

## Electronic Supplementary Material, File 07 (**ESM\_07.pdf**)

### **# Metadata**

Main article title:

Rockfalls: analysis of the block fragmentation through field experiments

Journal name:

Landslides

Author names:

J.A. Gili, R. Ruiz-Carulla, G. Matas, J. Moya, A. Prades, J. Corominas, N. Lantada, M.A. Núñez-Andrés, F. Buill, C. Puig, J. Martínez-Bofill, Ll. Saló, O. Mavrouli

E-mail address and Affiliation of the corresponding author (J.A. Gili): j.gili@upc.edu

Division of Geotechnical Engineering and Geosciences, Dept. of Civil and Environmental Engineering, Technical University of Catalonia - BarcelonaTech, Spain

Document edition date: March 2020

### **# Concise caption describing the content of the file:**

ESM\_07.pdf file contains the complete Tables 1 to 4.

### **# Contents**

In the main text, a shortened version of the Tables 1 to 4 is presented for the sake of space saving. The complete version of the tables is included here.

Table 1 (complete). Test 1 main results (single bench, limestone).

| Measured before drop |                                | Determined during the drop |                                 |                |                   |                    |                    | Computed from previous |                                                 | Overall performance |
|----------------------|--------------------------------|----------------------------|---------------------------------|----------------|-------------------|--------------------|--------------------|------------------------|-------------------------------------------------|---------------------|
| #Block<br>(-)        | Volume, V<br>(m <sup>3</sup> ) | Event<br>number            | #Impact (slope<br>or esplanade) | $v_i$<br>(m/s) | $\gamma_i$<br>(°) | $terr\_imp$<br>(-) | $geom\_imp$<br>(-) | $E_{kin}$<br>KJ        | $E_{kin}^*/m$<br>m <sup>2</sup> /s <sup>2</sup> | F(1)/NF(0)<br>(-)   |
| 1                    | 1.25                           | 1                          | 1 (slope)                       | 13.8           | 15.0              | 3.5                | 1                  | 315.4                  | 6.4                                             | 0                   |
|                      |                                | 2                          | 2 (esplanade)                   | 15.2           | 80.0              | 3.5                | 3                  | 383.7                  | 112.3                                           | 1                   |
| 2                    | 0.85                           | 3                          | 1 (slope)                       | 13.1           | 20.0              | 4                  | 1                  | 193.3                  | 10.0                                            | 0                   |
|                      |                                | 4                          | 2 (esplanade)                   | 14.3           | 85.0              | 3                  | 3                  | 230.3                  | 101.5                                           | 1                   |
| 3                    | 0.82                           | 5                          | 1 (slope)                       | 10.5           | 26.0              | 4                  | 3                  | 119.8                  | 10.6                                            | 0                   |
|                      |                                | 6                          | 2 (esplanade)                   | 14.5           | 58.7              | 4                  | 1.5                | 229.4                  | 77.1                                            | 1                   |
| 4                    | 1.18                           | 7                          | 1 (slope)                       | 11.8           | 21.0              | 4                  | 2                  | 217.7                  | 8.9                                             | 0                   |
|                      |                                | 8                          | 2 (esplanade)                   | 14.3           | 53.1              | 3                  | 1                  | 321.1                  | 65.7                                            | 0                   |
| 5                    | 1.91                           | 9                          | 1 (slope)                       | 11.8           | 19.0              | 4                  | 2                  | 352.4                  | 7.4                                             | 0                   |
|                      |                                | 10                         | 2 (esplanade)                   | 14.8           | 53.9              | 2                  | 1.5                | 554.3                  | 71.5                                            | 0                   |
| 6                    | 0.81                           | 11                         | 1 (slope)                       | 11.2           | 12.0              | 3                  | 1                  | 134.6                  | 2.7                                             | 0                   |
|                      |                                | 12                         | 2 (esplanade)                   | 12.7           | 54.4              | 2                  | 2                  | 172.3                  | 53.1                                            | 0                   |
| 7                    | 0.64                           | 13                         | 1 (slope)                       | 13.8           | 21.0              | 4                  | 3                  | 161.5                  | 12.2                                            | 0                   |
|                      |                                | 14                         | 2 (esplanade)                   | 14.3           | 52.1              | 2                  | 1.5                | 173.7                  | 63.8                                            | 0                   |
| 8                    | 1.00                           | 15                         | 1 (slope)                       | 6.1            | 7.0               | 4                  | 2                  | 49.3                   | 0.3                                             | 0                   |
