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Ratio between stone diameter and nominal diameter

analysis of measured data

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1. Introduction

For describing the dimensions of stones both the values d_{50} and d_{n50} are used. The value of d_{50} is determined by sieving a sample and d_{50} is the "median diameter", i.e. 50% of the total weight of the stones are larger than the value d_{50}. It is therefore relevant to know the relation between d_{50} and d_{n50}. The ratio between d_{50} and d_{n50} is given by:

$$d_{n50} = F_s^* d_{50} \qquad (1)$$

or

$$M_{n50} = F_s d_{50}^3 \qquad (2)$$

In literature (e.g. ROCK MANUAL [2007]) for F_s^* a value of 0.84 is given, while for F_s a value of 0.6 is given, with a range between 0.34 and 0.72. For small stones in laboratory experiments the range is between 0.66 and 0.70. In terms of F_s^* this means a value between 0.70 and 0.90 for armour stone and 0.87 and 0.89 for laboratory stones. However, good background information on this matter is missing. The only source for these values mentioned in the Rock Manual is a publication of Laan from 1981.

2. Earlier work

The earliest found reference to Fs by the author is in a publication of VAN BENDEGOM [1967, p6.4.29]. He mentions that F_s has a value of 0.5, however he does not give any reference or background. This implies an F_s^* of 0.8.

For the commonly used value of $F_s^* = 0.84$ is usually referred to LAAN [1981]. Unfortunately this publication is lost, so no information is available on the background and accuracy of the value 0.84. In a follow up publication [LAAN, 1996] is given that the mean value of F_s is 0,6 with a standard deviation of 0,07. This implies a mean value of F_s^* of 0,84 and a range from 0.81 to 0.88 (bandwidth of one standard deviation of F_s). In this research experiments are done to find data in order to determine F_s^*.

In an earlier report [LAAN, 1982] states that:

"… the relation between mass and diameter could be described by:

$$M = a \rho z^b \qquad (3)$$

in which a and b are constants to be determined from experiments. Reference is made to [LAAN 1979] and [LAAN 1981].

In order to determine the constants tests have been made by sieving many stones with sieves with mesh sizes varying from 30 to 180 mm. The errors in converting a mass-curve to a sieve curve were in general smaller than 10%, especially when the batches had only a limited number of stones with high elongation.

For light and heavy gradings the relation between mass and thickness has been determined [LAAN 1981]. Six batches were investigated varying from 60-300 kg to 6000-10000 kg. The average value of t/l for these stones varied from 0.57 to 0.53.

As stated above for four batches the relation between mass and sieve-size has been determined. Three of these four batches of smaller stones showed a mean value for t/l of about 0.44 and an average value for t/m of 0.75. The fourth batch consisted of very flat material with a mean value for t/l of 0.33 and a mean value for t/m of 0.59.

It has been assumed that the ratio $t/m = 0.75$ is also valid for light and heavy gradings, which then implies that for all types of investigated rock the relation between mass and thickness and between mass and sieve size can be determined. This results in the following equations:

$$M = 0.6 \rho m^3$$
$$M = 1.4 \rho t^3 \qquad (4)$$

The error in general application of these relations is usually limited to less than 10%.

The influence of the value *t/l* on the mass is not large. Besides an increase of *t/l* may imply as well as an increase or a decrease of the mass. When a decrease of *t/l* is caused by an increase of *l*, the mass is increased. However when the decrease of *t/l* is caused by a decrease of *t*, the mass is decreased."

(the above quote is a translation from the original Dutch text. The symbols have been adapted to the symbols used in this report:

m = mesh size of sieve where the stone is just passing
l = length of the stone
t = thickness of the stone)

The coefficient 0.6 in equation 4 is equal to F_s. The value of F_s^* can be found from the above numbers in the following way:

$$F_s = \frac{t/l}{t/m} = \frac{m}{l} = \frac{0.33}{0.59} = 0.56$$
$$F_s^* = \sqrt[3]{F_s} = 0.824 \qquad (5)$$

From the above one may also conclude that Laan has derived the value of F_s^* only from fine gradings (his maximum sieve size was 180 mm).

3. Definition of M_{50} and d_{n50}

Because for larger stones sieving is impossible the value of d_{50} is replaced by d_{n50}, which is often called the median nominal diameter:

$$d_{n50} = \sqrt[3]{V} = \sqrt[3]{\frac{M_{50}}{\rho}} \qquad (6)$$

In which ρ is the stone density in kg/m^3 and M_{50} the "median stone weight". According to the ROCK MANUAL [2007], the definition of the M_{50} (p 108): "M_{50} is the mass of the theoretical block for which half of the mass of the sample is lighter", or more general: "The block mass is expressed by M_y, where *y* per cent of the total (or cumulative) sample mass is lighter than *M*". But in the same document M_{50} is called the "median mass" (e.g. on page 107).

This is incorrect use of the term "median". In statistics and probability theory, the median is the numerical value separating the higher half of a data sample, a population, or a probability distribution, from the lower half. The median of a finite list of numbers can be found by arranging all the observations from lowest value to highest value and picking the middle one (e.g. the median of {3, 5, 9} is 5) [Wikipedia]. On basis of the full distribution, the median stone mass M_{me} is defined by:

$$\int_{-\infty}^{M_{me}} f(x)dx = \frac{1}{2}\int_{-\infty}^{\infty} f(x)dx \qquad (7)$$

However, because by definition $\int_{-\infty}^{\infty} f(x)dx = 1$ for a normalised distribution, this reduces to:

$$\int_{-\infty}^{M_{me}} f(x)dx = \frac{1}{2} \qquad (8)$$

In which $f(x)$ is the probability density function and M_{me} is the median stone mass. The equation for the M_{50} as given in the rock manual is:

$$\int_{-\infty}^{M_{50}} x \cdot f(x)dx = \frac{1}{2}\int_{-\infty}^{\infty} x \cdot f(x)dx \quad (9)$$

Example:
Given a set of 11 stones with a mass 1, 2, 2, 4, 5, 6, 7, 8, 9, 11, 15 kg. The total mass of this sample is 70 kg. The average mass is 70/11 = 6.36 kg. The median mass M_{me} of the sample is 6 kg, while the M_{50} is 7 kg.

