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Review Article

RISK MANAGEMENT OF SUBSIDENCE INDUCED BY TUNNEL EXCAVATION (PAPER CASE STUDY: MOSQUE OF KOOHSANGI PARK IN MASHHAD)

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ABSTRACT
Providing the safety of structures and urban facilities on the ground which are located near urban tunnels is very determinant both during tunnel construction (short term effect) and its exploitation (long term effect). Line 2 of urban subway project in Mashhad has been designed by the length of more than 14 Km along northeast to southwest of Mashhad. Regarding to the conditions of the pathway and advantages of using Tunnel boring machine for excavation, most of them are constructed as mechanized tunnel. Nowadays, tunneling by Earth Pressure Balance Shield, which was developed in Japan, is the most common way for tunneling soft grounds. Ground motions can be also under control theoretically through establishing balance on internal pressure of earth pressure chamber vs. external soil pressure during excavation.

Keywords: *Tunneling, Risk Management, Subsidence, TBM*

INTRODUCTION
Risk arises when there is a possibility of more than one outcome and the ultimate outcome is unknown. Risk can be defined as the variability or volatility of unexpected outcomes.Business activities have been always exposed to risks, the formal study of managing risk started in the later half of the last century. The word enterprise for Enterprise Risk Management, itself shows a different meaning than traditional risk management. Enterprise means to integrate or aggregate all types of risks (Meulbroek, 2002). It was argued that the term Enterprise Risk Managementhas quite similar meaning with Enterprise-Wide Risk Management, Holistic Risk Management, Corporate Risk Management, Business Risk Management, Integrated Risk Management and Strategic Risk Management (D'Arcy, 2001; Liebenberg *et al.,* 2003; Kleffner *et al.,* 2003; Hoyt *et al.,* 2006; Manab *et al.,* 2007; Yazid *et al.,* 2009).
Lam defines Enterprise Risk Management as an integrated framework for managing credit risk, market risk, operational risk, economic capital, and risk transfer in order to maximize firm value (Lam, 2000). Makomaski defines Enterprise Risk Management as a decision-making discipline that addresses variation in company goals (Makomaski, 2008). Alviunessen and Jankensgård (2009) point out that Enterprise Risk Management is concerned about a holistic, company-wide approach in managing risks, and centralized the information according to the risk exposures. Risk might impact on the future cash flow, profitability and continued existence of a company. In other words, risk universe is risk that could affect the entity of the company. If risk universe can be identified, the next step is to take an appropriate action such as risk mapping process, accessing the likelihood and impact and curb the risk based on the organizations' objective. Later in 1980s, political risks attracted more attention from multinational corporations as a result of different political regimes in different countries. For example, when the government announced a new policy, investors and corporations must make decision to reduce risk (Skipper and Kwon, 2007). Apart from the corporate scandals in Enron, WorldCom, Polly Peck and Parmalat, the last decade showed how serious the financial scandal was to corporations and banks (Jones, 2006; Benston *et al.,* 2003).
Despite of all efforts to identify earth behavior and complex modeling performed by the help of powerful software for different projects, exact prediction of such risks are still faced to problems. Although using modern technologies like tunneling by controlling the stability of tunnel working side and installing a

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holder in shield simultaneously has increasingly reduced the problems of subsidence in urban regions, the presence of some valuable structures and facilities sensitive to ground transformation such as Antiquities causes that forecasting earth reaction to tunneling in urban environment is still an updated subject for related fields like civil engineering, environment engineering, engineering geology, geo technique. Figure 1 shows that excavation of tunnel intentionally or unintentionallyleads to the displacement and transformations on adjacent soils.

