A METHODOLOGY TO OBTAIN THE BLOCK SIZE DISTRIBUTION OF A LARGE ROCKFALL DEPOSIT

Roger Ruiz[1], Jordi Corominas[1], Olga Mavrouli[1]

The block size distribution produced in a rockfall event is necessary for the study of the trajectories, run-out, the impact energies and for the quantitative assessment of the rockfall hazard. For large rockfall deposits, systematization is needed in order to obtain the size distribution of blocks. To this end, we present a methodology and its application in the Cadí massif, Eastern Pyrenees.

Keywords: rockfall, frequency-magnitude, block size distribution, large deposit

INTRODUCTION

The rock masses detached from the slope face at a rockfall event are composed of intact rock and discontinuities and may be characterized by an In situ Block Size Distribution (IBSD). In fragmental rockfalls [1], the rock mass is shattered after the firsts impacts with the ground. The blocks can be either separated, fragmented or both, and propagate independently downhill. The Rockfall Block Size Distribution (RBSD) is fundamental for the quantitative assessment of the rockfall hazard, since it is a prerequisite for predicting trajectories, the run out, the impact energies and the total number of blocks. Several researchers mainly working on rock blasts, have used photoanalytical techniques to obtain the fragment size distribution [2]. However these provide results only for the block area and not for the volume. In large rockfall deposits, the large amount of blocks and the extent of the deposits make difficult obtaining a RBSD. The scope of this work is the development of a methodology to obtain the RBSD based on field measurements, to be used as an input for the hazard assessment. At a later stage the RBSD may also be used for comparison with the IBSD, in order to analyse the fragmentation phenomenon during the rockfall propagation, as some researchers indicate a correlation between the two [3].

METHODOLOGY

Large fragmental rockfalls often generate a more or less continuous young cover of bouldery debris and large scattered blocks. Some debris covers have a large extent and display a progressive downhill increase of the average block size. Because of this, obtaining the RBSD may become a challenging task.

Two complementary approaches for measuring the blocks and obtaining the RBSD have been designed: a) selective sampling of the young debris cover (YDC); and b) systematic measurement of the large scattered blocks. The methodology is summarized in Fig. 1.

First, the YDC is divided into homogeneous zones of similar average block size based on field observation and orthophoto interpretation. At each zone, several sampling plots are defined in which all the blocks are measured to obtain the respective block size distribution of the plot. The sampling plots have a square shape and their size increases with the size of the blocks inside it. The large scattered blocks are georeferenced and measured one by one. Three lengths are measured at each block to estimate the volume, which is assumed having a prismatic shape.

[1] Technical University of Catalonia (UPC), Department of Geotechnical Engineering and Geosciences, Barcelona: roger.ruiz@upc.edu ; jordi.corominas@upc.edu ; olga-christina.mavrouli@upc.edu

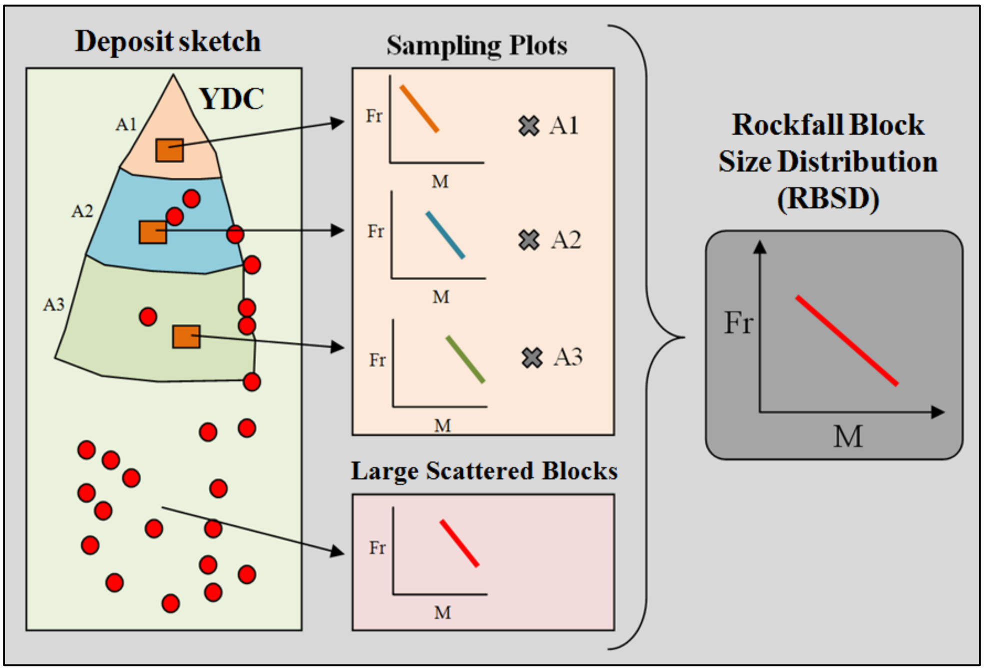

Fig. 1: Methodology followed to prepare the RBSD. The scheme shows the YDC, the sampling plots for each homogeneous zone A1 to A3, and the large scattered blocks. The plots display the block size distribution where "Fr" is the cumulative relative frequency for each block size bin "M".

