Ergonomic risk in the stages of construction of the storm water drainage system

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Abstract
The aim of this study was to analyze the ergonomic risks in implementing urban storm water micro drainage from a subdivision for residential and commercial use. Data were collected in a subdivision for residential and commercial use, with an area of 120,692.93 m\textsuperscript{2} and was comprised of 138 lots, divided into 8 blocks, in Porto Belo, Santa Catarina State, Brazil. A field study of exploratory and descriptive nature was conducted, with qualitative and quantitative approach, developed through a case study. For the analysis of the activities it was used the method Ergonomic Work Analysis (EWA). In the study it was decided to analyze the activities of execution of concrete pipes galleries, which is divided into the following steps: the excavation, the preparation of pipes, the prepare of the bottom of the ditch, the laying of pipes and the grouting and backfill. The analysis of the activity allowed the elaboration of a diagnosis and then recommendations for reducing the risk of accidents and musculoskeletal diseases, improvements to the health of workers were made. This work allowed the inclusion of ergonomic concerns and safety work in urban storm drainage step.

Practitioner Summary: Considering the importance of the sector to the economy and development of the country, it is necessary to seek improvements with respect to efficiency, safety and comfort of workers who work in this area, thus avoiding the risks of accidents which are frequent in this segment.

Keywords: urban storm water micro drainage, ergonomic work analysis, ergonomics in construction.

1. Introduction
According to Iida (2005) applications of ergonomics in civil construction does not occur with the desirable intensity. They are important, because this sector absorbs large contingent of labor, usually low-skilled and low-paying, involving arduous and dangerous tasks. Large companies already have an efficient organization and structured tasks, but this is not the case of most small businesses and the informal constructions.

The ergonomic intervention in civil construction is more complex than in other industries, due to the following factors: change in the daily workplace; high turnover of workers; many workers are employed by contractors and project owners claim to be unable to hire a specialist in ergonomics. (Schneider, 1995).

The worker to perform his activities does not care about his physical integrity. In accidents registers the lack of essential factors to worker protection. According to the Statistical Yearbook of Social Security (Anuário Estatístico da Previdência Social), the civil construction industry in Brazil recorded 171,398 workplace accidents in the period from 2009 to 2011. In Santa Catarina State only in the year of 2011 occurred 47,615 accidents, 168 of which resulted in death. (BRASIL, 2014).

The issues inherent in the safety and health of workers should not be only a legal obligation, but an integral part for obtaining satisfactory results, in accordance with goals and objectives to provide adequate working conditions, thus creating the workers’ satisfaction, improved performance, reduced absenteeism and increased productivity.

In this study we analysed the activities of micro drainage which is the set of techniques applied to the containment and control of runoff of rainwater in areas of lots and allotment. (CEPAM, 2006).

The drainage system is of vital importance to an urbanization organized and environmentally sustainable manner. According to the Fundação Estadual do Meio Ambiente (FEAM, 2006) the urban storm water drainage is “the set of existing infrastructure in a city to perform the collection, transportation and final
release of surface waters." This system consists of measures that attempt to minimize the risks to which the population is exposed, in order to reduce losses.

Most of the infrastructure projects it is necessary the construction of storm water drainage networks. In the region of Florianópolis in Santa Catarina, there is an increase in the number of private condominiums and lots, these works in that drainage is one of the main stages, usually at micro drainage level. The large number of works makes the existing workforce is not enough, by opening new places all the time (constantly). However, in most cases, these signings are not accompanied by training and specialization to work a job within the technical standards and work safety.

Concern about the health and welfare of construction workers is increasing, however was not found in the literature studies that address the ergonomic problems in urban storm water micro drainage step.

The aim of this study was to analyze the ergonomic risks in implementing urban storm water micro drainage from a subdivision for residential and commercial use.

This study was justified by the importance of the introduction of ergonomic principles in civil construction steps, specifically, in the micro drainage step, seeking (trying) to show a strong link between the improvement of working conditions and quality objectives: reducing costs, increasing productivity and improving the final product.

