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# Study of a snow avalanche accident along Chowkibal–Tangdhar road in Kupwara district, Jammu and Kashmir, India

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**An avalanche accident was occurred on 5 January 2018 on Chowkibal–Tangdhar road in Kupwara district, Jammu and Kashmir about 6 km from Chowkibal village. One light passenger vehicle was swept away in the avalanche and 10 persons lost their lives. In this communication, we study the cause of avalanche accident and simulate the snow avalanche flow using Rapid Mass MovementS model. Total snow depth recorded at the nearest observation location from the accident site was 31 cm and fresh snow of the storm was 24 cm. Avalanche condition on slope was building up and the Snow and Avalanche Study Establishment issued an avalanche warning of 'Low Danger' for the Chokibal–Tangdhar road axis. Maximum thickness of avalanche debris on road was observed to be 3.0 m. Flow simulation showed maximum velocity of avalanche to be ~25 ms$^{-1}$, maximum impact pressure ~9.39 × 10$^4$ kg m$^{-1}$ s$^{-2}$ and maximum height of avalanche flow ~3.0 m.**

**Keywords:** Avalanche accident, mountainous terrain, snow storm.

SNOW avalanche is the sudden downward motion of a huge mass of snow from a mountain top to the valley bottom, which is hazardous when people or property come in the way[1]. Snow avalanches are a common phenomenon in snow-bound mountainous regions. Generally, avalanches flow over an open channel or close gullies in a mountainous terrain. McClung[2] provided statistics of avalanche fatalities during 1895–2014 in the high mountains of Asia, i.e. Himalaya, Karakoram, Pamir, Hindu Kush, Tien Shan and Dazu Shan covering snow-bound regions of India, China, Pakistan, Nepal, etc. He observed that about three-quarters of the deaths resulted from improper camp placements and failure to forecast snow avalanches. Ganju *et al.*[3] studied the characteristics of avalanche accidents in the Western Himalayan region, i.e. snow-bound areas of Jammu and Kashmir (J&K), Himachal Pradesh and Uttarakhand, India and reported that a considerable proportion (~62%) of the total fatalities occurred when people were in movement and majority of the accidents took place during snowfall or immediately after cessation of snow storm. This study provides scientific insight regarding an avalanche accident in the Pir Panjal range of the Himalaya.

An avalanche accident occurred in J&K, on 5 January 2018. The accident took place on the Chowkibal–Tangdhar (C–T) road, about 6 km from Chowkibal village towards Tangdhar. One vehicle was swept away by the avalanche and buried under the debris. A total of 12 persons were caught in the avalanche – 2 were rescued alive and 10 persons were recovered dead. On the same day, an another avalanche accident took place on the same road axis, in which one Border Road Organization (BRO) official was buried in the debris and found dead. The C–T road axis is one of the roads in Tangdhar region of J&K, which is most vulnerable to snow avalanches. Other regions which are vulnerable to avalanches around Kashmir valley are Drass, Gurej, Keran, Machhal,

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Gulmarg, Naugam and Banihal[4]. Tangdhar is one of the well-studied regions for snow avalanches and many researchers have reported various avalanche prediction techniques for this road axis in the past[5–7]. Using the output from all these researches and experience of experts, the Snow and Avalanche Study Establishment (SASE), Chandigarh delivered a 'low danger' avalanche warning in advance for the road axis for the day of the accident. The present study simulates the flow of snow avalanche at the site and examines the accident.

Figure 1 shows the C–T road axis and avalanche sites along the same. The road axis is a part of the Pir Panjal range and joins Tithwal district with Kupwara in J&K. The road axis is about 36 km long and movement on the road was affected by frequent avalanches from 26 major avalanche sites during winter season[8]. Formation zones of the avalanche sites are generally in the elevation range 2800–3500 m. Tree line in the region exists up to 3300 m, beyond which the slopes are generally barren/rocky with scanty trees and few patches of seasonal grass[4]. SASE has a snow-met observation station Stage-II in the study area at an elevation of 2650 m amsl. Mean maximum and minimum temperature at the observation station for peak winter months (December–February) were observed to be 3.2°C and –9.0°C respectively, during the last decade. Mean cumulative snowfall recorded for these months was 688 cm. SASE collects and records snow avalanche occurrence data at its meteorological observatories in the Himalaya using ground reconnaissance, feedback from pedestrians and road travellers as well as from army personnel guarding the border. Figure 2 shows the number of avalanche occurrences during different years from 1992 to 2016, reported to SASE along the C–T road axis. As high as 84 avalanches have been reported during 2004 and an average of 33 avalanches per year has been reported during the past two decades. A total of 48 casualties have been reported due to avalanches on the C–T road axis during this period.