The RBSD is obtained according to the following procedure (Fig. 1):

(1) Blocks of each sampling plot are classified in bins of different block size ranges (0.01 to 0.02, 0.02 to 0.05, 0.05 to 0.1m^3 and so on). The block size distribution for each sampling plot (orange squares) is extrapolated to the whole homogeneous zone (A1 to A3).

The extrapolation is done multiplying the number of blocks of each block size class with a scaling factor R_i (Eq. 1):

$$R_i = A_i / A_{spi} \qquad \text{Eq. 1}$$

Where: R_i : is the scaling factor; A_i : the area of the homogeneous zone; A_{spi} : the area of the sampling plot.

(2) The block size distribution of the large scattered blocks is prepared independently. As all large scattered blocks have been measured, no scaling factor is applied to them.

(3) Finally, the RBSD is obtained by adding all of them.

APPLICATION TO A CASE-STUDY

The proposed methodology has been applied to obtain the RBSD of a large rockfall event occurred in November 2011 in the Cadí massif, Eastern Pyrenees. The rockfall detached a mass of about 10000 m^3 (Fig. 2, red area), and the YDC covers an area of 30000 m^2.

Six size-homogeneous zones in have been identified in the YDC (Fig. 2). A total of 1500 blocks larger than 0.015m^3 were measured, which include both the large scattered blocks (275), and the blocks inside the sampling plots (1252). The location of each large block, and of the corners of the sampling plots, were georeferenced with a GPS.

RESULTS

The block size distributions obtained in sampling plots 1 to 4 (Tab. 1) contain a similar concentration of small-size boulders (< 0.1 m^3) although they diverge slightly for bigger sizes (Fig. 3). These plots contain most of the smallest-size fraction of the rockfall deposit. Sampling plots 5 and 6, which are placed at the lowest end of the YDC, have a predominance of big blocks. It is noticeable that the slope of the linear segment of the relations is similar for all of them.

Following the above described procedure, the block size distributions of the sampling plots have been extrapolated to the corresponding homogeneous zone of the YDC and added together with the distribution of the large scattered blocks. The resultant RBSD is shown in red color in Figure 3.

The total volume of the rockfall deposit estimated with this procedure has given a total of approximately 8000 m^3, involving more than 60000 blocks.

The block size distributions of the sampling plots and the large scattered blocks can be fitted by a power law [4], characterized by: a) a constant (C) associated with the minimum significant block size, and b) an exponent (D) which is the slope of the distribution in a log-log representation. (Eq. 2)

$$Fr = C \cdot Vol^{-D} \quad \text{Eq. 2}$$

The exponent D of the fitted power laws vary between 0.8 and 1.2, for coefficients of determination R-squared between 0.94 and 0.98 (Tab. 1). The obtained RBSD was fitted by a power law with C=0.0135, D=-1.053 and coefficient of determination R-squared=0.987 (dashed orange in Fig. 3)