2. Method

A field research exploratory and descriptive in nature, with a qualitative and quantitative approach, developed through a case study, in the execution of an urban storm water micro drainage allotment.

2.1 Characterization of the study

The study was conducted in the municipality of Porto Belo, Santa Catarina, Brazil. The data were collected in a running plot for residential use and commercial, with 93120,692m² area and which will be formed by 138 lots, distributed in 8 blocks.

2.2 Data Collection

For the developing of the survey there were collected information about the influence of ergonomics at the workplace of the urban micro drainage. The theoretical reference aimed to provide support to the development of the method and understanding of the activities developed in steps present in the execution of micro drainage.

It was used the method of Ergonomic Work Analysis (EWA), which is one of the forms of ergonomic intervention used in studies that analyze the work activities (Guérin et al., 2001; Montmollin, 1990). The method of EWA was developed in accordance with the following steps: analysis of the demand; task analysis; analysis of the activity; diagnosis and ergonomic recommendations; validation of the intervention and efficiency recommendations.

For obtaining the information regarding population, the working environment and the organization of work in the implementation of storm water micro drainage, all stages of AET were developed using the following data collection techniques: observations; informal conversations; filming; photographs; semi-structured interviews; and verbalization of workers.

2.3 Treatment of the date

Data were analyzed qualitatively and quantitatively. The qualitative analysis of data was done through content analysis, in which they were created categories of analysis identified during the EWA. The quantitative analysis was used measures of central tendency and variability (percentages and frequencies).
3. Results

The WEA was held in an allotment in the municipality of Porto Belo, during execution of the galleries of concrete pipes, which is part of the micro drainage network of allotment.

The micro drainage network of allotment has all the mesh of concrete pipes converging on an artificial lake, and, from it, be forwarded to public drainage network.

Observing the jobs were extracted important ergonomic demands to be scanned. According to the view of analysts, of workers and the contractor of the work, the main problems highlighted are: postural problems in carrying out the activities, cargo handling, risk of accidents, physical fatigue, work in open environment, lack of signage.

3.1 Prescription of the task

It was observed during the EWA that there is not no prescription of the task, workers are perform activities according to your experience in day to day work, so one of the goals of the study was to prescribe the task properly by following the standards DNIT 030/2004-030-ES and ABNT 15645/2008.

a) Excavation: the excavations must be performed respecting dimensions and alignments indicated in drainage project. And the ditch width should exceed the diameter of the pipes in at least 60 centimeters (cm). According to NR 18.6 "excavations conducted on public roads or construction sites must have warning signs, including night, and insulating barrier around your perimeter." (BRASIL, 2014).

b) Preparation of the bottom of the ditch: the bottom of the ditch must be regular and uniform, and obey the declivity in design, can be used suitable material to fill the possible defects of the ditch. In firm land (terrains), dry and with satisfactory supportability can be support directly on the ground tubes. In land situated below the groundwater level should affect a gravel ballast 3 and 4, with a thickness between 10 cm and 15 cm, and later fine granular material layer with thickness of 5 cm. In unstable terrains and without mechanical conditions for minimum settlement, one should run a concrete slab, on gravel, gravel foundation, stone or piles with a minimum diameter of 0.20 meters (m) and minimum length of 2.00 m. In a rocky terrain, it should dig more 15 cm beyond the expected to the ditch, and fill this excess with granular thin material, to ensure that concrete pipes have perfect support.

c) Settlement the pipes and execution of the joints: first must clean the sides of the pipes and check if the same were not damaged. The settlement of the pipes shall conform to the dimensions and alignment indicated in design, and pipes shall have their bags based on the amount, to capture the run-offs downwardly water. Position the tip of the pipes by the subsequent tube bag already seated and proceed to pipe alignment, then perform the fitting between the pipes, pushing it manually, with the help of levers or through equipment. The rules guide the board is made of pipes with cement mortar and sand with 1: 3 ratio, but according to the allotment of the drainage project joints must be made with the use of geotextile.

d) Backfill: the backfill should only be authorized after fixed pipes and should be done, preferably with material of his own digging, since that presents the appropriate properties. When the soil is of poor quality, use of appropriate soil deposits. The backfill must be performed in layers with maximum thickness of 15 cm and with manual compression until the height of 60 cm above the upper pipe generatrix. Only after this point mechanical compression is allowed.

