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Avalanche Research Studies at Bozdağ

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Abstract Turkey may encounter some threatening avalanche events almost every winter season since approximately 70% of the land of the country is situated on high altitude mountains. Snow avalanche as a disaster might cause many people to lose their lives and damage to property. Fatal avalanche disasters occurred in the 1990s have triggered initiation of national academic studies and some projects aimed at reducing avalanche losses. However, studies in Europe on the subject date back to many decades. Prediction, prevention or damage reduction is possible precaution steps for an avalanche disaster. For this reason, it is indispensable to continue expanding the national studies focusing on prevention and damage reduction of snow and avalanche. Academic studies on the subject are in progress in Turkey. However, a central research institute is advised for a sustainable management of avalanche disaster. This institution will be able to carry out and evaluate some key issues such as field observations and data collections, analysis of the data collected, development of a forecast model, application of protection methods, risk management, research and pursuit of innovation etc. A research project is currently carried out by Gazi University at Bozdağ, İzmir. An automated station is established for data collection which will be used in analyze of avalanche disaster at Bozdağ.

***Index Terms*— Avalanche, Forecast, Disaster, National, Prevention.**

I. INTRODUCTION

One of the natural disasters encountered during every winter season in Turkey is snow avalanche. According to historical event records, especially Eastern, South-Eastern and Eastern Black Sea regions are faced to these natural phenomena. Also some specific ski resorts on the west of the country are under risk of avalanches. Archives of avalanche records indicated that avalanche events had been recorded due to loss of lives or damage of properties [1]. However many avalanche events could not be documented since difficult to reach or due to another reason. Whereas it is known that a number of avalanche events occur especially on highways every winter season.

After catastrophic avalanche events occurred in 1992 and 93 winter seasons in eastern Turkey, AFET, General Directorate of Disaster Affairs, a previous responsible governmental organization for avalanche incidents, initiated some projects aimed for mapping and prevention against snow avalanches. Avalanche mapping and some field measurements performed for some selected areas with collaboration by experienced European countries such as Switzerland and France. In this period, Gazi University worked together with AFET for giving academic support in this regard. However, after completion of the project, data gathering from the field could not been carried out regularly and new projects could not been put into practice for sustainable solution of avalanche problem in Turkey. Since then, it has not been launched any study about gathering meteorological and field measurements data especially from the starting zones which are supporting information in terms of avalanche forecasting and dynamic modeling efforts. Meteorological and snow cover data from starting zone are easier today to collect and record with the development of technology. Therefore, Gazi University, Civil Engineering Department proposed a research project recently collaboration with Prime Ministry Disaster and Emergency Management Authority (AFAD) and Turkish State Meteorological Service (MGM). The project has started on November 2014 and it is still in progress. The main aim of the project is to set up a meteorological station on Bozdağ release zone which was experienced a fatal avalanche event in the past. The avalanche weather station was assembled by the way in order to get both meteorological and snow data remotely.

Snow avalanche simulation on computer is nowadays

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another key issue in terms of proactive studies. A numerical based model RAMMS (rapid mass movement simulation) which was developed by SLF (Institute for Snow and Avalanche Research in Switzerland) will be used to simulate avalanches for possible releases area with different scenarios on the project site. Many engineering projects involving preparation of hazard maps, land use planning, ski resorts, motorways, electricity poles, avalanche barriers, tunnels etc. need to use avalanche simulation models. Therefore, it is emphasized with this study that the necessity of the subjects of academic initiative and developing solution strategies.

II. Literature Review

Theoretical model development studies started in early 1900s in Switzerland and Russia. Numerical models have been applied since 1980s with the rapid development of computer technologies. One of the preliminary numerical model developed by Perla in 1980 [2]. Stability of movement is based on two parameters in the model.

Especially European countries like Switzerland and Austria or Japan are leading development in this area. However, the models developed by those countries could not been widely applied across Turkey. So verification of the models was very limited so far.

SLF in Davos has been a leading role in avalanche research [3] in Europe since 1930s and dynamic modeling studies in the center continue since the 1950s. They have developed their first one-dimensional model AVAL-1D then improved two-dimensional model RAMMS (Mass Rapid Movement Simulation) has been released for practitioners. Avalanche movement and related results can be visualized on three-dimensional terrain in the model. Users are currently available from many different countries [4]. Therefore, RAMMS as a dynamic model will be applied to investigate suitability for the selected pilot area for ongoing research project.

