DIVERSITY OF THE RESULTS FROM DROP WEIGHT TESTS

Werner Gerber[1], Andrin Caviezel[2]

Here we show results of deceleration measurements from drop weight tests with cubic concrete bodies on soil layers with different compaction. In each experiment, the maximum deceleration was compared with an average deceleration resulting from the impact speed and the deceleration time. These *deceleration factors* show values in the range of 1.3-2.4. Also a *penetration factor* is determined for each test, which compares the penetration depth with a theoretical distance during the brake time. The combination of the two values reveal a large diversity of impact behavior.

Keywords: impact forces, drop weight test, deceleration, rockfall, penetration depth

INTRODUCTION

The dimensioning of protective dams against rockfalls depends on forces acting upon impacts. The calculation of such forces achieved by different methods [1]. However, the results are partly contradictory and show corresponding differences. Many models use parameters of the ground material as well as parameters of the stone itself, while other use only the energy to determine the impact force. In order to investigate these contradictions, more than 250 drop weight tests with cubic concrete blocks have been carried out at the WSL test side over the past years.

METHODS

Various soil strengths were used to stop the falling masses, but also combinations of concrete slabs and different layers were tested [2]. In this paper, we focus mainly on soil layer tests where different masses of 800 kg, 4000 kg and 8000 kg were dropped from different heights (2.5 m, 5 m, 10 m and 15 m), resulting in impact energies of 20-1200 kJ. Each impact process is filmed with high speed cameras and the deceleration has been measured with different sensors [3, 4]. Measured values like maximum deceleration values a_{max} and penetration depths p are shown in Figure 1.

Figure 1 depicts not only results of 186 experiments, but also lines representing the relationship between the maximum deceleration and the penetration depth given by the simple relation

$$a_{max} = \frac{v^2}{p} \qquad (1)$$

With a_{max} the maximum deceleration, v the velocity, and p the penetration depth [5].

[1] Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zuercherstrasse 111, 8903 Birmensdorf, Switzerland, +4144 7392111, werner.gerber@wsl.ch
[2] WSL Institute for Snow and Avalanche Research SLF, Fluelastrasse 11, 7260 Davos, Switzerland, +4181 4170111, andrin.caviezel@slf.ch

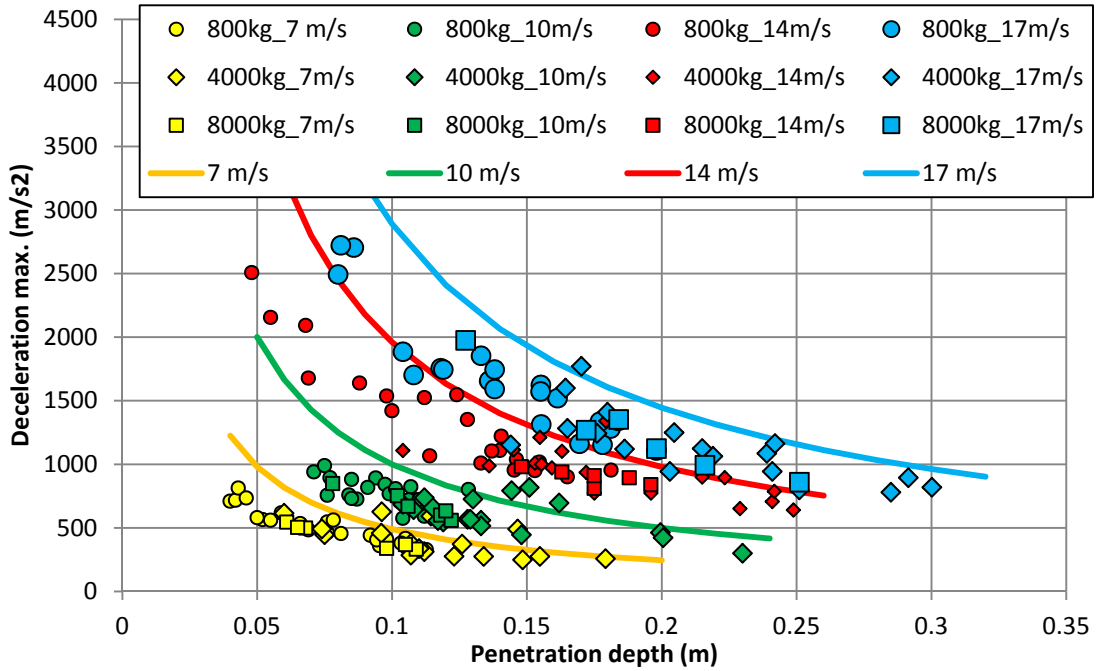

Fig. 1 Results of deceleration and penetration depth from 186 Impact tests.

