

# The Importance of Engineering Measurements and Risks Assessments in Preventing Of the Landslide Originated Problems in Highway Projects

Eray CAN<sup>1</sup> and Hikmet ERBIYIK<sup>2</sup>

<sup>1</sup> Associate Prof. Dr., Yalova University,

Engineering Faculty, Transportation Engineering Department,

77200, Yalova, Turkey

<sup>2</sup> Assistant Prof. Dr., Yalova University,

Engineering Faculty, Industrial Engineering Department,

77200, Yalova, Turkey

---

## ABSTRACT

*The landslides remain among the natural disasters of earthquake, flooding, tsunami, erosion, ..etc that affect the life of the societies adversely. These movements, may depend on the geologic, geophysical and topographic features of the earth at one side, they might arise due to the effects of climatic, flora and fauna, and land usage of human beings as well. Especially, it is more likely to meet with the landslide problems in a great extent, in design, construction and post-construction period of the highway implementation projects that remain among important infrastructure projects for urban and connects the urban living quarters. Since these engineering projects are the type of inter-disciplinary projects, the importance of joint and collaborative works increase dramatically among the relevant experts in civil, surveying, transportation, geology, geophysics and urban planning fields. In this study, while it is attempted to provide information about the encountered risks that may arise due to insufficient precautionary measures and some amendment, correction and prevention methods for the problems when encountered with landslide problems during the highway projects design, survey, and production stages, due care is also given for the importance of engineering measurements in these kind of experienced methods.*

**Key Words:** *Engineering measurements, Landslides, Highway projects, Infrastructure, Risk review and assessment.*

---

## 1. INTRODUCTION

The landslides, are regarded as among the movements that play important role in improvement and changing of the earth surface, on the other hand they also cause serious problems and affect the human life adversely as well as cause problems in infrastructure of urban areas and results natural disasters by carrying serious risks in themselves if the effective precautions are not taken properly when they emerge in urban settlement areas [3,6,7,9]. These earth movements, are emerged due to changing process of the geodetic factors such as geomorphologic and geo-physical type, they might also come out due to the effects of flora and fauna, climatic, hydrologic, and human estate usage and show up themselves in flowing, breakage, and falling down forms [1]. The landslides that have an important position among natural disasters emerge in the form of rock, debris, and soil materials or masses that are the mixture of those materials and move downwards with gravitation effect [10]. Some relevant concepts are given along with the general appearance of the landslide movements in Figure 1a and Figure 1b In addition to

devastating effects of the landslides with human life and property losses, in their affecting areas, they also cause destructions in highways, railways, pipelines, and agricultural fields [2,3,4,5,8,11,12,13]. Especially, in the areas that are not predicted or having landslide potentials, while designing or implementing highway projects, emerging or potential losses and damages including economic aspects of them have to be defined and relevant precautions have to be taken in advance of their emergence and relevant risks have also to be defined when appropriate measures are not taken in time. In defining above given issues, the works of the researchers and engineers present great importance. In this regard, in the landslide area in Highway Projects, or in a field that has the potential of landslide, it is necessary to define area geometry and borders by geodetic engineering and measurement studies by using sensitive levelling and GPS systems. However, to understand the landslide mechanism and relevant risks, it is also important to calculate the horizontal and vertical side parameters of landslide. (Figure 2a and Figure 2b). In transportation projects such as Highways, in solution of the landslide originated problems, in general various methods are utilized such as avoiding, excavation, drainage, holding structures and stabilizing the sliding mass and so on [1]. The avoiding technique, in this kind of landslide areas, is a kind of method that route changing or connecting by bridge alternatives are implemented, excavation process is a method that aids to solve the problem by carrying the sufficient amount moving mass in order to reduce the mass movement force. The drainage method depends on the base to keep away the water from moving mass or arresting the water before it contacts with the mass. In holding structures method, the structure is positioned in such a way perpendicular to the movement side of the moving mass and preventing the movement of the mass that is prone to hazard. In the other type of methods, it is attempted to stabilize the sliding mass with cement or other chemical substances and hence to increase its strength [1].