The first avalanche modeling studies in Turkey started with academic studies such as thesis and research papers. For example; Durak [5], Arslan [6], Uçar [7] used computer models to simulate snow avalanches on their thesis. Koçyiğit and Gürer [8], Aydın et al. [9], Aydın [10], Köse et al. [11] have published some research papers about modeling of avalanches in Turkey. Durak [5] in his MSc. thesis applied a numerical model developed by Lang[12] to study an avalanche event occurred in Bayburt-Üzengili. He estimated vulnerability for the project area due to avalanche pressure calculated by the numerical model and field observations. He also analyzed the houses destroyed or damaged by the avalanche event in his work. Arslan [6] used another calculation model to predict avalanche run-out distances and flow velocities. He applied AVAL-1D program which was developed by SLF [3]. He simulated an avalanche event occurred in Uzungöl village near to Black Sea situated on North-Eastern of Turkey. The village and the surrounding valley have become popular tourist attractions so that in addition to local people there are many visitors all around year. Arslan [6] used to the program continuous information on flow height, velocity and pressure along the entire Dorinori path which is one of Uzungöl avalanche tracks. He emphasized that the model predictions are compatible with run-out distance observations and damaged building assessment on the path. He concluded that Voellmy friction parameters mu (μ) and xi (ξ) used on the model are affecting on simulation results considerably. He also recommended that friction parameters should be evaluated with more detail study for Turkey. Sensitivity analysis of Voellmy friction parameters have been studied by Koçyiğit and Gürer [8].

Another academic thesis related computer modeling application on avalanche occurred in Turkey were performed by Uçar [7]. Primary aim of his work was to obtain potential hazard maps, input parameters to prepare the maps and their effect level on the size of avalanche with regard to field observations and model outputs. He chose Çoruh River Basin and around Palandöken Ski Centre as the project area. He used Geographic Information System (GIS) technique to produce a Digital Elevation Models (DEMs) for specified the area. He tested two dimensional GIS based numerical model ELBA+ which was developed some scenarios with different combinations of the model parameters by using 2D snow avalanche run-out simulation model.

Numerical model studies for avalanche studies have increasingly been adopted in Turkey especially in recent years. For example, Aydın et al [9] undertook a two-dimensional model studies to simulate some of the past avalanche incidents in Turkey. These numerical model simulations are usually calibrated against recorded runout distance and accumulated snow depth at runout zone. Since it is not possible to compare values of avalanche velocity, avalanche flow depth and avalanche impact pressure. Therefore, avalanche stopping point accumulated snow depth observed after avalanche incident and findings obtained from face to face conversations made with local people are used in numerical model verification and for estimation of several parameters. Hence, a numerical model set up under these conditions is ready to be run. The new generation of numerical models is being developed in conjunction with GIS. Numerical avalanche models such as ELBA+ and RAMMS work compatible with GIS and the simulation results obtained from such models can be visualized on three-dimensional digital maps [10]. A similar application of ELBA+ numerical model to simulate avalanche incidents occurred at Kayaarkası village of Kastamonu Province is an example of such studies [11].

III. Bozdağ, Project Area And Studies

Altitude, snow depth, aspect, vegetation, terrain topography, prevailing wind direction, snowpack condition, etc. parameters are used to determine the possibility of avalanche. Data related to snow are mostly collected and evaluated by governmental institutions in Turkey. However, some governmental institutions establish observation and data collection stations according to their needs so specific data for avalanche prediction needs were not systematically

collected. For instance, the General Directorate of Meteorology collects the most comprehensive snow data on a regular basis, however those recorded snow data cannot be used for determination of avalanche risk since those stations are not located at the altitudes where release zone may take place. For this reason, one of the goals of the project is to establish an automatic whether station to collect comprehensive snow data at the release zone near to mountain summit.

As a pilot project area, ski resort Bozdağ, situated in İzmir Province in Western Turkey is chosen taking into account factors such as transport, previous avalanches, topography of the area, snow conditions, economic conditions and safety issues of the research group during field studies.