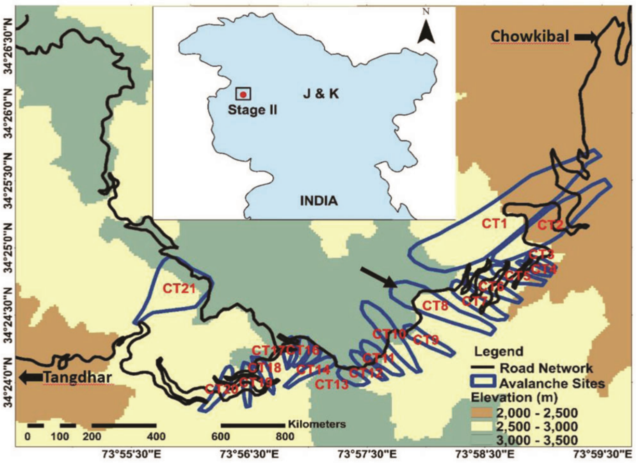


**Figure 1.** Chowkibal–Tangdhar (C–T) road axis and avalanche sites affecting movement on the road.

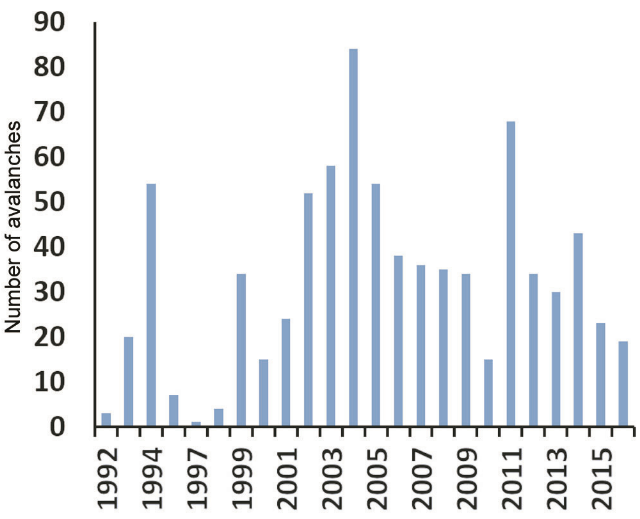


**Figure 2.** Avalanche occurrences during different years on C–T road axis.

Figure 3 shows the accident site, i.e. CT-8 avalanche site. This site has two gullies, i.e. left and right, as well as scanty trees. Topographic analysis using digital elevation model (DEM) shows that 4% area of the avalanche site has slope angle in the range 0°–12°, 32% in the range 12°–25°, 15% in the range 25°–30°, 47% in the range 30°–45° and only 1% area above 45°. Most of the area of the avalanche site is facing towards south (42%) and southeast (37%).

On 1 January 2018, the weather was clear; average wind was low, of the order of ~1.1 km/h and snow depth at the observation site was 8 cm. On 2 and 3 January high cloud started appearing over the observation site as the western disturbance was approaching. On 4 January 2018, the weather became cloudy with 8 Okta low clouds; average relative humidity was 83% and air temperature was 0°C during observation at 1700 h. Snowfall started in the early morning on 5 January and total fresh snow amount in the evening was 24 cm and snow depth at the observation station was 31 cm. On 4 January, the Weather Research and Forecast (WRF) model (model run at SASE on a daily basis for prediction of snowfall and weather) predicted snowfall for 5 January for road axis. Avalanche prediction models were run at SASE for prediction of avalanches by adding fresh snowfall amount predicted by the WRF model for the C–T road axis. 'Low danger' avalanche warning was predicted by the models and the same was issued for the C–T road axis. On 5 January 2018, around 1430 h, one passenger vehicle was parked on the middle of the CT-8 avalanche path on the road, awaiting snow clearance. Suddenly the CT-8 avalanche site was triggered by a huge sound and the vehicle was swept away in the snow cloud. The vehicle was later located in the gorges down below, buried under avalanche debris. Ten passengers lost their lives as the vehicle was wrongly

