MEASUREMENTS OF AVALANCHE LOADS EAST RIVERSIDE AVALANCHE SHED, COLORADO

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ABSTRACT

Avalanche-impact loads were measured on external pressure sensors mounted on the roof of the East Riverside avalanche shed, Highway 550, 8 km south of Ouray, Colorado, during the winters 1987/88, 1988/89, and 1989/90. The four small-to-moderate sized avalanches recorded produced pressures normal to the roof surface ranging from 4.8 to 17.0 KPa (100 to 355 lbs/ft^2) and pressures parallel to the roof ranging from 129 KPa to 210 KPa (2,700 to 4,400 lbs/ft^2). During two events low-density "powder-blast" pressures of 19 to 29 KPa (400 to 600 lbs/ft^2) preceded the main flowing avalanche mass by 0.5 seconds. The typical avalanche-loading event lasted 3 to 13 seconds, a time period in which 10 to 20 pressure peaks were recorded.

INTRODUCTION

The East Riverside is a large, frequent avalanche path that crosses Highway 550 approximately 8 km south of Ouray, Colorado in the northern San Juan Mountains. The path has a maximum vertical displacement of 1,000m with starting zones of approximately 300,000m^2 total combined area oriented from north through southwest. The complex and steep terrain has made timing of avalanches difficult to predict; control through placement of explosives by artillery or helicopter bombing is less effective than in paths of simpler terrain. Multiple events during a single storm are common. Five fatalities have occurred below the East Riverside in 3 accidents since 1963.

The Colorado Highway Department built a 55m long shed over Highway 550 below the central channel of the East Riverside in 1985. Although this shed does not protect the highway from the larger and wider avalanches, it does protect from the more frequent events. The shed may be extended to the north and south at some future date. The shed structure was built with 6 load cells and 32 strain gages welded to internal reinforcing steel during construction to determine the magnitude and characteristics of avalanche loads. The data thus obtained may aid in extension of this shed or in design of avalanche sheds at other locations.

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AVALANCHE LOAD SENSORS

Internal Sensors

The 38 internal load sensors (32 strain gages and 6 load cells) built into

the shed are intended to measure the deformation of internal structural members in response to avalanche dynamic and static loads. Strain and load data have been monitored continuously at 0.01-second intervals throughout the entire avalanche season, and are stored in a Megadac 2200 data acquisition system installed inside the shed. Details of the original experimental design are described in Mears (1986).

The winters of 1986/87, 1987/88, and 1989/90 all produced below-normal snowfalls and relatively small avalanches in the San Juan Mountains. As a result, internal strains did not reach the threshold values necessary to record strain and load events permanently within the Megadac system. This problem resulted not only from the light avalanche activity, but also from the fact that the shed was designed for very large "100-year" avalanche conditions, and therefore did not deform significantly. This lack of response to avalanches required installing external pressure sensors on the shed roof which would deform a measurable amount to the smaller, typical avalanche events.

External pressure sensors

External pressure sensors were mounted onto the 24° shed roof surface to measure (a) roof-normal pressures, and (b) roof-parallel pressures. To measure normal loads, a 45cm x 220cm simply-supported rectangular steel plate 2cm thick was mounted on the roof directly in the path of the most frequent avalanches. The plane of the plate was mounted 10cm above and parallel with the roof plane and supported near the ends. The plate was therefore free to deflect toward the roof in response to loads normal to the shed roof. Three strain gages were then welded on the bottom of the plate and wired into the Megadac 2200 data acquisition system.

The sensor used for roof parallel loads consisted of a circular plate with a surface area of $0.093m^2$ ($1.0 ft^2$) welded to a stiff steel bar 1.5m long with a rectangular cross section of 2cm x 5cm. The bar/plate system was then mounted such that the plate faced uphill, directly into the avalanche. The lower end of the bar was attached to the roof with a hinge such that it was free to deflect in the avalanche direction, but was then anchored in place with a 1cm diameter steel rod. The upper end of the rod passed through the circular plate and the lower end was attached to the shed roof, approximately 1.5m up the roof from the bar/plate system. Avalanche forces parallel with the shed roof, therefore, act normal to the circular plate and produce tension forces in the rod. Strain gages were welded onto the bar and also were wired to the Megadac data acquisition system. Normal and parallel pressure sensors are diagrammed in Figure 1.

Both the plate designed to record normal loads and the bar/plate system designed for parallel loads were then calibrated such that a known static load on each system produced an observed strain as recorded on the Megadac.

Data Obtained

Table 1 summarizes peak load data obtained in the slope normal and parallel directions for the four avalanche events in which data were obtained and shows the lengths of each event. Additional data, conclusions, and speculations are summarized in the subsequent section of this paper.

Table 1
East Riverside loads on external sensors

Avalanche date	Maximum normal	Maximum parallel	Duration
January 7, 1988	4.8 K Pa	(Not operating)	4.8 sec
December 24, 1989	17.0 K Pa	148 K Pa	3.0 sec
February 4, 1989	(Not operating)	210 K Pa	13.5 sec
February 24, 1990*	10.8 K Pa	210 K Pa	7.0 sec

* "Roof slide" may have produced high loads; see text.