|                      |                                | 16                         | 2 (esplanade)                   | 14.7           | 65.6              | 2.5                | 1                  | 285.5                  | 89.4                                            | 0                   |
| 9                    | 0.90                           | 17                         | 1 (slope)                       | 8.6            | 9.0               | 4                  | 2                  | 88.2                   | 0.9                                             | 0                   |
|                      |                                | 18                         | 2 (esplanade)                   | 13.9           | 64.1              | 2                  | 1                  | 230.4                  | 78.2                                            | 0                   |
| 10                   | 1.15                           | 19                         | 1 (slope)                       | 10.9           | 31.0              | 4                  | 3                  | 181.0                  | 15.8                                            | 1                   |
|                      |                                | 20                         | 2 (esplanade)                   | 15.0           | 57.0              | 1                  | 1                  | 246.8                  | 79.1                                            | 0                   |
| 11                   | 1.10                           | 21                         | 1 (slope)                       | 9.8            | 11.0              | 4                  | 2                  | 140.0                  | 1.7                                             | 0                   |
|                      |                                | 22                         | 2 (esplanade)                   | 14.2           | 64.8              | 3.5                | 1                  | 293.5                  | 82.4                                            | 1                   |
| 12                   | 1.16                           | 23                         | 1 (slope)                       | 13.3           | 6.0               | 4                  | 1                  | 271.9                  | 1.0                                             | 0                   |
|                      |                                | 24                         | 2 (esplanade)                   | 14.3           | 49.4              | 3.5                | 1.5                | 312.1                  | 58.5                                            | 0                   |
| 13                   | 1.26                           | 25                         | 1 (slope)                       | 11.2           | 31.0              | 2                  | 2                  | 209.4                  | 16.6                                            | 0                   |
|                      |                                | 26                         | 2 (esplanade)                   | 14.7           | 68.6              | 3                  | 1.5                | 361.7                  | 93.9                                            | 0                   |
| 14                   | 1.61                           | 27                         | 1 (slope)                       | 11.5           | 24.0              | 4                  | 2                  | 282.1                  | 10.9                                            | 1                   |
|                      |                                | 28                         | 2 (esplanade)                   | 14.3           | 62.4              | 3                  | 1                  | 408.0                  | 80.7                                            | 0                   |
| 15                   | 0.63                           | 29                         | 3 (esplanade, intert)           | 11.9           | 80.0              | 4                  | 2                  | 280.9                  | 68.7                                            | 1                   |
|                      |                                | 30                         | 2 (esplanade)                   | 14.9           | 52.5              | 3.5                | 1                  | 186.1                  | 70.1                                            | 1                   |
| 16                   | 1.59                           | 31                         | 1 (slope)                       | 13.8           | 40.0              | 4                  | 2                  | 401.2                  | 39.3                                            | 0                   |
|                      |                                | 32                         | 2 (esplanade)                   | 15.9           | 60.0              | 2.5                | 1.5                | 533.3                  | 94.9                                            | 0                   |
| 17                   | 1.40                           | 33                         | 1 (slope)                       | 12.6           | 35.0              | 4                  | 2                  | 294.5                  | 26.1                                            | 0                   |
|                      |                                | 34                         | 2 (esplanade)                   | 14.2           | 51.5              | 3                  | 3                  | 375.1                  | 61.9                                            | 0                   |
| 18                   | 1.23                           | 35                         | 3 (esplanade, intert)           | 6.5            | 90.0              | 4                  | 3                  | 78.4                   | 21.1                                            | 1                   |
|                      |                                | 36                         | 1 (slope)                       | 12.4           | 30.0              | 2.5                | 1                  | 250.6                  | 19.2                                            | 0                   |
| 19                   | 0.62                           | 37                         | 2 (esplanade)                   | 13.8           | 62.3              | 3.5                | 3                  | 310.8                  | 74.8                                            | 0                   |
