

| Laboratory experiments | | | | | | |
|------------------------|------------|------------|---------------|------------|------------|--|
| Scattered blocks | | | | | | |
| case1 | | | case2 | | | |
| laser-scanner | water-tank | desk-split | laser-scanner | water-tank | desk-split | |
| 4 | 4 | 3.8 | 4.1 | 4 | 3.7 | |
| 5 | 5 | 4.2 | 4.9 | 5 | 4.3 | |
| 6 | 6 | 4.8 | 5.5 | 6 | 4.8 | |
| 8 | 8 | 7.9 | 8 | 8 | 8.1 | |
| 8.4 | 8.4 | 7.3 | 8.4 | 8.4 | 8.3 | |
| 8.8 | 9 | 9 | 8.8 | 9 | 9.2 | |
| 9.2 | 9.5 | 9.5 | 9.2 | 9.5 | 9.5 | |
| 9.8 | 9.8 | 9.3 | 9.8 | 9.8 | 9.3 | |
| 10.1 | 10.1 | 9.7 | 10 | 10.1 | 9.7 | |
| 10.5 | 10.6 | 10.6 | 10.3 | 10.6 | 10.6 | |
| 10.8 | 10.8 | 9.7 | 10.5 | 10.8 | 9.7 | |
| 11.2 | 11.2 | 9.4 | 11.2 | 11.2 | 9.4 | |
| 11.7 | 11.7 | 8.7 | 11.7 | 11.7 | 8.7 | |
| 12 | 12 | 11 | 12 | 12 | 11 | |
| 11.6 | 12.4 | 12.4 | 11.6 | 12.4 | 12.4 | |
| 12.1 | 12.2 | 12.2 | 12.1 | 12.2 | 12.6 | |
| 12.9 | 12.9 | 12.6 | 12.5 | 12.9 | 12.9 | |
| 12.2 | 13.2 | 13.2 | 12.2 | 13.2 | 13.2 | |
| 12.4 | 12.5 | 12.5 | 12.4 | 12.5 | 12.5 | |
| 12 | 13.2 | 13.2 | 12 | 13.2 | 13.2 | |
| 13.6 | 13.6 | 13.5 | 13.2 | 13.6 | 13.3 | |
| 13.5 | 14.6 | 14.6 | 13.5 | 14.6 | 14.6 | |
| 14 | 14.2 | 14.2 | 14 | 14.2 | 14.2 | |
| 14.5 | 14.5 | 14.3 | 14.5 | 14.5 | 14.3 | |
| 15 | 15 | 14.8 | 15.1 | 15 | 14.5 | |
| 16.1 | 16 | 15.2 | 15.9 | 16 | 15.2 | |
| 17.1 | 17.2 | 16.2 | 17.2 | 17.2 | 16.2 | |
| 18.1 | 18 | 17.6 | 18.1 | 18 | 17.4 | |
| 19.4 | 19.4 | 18.3 | 19.4 | 19.4 | 18.3 | |
| 22.3 | 22.3 | 19.4 | 22.3 | 22.3 | 22.1 | |
| 24.6 | 24.6 | 24 | 24.6 | 24.6 | 23.7 | |
| 26 | 26 | 25.6 | 26.2 | 26 | 25.8 | |

Laboratory experiments

heaped blocks

| case1-sur | | | | | | case2-sur | | | | | |
|---------------|-----------|-------------|-----------|-------------|-----------|---------------|-----------|-------------|-----------|-------------|-----------|
| laser-scanner | | desk-split | | water-tank | | laser-scanner | | desk-split | | water-tank | |
| diameter/cm | passing/% | diameter/cm | passing/% | diameter/cm | passing/% | diameter/cm | passing/% | diameter/cm | passing/% | diameter/cm | passing/% |
| 3.6 | 7.71E-04 | 3 | 0 | 5.3 | 7.71E-04 | 3.496 | 6.91E-04 | 3 | 0 | 4.2 | 5.29E-04 |
| 5.4 | 0.00337 | 6 | 0.00409 | 8.0 | 0.00337 | 4.416 | 0.00208 | 6 | 0.00409 | 6.1 | 0.00215 |
| 7.56 | 0.01051 | 9 | 0.02287 | 11.2 | 0.01051 | 6.716 | 0.00698 | 9 | 0.02287 | 9.6 | 0.00847 |
| 8.1 | 0.01928 | 12 | 0.10153 | 12.0 | 0.01928 | 7.268 | 0.01319 | 12 | 0.10153 | 10.2 | 0.01605 |
| 8.55 | 0.02961 | 15 | 0.34676 | 12.6 | 0.02961 | 8.004 | 0.02148 | 15 | 0.34676 | 10.8 | 0.02505 |
| 8.82 | 0.04094 | 18 | 0.51584 | 13.0 | 0.04094 | 8.556 | 0.03161 | 18 | 0.51584 | 11.4 | 0.03563 |
| 9.72 | 0.0561 | 21 | 0.58272 | 14.4 | 0.0561 | 8.74 | 0.0424 | 21 | 0.58272 | 11.6 | 0.04678 |
| 9.9 | 0.07213 | 24 | 0.69416 | 14.6 | 0.07213 | 8.924 | 0.05389 | 24 | 0.69416 | 11.7 | 0.05822 |
| 10.08 | 0.08904 | 27 | 1 | 14.9 | 0.08904 | 9.752 | 0.06889 | 27 | 1 | 11.9 | 0.07026 |
| 10.53 | 0.10832 | 30 | | 15.6 | 0.10832 | 10.12 | 0.08565 | | | 12.8 | 0.08524 |
| 11.16 | 0.13128 | | | 16.5 | 0.13128 | 11.408 | 0.12965 | | | 13.4 | 0.10243 |
| 11.25 | 0.15479 | | | 16.6 | 0.15479 | 11.5 | 0.13424 | | | 14.6 | 0.12466 |
| 11.61 | 0.18063 | | | 17.2 | 0.18063 | 11.592 | 0.15543 | | | 14.7 | 0.14735 |
| 11.7 | 0.20708 | | | 17.3 | 0.20708 | 12.144 | 0.18838 | | | 14.8 | 0.17051 |
| 11.88 | 0.23477 | | | 17.6 | 0.23477 | 12.544 | 0.21734 | | | 15.6 | 0.19763 |
| 12.69 | 0.26852 | | | 18.8 | 0.26852 | 13.064 | 0.25339 | | | 15.8 | 0.22581 |
| 12.78 | 0.30299 | | | 18.9 | 0.30299 | 13.432 | 0.29258 | | | 16.8 | 0.25968 |
| 13.14 | 0.34046 | | | 19.4 | 0.34046 | 13.616 | 0.32339 | | | 16.9 | 0.29416 |
| 13.5 | 0.38109 | | | 20.0 | 0.38109 | 13.984 | 0.34761 | | | 17.5 | 0.33244 |
| 13.59 | 0.42254 | | | 20.1 | 0.42254 | 14.904 | 0.41113 | | | 18.6 | 0.37841 |
| 15.48 | 0.53805 | | | 22.9 | 0.4838 | 16.192 | 0.49978 | | | 20.8 | 0.44269 |
| 16.2 | 0.59402 | | | 24.0 | 0.55402 | 19.228 | 0.78472 | | | 21.7 | 0.52569 |
| 17.46 | 0.66192 | | | 25.8 | 0.64192 | 22.08 | 0.92877 | | | 22.6 | 0.56815 |
| 20.7 | 0.7884 | | | 30.6 | 0.7884 | 23.552 | 1 | | | 32 | 0.78719 |
| 25.4 | 1 | | | 34.6 | 1 | | | | | 36 | 1 |