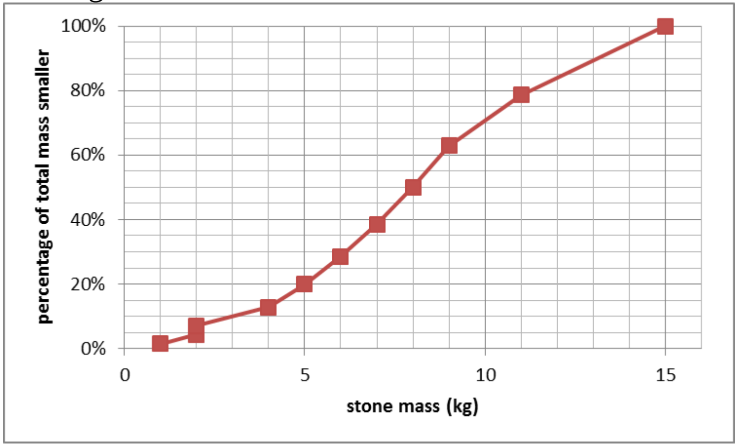

Figure 1: cumulative distribution of stone mass

Also for d_{50} often the term ”median grain size” is used. This is also incorrect, for the same reason as explained above why the term “median stone mass” is incorrect for M_{50}. However, this usually does not lead to confusion, because it is practically impossible to determine the value of d_{me} from a sample when the particles are smaller than 5 mm. For values between 5 and 100 mm one could determine the d_{me} by counting the individual number of stones on a sieve, but that is seldom done.

4. Experiments

In order to get more insight in the distribution of F_s^* a sample of stones has been measured in detail. Also for each stone elongation and blockiness have been determined. For the experiment a batch of 244 stones (609 kg) of stones from a depot were used. The stones were approximately in class 90/150 mm. However this was not a batch to be handled according to a given standard. The stones were provided by Rivierendriesprong in Papendrecht, Netherlands. All tests were performed on their yard. The stones were Belgium limestone.
All stones were sieved with standard sieves (31.5, 45, 63, 90, 125, 180, 250 and 360 mm) according to EN13383. Before sieving the stones were washed and before weighing the stones were dried. All stones were marked and numbered.

Figure 1: Normal stone (left) and stone with soft, white lime (right

It was conclude that the material was not completely homogeneous. Part of the stones consisted partly of some grey material. There were two variants of this material, a fast-drying version and a slow drying version. Sometimes the grey area had a clear white borderline.

Figure1: Sieves used to measure the stones

Also from all stones the weight was determined, as well as elongation and blockiness. Elongation was determined by determining the quotient of maximum length divided by the thickness (smallest diameter) of the stone.

Figure 2: Calliper to measure elongation

The blockiness was determined by measuring the smallest rectangular box which could fit the stone and dividing the volume of the stone by the volume of this box.

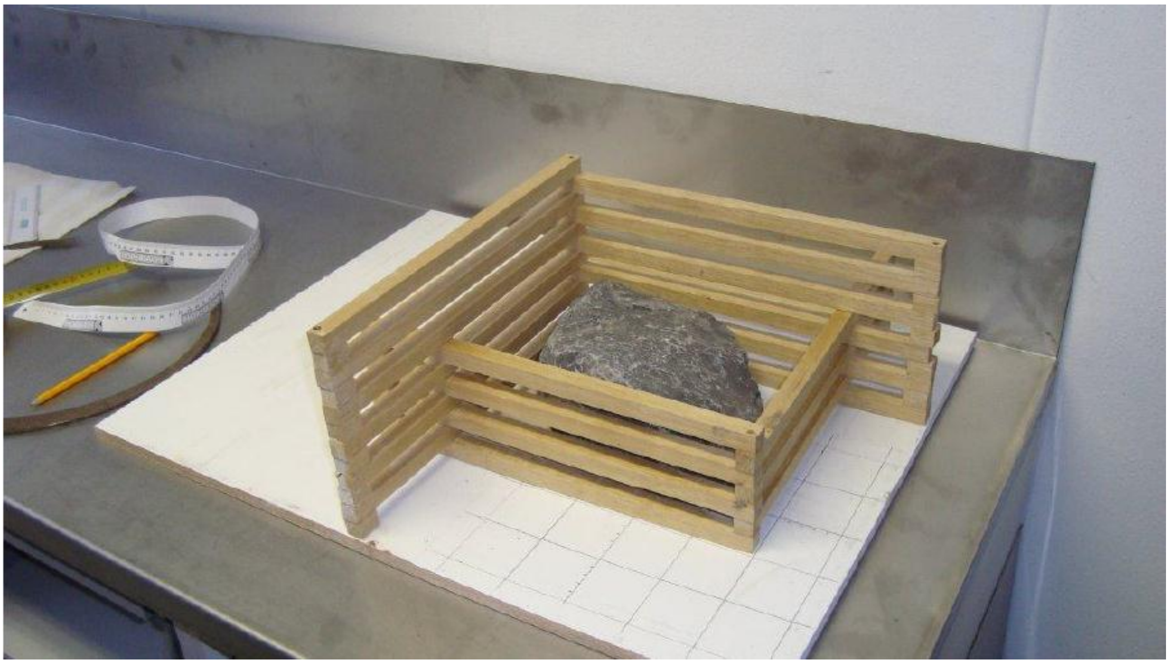

Figure 3: tool to measure the blockiness

From a selected number of stones also the density has been measured. The water content of the stones varied from 0.11 % to 0.9%. There were a few stones of different composition in the sample. The average density of the stones was 2660 kg/m^3, within a range from 2550 to 2750 (standard deviation 85 kg/m^3).

All data are presented in Annex 1.

The results of the sieving are presented in Figure 4:

Sieve size	Weight on sieve	Fraction on sieve	Fraction through sieve
mm	kg		
250	0,000	0,0000	1,0000
180	9,861	0,0162	0,9838
125	220,277	0,3617	0,6221
90	343,270	0,5636	0,0585
63	33,925	0,0557	0,0028
45	1,201	0,0020	0,0008
30	0,417	0,0007	0,0001
rest	0,085	0,0001	0,0000
total	609,034		

