Risks involved in vertical shafts construction for the eastern drainage tunnel in Mexico

Riesgos involucrados en la construcción de pozos verticales para el túnel de drenaje oriental en México

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Abstract

This article describes the main stages involved in the construction of the vertical shafts (large-diameter vertical wells), which are necessary for the subsequent construction of the tunnel´s sections. The different risk situations existing during the construction of the Eastern Drainage Tunnel in the valley of Mexico City (in Spanish, "Tunel Emisor Oriente") are analyzed. In order for this 52 km-long and 7.5 m-wide tunnel to carry part of the city's sewage, 25 shafts must first be built, ranging from 55 to 150 meters deep. The magnitude of such a project implies working in different geographical areas and varied geological strata involving the presence of groundwater, which increases the risks due to possible landslides or flooding during excavation. As digging will occur in different types of soil, varying procedures must be used depending on soil type. Likewise, due to the magnitude of this kind of project, detailed scheduling and planning are required as simultaneous works on different fronts are necessary to meet deadlines. The study mentions that, while projects like these involve high risks for workers, analysis of activities and situations are conducted precisely to demonstrate that such risks can be considerably reduced.

Keywords: *Risks, workers, shafts, construction, tunnel*

Resumen

Este artículo describe las principales etapas involucradas en la construcción de los pozos verticales (pozos verticales de gran diámetro), necesarios para la posterior construcción de los tramos del túnel. Se analizan las diferentes situaciones de riesgo existentes durante la construcción del Túnel de Drenaje Oriental en el valle de la Ciudad de México (en español, "Túnel Emisor Oriente"). Para que este túnel de 52 km de largo y 7,5 m de ancho lleve parte de las aguas residuales de la ciudad, primero se deben construir 25 pozos, de 55 a 150 metros de profundidad. La magnitud de un proyecto de este tipo implica trabajar en diferentes áreas geográficas y estratos geológicos variados que involucran la presencia de aguas subterráneas, lo que aumenta los riesgos por posibles deslizamientos de tierra o inundaciones durante la excavación. Dado que la excavación se realizará en diferentes tipos de suelo, se deben utilizar distintos procedimientos según el tipo de suelo. Asimismo, debido a la magnitud de este tipo de proyectos, se requiere una programación y planificación detalladas, ya que se requieren trabajos simultáneos en diferentes frentes para cumplir con los plazos. El estudio menciona que, si bien proyectos como estos implican altos riesgos para los trabajadores, se realizan análisis de actividades y situaciones precisamente para demostrar que dichos riesgos pueden reducirse considerablemente.

Palabras clave: Riesgos, trabajadores, pozos, construcción, tunel

1. Introduction

1.1 History of the Project of the Eastern Drainage Tunnel

Mexico City's metropolitan area is built over a closed watershed, it was composed by a system of lakes comprising five large lakes: Texcoco, Xaltocan, Zumpango, Xochimilco and Chalco.

During the highest raining seasons, the five lakes merged into one of an area of more than two thousand square kilometers. This explains the periodical flooding the inhabitants of the region suffered since the foundation of Tenochtitlan (Aztec capital before the Spaniards conquered it and changed its name to Mexico), as well as the great importance to make draining works in order to control and extract rainwater and sewage from the valley.

The construction of Mexico City over the location of the five lakes brought two permanent problems: the need to extract to rainwater in order to prevent flooding and the sinking due to the over extraction of the water from the aquifer. As a result, in 1975, the Central Drainage Tunnel 50 km long was opened, which is the main structure of the actual deep draining system of the valley (Aguilar, 2011).

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Nowadays, the capacity of Mexico City's draining system has been surpassed, causing serious problems. It is more than enough to compare its capacity in 1975 with the actual one which is 30% lower, and the population of the area has doubled since then. The decrease is mainly due to the sinking of Mexico City caused by the over-extraction of water from the groundwater reserves of Mexico City's valley (Alberto, 2010)

In order to fully solve the draining system problem, it was decided to build a new tunnel below the city: The Eastern Drainage Tunnel "EDT" (Tunel Emisor Oriente in Spanish), with a capacity of 150 m^3 per second of polluted water. Originally, the total estimated cost of the Project was 12 billion pesos (National Water Commission, 2011).