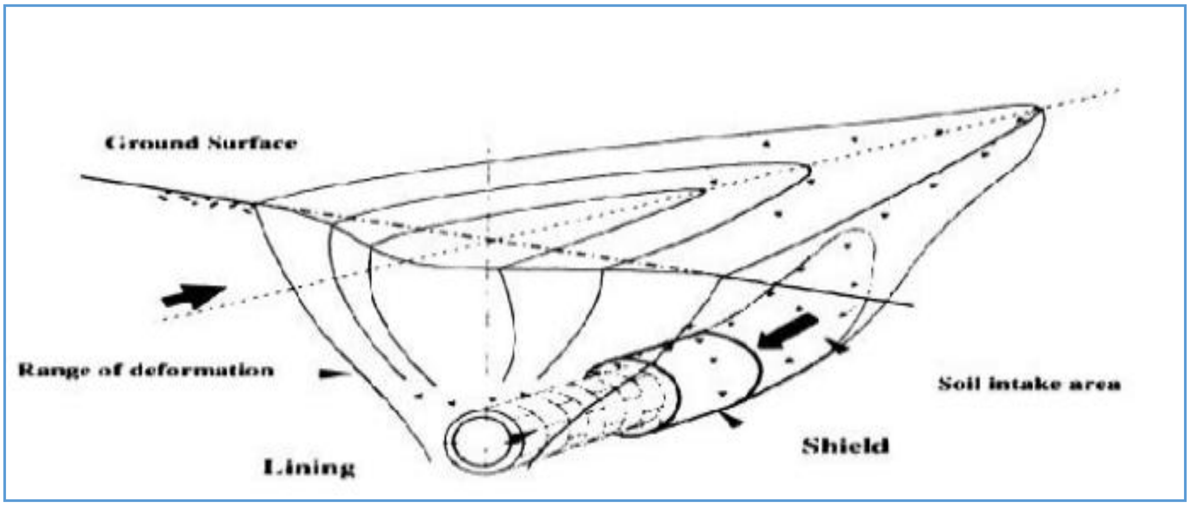

Figure 1

Figure 2 shows, these displacements, which are seen as subsidence on the ground, can impose many damages to urban spaces like adjacent buildings, urban facilities in subsidence area, street gradients…. the risk will be more critical when we are obliged to pass tunnel through crowded, historical, and valuable areas. Additionally, possible damages to other underground structures like piles, and foundations, existing tunnels, and underground tanks should be considered.

Figure 2

In order to reduce the risks induced by subsidence, in addition to select the most suitable excavation method in design step, the regions with high sensitivity should be possibly be prevented regarding to the conditions of geology. Then, illegal subsidence can be identified by appropriate estimation of subsidence and its zonation along the pathway. By studying structures existed in these regions, their vulnerability and consequently thenecessity of reinforcement and precautionary equipment before tunnel can be investigated. If necessary, when tunnel is close to danger area, certain Safety Tips should be performed.

Project Specifications and Purpose of the Study

Line 2 of urban subway project in Mashhad has been designed by the length of more than 14 Km along northeast to southwest of Mashhad, and it passes through northern Tabaris St, Rah Ahan Square, Shohada Square, Saadi Square, Shariaati Square, Koohsangi Park, Fazl bin Shadan Square and Javan square from the beginning of the line to its end. Regarding to the conditions of the pathway and benefits of using TBM, most of them will be excavated as Mechanized tunnel. However, excavation new technologies have reduced the risk of subsidence, investigation of Induced transformationsurround pathway, due to the close distance of tunnel and valuable structures and important centers of the city is necessary in order to identify possible risks and use proper policy to reduce the risk. Line 2 of Mashhad subway has been shown in figure3.Since both pathways of mechanized tunnels are approaching to dense regions of city center, investigating the subsidence and expert surveys are necessary in this field. Risk management of subsidence requires appropriate plan, expert human forces, and equipment. The studies are before the project, during and after the end of project. All above stages have been performed for Koohsangi Mosque, which are as follow.

Figure 3

Methodology and Performed Studies

After gathering technical information for the structure, present situation surveys were done, Figure 4 shows mentioned plan.