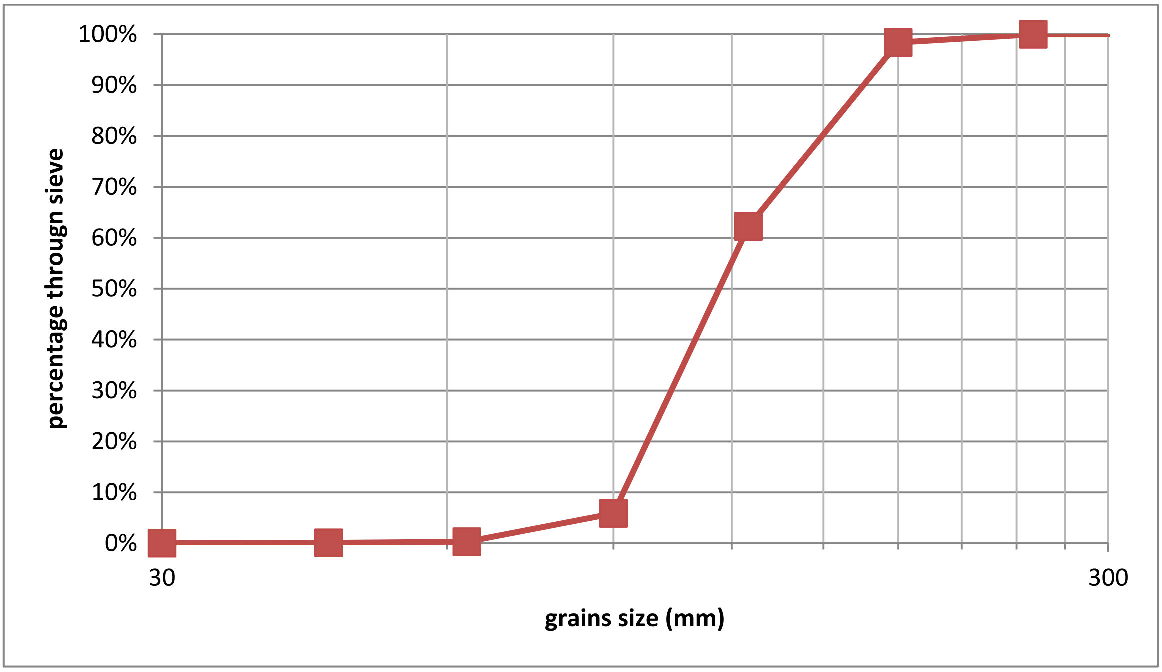

Figure 4: Results of the sieving

For the analysis one may consider stones smaller than 30 mm as splinters. They were probably created during handling of the batch and not representative of the stone class.

5. Determination of the d_{50} and the d_{n50}

By fitting a line through the sieve curve using linear interpolation between the measured point one finds a d_{50} of 117.4 mm (see figure 4). By fitting the data to Gauss curve, one finds a d_{50} of 117.3 mm, see figure 5.

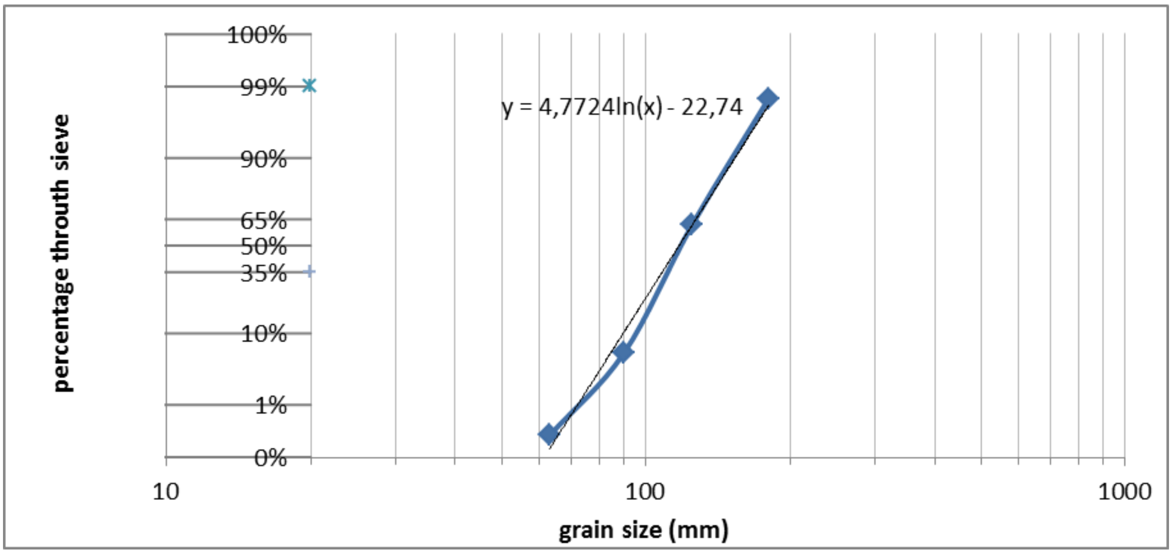

Figure 5: Results of the sieving with Gauss fit

In summary sieving resulted in the following values:

		value (mm)	
	perc	lineair	Gauss
D05 (ELL)	5%	85,88	83,12
D10	10%	92,58	89,69
D15 (NLL)	15%	95,68	94,42
D25	15%	95,68	94,42
D50	50%	117,42	117,32
D60	60%	123,63	123,72
D85	85%	159,65	145,78
D90 (NUL)	90%	167,26	153,47
D98 (EUL)	98%	179,42	180,42
D60/D10		1,34	1,38
D85/D15		1,67	1,54

From all individual stones also the dimensions were measured. From these dimensions one may calculate elongation and blockiness. In the appendix the values are given. Elongation is defined as:

$$LT = {}^{l}\!/_{t} \qquad (10)$$

Blockiness is defined as:

$$BLc = \frac{V_s}{xyz} = \frac{M}{\rho_s}\frac{1}{xyz} \qquad (11)$$

From each stone one may calculate the $d_n = (M/\rho_s)^{0.33}$.

After sorting all the stones following their weight one may plot an exceedance graph of d_n.