Note that is of great value prescription of tasks to allow better efficiency and optimization at work and reduced risks to workers, in that sense this study prioritized the prescription task.

3.2 Activity Analysis

In the study it was decided to analyze the activities of implementation of concrete tubes galleries, which is divided into the following steps: excavation, preparation of concrete pipes, preparation of the bottom of the ditch, settlement and implementation of the pipes together, and backfill. Are enclosed excerpts for execution
and each step only begins to be held after the end of the previous, in the passage set. The following activities were analyzed for each of these steps.

3.2.1 Preparation of concrete pipes

Before starting the excavation of the ditches, the backhoe carries the concrete pipes until the vicinity of ditches. Parallel to the excavation, workers tying the fabric (geotextile) around one end of each pipe (Figure 1).

![Figure 1. Workers tying the geotextile](image)

At this stage it was found that a worker in the performance of activities of postures adopts, especially (mainly) in the movement of push and pull the pipes by hand. Note the lack of personal protective equipment (PPE) and workers not using appropriate clothing, you can view the worker wearing shorts. Observe the risk of accidents (Figure 1) due to this activity be carried out very close to the excavation area and can cause accidents with backhoe.

3.2.2 Excavation

The excavation of the ditches is performed with the aid of a backhoe (Figure 2), making the excavation, while a worker remains inside the ditch.

![Figure 2. Worker inside the ditch](image)
The worker provides guidance as to the depth that needs to be excavated and will be hitting the bottom of the same using a hoe. In this step and in other steps there is a lack of signs indicating the desktop. It also verifies that the backhoe operator does not use any type of PPE, only safety shoe.

![Figure 3. Worker back to the backhoe](image)

It is evident the constant risk of accidents due to the workers remain inside the ditch and the shovel of the backhoe pass very close to the worker (Figure 3). The worker performs its activities back to the backhoe, so your field of vision is limited, requiring the attention of both the backhoe operator and other workers.

### 3.2.3 Preparation of the bottom of the ditch

After the excavation is completed, is placed a layer of coarse sand, deposited over the ditch with the help of the backhoe. Completed the placement of the sand layer, this is spread by workers making use of shovel and hoe (Figure 4).

![Figure 4. Workers spreading the sand in the ditch](image)

In this step again observed the lack of adequate clothing, intense physical activity and postural problems.
### 3.2.4 Preparation of the bottom of the ditch

In the settlement of the pipes, prepared with the trench, workers push the tubes with his hands into the trench. Workers position the way the pipes meet the alignment indicated on the drainage project. Later it is broken the geotextile mooring and uses rule of level for conference of declivity. It is placed another pipes in the ditch and fit in the previous pipe, again checking the alignment and gradient. (Figure 5). After fitting the workers, seal the joint between tubes with the geotextile. This cycle is repeated until the end of the trench excavated stretch.

In this step there is the handling of pipes with actions to lift, carry, push and depositing the same. It is observed that there is an intense physical activity with inadequate postures, postural discomfort and may cause musculoskeletal injuries.

![Figure 5. Workers fitting the pipes](image)

During the whole stage of settlement tube workers perform movements of flexion, extension and intensive work of upper and lower limbs which generate postural discomfort and muscle aches. It is observed in all stages the intense physical work and workers are exposed to the sun, wind and bad weather yet.

### 3.2.5 Backfill

The last step is to backfill ditches, which is run entirely by a excavator, from enclosed cabin. The single worker involved is the excavator operator. Is only effected the closure of ditch, no compression this will effected backfill only after the water and sewer networks are ready, preceding the allotment paving step. It was found again the lack of desktop signaling, which puts at risk not only workers, but anyone else who enter the space of the allotment.

With the analysis of the activities were evident accident risks to which workers are exposed during their workday, postural issues, exposure to bad weather, in addition to working with a backhoe.