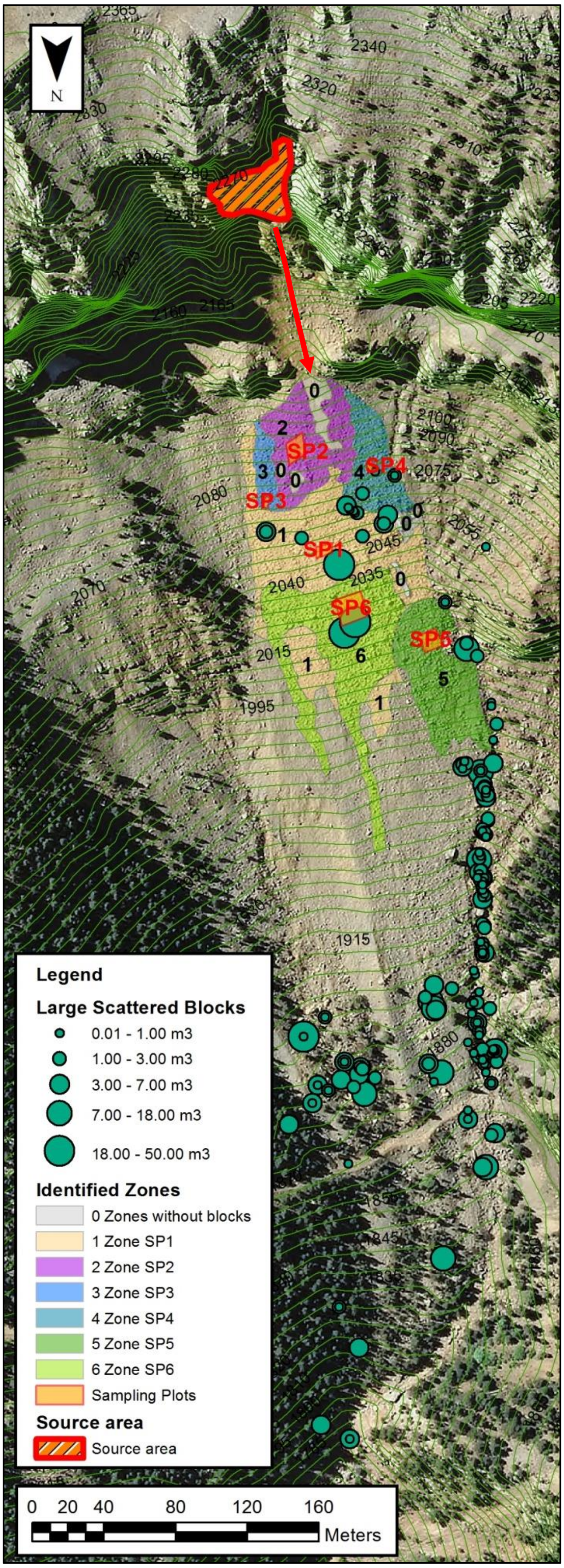

Fig. 2: Orthophoto map showing the location of the six homogeneous zones of the YDC, sampling plots, the large scattered blocks, and the source area.

Tab. 1: Summary of blocks measured, area of the sampling plots and the coefficients (Eq. 2) of the fitted power laws.

	Blocks measured	Sampling Plot area (m^2)	Power law Coef		
			C	D	R^2
SP1	284	100	0.011	-0.995	0.984
SP2	400	100	0.004	-1.219	0.973
SP3	113	25	0.011	-0.960	0.994
SP4	103	25	0.019	-0.892	0.942
SP5	209	400	0.080	-1.178	0.972
SP6	143	225	0.117	-1.017	0.983
LSB	275	-	0.559	-1.150	0.984
Total	**1527**	**875**			
RBSD	**60.259 (estimated blocks)**		**0.0135**	**-1.053**	**0.987**

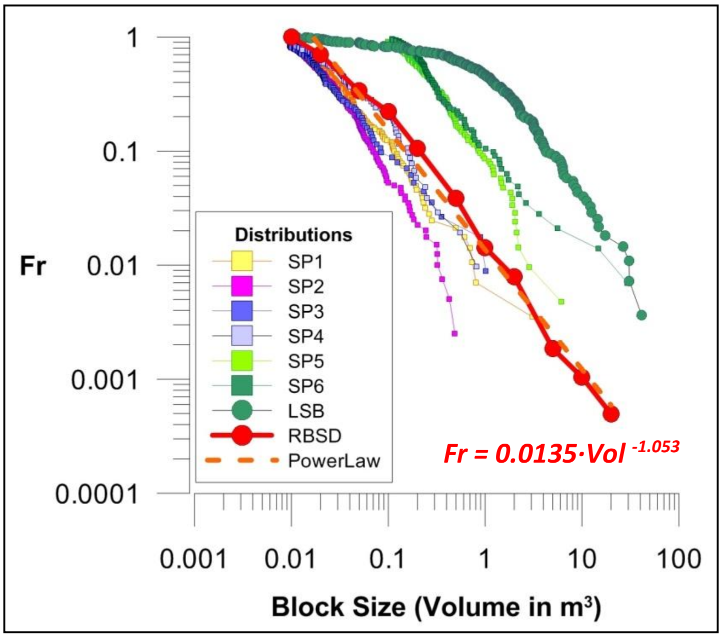

Fig.3: Block size distribution obtained from the 6 sample plots: SP1-6; from the large scattered blocks measured: LSB, the obtained Rockfall Block Size Distribution: RBSD, and the fitted power law (the four largest scattered blocks excluded).

CONCLUSIONS

The compilation of block size distribution data in real volume terms by field observations and measurements in large deposits is possible using the proposed methodology. The application to a case study, a big rockfall deposit in the Eastern Pyrenees, indicated that the obtained RBSD is well fitted by a power law with the exponent D= -1.053. The block size distributions obtained for the sampling plots are also well fitted by power laws with exponents between 0.8 and 1.2. The RBSD for this particular case lacks of the rollover effect, suggesting that there is no bias due to undersampling.

REFERENCES

[1] Evans S.G. & Hungr, O. (1993). The assessment of rockfall hazard at the base of talus slopes. Canadian Geotechnical Journal. 30: 620-636.

[2] Crosta G, Frattini P, Fusi F. (2007). Fragmentation in the Val Pola rock avalanche, Italian Alps. Journal of Geophysical Research, 112: p. F01006

[3] Lu P. (1997). The characterization and analysis of in-situ and blasted block size distribution and the blastability of rock masses.

[4] Dussauge-Peisser A. et al. (2002). Probabilistic approach to rockfall hazard assessment:potential of historical data analysis. Natural Hazards and Earth Systems Science 2: 15-26