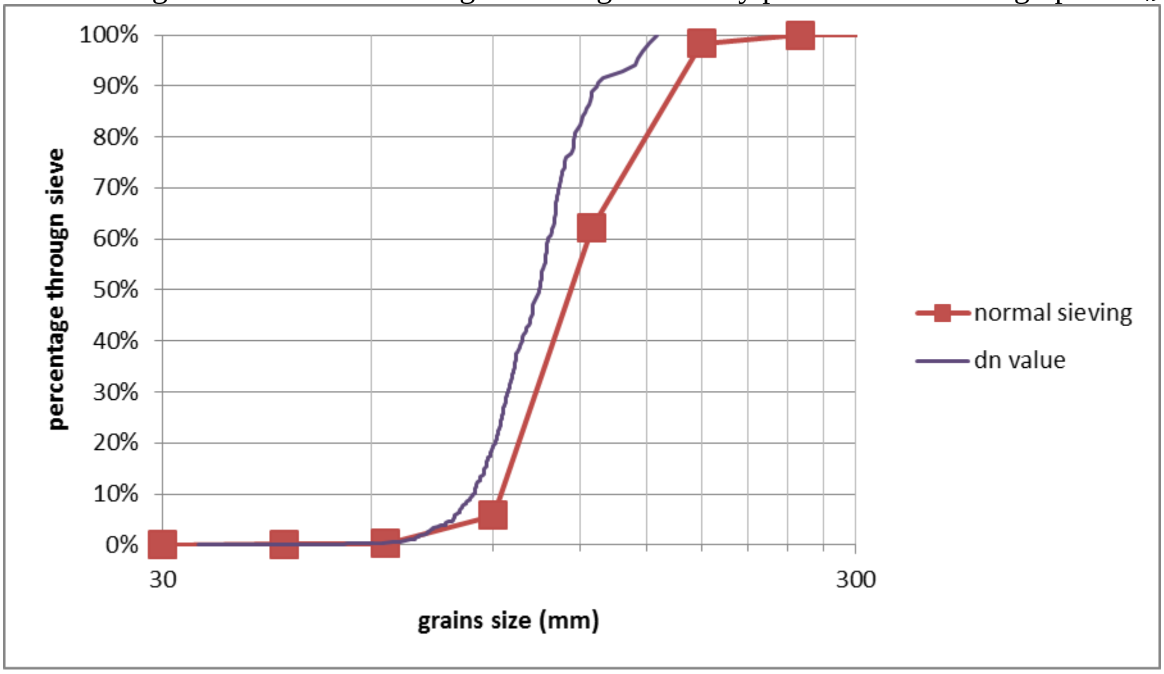

Figure 6 Sieve analysis of d_{50} and distribution of d_{n50}

From this graph one can read the value of d_{n50}. For this sample d_{n50} = 105 mm. From the sieve analysis (figure 4 or figure 5) followed that the d_{50} was 117 mm, so the ratio $F_s^* = d_{n50}/ d_{50}$ = 105.0/117.4 = 0,894 for this sample, which is a higher value than suggested by LAAN [1981]. However, the found d_{n50} is from a different stone than the found d_{50}.

Another disadvantage of this approach is that one can only compare the values from the uses sizes of the sieves, and interpolate in between. Using more sieves would give a better curve, however, this is not physically possible. Therefore a virtual sieve can be used.

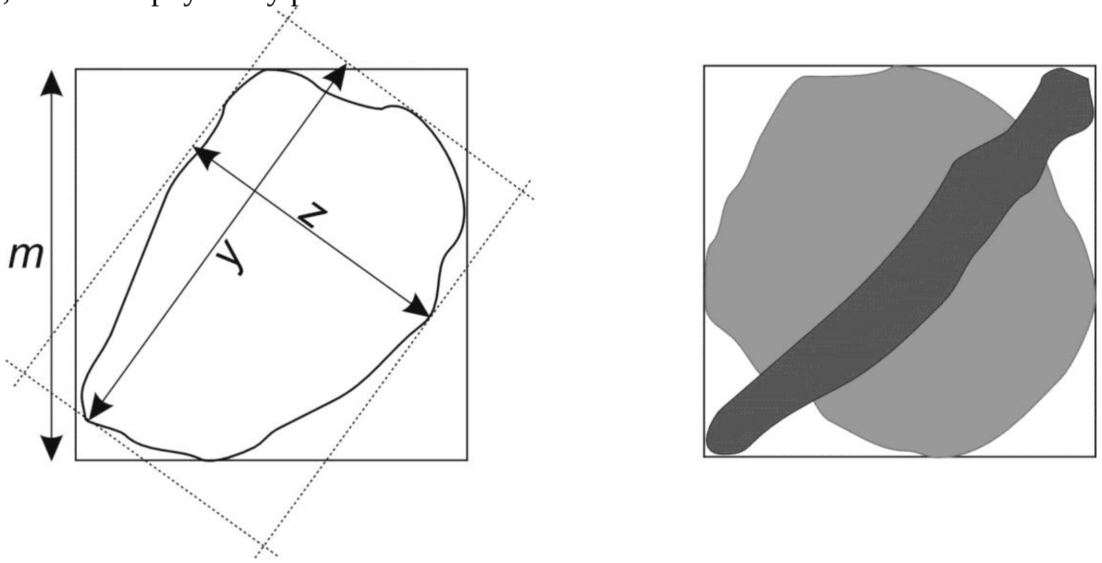

Figure 7: virtual sieve

From each stone the dimensions were determined. For the blockiness the values *x*, *y* and *z* are known. The longest value, *x*, is not relevant for this analysis. The values *y* and *z* determine if a stone may pass through the mesh of a sieve. See figure 7. When the stone is rather round (light grey stone in figure 7) the value of $y \approx z$. In that case the mesh size *m* equals *y*. In case the stone is rather flat (dark grey stone in figure 7) the value of $m = y/\sqrt{2} = y/1.4$. The following equation is an estimate for $0 < z < y$:

$$m > \frac{y}{1 + 0.45\left(1 - \frac{z}{y}\right)} \qquad (12)$$

In this equation the factor 0.45 is a geometrical fit factor. From the above considerations follow that for $z = y$ the value of this factor is not relevant, and for $z = 0$ this value has to be 0.4. A factor of 0.45 gives a good fit for the data points.

With the use of this formula, one may determine the virtual mesh size of each individual stone. As a next step one can sort stones on increasing mesh size and make an exceedance line.

One can plot the values of d_n also in the same exceedance graph, see figure 8. One may read from this graph that $d_{50virtual}$ is 121 mm, and d_{n50} is 105 mm. This gives an F_s^* value of 105/121 = 0.868.

However, the stone which provides the value of $d_{50virtual}$ is a different stone, than the stone providing the value of d_{n50} (in fact the $d_{50virtual}$ comes from stone #125-2, while the d_{n50} comes from stone #125-26). But because from each individual stone the value of $d_{50virtual}$ and d_{n50} is known it is possible to calculate $F_s^* = d/d_n$ for each individual stone.