Bozdağ Ski Resort is surrounded by Bozdağ (summit 2156 m asl), Çatalsivritepe (2138 m), Tozlutepe in the south, Aktaş Peak (2024 m), Kartal Peak (2040 m) in the east, Üçler Peak (1908 m) Ortadağ Peak (1641 m), Çavdar Peak, Sarıpınarlar Peak (1695 m) and Dorukkayaları site (1888 m) in the north. Slopes with the highest gradient in this region are the north-facing slopes of southern and eastern peaks. Especially at Bozdağ and Çatalsivri Peaks at which ski lift are established the maximum, minimum and average slopes overlooking ski resort are usually 55, 26 and 40 respectively. Dominating vegetation cover over the region includes very sparse foliage shrubs and herbaceous plants. Sparse pine forest are present at altitudes lower than 1600 m (asl) and as getting lower altitudes maquis shrub type cover the area. General view of the study area and avalanche paths is shown in Figure 1 and Figure 2.

Figure 1. Bozdağ Ski Resort in Winter Season (2016)

The altitude of Bozdağ summit is 2159m (asl) and cornice of snow are encountered at north-facing slopes. Figure 3 shows the snow cornice formed on northern slope at upper altitudes of Bozdağ and avalanche release zone. Under certain meteorological conditions, these cornices of snow might sometimes trigger avalanche and can create dangerous situations for skiers. During 2012/2013 winter season tracks and ski lifts at Bozdağ ski resort were damaged as a result of an avalanche so the ski resort was closed. The resort couldn't be opened for 2014 and 2015 winter seasons since the necessary repairs at damaged parts weren't done. One of the damaged poles of ski lift after avalanche incident is shown in Figure 4.

Figure 2. İzmir Bozdağ Ski Resort and Avalanche Paths

Examples of damages as a result of avalanche incidents observed during field studies are given in Figure 5 and Figure 6. Figure 5 shows that although the pole has a small cross-sectional area and made up of steel, the pole was twisted and fully bent starting from the ground level in the direction of avalanche. Wooden snow bridges used as snow supporting structures were partly damaged at the release zone as seen in Figure 6.

Figure 3. Avalanche Release Zone and cornices in Bozdağ summit in 2016 winter

Figure 4. Condition of Skilift Poles After Avalanche Incident in Bozdağ (2015)

Figure 5. Snow Poles Condition After Avalanche (2014) Dr. Ö. Koçyiğit

Figure 6. Wooden Snow Bridges and Their Condition After Avalanche (2015) –G. Arslan

Snow supporting structures manufactured from wood and located at upper altitudes of avalanche release zone to prevent avalanche were damaged by the avalanche itself because of some design deficiencies such as insufficient height and some of those damaged parts of the structures broke of and fallen down the slopes. The enormous avalanche pressure exerted on the wooden snow supporting structures can be figured out from Figure 7.

Figure 7. Damaged and Fallen Parts of Wooden Snow Supporting Structures (2014)

Significant avalanche paths in the area are determined according to field observations, aspect, altitude, GIS data such as curvature, land cover, field conditions such as channeling state of the area and face to face conversation with local people. Then these avalanche paths are processed on digital maps in the GIS environment. Determined possible avalanche paths are located on the northern slope of the mountain as shown in Figure 8.

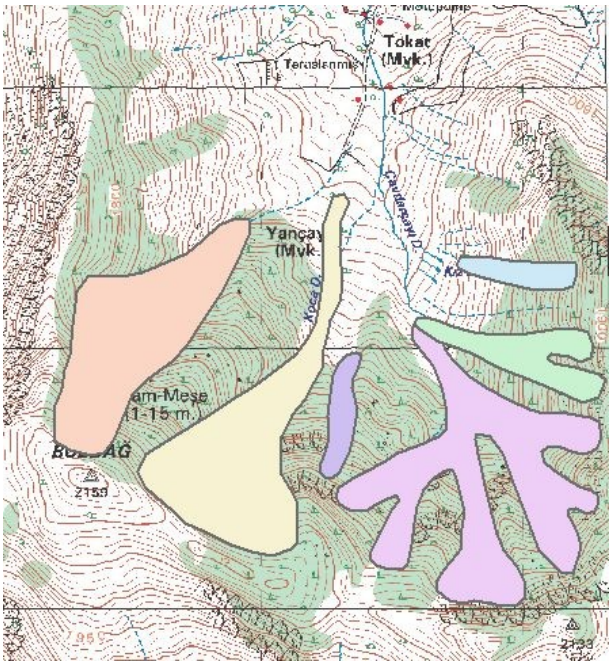

Figure 8. Possible Avalanche Paths on North Face of Bozdağ

One of the objectives of the project carried out by the research group is to measure the snow strength between

various snow layers formed in the snow pack during winter season and determine the weak layer(s) among others. Detailed study about this procedure given in Figure 9 was presented at 8th Engineering and Technology Symposium held at Çankaya University [13].