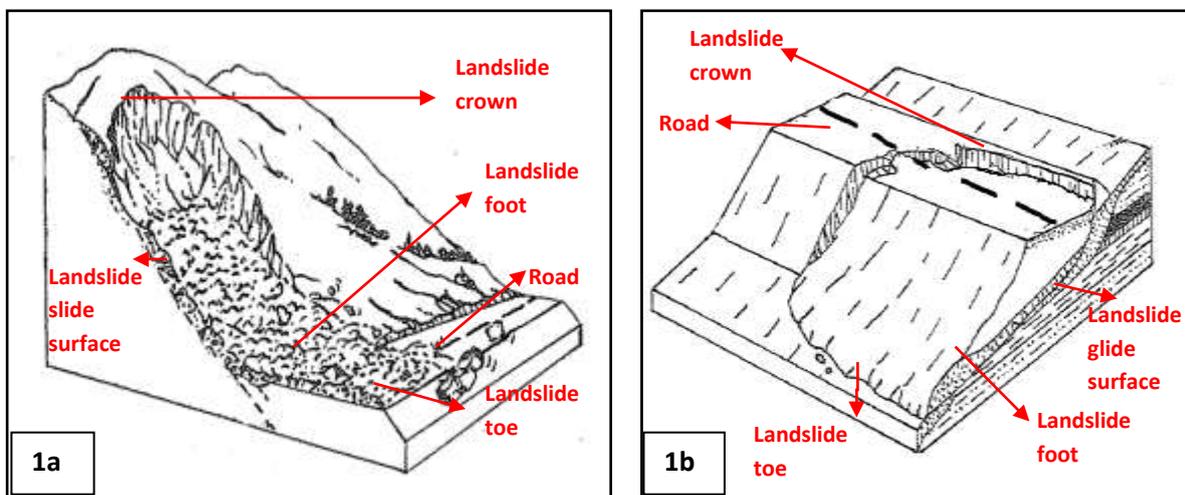


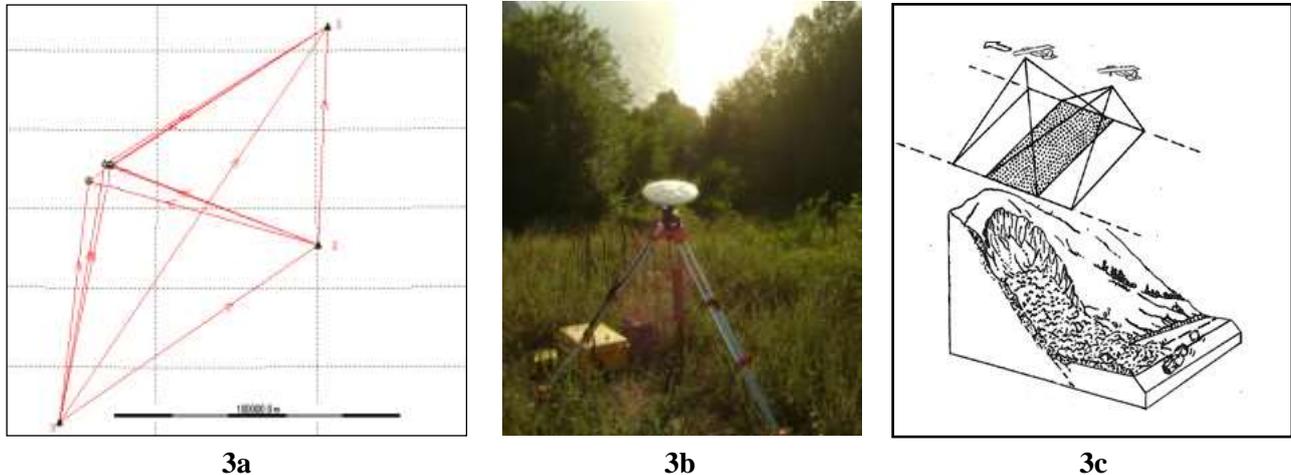
Figure 1 a,b The formation of landslides and their components in Highway Projects [1].