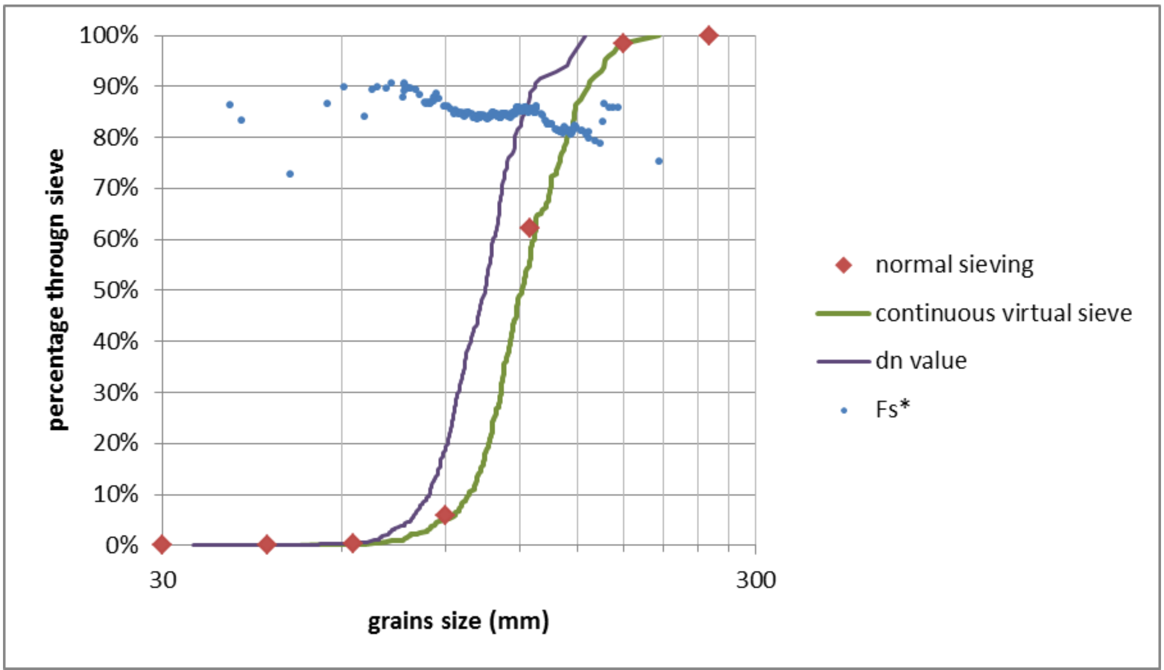

Figure 8 continuous virtual sieve results and individual values of F_s^* plotted as function of d_n

This value has also been plotted in figure 8 as a function of d. The average value $\overline{F_s^*}$ = 0.845. The median value $F_{s\ me}^*$ of is also 0.845, and the $F_{s\ 50}^*$ is 0,843 (i.e. the value of F_s^* exceeded by 50% of the total weight of the batch. The difference between these three types of "average" values is small. However it is clear that F_s^* reduces for the bigger stones in the batch. So it seems that F_s^* is decreasing when the stone size is increasing. The average value of $\overline{F_s^*}$ = 0.85 is very near to the suggested value of LAAN [1981], this in contrary to the value $d_{n50}/\ d_{50}$ which is 0,868.
However, it is assumed that the value of Laan is based on $d_{n50}/\ d_{50}$. The found value of F_s^* = 0.868 falls within the ranges for F_s^* as given in LAAN [1996]: $0.81 < F_s^* < 0.88$.

6. Relation with blockiness and elongation

One may expect a relation between F_s^* and the elongation or blockiness. In figure 9 and figure 10 these relations are given.

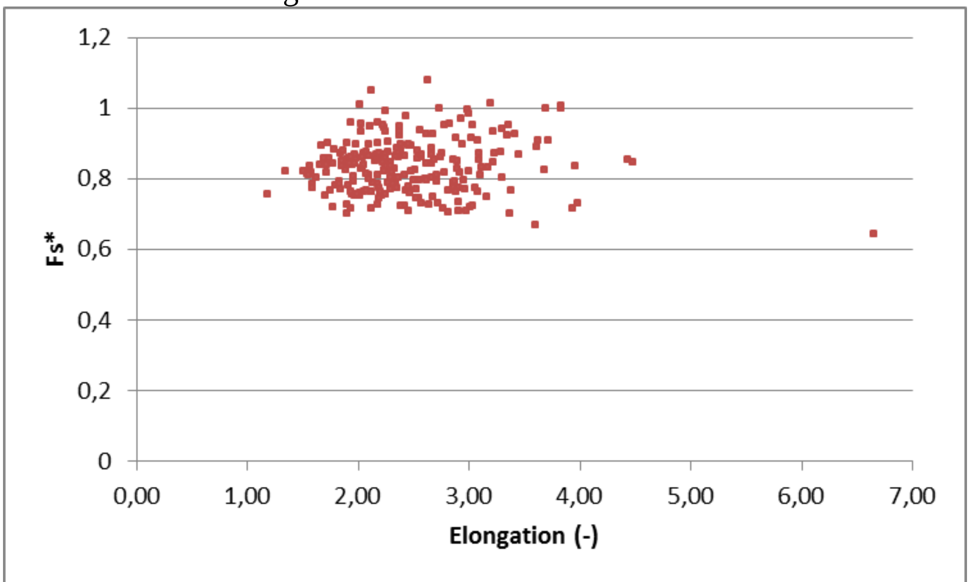

Figure 9: relation between elongation and F_s^*

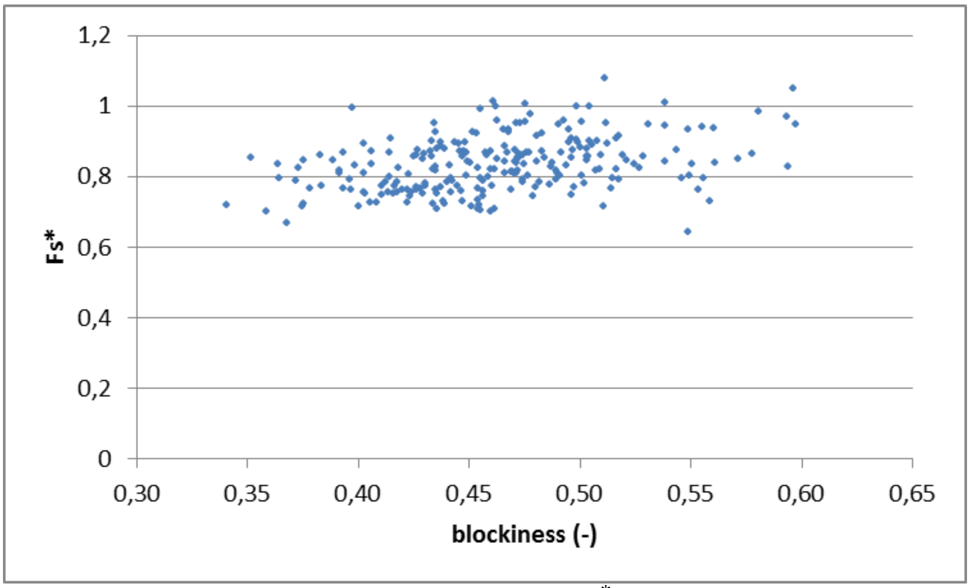

Figure 10: Relation between blockiness and F_s^*

From these figures it is obvious that in this sample there is no relation between elongation and F_s^*, and that there is a very week (and therefore not really significant) relation between blockiness and F_s^*.

7. Test with very small units

Recently VAN DEN HEUVEL [2013] did some sieve analysis on small scale stones to be used in a hydraulic model investigation. He determined the distribution both by sieving as well as by weighing individual stones. This resulted in the following data:

Non-exceeded percentages	5%	15%	50%	90%	98%	Density [kg/m^3]
Yellow Sun d [mm]	0.99	1.16	1.50	2.06	2.50	2679
Yellow Sun d_n [mm]	0.99	1.09	1.50	2.13	2.39	2679

Remarkable is that from this test follows that $d_n \approx d$. However, when comparing these results with figure 8 it seems indeed that when the diameter decreases F_s^* increases.