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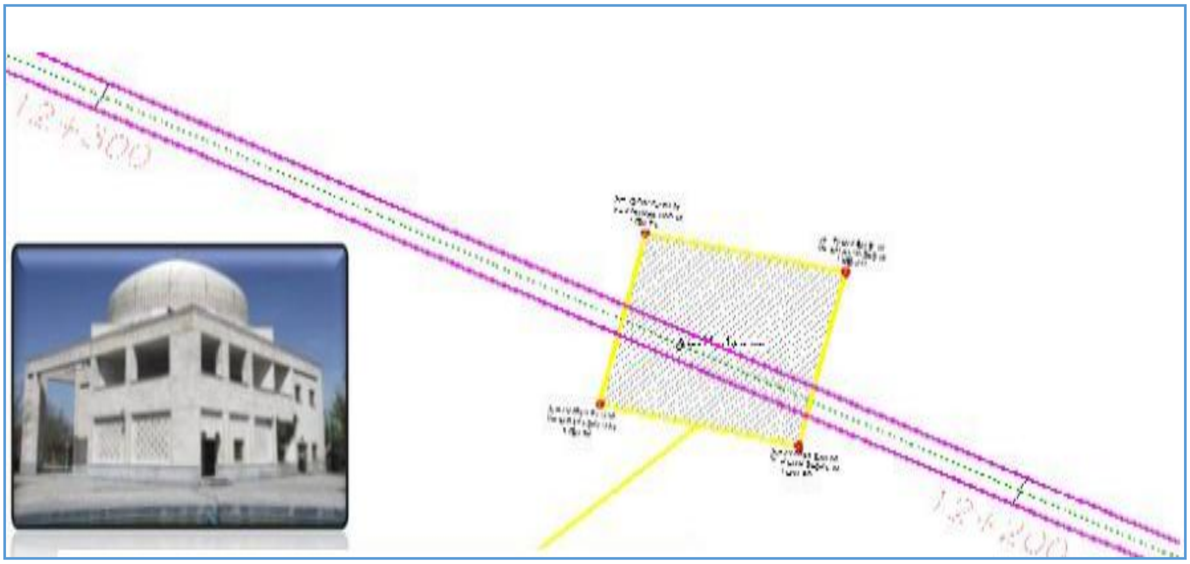

Figure 4

The result of filing Building Condition Survey (BCS) forms for the mosque and its vulnerability index with extracted risk level have been presented in table1.

Table 1

Warning level		Alarming level		Acceptance Level Risk	Degree of vulnerability	IV Index	Building name	Row
Smax	βmax	Smax	βmax					
15	1.350	20	1.250	II	Low	47	Mosque of Koohsangi	1

Generally, the inputs of mentioned forms include structural behaviors of the building, its location, building application, building façade, and general conditions of the building.After inquiry of structural specifications from complex management, and investigating given structure, topography of plan and structure's height were performed. Figure 5 shows topography of plan and structure's height.

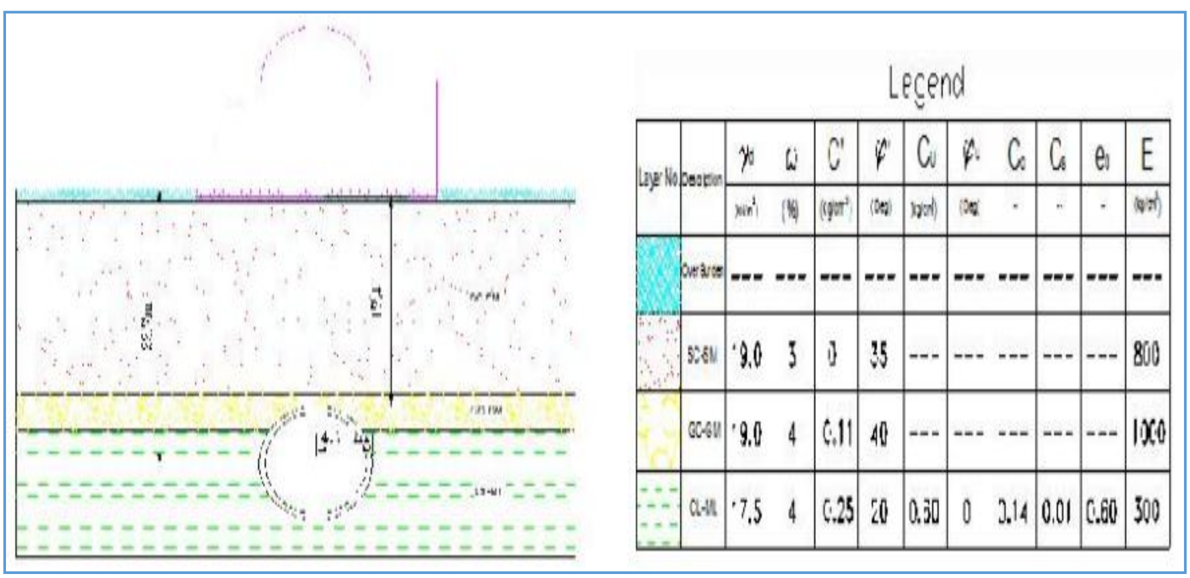

Figure 5

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Each building must have a specific reference code, and its information should be entered to a form prepared by a group of authorized structure engineers. The information is as follow for previous and next stages of construction:

Structure age, design plans, foundations' type and depth, number of floors, loading structure type, previous repairs date, added floors, structure type in terms of history, architectural and cultural value which can introduce it as a sensitive structure.By an overview on structure's conditions, all parts of the building should be inspected and reported including facilities, cracks, being vertical, being wet, deficits, captured images… Cracks in captures before construction are categorized as follow: narrow cracks (only can be observed by naked eye), up to 2mm openness, over 2mm. Therefore, the conditions of existing cracks in the building before construction were captured, some samples are shown in figure 6.