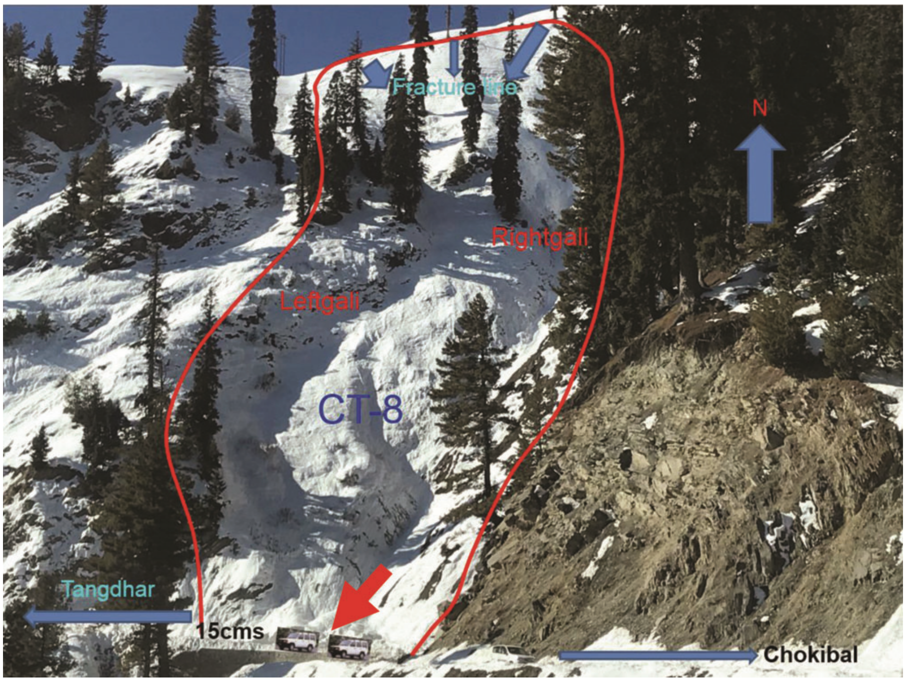


**Figure 3.** CT-8 avalanche site and accident location (red arrow).

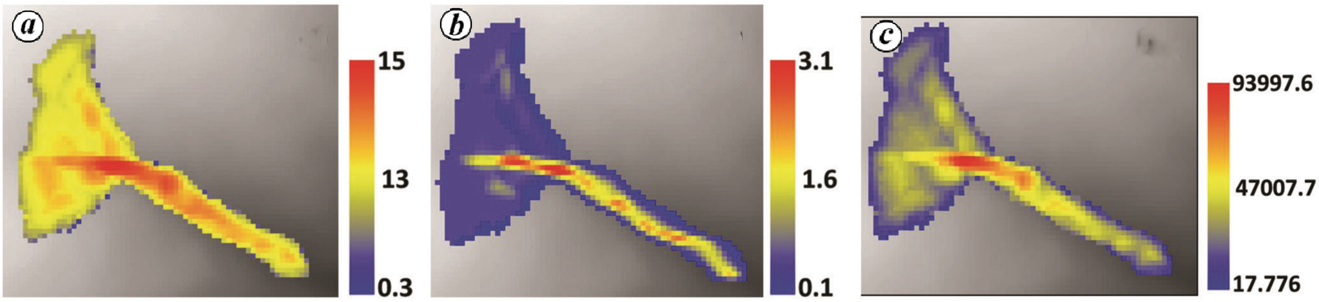


**Figure 4.** Simulation results of avalanche flow for (***a***) velocity (m $s^{-1}$), (***b***) avalanche flow height (m) and (***c***) pressure (kg $m^{-1}$ $s^{-2}$).

parked in the avalanche path. The passengers and the driver were not aware about the standard operating procedures to be adopted while travelling in avalanche-prone areas. This avalanche was triggered during snowfall due to overburden pressure of fresh snow on the snow layers already existing in the formation zone of the avalanche. The avalanche sites along the C–T roads axis are frequently triggered due to specific topographic and snowpack conditions as formation zones are around 30–45° slopes and surfaces are generally smooth and barren with scanty trees. Snow cover depth of ~20 cm in the formation zone of the avalanche site generally covers the surface undulations and makes the surface smooth for triggering of avalanches due to any fresh snowfall over it. Generally, these avalanche sites are triggered 2–3 times in winter season from December to April, mainly due to overburden pressure of fresh snowfall on existing weak layers in the snowpack.