8. Conclusions and recommendations

From the test with the stone batch followed that the average value of F_s^* is nearly equal to the value as presented by LAAN [1981]. However, one has to determine the d_{50} and the d_{n50} separately, one should not calculate the d_{n50} from the data of the weight of a stone with size d_{50}. It seems that for smaller stones F_s^* approaches a value of 1. Blockiness and elongations seems to have no influence on the value of F_s^*.
Because of the differences between F_s^* and $\overline{F_s^*}$, one cannot use the value of F_s^* to calculate for example the d_{15} from the d_{n15}.
It is recommended to repeat this measurement with other batches, especially of a batch with a larger size, but also see the differences with other types of stones.

References

LAAN, G. [1979] De relatie tussen de korrelverdeling en de massaverdeling, report RL-KO-79.04 Rijkswaterstaat, Wegbouwkundige Dienst, Delft

LAAN, G. [1981] De relatie tussen vorm en gewicht van breuksteen (the relation between shape and weight of pieces of rock), report MAW-R-81079, Rijkswaterstaat, Wegbouwkundige Dienst, Delft (Laan refers in another paper to this report with a slighly different title: "De relatie tussen de vorm en de massa van stukken breuksteen"

LAAN, G. [1982] Kwaliteit en kwaliteitscontrole van breuksteen in de waterbouw, report MAW-R-81054, WKE-R-82002, Rijkswaterstaat, Wegbouwkundige Dienst, Delft

Laan, G [1996] De relatie tussen eisen aan loskorrelige steenmaterialen en ontwerpparameters, report P-DWW-096.069, Rijkswaterstaat, DWW

ROCK MANUAL [2007] The Rock manual, the use of rock in hydraulic engineering, CIRIA publication C683, CIRIA-CUR-CETMEF, London

VAN BENDEGOM, L. [1967] Algemene waterbouwkunde, deel IIa, de natuur, Lecture notes TU Delft

VAN DEN HEUVEL, H.P.A. [2013] The effect of multiple storms on the stability of near bed structures, M.Sc. –thesis TU Delft

Symbols used

d	diameter of the stone, defined as the mesh through which the stone is just passing
d_n	nominal diameter of the stone, as defined by eq. 4
l	longest size of the block (length)
m	mesh size of a sieve
t	shortest size of the block (thickness)
F_s	ratio between stone diameter and volume
F_s^*	ratio between stone diameter and nominal diameter
M	mass of the stone

Annex 1: Data

			Elongation		Blockiness				mass		Volume (ml)	
Sieve size	Stone nr	Mass (g)	Length (cm)	Thickn (cm)	X (cm)	Y (cm)	Z (cm)	Remarks	M,before	M,dry	Water	Water/stone
250	1	9860,7	31,4	10,8	28,9	26,0	10,9		9853,3			
180	1	3551,8	20,8	8,9	17,8	14,8	8,8					
	2	3857,5	20,0	8,6	16,9	16,1	9,0					
	3	3116,5	23,2	5,9	20,4	18,8	6,0					
	4	5461,4	22,2	10,3	20,2	17,5	10,2					
	5	5777,1	28,5	9,8	24,7	20,1	10,2					
	6	8649,7	33,1	10,7	32,8	20,2	10,7					
	7	4008,1	19,6	10,1	17,1	15,6	10,1					
	8	5091,1	23,9	9,3	22,5	20,7	9,4					
	9	9193,7	30,4	11,4	29,7	21,3	11,4					
	10	3086,2	18,2	9,8	15,3	14,1	9,8					
	11	4303,9	22,5	7,6	21,9	18,6	8,3					
	12	4627,5	26,1	7,1	26,0	18,2	7,0					
	13	3592,1	22,6	7,6	19,4	19,4	7,8					
	14	4859,0	28,3	8,2	27,1	16,8	8,8					
	15	6989,3	27,1	11,2	26,9	18,5	11,2					
	16	8193,8	30,1	10,3	28,9	17,5	10,3					
	17	4301,8	26,5	8,6	25,0	15,2	8,6					
	18	7947,7	32,0	11,1	30,6	18,2	11,2					
	19	4295,8	23,3	10,7	20,6	15,4	10,8					
	20	3832,6	21,3	9,4	20,6	14,7	9,6					

	21	5161,9	23,9	8,5	22,6	22,0	8,6	
	22	4466,6	25,1	10,6	24,4	14,1	10,8	
	23	3519,4	22,6	8,5	20,1	16,3	8,5	
	24	3796,5	23,6	7,0	21,9	20,3	7,0	
	25	3260,5	21,5	7,4	19,2	18,8	7,5	
	26	3703,4	21,5	9,5	21,0	13,9	9,6	
	27	4355,5	22,5	9,8	21,8	17,4	9,8	
	28	5492,1	28,1	9,2	25,3	20,0	9,2	
	29	4882,0	24,7	7,5	23,5	19,0	7,5	
	30	3278,1	22,1	8,0	18,6	18,4	8,0	
	31	3579,6	20,7	10,1	20,3	13,8	10,8	
	32	5173,9	25,6	8,5	23,1	21,6	8,6	
	33	4190,8	20,0	10,2	17,5	17,1	10,2	
	34	3623,6	24,3	8,5	22,3	17,3	8,5	
	35	4686,3	25,5	10,7	24,4	15,4	10,8	
	36	3463,6	18,2	11,8	16,2	14,2	12,1	
	37	3317,9	19,3	9,6	17,2	16,6	9,6	
	38	4697,8	26,7	11,3	26,0	15,6	11,4	
	39	3554,9	18,3	11,7	17,1	14,1	11,7	
	40	3438,6	20,1	9,1	19,1	17,2	9,2	
	41	3171,3	21,0	8,7	17,9	17,7	8,7	
	42	5010,9	22,9	9,0	20,1	18,8	9,0	
	43	3591,2	22,0	8,1	20,1	18,6	8,1	
	44	3271,9	21,3	8,5	20,9	15,3	8,5	
	45	3342,5	19,0	11,5	16,4	13,7	11,5	
	46	3936,1	21,2	10,1	21,1	14,2	10,0	*
	47	1884,8	20,9	5,8	19,7	16,9	5,8	Flat
	48	3714,6	20,9	8,6	18,0	17,6	8,6	
	49	2019,8	22,6	3,4	21,6	18,9	3,4	Flat
	50	3953,8	18,3	11,3	16,9	15,9	11,3	
125	1	1879,1	16,1	10,4	12,7	11,3	10,5	