Figure 2a,2b GPS and Levelling Measurements toward Defining Landslide Movements.

In reclaiming and preventing the landslide originated problems, while the above defined methods are implemented, on the other hand, topographic network connected geodetic photogrammetric, and satellite based measurements and precision implementation works that are designed in a sensitive manner also present importance (Figure 3a, Figure 3b and Figure 3c). There are some

standard information to be applied for landslide problems for each reclaiming method. In obtaining and implementing the above given information, the magnitude of the landslide mass (big or small) and the type of landslide movement becomes important. While it is sufficient to know the amount of the moving mass for small landslides, on the other hand, for the big size landslides of having high reclaiming cost, it is necessary to carry out complete geologic, geodetic, and geophysical ground analysis. Furthermore, to define the emerging landslide with regard to matching with one of the relevant classified types of; falling down, sliding, or flowing plays an important role for proper selection of precautionary measures and reclaiming methods in a highway project in the landslide area.



**Figure 3a, 3b, 3c** The topographic and photogrammetric measurements that are made for defining the landslide geometry and parameters in connection with the geodetic network.

## 2. PRECAUTIONARY ACTIONS AND RECLAIM METHODS TO BE TAKEN FOR LANDSLIDE TYPES

It is not always possible to attribute the any certain clear reason for any landslide. The reason of the movement that causes developing of a landslide depend on the formation of existing rock, even to the period of the geological eras that main physical feature of the rock was generated. However, likelihood of the formation of landslide increases with, the endurance of the landslide mass shell against earthquake, climatic conditions in the concerned area, and the wearing of the rocks due to erosion. One or more of the above defined factors may be sufficient enough to move the part or whole of the landslide mass downwards from the scarp. It is usually difficult to decide what is the exact reason for causing the disruption of the balance of the landslide mass in formation of landslide. For that reason, it is necessary to carry out periodical geodetic, geologic and meteorological monitoring in the potential landslide area. It will become rather healthy to collect landslide parameters data by way of this kind of measurements and monitoring. There are basically 3 main forms of landslide movements these could be classified as; falling down, slidings, and flow [1,2,10]. Falling down or break up type landslide formations could be encountered very often in the nature. In the case of falling downs of soils or the rocks, the relevant mass makes free fall movement in the air, leaping, bouncing or rolling movement and interactive effects of the moving units to each other is rather very low during this falling down [10]. The sliding type landslides are generated due to the reduction of strength along with the one or more frictioning surface [10]. Furthermore, these surface have also features of visibility and predictability in terms of landslide. The landslide types of flow are formed due to replacement or movement of the hillside debris and separated and loose materials on wet or dry surface [10]. The basic reason of these movements is water hence they are seen very often in the extreme rainfall areas. In fountain waters or afterward of the intensive winter season, the dissolving of the ground might trigger the movement of the mass in the hillside. The sliding mass, might be very wet as well as dry due to the reasons that the rocks might lose their natural features and the cracks in their inner structure expands and property and human life lost could be suffered resultantly [10].When encountered with the falling down or break up type landslide problems in highway projects, the following methods are recommended usually; [1]

- Route changing method,
- Slope tilting method,
- Surface drainage methods,
- Holding structure methods (constructing reinforced concrete wall, steel network, and steel wire designs)
- Excavation methods,

it can be listed [1].Since the falling down and break up type landslide types can be differentiated easily from other landslide types, and their formation mechanism can be better realized, it is also rather easier to decide the most suitable

reclaiming method. Whatever method is implemented among reclaiming and precautionary methods, the planned geodetic and satellite based measurements in the landslide region, present importance while they are considered along with the economic and costing aspects of the work. When encountered with the sliding type landslides, among the recommended reclaiming and precautionary methods for landslides the following methods can be cited; [1].