1.2 Geotechnical conditions of Mexico City's Valley

Due to the great length of the EDT, the project had to be completed in soils with different properties, for example: soft soil (muds) under the lake area, which main feature is its high compressibility, and whose consolidation process is in the first stage with a sinking yield of 30 cm per year (Contreras, 2010).

Other important aspects to consider is that the tunnel runs on the edge of a draining channel with polluted water (with no concrete wall or coating), and in some other area, it runs just 10 m from a lagoon (Holguín et al., 2010).

In general, the vertical shafts described in this paper are built in soft soils which main features are its low shear resistance, high compressibility, low permeability, and the underground water in hydrodynamic conditions (Juárez et al., 2010).

1.3 Risk Management

We have to say and accept that, in general, the activities required in the construction sector involve its own risks and can appear at any time. This is particularly important in the underground projects that have a high risk in all its phases.

For example, there are different ground strata and can change from one point to the other, thus increasing the landslides risk during the excavations. Rivers and lakes in the surrounding areas increase the flooding risk during the tunneling. This situation can worsen if the ground strata is too permeable, or it may even have underground hollows or caves.

Risk management require that all the unfavorable situations to be planned, including the most least frequent events, such as earthquakes, storms, hurricanes, etc.

For such reasons, it is compulsory to consider that those situations can appear at any time, even with the most detailed and strict prevention planning, and thus the planning and programming will have to include the activities necessary to face all the unforeseen situations, that is, even consider how to get the risk control stage involved. According to the principles of risk management, it is necessary, and it is justified that the preliminary studies required to analyze and understand the subsoil where to project will be constructed.

On the other hand, before starting the execution of the project, the construction company must plan and schedule the high-risk activities, so that by the time these activities are done, they can be executed in the predicted time, with the necessary resources and on site. This means that at the construction site the scheduled activities will be followed to continue with the stages of organization and management, and only this way can we prevent improvising and consequently minimize the labor risks.

2. Shafts

Shafts are vertical or inclined accesses that serve to carry out through them all auxiliary operations in a tunnel construction (Figure 1): digging, ventilation, pumping, salvage material extraction, vertical transport, electric and compressed air installations, personnel access, etc. Shafts also serve to capture water from surface collectors to lead it to the deep drainage tunnel (Luna, 2010).

The underground works of the drainage system and the subway in Mexico City, by their magnitude and subsoil characteristics, left great knowledge in the construction of shafts in soft soils; this has resulted in the possibility of having an advanced planning of the construction of the shafts and to obtain the labor risks analysis to minimize the possibility of having accidents (Méndez, 2009).

Figure 1. *Aerial view of one of the shafts of the EDT*

2.1 Constructive Procedures of the Shafts

Shafts built in the first stage of the drainage system, in soft clay soils of the transition zone and under the lake area of Mexico City, were made with the Mexican technique (Solum), with the French technique (Soletanche), and two others with the Italian technique (Icos). The procedures are quite similar, excavations are done by sectors and stabilized with bentonitic mud; then with a tremie pipe the walls are poured with concrete; then the core is excavated, and at the end the bottom is filled also with concrete.

During the execution of these tasks countless technical problems appeared, but the attention paid in the procedures derived in the successful construction of the shafts in clay soils. This in turn served as a great experience of the behavior of subsoils, mainly found in Mexico City's Valley (Monroy et al., 2010).

