6122*: Projeto e execução de fundações. Rio de Janeiro, 91 p., 2010.

ABNT – Associação Brasileira de Normas Técnicas. *NBR 6118*: Projeto de Estruturas de concreto. Rio de Janeiro, 221p, 2007.

ABNT – Associação Brasileira de Normas Técnicas. *NBR 10004*: Resíduos sólidos – Classificação. Rio de Janeiro, 48 p.,2004.

AZEVEDO, G. O.; KIPERSTOK, A.; MORAES, L. R. Resíduos da construção civil em salvador: os caminhos para uma gestão sustentável. *Engenharia Sanitaria e Ambiental*, v. 11, n. 1, p. 65-72, 2006.

CARDOSO, F. F. E.; SHIMIZU, J. Y. *Sistemas de contenção*. Apostila DepartamentodeEngenhariaeConstruçãoCivil,Escola Politécnica da Universidade de São Paulo, São Paulo, p. 285, 2002.

DIAS, J. A construção civil e o meio ambiente. In: CONGRESSO ESTADUAL DE PROFISSIONAIS CREA. Uberlândia, *Anais*... Minas Gerais: CREA MG, 2004.

GOMES, C. F. et al. Multicriteria decision making applied to waste recycling in Brazil. *Omega*, v. 36, n. 3, p. 395-404, 2008.

IBGE – Instituto Brasileiro de Geografia e Estatística. Perfil dos Municípios Brasileiros 2011. Disponível em: <http://www.ibge.gov.br>. Acesso em: 13 mar. 2013.

LUMMUS, J. L.; AZAR, J. J. *Drilling fluids optimization a practical field approach*. Tulsa, Oklahoma: PennWell Publishing Company, p. 352, 1986.

MOTA, C. B. N. *Estudo comparativo do impacto ambiental produzido pelo uso de lama bentonítica e de polímero em obras de fundações na construção civil*. 2010. 95 p. Dissertação (mestrado)–Instituto de Pesquisas Tecnológicas do Estado de São Paulo, São Paulo, 2010.

MORAIS, G. M. D. *Diagnóstico da deposição clandestina de resíduos de construção e demolição em bairros periféricos de Uberlândia*: subsídios para uma gestão sustentável. 2006. 220p Dissertação (mestrado)–Faculdade de Engenharia Civil, Universidade Federal de Uberlândia, Uberlândia, 2006.

SAES, J. L.; HACHICH, W.; FALCONI, F. F. *Fundações*: teoria e prática. São Paulo: Pini. 452 p., 1998.

ULSEN, C. et al. Composição química de agregados mistos de resíduos de construção e demolição do Estado de São Paulo. *Revista da Escola de Minas*, v. 63, n. 2, p. 339-346, 2010.

Recebido em 14 out. 2013 / aprovado em 6 dez. 2013

Para referenciar este texto
PASCHOALIN FILHO, J. A.; GUERNER DIAS, A. J.; DUARTE, E. B. L. The use of polymer slurry as an economic and sustainable way to build diaphragm walls – a case study of a construction work in São Paulo/Brazil. *Exacta – EP*, São Paulo, v. 11, n. 3, p. 299-306, 2013.