- Route changing method,
- Excavation of the sliding zone of the surface; inclination of the slopes, to generate slope structure in sequences in the concerned topographic surface.
- Surface drainage method with open ducts; rearrange the surface slope or closing the surface cracks.
- Underground drainage methods to be made with horizontal drains,
- Construction of reinforced sustaining concrete walls,

it can be listed [1]. In this kind of landslides, whatever method should be selected has to be assessed according to the results of geodetic measurements and geologic, environmental, meteorological and geomorphologic analyses in the landslide area. Furthermore, with the experts from this sector, economic and costing calculations have to be made, and transaction type to be defined. When encountered with flowing type landslides in highway projects, among the methods in order to reclaim and prevent the landslides, the following methods can be cited;

- Route changing method
- Excavation method by tilting the slopes; stepping the slopes or removing the slopes completely,
- Surface drainage method by open trenches; to arrange the surface and closing the surface cracks,
- Drainage method by horizontal drains,

it can be listed [1]. As it is seen in the sliding type landslides, if the highway project is affected with a shallow flowing type landslide, the reinforced concrete wall construction can be used as a suitable method. As it is mentioned earlier, in this type of landslide the definition of the landslide parameters that will be obtained as a result of the geodetic measurements and analyses present importance for selecting the most suitable method. In the formation of landslides; erosion, excavation activities of human beings, construction activities, rain, snow, the weight of the fountain waters, temporary soil strains, earthquakes, slope state of the topography, sub-wearing of coasts due to waves and rivers effect, underground erosion, mine fields, underground cracks and cavities and swellings in this areas,...etc. factors play an effective role. Understanding of effects of a landslide will be important in terms of the following factors;

- The definition of the most economic reclaiming method,
- The realization of legal analyses,
- Consisting of a guide for possible prevention of landslides in the future [1],

The extent of well understanding the history of a landslide, and the main and side effects that cause the landslide movement will result the selection of most suitable reclaiming and precaution methods in a better and precise manner.

### **3. THE AVOIDANCE METHODS IN LANDSLIDE CONTROL AND RECLAIM**

In this method, route changing and passing with bridge methods are among the possible alternatives that have to be implemented and followed up [1]. As the result of the implementing above two methods, it is possible to keep away from the landslide area however implementation of these methods will not be relevant with surface stability. Route changing and passing with bridge methods will be able to implement in possible landslide zones instead of active landslide zones in general. In most cases and especially in topographically mountainous areas, in landslide area, these methods have to be implemented with minimum cost and minimum amount of change in the route. Otherwise, this method will have very high cost and will give heavy economic burden.

Avoidance Method is one the used methods in our days however, one of its advantages; it maintains that the route follows the ways via more healthy areas in terms of the geologic and topographic manner, and enables the highway route being more uniform. In the avoidance from landslide area method by way of route change, the route change must be in a state to meet expectations in terms of yielding benefits. For example, new Project elevation, new curve parameters, new excavation and cubage calculations and new drainage of the highway must be in an acceptable state.

Furthermore, due care has to be given that the ground to be in a stable state in the bottom and top zones of the new route. Passing with bridge method, is a very costly one, it could be implemented in the cases that route change is not desired and could not be implemented. In this method, it is very important that bridge piers must sit on a stable ground in a careful and precise manner. This could be made possible by making precise geodetic, geologic and geo-physical measurements and drillings. In Table 1, a summary table is given for Avoidance Method that is one of the landslide reclaiming (corrective and preventive) methods in highway projects.