2.1.1 Solum Technique

a) *This technique is the most used in construction of shafts in clay soils and these are the procedures:*
After marking the center of the shaft in the ground and the boundaries of the lining, the area is divided into six equal parts, each with an angle of 60º. Then, a sequence of vertical tunnels of 0.60m in diameter and forming a ring are drilled, with a separation of about 0.50m from each other, so leaving a part of the ring soil undrilled.
Everything is stabilized with bentonite mud. Once the drilling of the ring is finished. The remaining material is extracted with a grab crane, always replacing the extracted material with equal amounts of bentonite mud.
After excavating this first annular sector, the walls must be poured, which consists in lowering the frame by pouring concrete from the bottom through a tremie pipe, displacing the bentonite mud by difference of densities. The same drilling and framing procedures are performed for the next annular sector alternately until the drilling and framing of the wall of the shaft is finished (Mooser, 2009).
b) *The core excavation is done with a grab crane up to the depth where no expansions are yet present due to discharges of the ground, accordingly to soil mechanics calculations and with observations form instrumentation and measurements. Upon reaching this level, all work is suspended, and the weight of the excavated material is replaced by an equivalent volume of water to prevent swelling. The core excavation can then proceed, extracting the necessary material under water until it reaches the designed depth (Figure 2).*

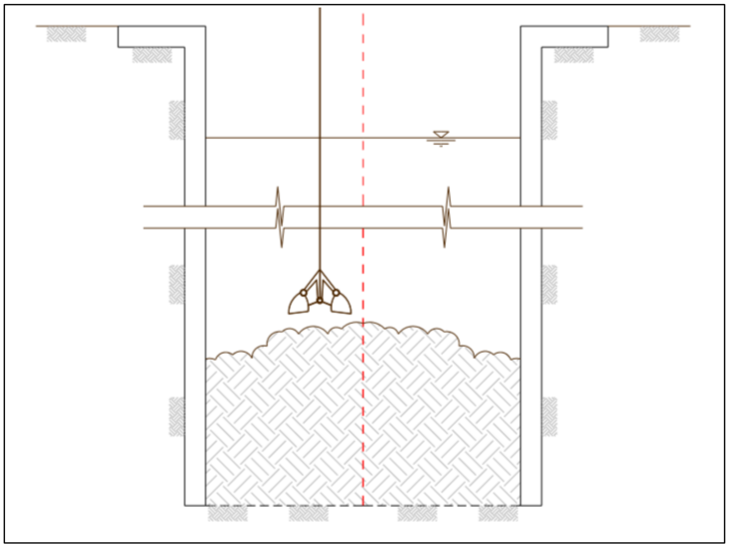

Figure 2. *Core excavation*

c) *After finishing the excavation, a first concrete floor is poured, forming a stopper or just a solid layer, leaving it enough time to forge. The silt is then cleaned, and an assembly grill is lowered to pour a second concrete layer under the water. Once done, the water is extracted through the shaft and then the required personnel are lifted down to seal (calk) the bottom and thus prevent water or material leaking. The last process is to pour reinforced concrete at the bottom and anchoring it to the walls of the shaft (Paniagua, 2002).*

2.2 Labor risks in the construction of the shafts

Once the different construction procedures for the shafts have been described, it can be deducted that, in general, the technique to be chosen depends to a large extend on the characteristics of the ground, and therefore, as a first point, it is essential to have the subsoil preliminary results and, in particular, of the area where it is intended to build each shaft.

2.2.1 Labor risk analysis in the construction of the shafts

The Mexican Official Regulation (NOM 031-STPS-2011; section 5.3) requires that the employers of the construction sector have the analysis of potential risks for all and each one of the activities they perform. The risk analyses are defined as the documents containing the characteristics of the construction work and the associated risks to each of the activities carried out, as well as the preventive measures for each identified risk.

For this purpose, there is a scheme in which, for each activities and processes, the potential dangers and risks are presented, thus allowing to obtain at the end the degree of risk for each activity.