2	2143,5	17,7	7,9	17,4	14,6	7,9
3	1925,9	16,8	8,1	15,4	13,6	8,1
4	1663,0	15,8	8,3	13,7	13,6	8,3
5	1582,7	13,9	8,0	12,9	10,8	8,1
6	2977,1	19,1	8,8	17,8	13,8	8,8
7	2403,2	17,4	8,2	15,7	15,0	8,2
8	1877,9	17,2	8,7	17,1	10,6	8,8
9	2180,4	21,1	6,4	19,6	11,8	6,4
10	1938,9	16,0	9,4	14,2	13,3	9,6
11	3595,2	23,5	7,3	23,2	15,9	7,3
12	3639,1	21,0	9,4	20,7	13,1	9,4
13	2480,0	16,9	9,5	16,4	12,0	9,5
14	2807,7	19,4	8,2	17,6	13,5	8,2
15	1771,5	19,1	6,3	16,2	14,9	6,3
16	2125,8	19,3	6,1	17,2	15,4	6,1
17	2882,9	20,1	10,0	19,6	10,3	10,0
18	2290,5	19,6	9,0	19,0	11,4	9,2
19	2699,6	22,2	9,9	21,7	10,2	10,1
20	2328,7	23,0	7,4	21,9	13,6	7,4
21	2419,5	18,9	7,5	18,9	15,1	7,5
22	2533,3	19,1	9,2	17,6	12,4	9,3
23	2279,5	19,9	7,8	17,0	15,3	7,8
24	2632,8	19,2	7,5	19,2	12,3	7,5
25	3009,8	22,6	8,5	21,2	13,5	8,5
26	3076,6	25,3	7,4	25,0	13,4	7,4
27	1630,0	15,3	7,5	14,3	11,1	7,6
28	1607,7	15,8	8,6	13,1	12,3	8,6
29	2000,0	17,3	8,5	14,6	12,3	8,5
30	2446,4	21,2	7,9	18,5	13,2	8,0
31	2058,2	17,5	10,2	12,6	11,9	10,2
32	1981,8	16,2	7,9	15,9	12,3	8,1
33	2086,8	21,4	5,9	21,0	12,3	5,9

34	1696,2	13,7	10,2	13,5	10,6	10,3					
35	3116,4	18,1	10,7	16,4	13,3	10,7					
36	1141,2	14,2	5,8	13,1	13,0	5,8					
37	2113,2	17,2	7,7	15,1	13,1	7,8					
38	2936,9	19,8	9,4	18,8	11,8	9,4					
39	3309,7	17,6	11,1	15,6	15,2	11,1					
40	3664,7	25,1	9,6	24,7	13,4	9,6					
41	2155,9	18,0	8,6	17,7	13,1	8,7	Much soft white	2147,9	2141,3	1720,0	2620
42	1057,8	13,1	7,5	12,3	10,7	7,7					
43	3728,5	22,0	9,8	21,9	14,6	9,8					
44	2366,7	18,7	9,3	15,7	14,7	9,3					
45	3744,6	28,9	8,6	28,0	13,5	8,6					
46	1626,3	15,5	6,7	14,2	12,8	7,0					
47	3602,8	22,0	10,1	22,0	12,4	10,1					
48	3149,7	21,5	7,8	21,5	14,3	8,0					
49	2407,8	19,4	7,9	17,9	12,1	8,4					
50	4280,7	22,2	10,5	22,0	11,5	10,7	Blocky?				
51	4344,4	28,1	8,7	27,2	16,0	8,7					
52	3948,6	28,4	8,9	28,4	12,5	9,1					
53	2757,9	23,2	7,9	22,4	13,1	7,9					
54	2076,0	17,1	7,2	16,4	11,1	7,2					
55	3305,6	19,9	9,8	19,9	14,7	9,8					
56	2918,1	19,3	9,8	18,0	13,1	9,8					
57	3134,2	19,8	8,8	19,5	14,0	8,8					
58	2520,7	20,9	9,4	19,2	12,1	10,9					
59	2603,3	19,2	10,0	16,9	12,8	10,1					
60	1997,7	19,7	7,4	18,0	12,1	7,4					
61	1629,2	18,6	6,0	17,0	12,7	6,1					
62	2074,3	17,3	7,9	16,1	13,6	8,7					
63	3253,0	21,1	9,7	18,3	15,7	9,7	* Pictures				
64	1582,1	15,7	8,4	15,7	10,3	8,4					
65	2146,9	19,5	7,7	19,2	12,4	8,0					

66	2434,2	18,7	8,0	18,5	14,5	8,3					
67	1815,0	18,8	6,1	18,8	14,2	6,1					
68	2044,1	18,2	9,0	18,0	10,0	9,0					
69	2273,9	23,0	7,0	22,4	12,8	7,0					
70	2030,4	17,1	8,7	15,6	12,1	8,7					
71	1423,2	15,8	7,1	15,4	9,2	7,4					
72	1389,8	15,7	5,8	15,1	12,0	5,9					
73	1693,3	15,5	8,0	13,7	12,9	8,3	softwhite border	1687,6	1683,4	1725,0	2390,0
74	1378,6	15,9	7,6	15,4	10,2	7,7					
75	1703,4	14,3	9,0	12,5	12,4	9,0					
76	1607,9	14,0	9,3	13,0	10,9	9,3					
77	2163,8	20,4	8,4	19,7	10,2	8,5					
78	1203,0	15,2	6,0	14,4	10,1	6,2					
79	1502,6	13,6	7,1	12,4	12,3	7,4					
80	1366,4	12,1	10,2	11,2	10,9	10,2	large softwhite border	1362,3	1357,8	1715,0	2250,0
81	1479,7	15,5	6,2	14,1	12,4	6,2					
82	1612,3	14,7	8,2	14,0	12,3	8,2					
83	1759,0	18,3	7,0	16,0	13,0	7,0					
84	1944,5	19,3	8,2	18,1	11,3	8,2					
85	2398,7	17,9	9,4	17,9	12,4	9,4					
86	2190,7	16,9	8,6	15,2	14,5	8,6					
87	2183,6	17,4	9,0	16,6	11,9	9,1					
88	2046,3	16,0	10,2	15,7	11,2	11,2					
89	1826,5	15,4	9,0	14,9	11,4	9,0					
90	2101,7	17,1	9,3	16,7	11,4	9,3					
91	2313,1	19,2	8,5	19,2	13,0	8,6					
92	2361,6	22,2	7,9	20,0	14,9	7,9					
93	1988,8	16,6	7,6	14,9	14,5	7,6					
94	1917,6	21,0	7,9	19,8	11,6	8,0					
95	1704,3	16,6	7,8	13,9	12,5	8,1					
96	2808,4	22,6	9,2	20,3	12,6	9,3					
97	1816,8	16,6	8,5	15,5	12,3	8,5					