Table 1. Summary Data for Avoidance Method for Landslide Originated Problems

<b>The used emending and prevention Method</b>	<b>The location of used Method on the landslide</b>	<b>Implementation of Method, its borders, measurement works, and Working team</b>	<b>Potential risks in case of insufficient precautions</b>
Avoidance Methods:			
1) Displacement	Outside the Landslide sliding border	If the new route design and implementation is economic, it is the most suitable method. Precise GPS and levelling measurements and photogrammetric and satellite based measurement methods can be used.  Working Team: Civil, Surveying, Geology, Transportation Engineers.	It causes failure in using highway due to serious destruction and deformations are generated on the highway. Serious economic losses are suffered. Travelling safety affected adversely.
2) Passing with bridge	Outside the landslide sliding border	It could be implemented in scarp and steep hillsides, provided that the distance is short and in the same direction with axis. It requires sensitive application and measurement cases.  Working Team: Civil, Surveying, Geology, Transportation and Bridge Engineers	

#### 4. EXCAVATION METHODS IN CONTROL AND RECLAIM OF LANDSLIDES

Excavation methods in control and reclaiming of landslides problems are usually implemented in highway projects, in order to reduce the forces that causes slidings and hence to bring the landslide mass into a stable state. In this method, activities can be cited as; taking away the landslide upper part by excavation, inclination of the scarps, stepping implementations in scarps, and moving away all non-stable materials from landslide area [1]. Excavation methods are very effective methods in preventing and amendments of landslides however, in case of big sized landslides the costing of this methods increases in a great extent. Furthermore, in afterward of the excavation, ‘where to dispose the excavated materials’, also bring the ownership problems and expropriation costs resultantly. In considering landslide problems, while implementing excavation methods, it is important to define the right types for landslide, which one of the following types suits; sliding, falling, or flowing and definition of flowing surface that it has a structure type of plane or curved, present great importance. In table 2, a summary table is given for excavation method which is one of the methods to be used for preventing and reclaiming landslides in highway projects.

**Table 2. Summary Data for Excavation Method for Landslide Originated Problems**

<b>The used emending and prevention Method</b>	<b>The location of used Method on the landslide</b>	<b>Implementation of Method, its borders, measurement works, and Working team</b>	<b>Potential risks in case of insufficient precautions</b>
II)Excavation Methods:			
1) Removal of upper part of landslide	On the upper part of landslide	It must be implemented in big thickness cohesion materials. Excavation measurements and cubage calculations must be made in connection to a sensitive geodetic network.  Working Team: Civil, Surveying, Geology, Transportation Engineers.	In case of insufficient precautions  Travelling safety affected adversely.  There are serious destruction and deformations are generated on the highway.
2) Inclination of scarps	On the upper part of road or structure	It must be made on main rock and on the cohesion surface. Precise measurements have to be made on the field for providing scarp geometry as per the Project.	
3) Stepping of scarps	On the upper part of road or structure	Working Team: Civil, Surveying, Geology, Transportation Engineers.	
4) Removal of whole sliding mass	On the whole of the sliding mass  (on the whole of the landslide)	It has to be implemented in the cases that sliding materials rather small and its thickness fairly little  Precise geodetic measurements have to be made in order to make the sensitive excavation calculations.  Working Team: Civil, Surveying, Geology, Transportation Engineers.	

In preventing and reclaiming landslide problems in highway projects, whatever way is used for excavation method, the importance of precise measurements in the field and the cubage calculations that will depend on these measurements will be revealed clearly in terms of project costs and economic aspects.