### 3.3 Diagnostic and recommendation

From the points made previously in demand analysis and the analysis of the activities elaborated the diagnosis with the relevant recommendations.

a) Postures, postural discomfort, handling of loads, fatigue and body aches

Throughout all stages, except in step of backfill of the ditches, there was inadequate postures, intense physical activity and use of physical force mainly in handling of the pipes. Second, workers report they feel body aches at the end of the day, due to the intense physical activity during the performance of activities. This situation could be minimized by providing constant professional guidance and training for workers. In
relation to the handling of loads, there is a lack of orientation and mechanical devices that assist in the transport of pipes.

b) Risk of accidents

Accident risks are at all stages of the implementation of the concrete pipes galleries. The activities carried out by workers in conjunction with the backhoe puts them in constant risk of accidents. It is observed, in some cases, also the overconfidence on the part of workers and in some cases the lack of attention from them.

It is recommended that the employee does not remain in the ditch during the activity with the backhoe, so that when he needs to make the adjustments and check the depth of the ditch the backhoe is turned off. The preparation of concrete pipes and mooring of geotextile must be performed at a safe distance from the backhoe.

c) Work out in the open

As the micro drainage is made in open land, workers are exposed to bad weather that can cause diseases caused by abrupt changes in temperature. Another serious risk is exposure to the sun during the workday, and may result in skin problems, burns and sunburn.

For exposure to the sun is of extreme importance that the employers provide sunscreen and guidance as to its use. For inclement weather it is recommended that the employer make raincoats for workers’ protection in rainy days.

Due to the presence of undergrowth in the allotment can be the presence of poisonous animals, endangering workers. It is suggested that a cleanup is carried out of the ground, with cutting undergrowth, so as to avoid the presence of these animals.

d) Personal protective equipment

The Regulatory Norm (NR) 6 deals specifically about the use of PPE by regulating the responsibilities of the employer and the worker when the use and conservation of the same. It is the duty of employers to acquire appropriate PPE to the risks of each work activity, require their use, administer training for their correct use and its conservation, and register the delivery workers. Workers have a responsibility to use the PPE, store them and keep them appropriately (BRASIL, 2014).

It was verified during the analysis of the activities that the workers did not use any type of PPE beyond the protective shoe and must wear protective helmets.

For the work performed is indicated using appropriate attire, consisting of trousers made of durable material, usually denim or twill, and a t-shirt with the company’s identification. This uniform should be provided by the employer. In order to improve contact with the tools and protect workers’ hands from cuts and abrasions we recommend the use of safety gloves, while using shovel and hoe and the handling of concrete pipes.

Workers who operate the backhoe and excavator is required the use of hearing protection, as a result of exposure to noise, which is intense. No measurements were made in the workplace, but it is recommended that measurements are made in order to protect workers.

e) Signaling

The lack of workplace signaling exposes workers and strangers who enter the work the accident risks, because it is a totally open allotment, the entry of any person is possible. It is recommended that walls are implemented, fences around the allotment and an access gate, preventing the entry of unauthorized persons in the areas under construction and that appropriate signaling to the activity performed.

4. Conclusions

The present work applied the method of EWA at the workplace of the galleries of concrete pipes, in the development of the micro drainage step of an allotment. When performing the EWA was unable to identify how the activity is conducted and diagnose the risks to which workers are exposed during its realization. In
this study it is concluded that the main risks are related to ergonomic postures, postural, handling cargo discomfort, physical fatigue; risk of accidents, work out in the open and subject to weather, non-use of personal protective equipment and lack of signage in the workplace.

The EWA has allowed the development of a diagnosis and subsequently were made recommendations for reducing the risks of accidents and musculoskeletal diseases (primarily the spine), improvements to the health of workers and, mainly, through the use of PPE.

This work allowed the insertion of ergonomic concerns and safety of the work on urban storm water drainage step. It is suggested that further studies are performed to address not only the ergonomic issues, but also everything that can be done to make the work environment on urban storm water micro drainage and safe with good conditions for its execution.

References