98	1896,2	16,2	7,9	15,5	13,7	7,9
99	2881,9	19,0	9,6	16,5	13,2	9,9
100	1378,3	16,2	6,3	16,0	10,8	6,3
101	2588,6	21,8	8,7	20,9	14,4	8,9
102	1424,4	20,7	6,7	20,7	11,0	6,7
103	1439,2	16,8	5,8	16,0	11,8	5,9
104	2801,2	20,2	9,0	19,1	13,3	9,3
105	2016,8	18,0	6,1	16,2	14,1	6,1
106	2143,8	17,4	7,6	15,6	13,0	7,6
107	2856,7	21,3	8,3	19,5	13,7	8,5
108	1768,1	16,7	7,3	13,7	13,4	7,3
109	2585,9	21,6	7,4	20,9	14,5	7,4
110	1299,5	15,4	6,1	13,1	12,8	6,1
111	1115,1	15,3	5,8	13,5	12,5	5,9
112	1534,1	15,6	8,2	14,0	13,7	8,4
113	2439,5	18,6	8,1	17,5	14,1	8,3
114	2316,7	19,2	8,6	18,4	13,2	8,6
115	2219,5	19,0	8,8	18,4	11,8	9,3
116	2111,5	20,9	6,6	20,4	13,4	6,6
117	1019,8	14,3	6,0	14,1	12,1	6,0
118	2547,7	17,7	10,6	15,5	11,3	10,7
119	3489,2	24,0	8,5	23,6	13,1	8,5
120	3281,6	22,4	9,8	22,4	14,2	10,0
121	2822,2	23,0	9,3	22,3	12,6	9,4
122	2883,9	23,0	8,6	22,4	12,5	8,6
123	3109,0	19,6	9,0	18,1	15,1	9,1
124	3363,7	22,4	10,0	20,3	12,5	10,1
125	1483,7	17,1	6,4	16,0	13,3	6,4
126	2077,2	17,8	8,2	15,6	15,0	8,2
127	3060,1	21,2	8,6	18,2	16,5	8,6
128	1750,4	15,7	8,5	14,8	11,2	8,6
129	3088,2	21,7	7,6	21,0	14,7	7,6

	130	1537,4	17,4	8,2	14,2	12,4	8,3					
	131	2258,7	19,3	7,4	17,8	14,1	7,4					
	132	2218,7	18,8	9,3	18,0	10,5	9,5					
	133	1834,7	18,0	6,0	17,3	13,1	6,0					
	134	2412,3	18,0	9,5	16,4	11,5	9,5					
	135	1348,8	15,0	7,5	13,1	12,2	7,5					
	136	2436,6	18,3	10,0	13,8	13,6	10,0					
	137	3219,9	20,9	8,5	17,9	16,4	8,5					
	138	3814,9	26,0	9,1	25,0	17,0	9,1					
	139	2651,2	19,6	9,3	19,4	11,3	9,3					
	140	2352,2	21,3	6,3	20,0	15,5	6,3					
	141	2325,6	21,5	7,5	20,5	14,4	7,5					
	142	2693,0	19,3	8,5	17,7	14,9	8,7					
	143	2193,7	20,8	6,9	19,3	12,0	6,9					
	144	1791,2	17,3	6,4	16,6	13,4	6,4					
	145	1811,0	16,5	6,3	16,1	12,5	6,3					
	146	2854,4	23,0	9,5	20,1	14,4	9,5					
	147	2242,7	21,4	7,7	20,8	11,2	7,7					
	148	1774,6	15,4	7,9	14,2	13,5	7,9					
	149	1322,4	14,5	7,3	13,4	12,2	7,3	much soft lime	1321,6	1314,8	1700	2250
	150	1553,1	17,5	4,4	16,2	14,7	4,4	flat				
90	1	760,1	12,4	4,3	11,0	10,7	4,4					
	2	976,8	15,1	6,9	14,6	9,0	6,9					
	3	1038,6	14,5	7,5	11,9	11,7	7,5					
	4	904,2	13,6	6,5	12,6	9,9	6,6					
	5	1198,4	13,3	7,5	12,8	10,0	7,5					
	6	590,0	12,9	5,5	11,5	9,0	5,6	normal stone	590,0	589,0	710,0	925,0
	7	884,6	13,9	5,0	13,1	10,2	5,1	normal stone with thin border	884,4	881,3	1405,0	1750,0
	8	920,7	17,7	4,8	17,0	8,1	5,0	Normal soft stone with soft white border	920,7	918,7	1400,0	1755,0
	9	1610,5	16,6	7,0	15,5	10,2	7,0					

	10	797,4	15,1	5,5	13,9	8,9	5,7	Normal stone	797,4	797,1	710,0	1005,0
	11	1321,2	15,6	6,3	14,7	11,3	6,5					
	12	1007,3	17,4	5,4	16,7	9,0	5,4					
	13	1307,8	18,6	6,8	18,2	8,5	6,9					
	14	985,4	16,7	5,0	16,4	9,2	5,1					
	15	1808,8	23,6	7,9	23,1	9,4	7,9					
	16	1065,2	14,1	7,7	12,0	10,4	7,7	soft normal stone	1064,9	1058,7	1400,0	1805,0
	17	700,0	13,1	5,7	10,9	9,0	5,7	normal stone	700,1	699,0	700,0	960,0
	18	1036,4	18,6	4,2	17,7	10,6	4,3					
	19	839,0	12,7	6,0	11,2	11,2	6,3	Normal soft stone with soft white border	839,1	838,2	1400	1705
	20	886,4	18,4	4,8	18,3	8,0	4,8	Normal soft stone with soft white border	886,4	884,8	2000	2330
	21	1002,1	14,1	6,4	12,6	11,1	6,4	soft stone	1002,1	999,5	2000	2370
	22	1617,9	17,9	7,5	17,2	10,4	7,8	soft stone with hard white	1617,9	1608,6	1995	2620
	23	634,7	17,0	4,3	17,0	9,0	4,3	soft stone	634,7	634	1990	2220
	24	915,2	13,1	7,6	11,4	7,9	7,6	normal stone	913,8	906,9	1990	2345
	25	1292,4	17,1	5,7	16,0	9,2	5,7					
	26	1199,3	15,5	8,0	15,1	7,8	8,3					
	27	1823,0	23,0	6,0	22,3	10,3	6,0					
	28	1276,0	20,4	5,5	19,8	10,1	5,8					
	29	1227,3	18,1	6,9	17,7	7,2	7,1					
	30	887,9	13,0	5,5	11,5	10,2	5,7	mainly hard stone	887,8	886,7	1975	2300
	31	1410,6	19,1	6,3	18,4	9,7	6,3					
63	1	319,0	11,3	3,9	10,2	6,7	4,1					
	2	432,5	11,3	6,0	10,4	7,0	6,0					
	3	449,0	13,0	3,6	12,4	7,5	3,6					
45	1	103,7	8,5	1,9	7,9	5,0	1,9					
	2	122,3	6,9	3,9	6,0	5,5	4,1					
	3	101,6	6,2	3,0	5,6	4,7	3,1					

4	88,9				
5	30,7				
6	25,2				
7	10,5				
8	8,9				
9	9,2				