It should be noted that this analysis is poorly valid if the company does not have:

a) *Experience in the activities to be carried out (project type)*
b) *Work safety experience*
c) *Commitment and sincerity to labor security*

The recommended risk analysis schemes (Table 1) it has to be mainly considered:

- *The number of people at risk*
- *The existence of constructive procedures*
- *The existence of risk prevention training*
- *The number of times the worker is exposed to risk*
- *The degree of injury that could suffer the worker*

Table 1. *Potential risk analysis scheme*

Index	*Probability*				*Severity*
	Exposed workers EWI	*Existing procedures EPI*	*Training TI*	*Risk exposure REI*	
1	*From 1 to 3*	*Satisfactory*	*Satisfactory*	*Low (1 a year)*	*Injuries with no disability*
2	*From 4 to 12*	*Not satisfactory*	*Not satisfactory*	*Medium (1 a month)*	*Disbility injury*
3	*More tan 12*	*Not available*	*Not available*	*High (daily)*	*Irreversible damage injuries*

In the same risk analysis scheme, at the end, a score is obtained and can be translated into degree of potential risk exposure for the workers. The range of risk are classified from trivial to intolerable (Table 2). Therefore, if the analyses are done with professionalism and sincerity (without the aim of concealing the degree of risk), they should be indispensable tools in the prevention of labor risks.

It must be mentioned that it is also very important that those responsible for the area of occupational safety and hygiene are empowered (authority and support) in the field of action, starting by providing the personnel with individual protective equipment (IPE), in accordance with the activities to be carried out, with the quality specified in the regulations and for each of the workers involved

Table 2. *Risk exposure according to the score obtained in the analysis*

Score	*Risk exposure*
4	*Trivial (T)*
5 to 8	*Tolerable (TO)*
9 to 16	*Moderate (M)*
17 to 24	*Important (I)*
25 to 36	*Intolerable (IN)*

Below is the analysis of potential risks for the main activities carried out during the construction of the shafts. Preliminary activities (Table 3). These activities mainly involve the layout and leveling; work is carried out at ground level, thus the predominant risk is the direct exposure to the inclement weather, but the existence of animals in the area can also be considered as risks, so all that contains or is being involved in the work area (e.g: crime or other social problems) must be considered.

Table 3. *Risk analysis for the preliminary activities*

ACTIVITY: PRELIMINARY ACTIVITIES											
Process	*Hazards*	*Risks*	*PROBABILITY*					*Severity Index*	*(REI)(Severity)*	*Risk Exposure*	*Proposed Actions*
			EWI	*EPI*	*TI*	*Sum of Indexes*	*REI*				
1. Lay out	*UV rays exposure*	*Insolation*	*1*	*1*	*1*	*3*	*6*	*1*	*6*	*TO*	*Use of wide-brimmed helmet* *Water supply*
2. Leveling	*UV rays exposure*	*Insolation*	*1*	*1*	*1*	*3*	*6*	*1*	*6*	*TO*	*Use of wide-brimmed helmet* *Water supply*

Construction of the concrete crown of the shaft: the concrete crown of the shaft is a concrete structure that serve as vertical guide so that the excavation equipment can be aligned. Therefore, one exterior and one interior are required. These activities start at ground level and up to a depth of 2m, so the most common hazards are direct exposure to sun light, the use of tools and machinery and loads lifting of that can result in risks for the workers (Table 4).

Table 4. *Risk analysis for the construction of the concrete crown of the shafts*

ACTIVITY: PRELIMINARY ACTIVITIES											
Process	*Hazards*	*Risks*	*PROBABILITY*					*Severity Index*	*(REI) (Severity)*	*Risk Exposure*	*Proposed Actions*
			EWI	*EPI*	*TI*	*Sum of Indexes*	*REI*				
1.Excavation up to 2m depth	*UV rays exposure*	*Insolation*	*1*	*1*	*1*	*3*	*6*	*1*	*6*	*TO*	*Use of wide-brimmed helmet*
2. Steel grid and framework assembly	*Use of tools, machinery and loads lifting*	*Impacts, wounds, bruises, back injuries*	*1*	*1*	*1*	*3*	*6*	*2*	*12*	*MO*	*Use of IPE´s*