|                      |                                | 38                         | 1 (slope)                       | 13.9           | 30.0              | 3.5                | 3                  | 158.7                  | 24.2                                            | 1                   |
| 20                   | 0.71                           | 39                         | 1(slope)                        | 13.7           | 30.0              | 3.5                | 2                  | 176.6                  | 23.5                                            | 0                   |
|                      |                                | 40                         | 2(esplanade)                    | 13.8           | 58.8              | 2.5                | 2                  | 180.2                  | 70.1                                            | 0                   |
| 21                   | 1.25                           | 41                         | 1(slope)                        | 15.0           | 25.0              | 3.5                | 1                  | 372.7                  | 20.1                                            | 0                   |
|                      |                                | 42                         | 2(esplanade)                    | 14.2           | 53.7              | 3                  | 1                  | 334.0                  | 65.5                                            | 0                   |
| 22                   | 0.98                           | 43                         | 1(slope)                        | 12.5           | 35.0              | 3                  | 2                  | 202.9                  | 25.7                                            | 0                   |
|                      |                                | 44                         | 2(esplanade)                    | 14.5           | 60.0              | 3                  | 3                  | 273.0                  | 78.8                                            | 1                   |
| 23                   | 4.59                           | 45                         | 1(slope)                        | 10.5           | 35.0              | 3                  | 2                  | 670.5                  | 18.1                                            | 0                   |
|                      |                                | 46                         | 2(esplanade)                    | 14.2           | 56.0              | 3                  | 1                  | 1228.1                 | 69.4                                            | 0                   |
| 24                   | 1.24                           | 47                         | 1(slope)                        | 13.5           | 35.0              | 3                  | 1                  | 299.4                  | 30.0                                            | 0                   |
|                      |                                | 48                         | 2(esplanade)                    | 15.3           | 47.6              | 3                  | 1                  | 384.6                  | 63.8                                            | 0                   |
| 25                   | 0.19                           | 49                         | 1(slope)                        | 12.4           | 20.0              | 2                  | 2                  | 38.7                   | 9.0                                             | 0                   |
|                      |                                | 50                         | 2(esplanade)                    | 14.2           | 58.5              | 3                  | 3                  | 51.0                   | 73.7                                            | 0                   |
| 26                   | 1.52                           | 51                         | 1(slope)                        | 15.2           | 17.0              | 3.5                | 1                  | 465.3                  | 9.9                                             | 0                   |
|                      |                                | 52                         | 2(esplanade)                    | 13.3           | 54.6              | 3                  | 3                  | 356.3                  | 58.8                                            | 0                   |
| 27                   | 0.87                           | 53                         | 1(slope)                        | 12.0           | 28.0              | 2.5                | 1                  | 166.0                  | 15.9                                            | 0                   |
|                      |                                | 54                         | 2(esplanade)                    | 13.9           | 62.8              | 3.5                | 3                  | 224.0                  | 76.9                                            | 0                   |
| 28                   | 0.28                           | 55                         | 1(slope)                        | 9.3            | 5.0               | 4                  | 3                  | 32.1                   | 0.3                                             | 0                   |
|                      |                                | 56                         | 2(esplanade)                    | 14.9           | 58.5              | 3                  | 3                  | 82.8                   | 81.1                                            | 1                   |
| 29                   | 0.41                           | 57                         | 1(slope)                        | 11.1           | 31.0              | 3                  | 1.5                | 66.9                   | 16.3                                            | 0                   |
|                      |                                | 58                         | 2(esplanade)                    | 14.7           | 62.7              | 2                  | 2                  | 117.2                  | 85.2                                            | 0                   |
| 30                   | 1.78                           | 59                         | 1(slope)                        | 14.2           | 16.0              | 3.5                | 3                  | 475.6                  | 7.7                                             | 1                   |