ADDITIONAL DATA, CONCLUSIONS, AND SPECULATIONS

The following additional information relates to the assumed structure of the avalanches and the shed response to the avalanche load.

a. The events of 12/7/88 and 2/24/90 were the only two in which both roof- parallel and roof-normal sensors were operating. During both events the roof-parallel sensor experienced avalanche pressure approximately 0.5 seconds before the roof-normal sensor. After this initial loading period, the normal sensors received load and the parallel sensors received much larger loads. It is assumed that a powder blast of low-density snow in suspension preceded the main flow and that this accounts for the initial load period.

b. As shown in Table 1, avalanche-loading events lasted from approximately 3.0 to 13.5 seconds. Up to approximately 20 pressure peaks were recorded during avalanches. These peaks typically were 2-3 times the "average" pressure during the avalanche.

c. The avalanche of 1/7/88 also was recorded on the internal strain gages welded onto the reinforcing steel in the shed roof slab. The strains in the reinforcing steel, however, were only about 20% of the values that should have been produced by the load measured in the external sensors. This difference between measured and expected strains probably resulted because the concrete component of the reinforced roof was providing tensional resistance to slab bending, therefore the reinforcing steel was not supporting all of the avalanche load.

d. The large loads measured in the 2/24/90 avalanche probably occurred as the entire winter snowcover released from the 24° shed roof as a slab underlain with temperature-gradient snow, which acted as a small starting zone. The large forces, therefore, represent the thrust force of this slab pushing on the sensors, not the small, dry-snow avalanche released from the upper part of the East Riverside starting zone.

REFERENCES

Mears, A. I., 1986, "Instrumentation of Avalanche Loads, East Riverside Avalanche Path, Colorado," Proceedings of the International Snow Science Workshop, Lake Tahoe, pp. 108-110.

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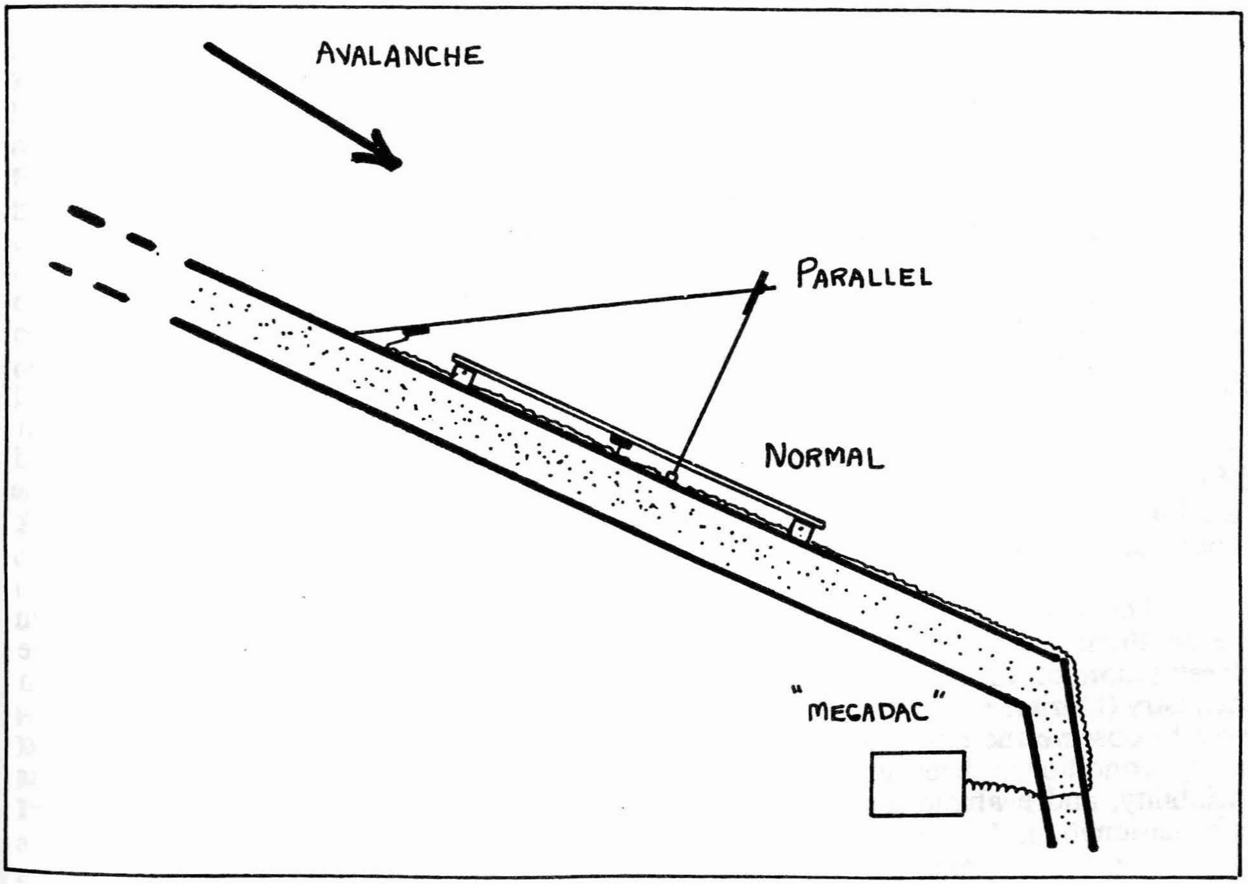

Figure 1 External pressure sensors, East Riverside shed