Construction of the Milan walls. Milan walls are vertical concrete walls, which normally form hexagonal boards. These walls are usually built up to 40m deep, requiring first the guiding concrete crown of the shaft (Figure 3)

Figure 3. *Activities required for the construction of the Milan walls*

The most common hazards in these construction processes are the dirt moving done with heavy machinery (grab cranes, cranes, tractor shovels and trucks), the use of welding and cutting equipment, open air excavations, the handling of bentonitic muds and the reinforced steel grid hoisting (Table 5).

Table 5. *Risk analysis for the construction of the Milan walls*

ACTIVITY: PRELIMINARY ACTIVITIES											
			PROBABILITY								
Process	*Hazards*	*Risks*	*EWI*	*EPI*	*TI*	*Sum of Indexes*	*REI*	*Severity Index*	*(REI)(Severity)*	*Risk Exposure*	*Proposed Actions*
1.Excavation up to 40m depth	*Use of machinery*	*Personnel crushes, impacts and falls*	*3*	*2*	*2*	*3*	*10*	*2*	*20*	*I*	*Training and construction procedures*
2. Steel grid and framework assembly	*Tools, welding metal grid hoisting*	*Burns, cuts, hits, bruises*	*3*	*2*	*2*	*3*	*10*	*2*	*20*	*I*	*Training and construction procedures*
3. Concrete pouring	*Concrete machinery*	*Hits, falls, bruises*	*2*	*2*	*2*	*2*	*8*	*2*	*16*	*MO*	*Training and construction procedures*

Excavation of the nucleus: The natural terrain that is located within the Milan walls considered the core and it must be excavated to leave a vertical hole (like a tube), called the shaft. As the construction activities are performed at the same time at the bottom and on the walls, the most common hazards in these processes appear when, at the bottom of the excavation the machinery is excavating (back digger) and the charging skip or clamshell bucket must be up or down loaded with the excavated material, so there is a risk that material may fall on workers at the bottom of the shaft. It should be noted that when shafts are in areas where underground water currents exist, there is a risk of flooding or sudden collapses (Table 6).

Table 6. *Risk analysis for the excavation of the nucleus*

ACTIVITY: PRELIMINARY ACTIVITIES											
			PROBABILITY								
Process	*Hazards*	*Risks*	*EWI*	*EPI*	*TI*	*Sum of Indexes*	*REI*	*Severity Index*	*(REI)(Severity)*	*Risk Exposure*	*Proposed Actions*
1. Excavation with machinery at the bottom of the shaft	*Collapse and flooding*	*Crushing, drowning, hits*	*1*	*1*	*1*	*3*	*6*	*3*	*18*	*I*	*Training and procedures*
2. Material up or download	*Material fall*	*Crushing, hits*	*1*	*1*	*1*	*3*	*6*	*2*	*12*	*MO*	*Training and procedures*
3. Material transfer to and from the shaft or deposit area	*Vehicle maneuvering*	*Run over and hits*	*2*	*1*	*1*	*3*	*7*	*2*	*14*	*MO*	*Training and procedures*

Primary coating. For the cases where the terrain is firm or rocky the procedure for the construction of the shaft changes. In these situations, the nucleus is excavated to an average depth of 1.5m, a circular or polygonal metal ring (which will be used as shore) and concrete (pressure-poured) with an average thickness of 30cm.

Figure 4. *Workers' descent in an improvised bucket*

The most representative hazards in this process are related to the workers' descent to the bottom of the shaft, even though it is forbidden the use baskets or buckets for the transport of personnel, the rush of activity and the tolerance of the construction managers cause the staff to take risks (Figure 4). on the other hand, load lifting and concrete pouring are also important in terms of risk degree, although they don't reach a fatality risk (Table 7).