$v_i$  : block velocity just before the impact

$\gamma_i$  : incidence angle, relative to the terrain slope (main text, Fig.14)

$terr\_imp$ ,  $geom\_imp$ ,  $E_{kin}$ ,  $E_{kin}^*/m$ : see explanations in the main text (tables 6-8)

Table 2 (complete). Test 2 main results (double benched slope, limestone)

| Measured before drop |                                | Determined during the drop |                                 |                |                   |                    |                    | Computed from previous |                                                 | Overall performance |
|----------------------|--------------------------------|----------------------------|---------------------------------|----------------|-------------------|--------------------|--------------------|------------------------|-------------------------------------------------|---------------------|
| #Block<br>(-)        | Volume, V<br>(m <sup>3</sup> ) | Event<br>number            | #Impact (slope<br>or esplanade) | $v_i$<br>(m/s) | $\gamma_i$<br>(°) | $terr\_imp$<br>(-) | $geom\_imp$<br>(-) | $E_{kin}$<br>KJ        | $E_{kin}^*/m$<br>m <sup>2</sup> /s <sup>2</sup> | F(1)/NF(0)<br>(-)   |
| 1                    | 0.39                           | 60                         | 1(slope)                        | 10.0           | 25.0              | 4                  | 1                  | 51.3                   | 8.9                                             | 0                   |
| 2                    | 0.35                           | 61                         | 1(slope)                        | 9.8            | 26.3              | 4                  | 2                  | 43.9                   | 9.4                                             | 0                   |
|                      |                                | 62                         | 2(esplanade)                    | 16.9           | 80.0              | 3                  | 3                  | 130.6                  | 138.5                                           | 1                   |
| 3                    | 0.33                           | 63                         | 1(slope)                        | 9.5            | 26.0              | 4                  | 1                  | 39.3                   | 8.7                                             | 0                   |
| 4                    | 0.32                           | 64                         | 1(slope)                        | 9.3            | 24.9              | 4                  | 1.5                | 36.2                   | 7.6                                             | 0                   |
| 5                    | 0.56                           | 65                         | 1(slope)                        | 10.5           | 27.0              | 4                  | 3                  | 81.4                   | 11.4                                            | 0                   |
|                      |                                | 66                         | 2(slope)                        | 8.3            | 20.6              | 4                  | 1                  | 51.5                   | 4.3                                             | 1                   |
| 6                    | 0.41                           | 67                         | 1(slope)                        | 11.0           | 23.7              | 4                  | 1                  | 65.0                   | 9.7                                             | 1                   |
|                      |                                | 68                         | 3(esplanade)                    | 16.0           | 75.0              | 3                  | 1                  | 138.1                  | 119.4                                           | 0                   |
| 7                    | 0.48                           | 69                         | 1(esplanade)                    | 14.7           | 81.0              | 3                  | 1                  | 137.2                  | 105.1                                           | 1                   |
| 8                    | 0.30                           | 70                         | 1(esplanade)                    | 14.8           | 79.0              | 3                  | 1                  | 87.0                   | 105.1                                           | 0                   |
| 9                    | 0.38                           | 71                         | 1(slope)                        | 9.1            | 23.3              | 4                  | 3                  | 41.5                   | 6.4                                             | 0                   |
| 10                   | 0.37                           | 72                         | 1(slope)                        | 10.6           | 24.2              | 4                  | 2                  | 55.1                   | 9.4                                             | 0                   |
|                      |                                | 73                         | 2(esplanade)                    | 14.9           | 85.0              | 3                  | 3                  | 109.1                  | 110.2                                           | 1                   |
| 11                   | 0.47                           | 74                         | 1(slope)                        | 10.5           | 26.2              | 4                  | 2                  | 69.3                   | 10.8                                            | 0                   |
| 12                   | 0.31                           | 75                         | 1(slope)                        | 10.5           | 26.1              | 4                  | 3                  | 46.0                   | 10.7                                            | 0                   |
| 13                   | 0.35                           | 76                         | 1(slope)                        | 10.4           | 27.2              | 4                  | 1                  | 49.5                   | 11.2                                            | 0                   |
| 14                   | 0.27                           | 77                         | 1(slope)                        | 9.6            | 26.4              | 4                  | 2                  | 32.7                   | 9.1                                             | 0                   |
| 15                   | 0.38                           | 78                         | 1(slope)                        | 11.3           | 24.9              | 4                  | 2                  | 63.1                   | 11.2                                            | 1                   |
| 16                   | 0.25                           | 79                         | 1(slope)                        | 8.8            | 29.0              | 4                  | 1.5                | 25.1                   | 9.1                                             | 1                   |
| 17                   | 0.23                           | 80                         | 1(slope)                        | 13.0           | 26.6              | 4                  | 1                  | 51.2                   | 16.9                                            | 0                   |
| 18                   | 0.54                           | 81                         | 1(esplanade)                    | 13.4           | 78.0              | 3                  | 2                  | 128.3                  | 85.6                                            | 0                   |
| 19                   | 0.33                           | 82                         | 1(esplanade)                    | 16.1           | 82.0              | 3                  | 1                  | 112.0                  | 126.9                                           | 0                   |
| 20                   | 0.41                           | 83                         | 1(slope)                        | 10.2           | 27.0              | 4                  | 3                  | 56.0                   | 10.8                                            | 1                   |
| 21                   | 0.92                           | 84                         | 1(slope)                        | 12.3           | 26.5              | 4                  | 3                  | 184.0                  | 15.0                                            | 1                   |
| 22                   | 0.38                           | 85                         | 1(slope)                        | 11.2           | 27.5              | 4                  | 2                  | 63.4                   | 13.3                                            | 0                   |
| 23                   | 0.47                           | 86                         | 1(slope)                        | 9.6            | 25.8              | 4                  | 3                  | 58.1                   | 8.8                                             | 0                   |
| 24                   | 0.31                           | 87                         | 1(slope)                        | 10.0           | 29.8              | 4                  | 1                  | 41.6                   | 12.3                                            | 0                   |
| 25                   | 0.39                           | 88                         | 1(slope)                        | 12.5           | 27.0              | 4                  | 2.5                | 82.1                   | 16.2                                            | 1                   |
| 26                   | 0.42                           | 89                         | 1(esplanade)                    | 15.9           | 82.0              | 3                  | 2                  | 139.5                  | 123.3                                           | 1                   |

$v_i$  : block velocity just before the impact

$\gamma_i$  : incidence angle, relative to the terrain slope (main text, Fig.14)

$terr\_imp$ ,  $geom\_imp$ ,  $E_{kin}$ ,  $E_{kin}^*/m$ : see explanations in the main text (tables 6-8)

Table 3 (complete). Test 3 main results (granitoids quarry)