Figure 9. Snow Pit on Bozdağ North Face and Simple Snow Stability Tests (Dr. E. Tekin-2015)

The automated avalanche station was established at Bozdağ upper altitudes after a detailed investigation of the area. The location of the station shown in Figure 10 has been decided by taking in consideration the aspect, altitude, snow cornice condition, wind, foundation condition and risk of avalanche formation. Established station consists of the following components:

1.Anemometer and gauge of wind direction
2.Lightning conductor
3.Snow depth sensor
4.Rain gauge
5.Snow surface temperature sensor
6.Solar panel
7.Control panel (battery, data logger, data storage cards etc.)
8.Gauges for air temperature and relative humidity
9. Incoming and reflected radiation (albedo) gauges
10.Manual snow depth staff gauge
11.Main frame carrying station load
12.Tensioning ropes
13. Lightning conductor grounding connection
14. A total of 8 snow temperature measurement sensors
15.Data cables

According to the project all data are measured at every 2 seconds and average values of all measured data during 10 minutes are transmitted to a server established at Gazi University Civil Engineering Department. Data are automatically obtained through software which uses remote access and communication transmission lines. Moreover, transferred data from station are evaluated and analysis between parameters can be performed through software installed at the server.

Another objective of the project is to simulate the avalanche incidence happened in the region using numerical modeling. Hence, studies on RAMMS, a numerical model developed by SLF has started with preliminary test simulations.

Figure 10. Automated Weather Station For Avalanche Studies on Bozdağ Summit (Ö. Koçyiğit and G. Arslan-2016)

IV. Conclusion And Recommendation

Awareness against avalanche disaster hasn't been developed in society and at institutions in Turkey since avalanche isn't frequently confronted at residential areas. Therefore social institutional awareness against avalanche should be developed especially at technical departments of state institutions such as General Directorate of Highways responsible for motorways, Turkish State Railways responsible for railways, Minister of Energy and natural Resources responsible for power transmission lines, governorships, municipalities for planning and control of ski resorts. In the frame of the project carried out by authors as mentioned in the article, meetings at relevant governmental institutions with directors and technical staff in particular are to be held to raise awareness against avalanche and to give information about possible countermeasures that should be

taken in reducing avalanche damages.

In Turkey, data necessary for analysis of avalanches isn't available yet. On the other hand, countries in Europe with lots of experience with avalanches continue to build new stations with new technologies to further increase available avalanche data. Thus a pioneering work to collect national data for avalanche analysis is carried out in which an avalanche station was established at Bozdağ, İzmir, to collect data automatically. The findings of this study will be shared with relevant institutions and agencies.

Problems encountered during establishment of the station and the solutions adopted during this process will be shared at final report of the project. Therefore, the meteorological and snow data specifically used in analysis of avalanche would be collected from altitudes very close to summit and then evaluated scientifically, expecting to give serious contribution to the national avalanche studies. Since these avalanche data are essential for each and every type of study involving avalanche disaster.

Some of the outcomes aimed at the end of the project are as follows:

- Prepared avalanche hazard zone map of the pilot area using digital maps and field observations,
- Establishment of an automatic station to collect meteorological and snow data, transmit these data continuously to the research group and observe the likely avalanche paths for any avalanche formation,
- Determination of meteorological parameters affecting formation of avalanche for conditions for the pilot area,
- If an avalanche takes place in the project area, this would be analyzed by using recorded data,
- To discuss the adoptability of the results to be obtained at the end of this study from pilot area to other regions of the country,
- Determination of the relationship between the snow profile obtained from field studies and that obtained using data from automatic station.

Prediction of avalanche hazard, its prevention or reduction of its damages is possible with today's technologies and scientific knowledge. Hence, it is very important to develop a national program in which necessary countermeasures would be taken and likely damages of avalanches to be reduced. Besides this institutional program, academic studies on the issue should also continue with involvement from wider circle of academic researchers. Furthermore, there is an urgent need of setting up an institutional organization for sustainable management of avalanche problem in Turkey. Thus, with this institution, data collection, analysis of data, development of an avalanche forecasting model, implementation of prevention methods against avalanche, risk planning, pursuit of research and innovation would successfully be organized, evaluated and outcomes would be publicized.

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