Table 7. *Risk analysis por the Primary Coating*

ACTIVITY: PRELIMINARY ACTIVITIES											
Process	Hazards	Risks	PROBABILITY					Severity Index	(REI) (Severity)	Risk Exposure	Proposed Actions
			EWI	EPI	TI	Sum of Indexes	REI				
1. Metal ring positioning	Load lifting	Hits, crushing, drop	2	1	1	3	7	1	7	TO	Lifting machinery
2. concrete high pressure pouring	High pressure equip-ment	Hits, drops, skin burns	2	1	1	3	7	2	1 4	MO	Training, use of special cloths and masks

Topographical leveling. The topographical activities are required throughout during all the stage of construction of the shafts (Table 8), but the risk degree highly increases when these activities are performed at great depths and topographers require measurements or fixing tools in hard-to-reach places and without protection (Figure 5).

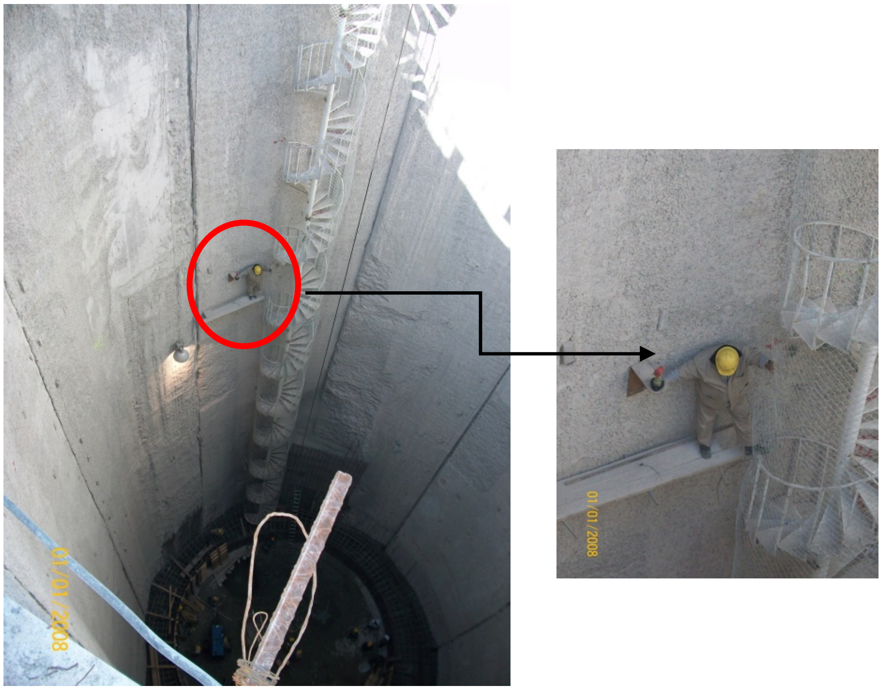

Figure 5. *Worker performing topographical activities*

Table 8. *Risk analysis for topographical activities*

ACTIVITY: PRELIMINARY ACTIVITIES											
			PROBABILITY								
Process	*Hazards*	*Risks*	*EWI*	*EPI*	*TI*	*Sum of Indexes*	*REI*	*Severity Index*	*(REI)(Severity)*	*Risk Exposure*	*Proposed Actions*
Vertical and horizontal leveling	*Activities in the height*	*Falls*	*1*	*2*	*2*	*3*	*8*	*3*	*24*		*Use of safety harness and lifelines*

Bottom slab. Bottom slab are structures made of reinforced concrete that are built once the core is excavated, at the bottom or floor of the shaft. These structures are required to be very thick (from 1m to 5m) to compensate the pressure existing under them, depending on the depth, soil conditions and underground water currents. The processes that are necessary and represent a high risk are mainly the pressure of the underground water streams, the descent of the reinforced steel structure and the concrete pouring itself (material descent).