### 5. DRAINAGE METHODS IN CONTROL AND RECLAIM OF LANDSLIDES

The drainage methods in highway projects, in preventing and reclaiming landslide problems, is one of the primary methods in terms of implementation capability [1]. Regardless of the type of landslide movement, surface drainage method is always important and it could be used with the other methods all together with a negligible additional cost in most cases. Underground drainage on the other hand, will be more appropriate for falling type landslides and it is used rarely. One of the advantages of the drainage method; in case of big sized landslide movements, in reducing movement factors in a minimum level, it provides economic advantage with minimum cost. In the surface drainage method that is used in solving landslide problems; scarp arrangement, Project elevation changing, and closing the breakage and cracks afterward of the landslide type activities could be monitored [1]. Among those methods, the objective in scarp arrangement is to increase the stability of the made scarps. Furthermore, there are different kind of implementations for this method, such as; sodding of the surface or forestation, constructing thin stone or concrete walls, providing filled rocks,...etc. The methods of changing Project elevation, and closing the breakage and cracks afterward of the landslide may give positive results, provided that they are implemented all together. In underground drainage method, horizontal drain implementations are used quite often. In horizontal drains method, to drain the water in the landslide area, in order to change the location of water resource or water accumulation, is realized by reducing the water level in sliding mass as much as possible, and forwarding into a permeable layer. In this method, if the water resource could be prevented from entering into the landslide sliding mass, or changing the direction of water by way of drain, in that case the outcome of the method will be very beneficial. During the prevention and reclaiming of the landslides, if we expect substantial success from the implementation of this method as it is happened in the other methods, precise measurement, analysis, and implementation works over ground to be made in the concerned area will present great importance. In table 3, a summary data is given for drainage method that is one of the methods for preventing and reclaiming landslides.

**Table 3 Summary data for drainage method for solving landslide originated problems**

<b>The used emending and prevention Method</b>	<b>The location of used Method on the landslide</b>	<b>Implementation of Method, its borders, measurement works, and Working team</b>	<b>Potential risks in case of insufficient precautions</b>
III) Drainage Methods:			In case of insufficient precautions travelling safety affected adversely. There are serious destruction and deformations are generated on the highway.
1) Surface Drainage		It could be implemented for all landslide types and on the rock surface in order to control the water leakage.  Precise geodetic measurement methods will be able to used.  Working Team: Civil, Surveying, Geology, Transportation Engineers.	
a) Scarping arrangement	On the sliding mass surface		
b) Changing Project elevation	On the road project		
c) Closing the breakage and cracks afterward of the landslide	Between the top (crown) and bottom part of the whole mass (on the landslide)		
2) Underground Drainage		It could be implemented in deep and wide earth masses that have underground Water  It requires precise application and measurement works as per the design project.  Working Team: Civil, Surveying, Geology, Transportation Engineers.	
a) Horizontal drains	They will be placed in such a way to prevent and remove underground water.		

**6. RETAINING STRUCTURES IN CONTROL AND RECLAIM OF LANDSLIDES**

Retaining structures that are implemented for preventing and reclaiming the landslide problems in highway projects, are used by exerting strength against the landslide movements in order to control and prevent the landslides. Among these type structures, sustaining concrete walls, pilings of fixed on the landslide sliding surface, holding reinforced steel bars are being used. In our days, during the implementation of these methods, fairly successful results are being obtained toward preventing and reclaiming landslide movement. The structures that are used in this method are used to control the landslide movements of small sized in sliding forms [1]. One of the important advantages of the retaining structures that are implemented in preventing and reclaiming landslide problems in highway projects; they do not impose high cost in their construction in economic aspect. Furthermore, their implementation areas do not require larger space and their expropriation costs are also fairly low. If a successful holding structures implementation is required, in control and reclaiming of landslides in addition to realization of geologic surveying in the ground implementation of precise application work also will be necessary and important. In Table 4, a summary data table is given in highway projects for holding structure method that is one of the most used methods for preventing and reclaiming of the landslides.