| Measured before drop |                                |                 | Determined during the drop |                                 |                         |                       |                 |                 | Computed from previous |                                                                    | Overall performance |
|----------------------|--------------------------------|-----------------|----------------------------|---------------------------------|-------------------------|-----------------------|-----------------|-----------------|------------------------|--------------------------------------------------------------------|---------------------|
| #Block<br>(-)        | Volume, V<br>(m <sup>3</sup> ) | i_pundit<br>(-) | Event<br>number            | #Impact (slope<br>or esplanade) | v <sub>i</sub><br>(m/s) | γ <sub>i</sub><br>(°) | terr_imp<br>(-) | geom_imp<br>(-) | E <sub>kin</sub><br>KJ | E <sup>*</sup> <sub>kin</sub> /m<br>m <sup>2</sup> /s <sup>2</sup> | F(1)/NF(0)<br>(-)   |
| 1                    | 1.32                           | 2               | 90                         | 1(slope)                        | 9.4                     | 30.0                  | 1               | 2               | 154.5                  | 11.0                                                               | 0                   |
| 2                    | 0.75                           | 1               | 91                         | 2(esplanade)                    | 17.6                    | 55.9                  | 2.5             | 1.5             | 541.8                  | 106.4                                                              | 0                   |
|                      |                                |                 | 92                         | 1(slope)                        | 9.6                     | 37.0                  | 1               | 2               | 91.6                   | 16.7                                                               | 0                   |
| 3                    | 0.42                           | 1               | 93                         | 2(esplanade)                    | 18.7                    | 66.3                  | 2.5             | 2               | 347.5                  | 146.6                                                              | 0                   |
|                      |                                |                 | 94                         | 1(slope)                        | 9.9                     | 32.0                  | 1               | 1.5             | 54.4                   | 13.8                                                               | 0                   |
| 4                    | 0.61                           | 1               | 95                         | 2(esplanade)                    | 17.3                    | 69.8                  | 2.5             | 1               | 166.2                  | 131.8                                                              | 0                   |
|                      |                                |                 | 96                         | 1(slope)                        | 10.7                    | 34.0                  | 1               | 1               | 93.0                   | 17.9                                                               | 0                   |
| 5                    | 0.40                           | 1               | 97                         | 2(esplanade)                    | 18.1                    | 72.1                  | 2.5             | 3               | 265.5                  | 148.0                                                              | 0                   |
|                      |                                |                 | 98                         | 1(slope)                        | 9.7                     | 37.0                  | 1               | 2               | 49.4                   | 17.0                                                               | 0                   |
| 6                    | 0.70                           | 2               | 99                         | 2(esplanade)                    | 17.9                    | 69.7                  | 2               | 1               | 168.5                  | 141.2                                                              | 0                   |
|                      |                                |                 | 100                        | 1(slope)                        | 8.3                     | 36.0                  | 1               | 2               | 63.7                   | 11.9                                                               | 0                   |
| 7                    | 0.17                           | 1               | 101                        | 2(esplanade)                    | 18.5                    | 65.1                  | 2               | 1               | 316.4                  | 140.8                                                              | 0                   |
|                      |                                |                 | 102                        | 1(slope)                        | 9.9                     | 38.0                  | 1               | 1               | 22.4                   | 18.6                                                               | 0                   |
| 9                    | 1.23                           | 3               | 103                        | 2(esplanade)                    | 16.9                    | 37.0                  | 1               | 3               | 65.3                   | 51.7                                                               | 0                   |
|                      |                                |                 | 104                        | 1(slope)                        | 9.1                     | 34.0                  | 1               | 1               | 134.4                  | 12.9                                                               | 0                   |
| 10                   | 5.03                           | 3               | 105                        | 2(esplanade)                    | 16.9                    | 72.0                  | 2               | 3               | 464.7                  | 129.5                                                              | 0                   |
|                      |                                |                 | 106                        | 1(slope)                        | 9.4                     | 38.0                  | 1               | 2               | 588.9                  | 16.7                                                               | 0                   |
| 11                   | 0.45                           | 3               | 107                        | 1(slope)                        | 10.7                    | 36.0                  | 1               | 1               | 67.9                   | 19.8                                                               | 0                   |
|                      |                                |                 | 108                        | 2(esplanade)                    | 16.9                    | 39.0                  | 1               | 1               | 169.9                  | 56.7                                                               | 0                   |
| 12                   | 0.31                           | 3               | 109                        | 1(slope)                        | 9.9                     | 37.0                  | 1               | 1               | 39.8                   | 17.7                                                               | 0                   |
|                      |                                |                 | 110                        | 2(esplanade)                    | 17.1                    | 90.0                  | 4               | 2               | 118.1                  | 145.4                                                              | 1                   |
| 13                   | 0.28                           | 1               | 111                        | 1(slope)                        | 9.8                     | 36.0                  | 1               | 2               | 35.5                   | 16.6                                                               | 0                   |
|                      |                                |                 | 112                        | 2(esplanade)                    | 15.7                    | 45.0                  | 1               | 3               | 91.4                   | 61.8                                                               | 0                   |
| 14                   | 0.21                           | 1               | 113                        | 1(slope)                        | 8.4                     | 39.0                  | 1               | 3               | 20.0                   | 14.0                                                               | 0                   |
|                      |                                |                 | 114                        | 2(esplanade)                    | 16.9                    | 48.0                  | 1               | 3               | 81.2                   | 79.2                                                               | 0                   |
| 15                   | 0.47                           |                 | 115                        | 1(slope)                        | 9.7                     | 38.0                  | 1               | 3               | 58.4                   | 17.8                                                               | 0                   |