The results show that almost all values are below the corresponding line with a few isolated values above the corresponding lines. In this article, we will clarify these diversities and calculate a deceleration factor f_d and a penetration factor f_p

$$f_d = a_{max} \frac{t}{v} \tag{2}$$

$$f_p = \frac{d}{v \cdot t} \tag{3}$$

Where t is the deceleration time during which the velocity v is reduced to zero and the penetration depth d is reached. The deceleration factor f_d compares the maximum deceleration a_{max} with an average deceleration calculated from the velocity v and the braking time t. The penetration factor compares the penetration depth with a distance theoretically traveled over braking time. In both of these factors, the acceleration due to gravity has been omitted since its influence is relatively small during the observed deceleration times of 10-50 milliseconds.

RESULTS

The results of the whole experimental ensemble bear no uniform distribution. There exist two areas, where the deceleration factors reach higher values than 2. This is, on the one hand, a penetration factor less than 0.44 and, on the other hand, a value of more than 0.58 (Figure 2).

Detailed analysis of the data set reveal, that for those two areas special experimental conditions have prevailed, which significantly differ from "normal" conditions, i.e. an uncompacted, thick enough deposition layer. In the area of small penetration factors, the results of tests with 800 kg mass are mainly based on compacted soil, as they were dropped into existing footprints of a larger block. These have relatively high deceleration factors of 1.8-2.4 and small penetration factors of 0.34-0.46. The other results with high penetration factors are tests

with a thin soil layer an relatively large mass. The masses of 4000 kg have been dropped on a layer of only 0.5 m in these 12 tests. They also show high decelerations factors of 1.5-2.1, but relatively high penetration factors of 0.57-0.64 (Figure 3). Due these differing experimental condition, those values - 15 data pairs (800 kg) on compacted soils, 12 data pairs (4000 kg) with the thin soil layer – have been discarded from further treatment. In addition, eleven data points from the other series offered similar experimental deficiencies an have been consequently omitted as well. Thus, 148 experiments yield the basis for the performed statistical analysis.

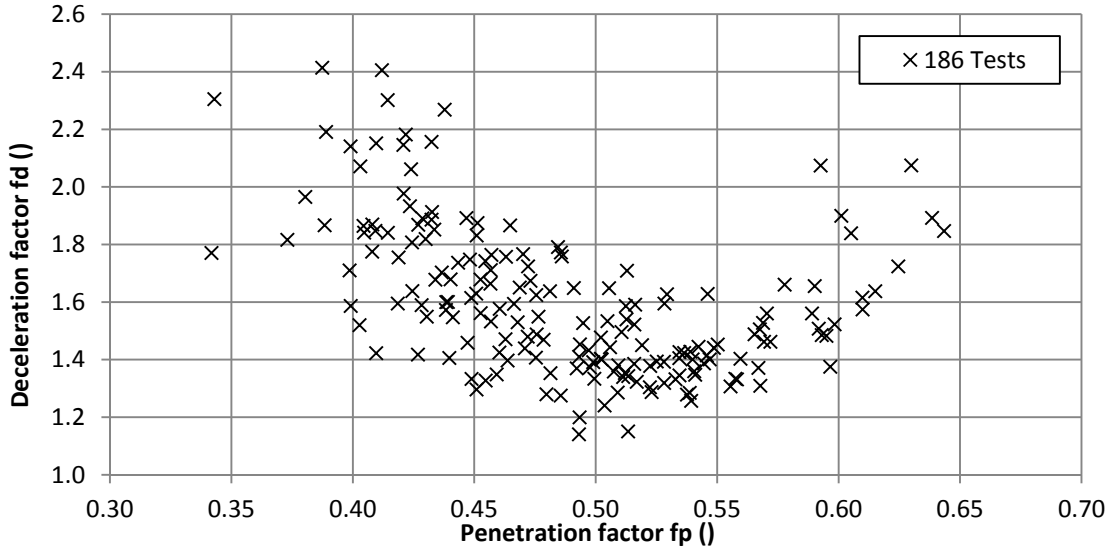

Fig. 2 Results of deceleration factors and penetration factors.

In the case of the deceleration factors, a mean value of f_d = 1.52±0.18. The penetration factors shows an average value of f_p = 0.49±0.05 (Figure 4).