Figure 6

Gadget software was installed with some changes within appropriate intervals before TBM reaching to structure privacy, their records were performed accordingly. The results of subsidence control pins records are presented in table2.

Table 2

	Original HZ ANGLE	Original HZ DIST	Marginal HZ ANG	Marginal HZ DIST
TAPE 3	188.8360	19.199	188.8320	19.197
TAPE 4	88.5125	26.485	88.5080	26.488
HZ DIST FROM bm TO BM TAPE 4 =12.910 HZ DIST FROM bm TO BM TAPE 3 =50.420 AND HZ ANGLE SET · FROM BM TAPE 3 &4				

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The position of installing given tilt meter has been shown in figure 7.

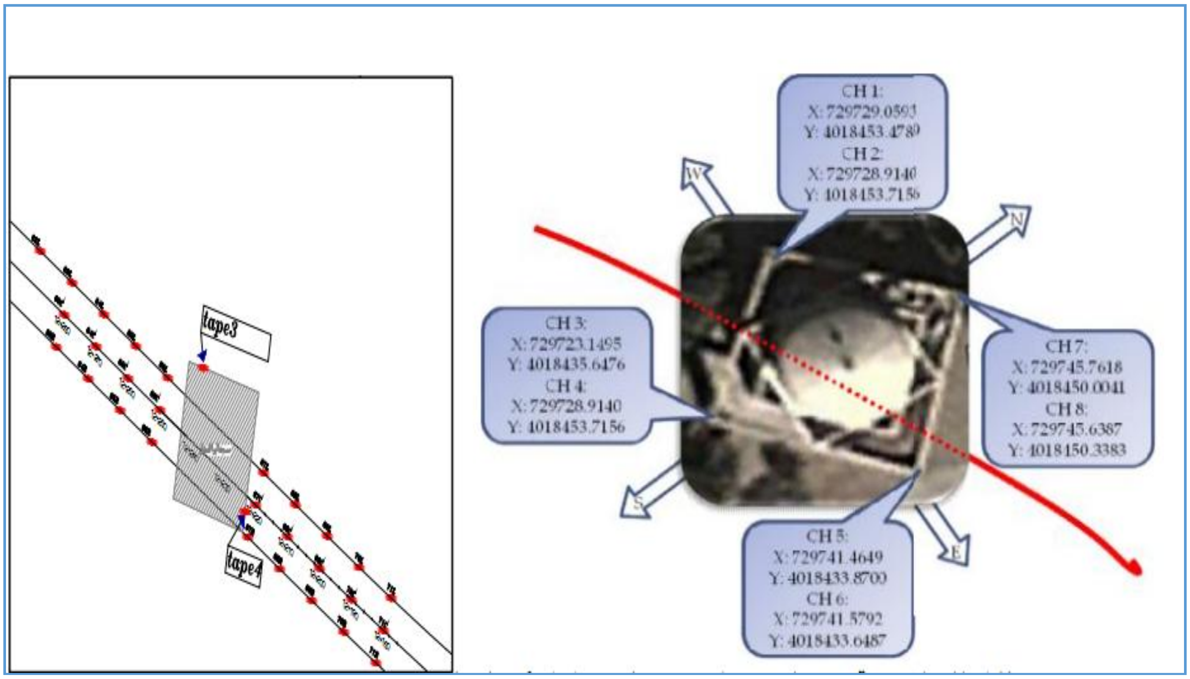

Figure 7

Preventive Activities in Tunnel to Control Subsidence

Regarding to the fact that excavating a tunnel underground and also providing an extremely rigid cover on its walls, is not possible, so that prevent any transformation. A certain amount of displacement and transformation will be inevitable. By development of excavation machine technologies for all the intersection of the tunnel such as EPB, subsidence control methods also were developed and some special measures were developed in order to control each part of the system where subsidence occur. Some of them are as follow:

- Development of system design including foam injection, Bentonite; and increase of soil improvement material range in order to control bench pressure properly to prevent subsidence toward cutter head
- Bentonite injection system around EPB machines shield in order to prevent subsidence in this situation
- Development of grout injection system behind segment and improvement of grout materials mixture methods in order to prevent subsidence in segmentationand grout injection
- Development of monitoring systems in order to monitor tunnel pathway on the ground and deep layers of the soil in order to control their behaviors before and after tunnel excavation accurately; as well as certain geological areas where there is high potentials for subsidence such as aqueducts and cavities; and also controlling long term subsidence

All of mentioned measures are accessible in line 2 subway project of Mashhad and is considered in system design. Regarding to the standards, recommendations, and existing technical texts (such as BTS, ITA, AFTES, and Japan tunneling community standards)to control ground displacement after EPBexcavation and consequently reduction of subsidence, necessary pressures around excavated area must be maintained in different stages. So that the ground toward system should be protected by bench pressure control, in shield situation by injecting bentonite with proper pressure, and at the end of the shield and the gap behind segment by injecting grout with proper pressure.In comparison of different areas of subsidence, most of subsidence in urban projects by EPB excavation machine is recorded in segmentation and grout injection situation. The reason should be in the type of grout injection. Necessary pressures in different situation for EPB excavation have been shown in figure 8.

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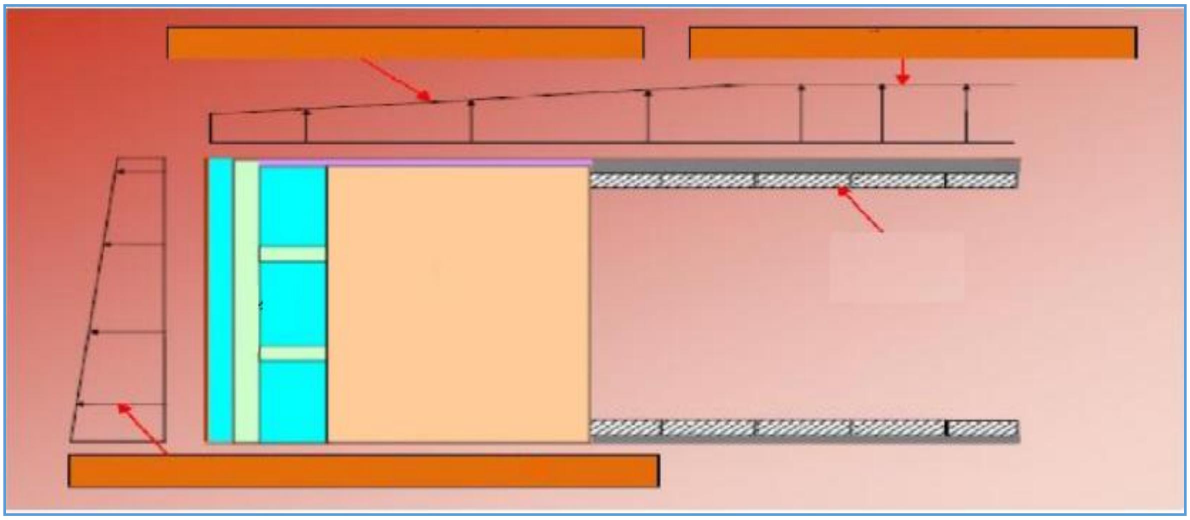

Figure 8

CONCLUSION

Factors affecting subsidence rate basically include the following items:

A) Geo technical specifications (resistance, rigidity, texture, permeability) and underground water conditions

B) Geometrical position and features of tunnel

C) Tunnel construction method and its cover

D) The skill of tunnel execution team

Before excavator machine reaches to the close distance of Mosque in Koohsanngi, proper studies were performed about current conditions of the structure, such as existing cracks and risk level as well as precaution for transformation and its subsidence were defined according to the technical situation. Then, gadget plan was underpinned and after installing topography signs and tilt meters, their records began and continued until the end of transformations. Attention to the excavation under normal conditions in terms of EPB pressure maintenance and grout injection as the specificationof the project, the subsidence of given building has been much less than threshold limits of danger and risk. As the result of monitoring and instrumentation shows, induced transformations from the project to the mosque are not so much that leads to the generation of new cracks or intangible development of existing cracks.

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