|                      |                                |                 | 116                        | 2(esplanade)                    | 18.1                    | 71.4                  | 3               | 3               | 203.6                  | 147.3                                                              | 1                   |
| 16                   | 1.01                           |                 | 117                        | 1(slope)                        | 9.1                     | 37.0                  | 1               | 3               | 110.7                  | 15.0                                                               | 0                   |
|                      |                                |                 | 118                        | 2(esplanade)                    | 16.8                    | 74.9                  | 3               | 1               | 378.7                  | 132.0                                                              | 0                   |
| 17                   | 0.38                           |                 | 119                        | 1(slope)                        | 8.5                     | 35.0                  | 1               | 2               | 36.2                   | 11.9                                                               | 0                   |
|                      |                                |                 | 120                        | 2(esplanade)                    | 16.4                    | 44.0                  | 1               | 3               | 133.9                  | 64.5                                                               | 0                   |
| 18                   | 1.05                           |                 | 121                        | 1(slope)                        | 10.3                    | 33.0                  | 1               | 3               | 148.2                  | 15.7                                                               | 0                   |
|                      |                                |                 | 122                        | 2(esplanade)                    | 17.1                    | 55.5                  | 1.5             | 3               | 409.0                  | 99.4                                                               | 0                   |
| 19                   | 1.23                           |                 | 123                        | 1(slope)                        | 9.9                     | 30.0                  | 1               | 3               | 159.6                  | 12.3                                                               | 0                   |
|                      |                                |                 | 124                        | 2(esplanade)                    | 17.1                    | 60.0                  | 1               | 1               | 477.8                  | 110.0                                                              | 0                   |
| 20                   | 0.32                           |                 | 125                        | 1(slope)                        | 8.0                     | 37.0                  | 1               | 1               | 27.1                   | 11.6                                                               | 0                   |
|                      |                                |                 | 126                        | 2(esplanade)                    | 17.2                    | 55.0                  | 4               | 1               | 125.4                  | 99.4                                                               | 1                   |
| 21                   | 1.68                           |                 | 127                        | 1(slope)                        | 10.0                    | 37.0                  | 1               | 3               | 222.5                  | 18.1                                                               | 0                   |
|                      |                                |                 | 128                        | 2(esplanade)                    | 18.1                    | 56.2                  | 2               | 1               | 728.8                  | 113.1                                                              | 0                   |
| 22                   | 0.48                           |                 | 129                        | 1(slope)                        | 9.6                     | 36.0                  | 1               | 1               | 59.2                   | 15.9                                                               | 0                   |
|                      |                                |                 | 130                        | 2(esplanade)                    | 17.9                    | 54.0                  | 2               | 3               | 204.8                  | 104.4                                                              | 0                   |
| 23                   | 0.55                           |                 | 131                        | 1(slope)                        | 9.9                     | 37.0                  | 1               | 2               | 71.4                   | 17.7                                                               | 0                   |
|                      |                                |                 | 132                        | 2(esplanade)                    | 16.4                    | 45.0                  | 4               | 1               | 196.0                  | 67.2                                                               | 1                   |
| 24                   | 0.30                           |                 | 133                        | 1(slope)                        | 9.9                     | 36.0                  | 1               | 1               | 39.5                   | 16.9                                                               | 0                   |
|                      |                                |                 | 134                        | 2(esplanade)                    | 17.6                    | 64.0                  | 2               | 1               | 125.3                  | 125.7                                                              | 0                   |
| 25                   | 0.51                           |                 | 135                        | 1(slope)                        | 10.2                    | 35.0                  | 1               | 2               | 70.2                   | 17.1                                                               | 0                   |
|                      |                                |                 | 136                        | 2(esplanade)                    | 17.7                    | 58.5                  | 3               | 3               | 211.4                  | 113.9                                                              | 0                   |
| 26                   | 1.48                           |                 | 137                        | 1(slope)                        | 10.9                    | 36.5                  | 1               | 3               | 233.3                  | 21.0                                                               | 0                   |
|                      |                                |                 | 138                        | 2(esplanade)                    | 16.1                    | 58.6                  | 1               | 3               | 511.5                  | 94.9                                                               | 0                   |
| 27                   | 0.80                           |                 | 139                        | 1(slope)                        | 10.4                    | 37.5                  | 1               | 1               | 114.2                  | 20.0                                                               | 0                   |
|                      |                                |                 | 140                        | 2(esplanade)                    | 18.0                    | 67.1                  | 4               | 3               | 341.2                  | 137.2                                                              | 1                   |
| 28                   | 0.47                           |                 | 141                        | 1(slope)                        | 10.9                    | 38.0                  | 1               | 1               | 74.3                   | 22.5                                                               | 0                   |
|                      |                                |                 | 142                        | 2(esplanade)                    | 16.8                    | 53.7                  | 1               | 1               | 176.4                  | 91.7                                                               | 0                   |
| 29                   | 3.98                           |                 | 143                        | 1(slope)                        | 9.9                     | 35.0                  | 1               | 2               | 517.4                  | 16.1                                                               | 0                   |
|                      |                                |                 | 144                        | 2(esplanade)                    | 16.7                    | 71.0                  | 2               | 1               | 1468.8                 | 124.4                                                              | 0                   |
| 30                   | 2.01                           |                 | 145                        | 1(slope)                        | 9.3                     | 33.0                  | 1               | 1               | 230.0                  | 12.8                                                               | 0                   |
