

RECENT DEVELOPMENTS OF AVALANCHE RESEARCH IN TURKEY

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ABSTRACT: Approximately 70% of land in Turkey is situated on high altitude mountains where formation of snow avalanche is an inevitable natural phenomenon. This natural disaster had destructive and fatal consequences in some winter seasons in Turkey. For example many people lost their lives in Eastern Turkey in 1990's avalanches. However, many studies confirm that prediction, prevention or damage reductions are possible precaution steps on this disaster. Hence several projects involving avalanche mapping and snow profile recording were undertaken to reduce avalanche losses at several selected risky sites. However, necessary investigation and possible precaution steps could not be carried out in Turkey whereas studies on the subject in the USA and in Europe date back to many decades. For this reason, a research project is currently undertaken to establish an automated weather station to collect comprehensive snow data at the release zone in a selected site which experienced an avalanche resulting in a loss of life and damaged skiing facility in 2012-13 winter season. This is the first automated weather station in Turkey established and recorded data has being transmitted by GSM facilities since November 2015. The aim of this paper is (1) to present the avalanche history in Turkey, and (2) academic studies and past experiences, (3) to give details of the current research and discuss about primitive findings, and (4) to give information about planned further studies in Turkey.

KEYWORDS: Snow, Precaution, Weather station.

1. INTRODUCTION

Eastern, South-Eastern and Eastern Black Sea regions shown in Fig 1 in Turkey are faced to snow avalanche disaster every winter season. Also some specific ski resorts on the west of the country are under risk of avalanches.



Fig 1. Avalanche map of Turkey

After many catastrophic avalanche incidents arisen in 1992 and 93 winter seasons in eastern Turkey, an international cooperation has been

initiated among SFISAR (Swiss Federal Institute for Snow and Avalanche Research, SLF), CEMAGREF (Institut National de Recherche en Sciences et Technologies pour L'environnement et L'agriculture) and AFET (Turkish Ministry of Public Works and Settlement, General Directorate of Disaster Affairs) within the program of the International Decade of Natural Disaster Reduction (1990–2000). This three-year project started in 1994 was the first serious avalanche research and development project in Turkey regarding avalanche forecasting, mapping, zoning and paravalanche construction technologies. For the pilot project area, the Soganli Mountains located in north-eastern Turkey were chosen, covering an area of approximately 40 by 30 km. After training the Turkish engineers, the basic technologies in avalanche forecasting and avalanche mapping were transferred from Switzerland and France to Turkey with the necessary infrastructure. The difficulties faced in meteorological data collection with the help of local observers and the limited data available caused some delay in avalanche forecasting. Outcomes of the project resulted with necessity of establishing automatic weather stations for the realization of quick prognosis (Gurer, 1998).

However, after completion of the projects, data gathering from the field could not be carried out regularly and new projects could not be put into

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practice for sustainable solution of avalanche problem in Turkey. Since then, it has not been launched any study until recent years 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. Moreover, meteorological and snow cover data from summit are easier today to collect and record with the development of technology. Therefore, Gazi University, Civil Engineering Department proposed a new research project in order to collaborate 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. So the main aim of the project is to set up an automatic meteorological station on Bozdag summit which was experienced fatal avalanche events in the past.

2. EARLIER STUDIES

Avalanche research in Turkey has focused on academic studies such as academic thesis and papers. Gurer has published many papers in Turkish and in English languages to explain snow avalanche problem in Turkey and possible prevention methods for the problem. Gurer (1998); Gurer, et. al. (1995); Gurer and Kocyigit (1995); Naaim and Gurer (1998) and Kocyigit and Gurer (2007) are some paper examples.

Some academic thesis have been written in Turkish such as Kocyigit (1997), Durak (2011), Arslan (2014), and Ucar (2014) all have modeled snow avalanches using computer programs on their thesis. Similarly, some academic thesis works are being carry on at Gazi University.

Durak (2011) in his MSc. thesis applied a numerical model developed by Lang (1983) to examine an avalanche event occurred in Bayburt-Uzengili village which is situated on the North-eastern of Turkey. He estimated vulnerability due to avalanche pressure calculated by the numerical model and field observations. He analyzed the houses destroyed or damaged by the avalanche event. Arslan (2014) used another calculation model to predict avalanche run-out distances and flow velocities. He applied AVAL-1D program which was developed by SLF. He simulated avalanche event occurred in Uzungöl village situated on North-Eastern of Turkey. Its 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 (2014) used to the program continuous information on flow height,

velocity and pressure along the entire Dorinori path which is one of Uzungol Avalanche tracks. He emphasized that the model predictions are compatible with run-out distance observations and damaged building examination on the path. He concluded that Voellmy friction parameters μ (μ) and ξ (ξ) used on the model are affecting on simulation results considerably. He also recommended that friction parameters should be surveyed with more detail study for Turkey. Sensitivity analysis of Voellmy friction parameters have been studied by Kocyigit and Gurer (2007).

Another academic thesis related computer modeling application on avalanche occurred in Turkey were performed by Ucar (2014). Primary aim of the 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 Coruh River Basin and around Palandoken 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.

Recently RAMMS model developed by SLF is being applied some different research projects and papers.