**Table4. Summary data for Holding Structure Method for Solving Landslide Originated Problems**

<b>The used emending and prevention Method</b>	<b>The location of used Method on the landslide</b>	<b>Implementation of Method, its borders, measurement works, and Working team</b>	<b>Potential risks in case of insufficient precautions</b>
IV) Retaining Structures			It causes failure in using highway due to serious destruction and deformations are generated on the highway. Serious economic losses are suffered. In case of insufficient precautions travelling safety affected adversely.
1) Sustaining concrete walls	The landslide is on the toe zone	They are implemented in the zones that sliding mass is rather small. It requires sensitive application and measurement works.  Working Team: Civil, Surveying, Geology, Transportation Engineers	
2) Pilings that are fixed on the landslide sliding surface	The landslide is on the toe zone	Sliding resistance of sliding surface by providing pilings. It requires sensitive application and measurement works .  Working Team: Civil, Surveying, Geology, Transportation Engineers	
3) Fixation of the rocks with connecting steel re-bars	Top portion of the road or structure	Rock layers are fixed with each other with connection steel re-bars. It requires sensitive application and measurement works  Working Team: Civil, Surveying, Geology, Transportation Engineers	

**7. STABILIZATION OF SLIDING MASS IN CONTROL AND RECLAIM OF LANDSLIDES**

Another method implemented for preventing and reclaiming landslides in highway projects is stabilization of sliding mass. Stabilization of sliding mass in landslide problems will be able to made by applying cement or structural chemical substances on the ground, this process increases the sliding resistance of the sliding mass especially along with the whole or partial sliding surface [1]. This method is usually applied into sliding type landslides, it is also recommended to apply this method in flow type landslide movements.

Applicability and economical aspect of this method will be depending on the magnitude of the landslide zone another advantage of this method is that it does not hamper the smooth traffic in the landslide zone highway when implemented. Due care must be given to location of landslide zone, ground character, highway project line level, and drainage features of the ground during the implementation of this method. In case of implementing this method, if it is required to make the costing and cubage calculations in sensitive manner, horizontal and vertical position measurements in the area as being connected to a sensitive geodetic network present importance. In Table 5, a summary table is given for stabilization of sliding mass method that is one of the most used methods for preventing and reclaiming landslides in highway projects.

**Table 5 Summary data for Stabilization of Sliding Mass Method in Landslide Originated Problems**

The used emending and prevention Method	The location of used Method on the land slide	Implementation of Method, its borders, measurement works, and Working team	Potential risks in case of insufficient precautions
V) Stabilization of Sliding Mass			
1) To increase ground strength by applying cement or structural chemical substances	In the zones that landslide sliding takes place	It must be implemented in non-cohesion grounds. It requires horizontal and vertical position measurements as being connected to a sensitive geodetic network.  Working Team: Civil, Surveying, Geology, Transportation Engineers	It increases landslide formation potential on the highway, in case of insufficient precautions. This also causes adverse affection of infrastructure and transportation in the zone.
a) Stabilization of landslide toe	The landslide is on the toe zone		
b) Stabilization of whole sliding mass due to landslide	In the whole mass in which landslide sliding is generated		

## 8. RESULTS

The landslides that are known as earth sliding movements, are encountered very often in the world, they are the leading earth incidents in the sense that they cause destructions in the infrastructure. Especially in the highway transportation projects and implementations in order to connect the urban areas with each other, their destructions and imposed economic losses are always evident and considerable. For that reason, in the areas that are selected for both transportation and settlement reasons, the relationship between topographic, geologic, geo-physical, geo-morphologic and climatic features and mass movements must be defined clearly. Therefore, theoretical and applied multidisciplinary works (Surveying, geology, civil, geophysics, transportation, geomorphology,...etc engineering ) must be carried out all together.. Especially, in case that if the multidisciplinary works are not carried out in the areas of highways that have high landslide potential, landslide monitoring will not be able to made and in the case of landslide formation travel safety and security will be affected adversely in the highway. Nevertheless, while implementing highway projects, especially in route selection, landslide sensitive areas must be considered and design and implementation projects must be handled in that basis. Especially, in the mountainous and high altitude areas, landslide sensitivity must be monitored, measured and defined in a very precise manner. In the afterward of these measurements, and according to the type of landslides (flow, falling down, sliding, ..) right decision must be given for selecting one of the methods for the planned preventive and reclaiming actions. Prior to the selection of these methods (Relocation, passing with bridge, excavation, drainage, retain structures, stabilization of sliding mass,...etc.) both the horizontal and vertical direction geodetic and satellite based engineering measurements and monitoring must be made by expert and educated personnel in this field and