|                      |                                |                 | 146                        | 2(esplanade)                    | 17.4                    | 65.0                  | 3               | 3               | 805.0                  | 124.3                                                              | 0                   |
| 31                   | 1.34                           |                 | 147                        | 1(slope)                        | 8.8                     | 34.0                  | 1               | 2               | 137.8                  | 12.1                                                               | 0                   |
|                      |                                |                 | 148                        | 2(esplanade)                    | 17.1                    | 58.3                  | 2               | 2               | 519.0                  | 105.6                                                              | 0                   |
| 32                   | 1.51                           |                 | 149                        | 1(slope)                        | 9.9                     | 36.0                  | 1               | 1               | 196.0                  | 16.9                                                               | 0                   |
|                      |                                |                 | 150                        | 2(esplanade)                    | 17.2                    | 68.0                  | 3               | 1               | 591.7                  | 127.2                                                              | 0                   |
| 33                   | 0.32                           |                 | 151                        | 1(slope)                        | 9.4                     | 34.0                  | 1               | 1               | 37.5                   | 13.8                                                               | 0                   |
|                      |                                |                 | 152                        | 2(esplanade)                    | 15.1                    | 50.0                  | 1               | 3               | 96.7                   | 66.9                                                               | 0                   |
| 34                   | 0.60                           |                 | 153                        | 1(slope)                        | 10.1                    | 35.0                  | 1               | 1               | 80.9                   | 16.8                                                               | 0                   |
|                      |                                |                 | 154                        | 2(esplanade)                    | 17.1                    | 55.0                  | 3               | 1               | 232.0                  | 98.1                                                               | 0                   |
| 35                   | 0.82                           |                 | 155                        | 1(slope)                        | 10.2                    | 35.5                  | 1               | 1               | 112.8                  | 17.5                                                               | 0                   |
|                      |                                |                 | 156                        | 2(esplanade)                    | 17.8                    | 66.0                  | 2               | 2               | 343.5                  | 132.2                                                              | 0                   |
| 36                   | 4.80                           |                 | 157                        | 1(slope)                        | 9.8                     | 36.0                  | 1               | 1               | 611.2                  | 16.6                                                               | 0                   |
|                      |                                |                 | 158                        | 2(esplanade)                    | 17.5                    | 62.0                  | 3               | 3               | 1944.5                 | 119.1                                                              | 0                   |
| 37                   | 2.82                           |                 | 159                        | 1(slope)                        | 8.1                     | 34.0                  | 1               | 2               | 245.5                  | 10.3                                                               | 0                   |
|                      |                                |                 | 160                        | 2(esplanade)                    | 17.0                    | 58.0                  | 2               | 3               | 1083.9                 | 104.2                                                              | 0                   |
| 38                   | 1.55                           |                 | 161                        | 1(slope)                        | 9.0                     | 34.0                  | 1               | 1               | 166.6                  | 12.7                                                               | 0                   |
|                      |                                |                 | 162                        | 2(esplanade)                    | 17.1                    | 59.0                  | 2.5             | 1               | 601.6                  | 107.4                                                              | 0                   |
| 39                   | 0.96                           | 1.5             | 163                        | 1(slope)                        | 8.9                     | 35.0                  | 1               | 3               | 101.1                  | 13.0                                                               | 0                   |
|                      |                                |                 | 164                        | 2(esplanade)                    | 16.2                    | 41.0                  | 1               | 1               | 334.9                  | 56.5                                                               | 0                   |
| 41                   | 2.26                           |                 | 165                        | 1(slope)                        | 10.8                    | 37.0                  | 1               | 2               | 348.5                  | 21.1                                                               | 0                   |
|                      |                                |                 | 166                        | 2(esplanade)                    | 16.7                    | 65.0                  | 4               | 1               | 833.3                  | 114.5                                                              | 1                   |
| 42                   | 0.90                           | 3               | 167                        | 1(slope)                        | 9.2                     | 37.0                  | 1               | 1               | 100.5                  | 15.3                                                               | 0                   |
|                      |                                |                 | 168                        | 2(esplanade)                    | 17.5                    | 47.0                  | 1               | 1               | 361.5                  | 81.4                                                               | 0                   |
| 44                   | 1.15                           |                 | 169                        | 1(slope)                        | 8.9                     | 36.0                  | 1               | 2               | 120.5                  | 13.7                                                               | 0                   |
|                      |                                |                 | 170                        | 2(esplanade)                    | 17.0                    | 45.0                  | 2               | 3               | 441.6                  | 72.6                                                               | 0                   |
| 45                   | 1.06                           |                 | 171                        | 1(slope)                        | 8.9                     | 37.0                  | 1               | 1               | 111.8                  | 14.3                                                               | 0                   |
|                      |                                |                 | 172                        | 2(esplanade)                    | 17.7                    | 47.0                  | 1               | 3               | 442.0                  | 83.8                                                               | 0                   |
| 46                   | 0.79                           | 1               | 173                        | 1(slope)                        | 8.2                     | 35.0                  | 1               | 2               | 70.6                   | 11.1                                                               | 0                   |
|                      |                                |                 | 174                        | 2(esplanade)                    | 15.1                    | 60.0                  | 1               | 1               | 240.3                  | 85.8                                                               | 0                   |