3. PROJECT AREA AND STUDIES

Altitude, snow depth, aspect, vegetation, terrain topography, prevailing wind direction 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, each governmental institution establishes observation and data collection stations according to their needs so specific data for avalanche could not systematically collected. For instance, the General Directorate of Meteorology collects the most comprehensive data on a regular basis in Turkey, 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 nearby to mountain summit.

As a pilot project area, ski resort Bozdag, situated in Izmir Province in Western Turkey is chosen tak-

ing 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.

Bozdag Ski Resort is surrounded by Bozdag (2156 m asl), Catal sivritepe (2138 m), Tozlutepe in the south, Aktas Peak (2024 m), Kartal Peak (2040 m) in the east, Ucler Peak (1908 m) Ortadag Peak (1641 m), Cavdar Peak, Saripinarlar Peak (1695 m) and Dorukkayalar site (1888 m) in the north as shown in Fig 2. Slopes with the highest gradient in this region are the north-facing slopes of southern and eastern peaks. Especially at Bozdag 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 vegetation cover the area. General view of the study area and avalanche paths is shown in Fig 3.



Fig 2. Case study area, Bozdag

The altitude of Bozdag summit is 2159m (asl) and cornice of snow are encountered at north-facing slopes. Fig 4 shows the snow cornice formed on northern slope at upper attitudes of Bozdag 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 Bozdag 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.



Fig 3. Bozdag Ski Resort in Winter Season (2016)



Fig 4. Avalanche Release Zone in Bozdag

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 of the procedure given in Fig 5 was presented by Kocyigit et. al. (2015) at 8th Engineering and Technology Symposium held at Cankaya University in Ankara.



Fig 5. Snow Pit on Bozdag North Face and Simple Snow Stability Tests (Dr. E. Tekin)

The automated avalanche station was established at Bozdag upper altitudes after a detailed investigation of the area. The station shown in Fig 6 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 a software installed at the server.



Fig 6. Automated Weather Station For Avalanche Studies on Bozdag Summit (O. Kocyigit and G. Arslan)

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 been applied during the project.

4. CONCLUSION AND RECOMMENDATION

Warning system against avalanche disaster hasn't been developed for the public in Turkey since avalanche isn't frequently confronted at residential

areas. Therefore, public 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 some 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, the USA and European countries have many 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 Bozdag, close to Izmir city, to collect data automatically. The further 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:

Establishment of avalanche disaster maps 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 to set up a camera to observe the most dangerous avalanche paths for any avalanche formation,

Determination of meteorological parameters affecting formation of avalanche for conditions in Turkey,

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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REFERENCES

- Arslan, Gokhan, 2014: Numerical Modeling of Snow Avalanches: Uzungol-Dorinori Case Study, MSc. Thesis, Gazi University, Institute of Science and Technology, Ankara (Original in Turkish)
- Durak, Ertugrul, 2011: Estimation of Vulnerability Against Snow Avalanches For Village-Type Turkish Buildings, MSc. Thesis, Gazi University, Institute of Science and Technology, Ankara (Original in Turkish)
- Gurer, I., 1998: International cooperation for solving the avalanche problem in Turkey. *Natural Hazards*, 18.1, 77-85.
- Gurer, I., Tumer, F., Yavas, O. M., Erenbilge, T., and Kocyigit, O., 1995: International Cooperation on Solution of Avalanche Problem in Turkey, *Proceedings of Symposium on International Cooperation in Disasters*, p. 9, 22 May 1995, Ankara.
- Gurer, I., and Kocyigit, O., 1995: Paravalanche Structures, *Proceedings of First Symposium on System Engineering and Defence Applications*, Military Academy, 12- 13 October 1995, 335-350, Ankara. (Original in Turkish)

- Kocyigit, O., and Gurer I.,2007: Effect of the Voellmy Coefficients on Determining Run-out Distance: A Case Study at Uzungol, Turkey., *Gazi University Journal of Science*, 20.3, 79-85.
- Kocyigit, Onder, 1997: Hydraulic Design of Avalanche Barriers, MSc. Thesis, Gazi University, Institute of Science and Technology, Ankara (Original in Turkish)
- Kocyigit, O., Tekin, E. and Arslan, G., 2015: Snow Profile Analysis for Avalanche Forecast, *Cankaya University, 8th Engineering and Technology Symposium*, 14-15 May 2015, Congress book, p.317-321, Ankara. (Original in Turkish)
- Kocyigit, O., Tekin, E. and Arslan, G., 2016: Avalanche Research Studies at Bozdag, *Disaster Science and Engineering*, 2-2,40-45
- Lang, T.E., 1983: Computer Programs for Avalanche Runout Prediction, *National research Center for Disaster Prevention Shinjo Branch*, Report, 79 p, Shinjo, Japan
- Naaim, M., and Gurer I.,1998: Two-phase numerical model of powder avalanche theory and application., *Natural Hazards* 17.2,129-145.
- Ucar, Ibrahim, 2014: Modeling Studies and the Effects of Model Inputs of Avalanche Flow: Case Study of Coruh Basin, Ph.D. Thesis, Gazi University, Institute of Science and Technology, Ankara (Original in Turkish)
- http://www.sif.ch/dienstleistungen/software/aval1d/index_EN