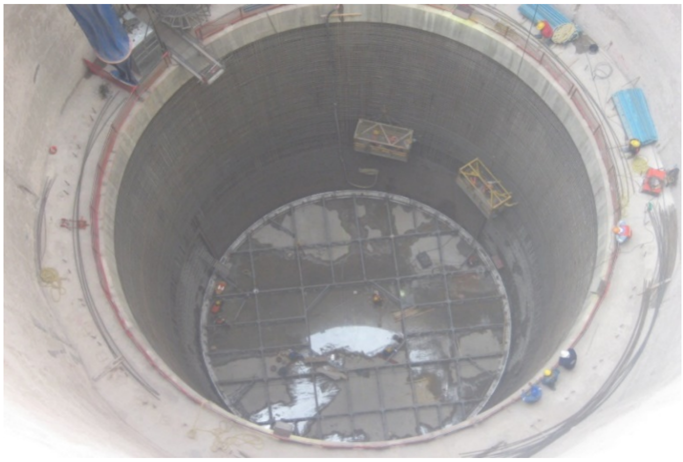


Figure 6. *Structure for the bottom slab (left) and Installation of the pipeline to pour the concrete (right)*

For such of activities, which represent a high risk (Table 9), specially for processes 1 and 3, the start of the construction should not be authorized until it is demonstrated with evidence on site that constructive procedures, a detailed risk analysis, an evacuation plan, machinery check-up (cranes) and the certification its operator are available (Figure 6).

Table 9. *Risk analysis for the bottom slab*

ACTIVITY: PRELIMINARY ACTIVITIES											
			PROBABILITY								
Process	Hazards	Risks	EWI	EPI	TI	Sum of Indexes	REI	Severity Index	(REI)(Severity)	Risk Exposure	Proposed Actions
1.Reinforced steel descent to the bottom of the shaft	Moving loads in the heights	Crushing, hits	2	2	2	3	10	3	30	IN	Training and procedures
2. Grid assembly	Confined areas	Hits, cuts, bruises	2	1	1	3	7	1	7	TO	Training and procedures
3. Concrete pouring	High pressure pipelines	Crushing and hits	3	2	2	2	9	3	27	IN	Training and procedures

Final coating of the shaft (Table 10). It consists of a structure formed by concrete and a reinforced steel grid, which reinforces the primary wall (primary coating). The associated risks in these activities are very high, as staff must work is the heights to form the steel grids that form the final wall (Figure 7).

Figure 7. *Assembly of the grids in the heights*

Another risk also with of high-risk degree, is the maneuvers necessary for the assembly of the platform that will serve as a sliding formwork (Figure 8).

Figure 8. *Assembly of the sliding formwork*

Table 10. *Risk analysis for the final coating*

ACTIVITY: PRELIMINARY ACTIVITIES											
			PROBABILITY								
Process	*Hazards*	*Risks*	*EWI*	*EPI*	*TI*	*Sum of Indexes*	*REI*	*Severity Index*	*(REI)(Severity)*	*Risk Exposure*	*Proposed Actions*
1. Steel grid assembly	*High altitude activities*	*Falls, hits, cuts*	*3*	*2*	*2*	*3*	*1 0*	*3*	*3 0*	*IN*	*Training and procedures*
2. Platform (formwork) assembly	*Lifting maneuver s*	*Crushing, falls*	*3*	*2*	*2*	*1*	*8*	*3*	*3 2*	*IN*	*Training and procedures*
3. Platform disassembly	*Lifting maneuver s*	*Crushing falls*	*3*	*2*	*2*	*1*	*8*	*3*	*3 2*	*IN*	*Training and procedures*

3. Observations

As we can see, when the risk analysis detects that the activity to be done involves high risk, i.e. intolerable type (IN), the proposed actions state that is compulsory to have the constructive procedures, in which planning of the activities must be involved, in order to minimize the risks. On the other hand, training for workers is provided in a very limited way, in many cases they are limited to five-minutes talks, before starting the working day (Figure 9).