$v_i$  : block velocity just before the impact

$\gamma_i$  : incidence angle, relative to the terrain slope (main text, Fig.14)

$terr\_imp$ ,  $geom\_imp$ ,  $E_{kin}$ ,  $E_{kin}^*/m$ ,  $i\_pundit$ : see explanations in the main text (tables 6-8)

Table 4 (complete). Test 4 main results (limestone, 42° bare rock plane).

| Measured before drop |                          | Determined during the drop |                                 |                |                              |                    |                    | Computed from previous |                            | Overall performance |
|----------------------|--------------------------|----------------------------|---------------------------------|----------------|------------------------------|--------------------|--------------------|------------------------|----------------------------|---------------------|
| #Block<br>(-)        | Volume, $V$<br>( $m^3$ ) | Event<br>number            | #Impact (slope<br>or esplanade) | $v_i$<br>(m/s) | $\gamma_i$<br>( $^{\circ}$ ) | $terr\_imp$<br>(-) | $geom\_imp$<br>(-) | $E_{kin}$<br>KJ        | $E^*_{kin}/m$<br>$m^2/s^2$ | F(1)/NF(0)<br>(-)   |
| 1                    | 0.68                     | 175                        | 1(slope)                        | 10.6           | 47.6                         | 4                  | 1.5                | 100.9                  | 30.6                       | 1                   |
| 2                    | 1.36                     | 176                        | 1(slope)                        | 10.7           | 47.1                         | 4                  | 2                  | 205.6                  | 30.7                       | 1                   |
| 3                    | 1.23                     | 177                        | 1(slope)                        | 11.4           | 48.1                         | 4                  | 3                  | 210.4                  | 35.8                       | 1                   |
| 4                    | 0.71                     | 178                        | 1(slope)                        | 12.5           | 47.6                         | 4                  | 2                  | 147.2                  | 42.7                       | 0                   |
|                      |                          | 179                        | 2(esplanade)                    | 15.9           | 82.0                         | 2.5                | 1                  | 237.8                  | 124.0                      | 0                   |
| 5                    | 1.55                     | 180                        | 1(slope)                        | 9.9            | 46.0                         | 4                  | 1                  | 201.6                  | 25.4                       | 1                   |
| 6                    | 2.25                     | 181                        | 1(slope)                        | 10.2           | 46.3                         | 4                  | 3                  | 309.1                  | 27.1                       | 1                   |
| 7                    | 0.90                     | 182                        | 1(slope)                        | 12.1           | 48.4                         | 4                  | 3                  | 176.1                  | 41.1                       | 1                   |
| 8                    | 0.90                     | 183                        | 1(slope)                        | 12.3           | 48.4                         | 4                  | 2                  | 179.2                  | 42.2                       | 1                   |
| 9                    | 0.88                     | 184                        | 1(slope)                        | 12.5           | 48.3                         | 4                  | 3                  | 183.3                  | 43.6                       | 1                   |
| 10                   | 0.85                     | 185                        | 1(slope)                        | 13.5           | 46.9                         | 4                  | 2                  | 203.7                  | 48.2                       | 1                   |
| 11                   | 1.58                     | 186                        | 1(slope)                        | 11.4           | 48.5                         | 4                  | 1                  | 272.3                  | 36.4                       | 0                   |
| 12                   | 0.66                     | 187                        | 1(slope)                        | 12.1           | 47.8                         | 4                  | 2                  | 128.2                  | 40.1                       | 0                   |
| 13                   | 1.93                     | 188                        | 1(slope)                        | 11.2           | 48.3                         | 4                  | 2                  | 320.1                  | 34.9                       | 1                   |
| 14                   | 1.66                     | 189                        | 1(slope)                        | 11.7           | 48.0                         | 4                  | 3                  | 299.3                  | 37.5                       | 1                   |
| 15                   | 1.37                     | 190                        | 1(slope)                        | 12.3           | 47.6                         | 4                  | 3                  | 271.8                  | 40.9                       | 1                   |
| 16                   | 0.55                     | 191                        | 1(slope)                        | 12.5           | 49.3                         | 4                  | 2                  | 112.9                  | 44.7                       | 1                   |
| 17                   | 0.81                     | 192                        | 1(slope)                        | 12.1           | 46.7                         | 4                  | 1                  | 156.2                  | 38.6                       | 1                   |
| 18                   | 0.68                     | 193                        | 1(slope)                        | 12.5           | 46.2                         | 4                  | 2                  | 140.1                  | 40.7                       | 1                   |
| 19                   | 0.58                     | 194                        | 1(slope)                        | 12.9           | 46.6                         | 4                  | 2                  | 128.8                  | 44.2                       | 1                   |
| 20                   | 2.43                     | 195                        | 1(slope)                        | 12.6           | 48.3                         | 4                  | 1                  | 512.1                  | 44.3                       | 0                   |
| 21                   | 0.50                     | 196                        | 1(slope)                        | 12.4           | 48.2                         | 4                  | 2                  | 101.7                  | 43.0                       | 1                   |
|                      |                          | 197                        | 2(esplanade)                    | 16.8           | 80.0                         | 2.5                | 2                  | 173.9                  | 136.9                      | 0                   |
| 22                   | 0.96                     | 198                        | 1(slope)                        | 13.3           | 48.3                         | 4                  | 2                  | 226.7                  | 49.5                       | 1                   |
| 23                   | 0.81                     | 199                        | 1(slope)                        | 12.7           | 49.4                         | 4                  | 3                  | 174.8                  | 46.7                       | 1                   |
| 24                   | 0.83                     | 200                        | 1(slope)                        | 12.0           | 47.7                         | 4                  | 1                  | 159.6                  | 39.7                       | 1                   |

$v_i$  : block velocity just before the impact

$\gamma_i$  : incidence angle, relative to the terrain slope (main text, Fig.14)

$terr\_imp$ ,  $geom\_imp$ ,  $E_{kin}$ ,  $E_{kin}^*/m$ : see explanations in the main text (tables 6-8)