relevant risks mitigated into a minimum level. Besides, the success of the selected method and obtaining maximum benefit with minimum cost will be depending on the sensitivity of the planned measurements and monitoring, hence the measurements must be made in a very sensitive manner.

## REFERENCES

- [1] Atalay, I. F., Bekaroğlu, N., 1973. *Landslides And Engineering Applications* General Directorate of Highways, Publication Number:200, 349 s., Ankara, Turkey (In Turkish)
- [2] Can, E., 2015. *Investigation of landslide potential parameters on Zonguldak–Ereğli Highway and adverse effects of landslides in the region*, Environmental Monitoring and Assessment, Springer 186:2435–2447, doi 10.1007/s10661-013-3550-3
- [3] Can, E., Erbiyik, H., 2017. *Description of failures and risks that are emerged from landslide measurement activities in infrastructure deformations*, Tehnički vjesnik, 24(3). doi:10.17559/TV-20160927182726
- [4] Can, E., Erbiyik, H., 2016. Determination of the Risks that are Emerged from the Use of Aerial Photographs in the Mapping Activities for Landslide Movements by FMEA and Pareto Analysis Methods and Suggested Solutions, *Procedia Engineering*, 161 ( 2016 ) 850 – 858
- [5] Düzgün H.S.B, Özdemir A., 2006. *Landslide Risk Assessment and Management by Decision Analytical Procedure for Dereköy, Konya, Turkey*, Natural Hazards, 39(2), pp. 245-263
- [6] Hua-xi, G., Kun-long, Y. 2014. *Study on spatial prediction and time forecast of landslide*, Nat Hazards (2014) 70:1735–1748 DOI 10.1007/s11069-011-9756-1
- [7] Jia, N., Mitani, Y., Xie, M. Tong, J., Yang,Z., 2015. *GIS deterministic model-based 3D large-scale artificial slope stability analysis along a highway using a new slope unit division method*, Nat Hazards 76: 873. doi:10.1007/s11069-014-1524-6
- [8] Klose, M., Damm, B., Terhorst, B., 2015. *Landslide cost modeling for transportation infrastructures: a methodological approach*, Landslides 12: 321. doi:10.1007/s10346-014-0481-1
- [9] Negi, I.S., Kumar, K., Kathait, A. Prasad,P.S., 2013. *Cost assessment of losses due to recent reactivation of Kaliasaur landslide on National Highway 58 in Garhwal Himalaya*, Nat Hazards 68: 901. doi:10.1007/s11069-013-0663-5
- [10] Öztürk K., 2002. *Landslides and effects on Turkey*, Gazi University, Journal of Gazi Education Faculty, Volume 22, Number 2, pp.35-50 (In Turkish)
- [11] Regmi, A.D., Cui, P., Dhital, M.R. Zou,Q.,2016. *Rock fall hazard and risk assessment along Araniko Highway, Central Nepal Himalaya*, Environ Earth Sci, 75: 1112. doi:10.1007/s12665-016-5905-x
- [12] Yalçınkaya M., Bayrak T., 2005 *Comparison of Static, Kinematic and Dynamic Geodetic Deformation Models for Kutlugun Landslide in Northeastern Turkey*, Natural Hazards, 34(1) pp. 91-110
- [13] Liu, S., Wang, H., Huang, J.,Wu L.(2015) High-resolution remote sensing image-based extensive deformation-induced landslide displacement field monitoring method, *Int J Coal Sci Technol*, 2(3):170-177, doi: 10.1007/s40789-015-0087-9.