Figure 9. *Five-minutes talks at 7 a.m*

When the results of the risk analyses for certain activities result as Intolerable (IN), they should not be carried out without the authorization for their execution. This is intended to involve the project managers, hygiene and security personnel and the related workers, to intervene and thereby minimizing the potential risks.

It should be mentioned that the analyses must always go beyond a simple filling of formats. Possible situations such as earthquakes, strong winds, hurricanes, thunderstorms, social problems in the site area, underground water currents etc. must be analyzed (Figure 10). Therefore, not only personnel impacts will be avoided, but also possible delays in the project.

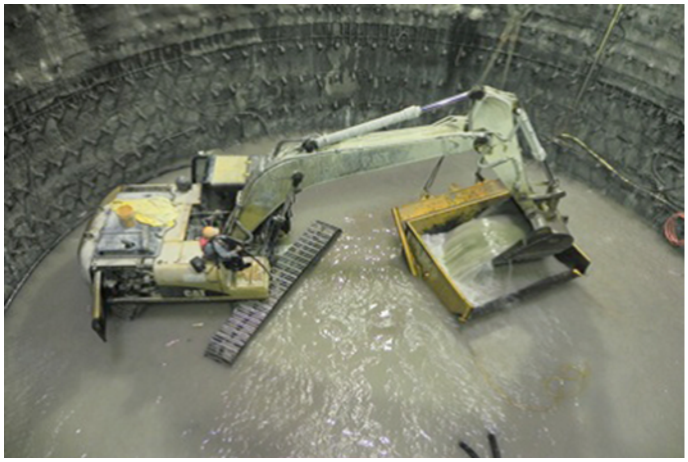

Figure 10. *Flooding inside one of the shafts do to leaking*

4. Conclusions

Even when it has been noted that risk analyses are an indispensable tool in the security and hygiene areas, many corporations still consider that labor risk prevention represents only a great expense, and they do not see it as an investment, thus originating that risk analyses are a simple requirement to be met and not an opportunity to avoid risks of accidents on site.

In addition, companies have hired staff that do not meet the required profile to be responsible for the safety of workers.

Some companies still have the wrong idea that worker's safety depends solely on them, and they act after an accident occurs instead of preventing it. For example: during the construction of the Eastern Drainage Tunnel, it was noted that personnel responsible for worker's safety on site had experience as firefighter and/or paramedic.

Certainly, the prevailing working culture in construction sites shows a tendency towards unsafe behavior often it seams that workers enjoy going against the rules; personnel are reluctant to use IPE with the argument that they interfere with their activities.

Another factor that negatively impacts job security is the time available and almost always tight for the execution of the construction projects. This situation results in that even the project managers themselves justify risky acts during the any process.

Worker's security in construction sites, while still showing deficiencies, has improved greatly compared to previous years. Much remains to be done and significant progress and results can only be expected only if prevention of construction labor risk is supported by high levels, starting with government authorities, workers Union, clients and entrepreneurs of the sector.

Internally, in the construction companies risk prevention must be considered from a systemic point of view, according to which, everyone must engage in a, active way. Thus, constructive procedures can be planned jointly with the security and hygiene area, and the most important, that the resulting strategies are followed on site.

5. Recommendations

The personnel responsible for the worker's safety must have knowledge of construction procedures to have the possibility to issue recommendations and supervise that workers are not exposed to risk of accidents.

On occupational safety issues, construction companies should think more about Prevention and not so much in Reacting after.

Construction entrepreneurs must see the area of safety and hygiene as an area of opportunities and not as an expense.

Safety and hygiene personnel must show high commitment and dedication to their activities and to protect their coworkers.

Job safety in constriction sites will only improve substantially when workers will be trained in prevention, construction chiefs will lead by example and the culture of risk prevention will be promoted.

Finally, all the above recommendations reveal the urgency of having construction managers who, in addition to construction experience, must have a solid knowledge in project management, in order to plan, program, organize, direct and control each and every stage and area involved in the project.

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