Spatial snow depth map was generated for the study area based on *in situ* observations of snow depth recorded at SASE observatory at stage II and other observation locations around Kashmir valley. Gusain *et al.*[9] have provided detailed methodology for the generation of spatial snow depth using *in situ* measurements in the Himalaya. Snow depth in the formation zone of the CT-8 avalanche site was estimated in the range 40–50 cm on the day of the accident. Keeping in view the 24 cm fresh snowfall recorded at the SASE observatory, fracture depth of 25 cm was chosen to run the flow simulation of the avalanche on CT-8 avalanche site. Release area of snow avalanche in the formation zone was estimated according to the method of Buhler *et al.*[10]. In the present study ALOS PALSAR DEM having spatial resolution of 12.5 m was used for the estimation of avalanche release area. Total release area of 61,800 $m^2$ was estimated and used for flow simulation in Rapid Mass MovementS

(RAMMS), a snow avalanche simulation toolbox. RAMMS is a computer model specially designed by WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland, for snow avalanche simulation and solves depth average numerical equations governing avalanche flow[11]. The model requires DEM, release zone area, fracture height and friction parameters as input variables. ALOS PALSAR DEM, release zone area polygon (estimated using the tools of Buhler *et al.*[10]) and fracture height of 25 cm were given input to RAMMS model. Friction parameters were generated by the software using automated procedures after extensive terrain analysis and estimated in the range 0.19–0.27. Figure 4 shows the simulation results of avalanche flow for velocity (m $s^{-1}$), avalanche flow height (m) and pressure (kg $m^{-1}$ $s^{-2}$). Maximum avalanche velocity was estimated to be ~25 $ms^{-1}$ in the middle zone of the avalanche. The avalanche flow height varied from ~0.1 m in the formation zone to ~3 m in the middle zone, and impact pressure varied from ~17.7 to ~$9.39 \times 10^4$ kg $m^{-1}$ $s^{-2}$. The mean impact pressure where the road crosses the avalanche site was estimated to be ~$6.0 \times 10^4$ kg $m^{-1}$ $s^{-2}$ in the simulation. This impact pressure had supposedly to hit the passenger vehicle parked on the road. A team of scientists from SASE visited the location of the accident site for ground reconnaissance and measured cross-sectional profile of avalanche debris on the road. Maximum height of avalanche debris on the road was measured to be 2.2 and 2.9 m respectively, in the left and right gully of the avalanche site. Maximum height of avalanche flow was estimated ~3 m, which was close to the maximum debris observed on the road. The distance of the avalanche flow from the road was simulated as ~700 m and ground measurement of aerial distance of the maximum debris flow from the road was observed to be ~ 650 m. The aerial distance of maximum flow was estimated using the field instrument VECTOR™ Class 1 Laser Product (Vectronix AG, Heerbrugg, Switzerland). Snowpack simulation result showed a hard melt–freeze (M–F) layer at the top of the snowpack before fresh snowfall on 5 January 2018. A soft layer of faceted grains was present below the M–F layer having low hand hardness index below 20N, indicating the presence of probable weak layer. With the overburden pressure of fresh snowfall, the layer might have failed.

McClung[2] reported that human actions and decisions govern the fatal avalanche patterns in high Asian mountains and attributed about three-quarters of the avalanche deaths to improper camp placements and failure to forecast snow avalanches. Ganju *et al.*[3] also observed that ignorance of the behaviour of the avalanche slopes has been main factor for the avalanche accidents in western Himalayan region. The present study also shows that improper site selection for parking of vehicle was the main cause of the avalanche accident on 5 January 2018, despite the avalanche warning on the C–T road axis. A proper avalanche awareness programme for people living in snow-bound, avalanche-prone areas, and avalanche danger signboards along the road axis may help in reducing such accidents in future.


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