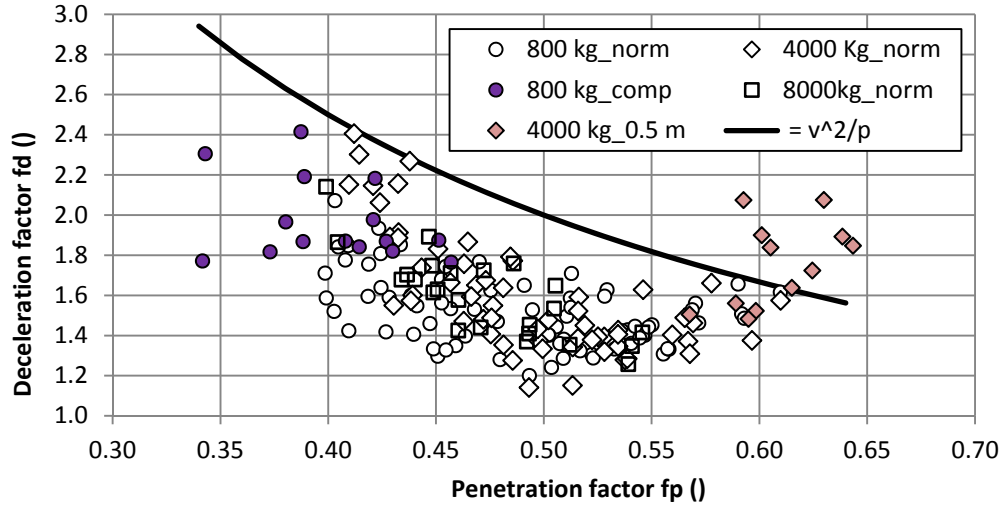

Fig. 3 Results of the different test series “compacted”, “normal” and “thin layer”.

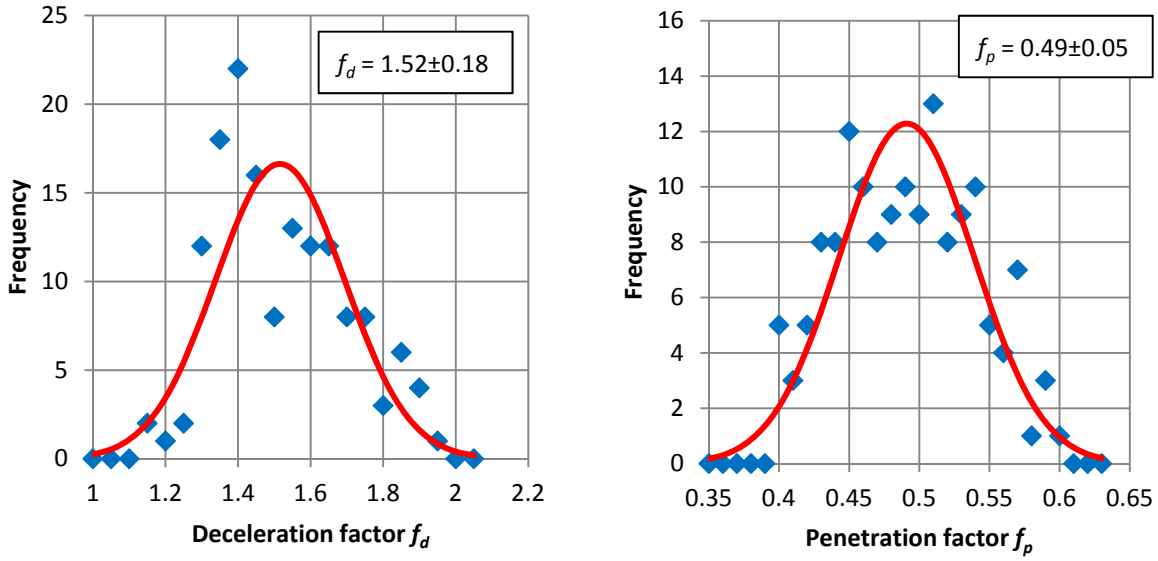

Fig. 4 Results of a 0.05 interval binning for the deceleration factor and a 0.01 interval binning for penetration factor.

CONCLUSIONS

The forces when impacting rocks depend not only on the properties of the soil, but also on the shape of the stone. In the presented data, standardized concrete bodies with flat ground surfaces have been used and therefore the decelerations are rather large and the penetration depths have been relatively small. On average, deceleration factors of 1.5 have been measured. Higher values occur with rather hard impacts. The harder the impact, the greater the deceleration factor. A deceleration factor of 1 means that an almost constant deceleration acts and the velocity decreases almost linearly. The penetration factor indicates the temporal occurrence of the maximum deceleration. For small values ($fp < 0.5$), the maximum lies in the first half of the braking time. At very high values ($fp > 0.6$), the maximum deceleration does not occur until nearly the end of the braking time. Whereas the penetrations factors have a relatively small standard deviation, the spread in the deceleration factors shows the diversity of impact behaviors even under standardized conditions as presented above.

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