Laboratory experiments

heaped blocks

| case1 - cps | | | | | | case2 - cps | | | | | |
|---------------|-----------|-------------|-----------|-------------|-----------|---------------|-----------|-------------|-----------|-------------|-----------|
| laser-scanner | | desk-split | | water-tank | | laser-scanner | | desk-split | | water-tank | |
| diameter/cm | passing/% | diameter/cm | passing/% | diameter/cm | passing/% | diameter/cm | passing/% | diameter/cm | passing/% | diameter/cm | passing/% |
| 3 | 7.71E-04 | 3 | 0 | 5.32224 | 7.71E-04 | 4.2 | 5.29E-04 | 3 | 0 | 3.9365 | 6.91E-04 |
| 6.0804 | 0.00337 | 6 | 0.00409 | 7.98336 | 0.00337 | 6.1 | 0.00215 | 6 | 0.00409 | 4.97242 | 0.00208 |
| 8.51256 | 0.01051 | 9 | 0.02287 | 11.1767 | 0.01051 | 9.6 | 0.00847 | 9 | 0.02287 | 7.56222 | 0.00698 |
| 9.1206 | 0.01928 | 12 | 0.10153 | 11.97504 | 0.01928 | 10.2 | 0.01605 | 12 | 0.10153 | 8.18377 | 0.01319 |
| 9.6273 | 0.02961 | 15 | 0.34676 | 12.64032 | 0.02961 | 10.8 | 0.02505 | 15 | 0.34676 | 9.0125 | 0.02148 |
| 9.93132 | 0.04094 | 18 | 0.51584 | 13.03949 | 0.04094 | 11.4 | 0.03563 | 18 | 0.51584 | 9.63406 | 0.03161 |
| 10.94472 | 0.0561 | 21 | 0.58272 | 14.37005 | 0.0561 | 11.6 | 0.04678 | 21 | 0.58272 | 9.84124 | 0.0424 |
| 11.1474 | 0.07213 | 24 | 0.69416 | 14.63616 | 0.07213 | 11.7 | 0.05822 | 24 | 0.69416 | 10.04842 | 0.05389 |
| 11.35008 | 0.07904 | 27 | 1 | 14.90227 | 0.08904 | 11.9 | 0.07026 | 27 | 1 | 10.98075 | 0.06889 |
| 11.85678 | 0.08832 | | | 15.56755 | 0.10832 | 12.8 | 0.08524 | | | 11.39512 | 0.08565 |
| 12.56616 | 0.13128 | | | 16.49894 | 0.13128 | 13.4 | 0.10243 | | | 12.84541 | 0.13965 |
| 12.6675 | 0.15479 | | | 16.632 | 0.15479 | 14.6 | 0.12466 | | | 12.949 | 0.14424 |
| 13.07286 | 0.18063 | | | 17.16422 | 0.18063 | 14.7 | 0.14735 | | | 13.05259 | 0.15943 |
| 13.1742 | 0.20708 | | | 17.29728 | 0.20708 | 14.8 | 0.17051 | | | 13.67414 | 0.18838 |
| 13.37688 | 0.21477 | | | 17.56339 | 0.23477 | 15.6 | 0.19763 | | | 14.27414 | 0.22342 |
| 14.28894 | 0.28852 | | | 18.7609 | 0.26852 | 15.8 | 0.22581 | | | 14.71006 | 0.25039 |
| 14.39028 | 0.29299 | | | 18.89395 | 0.30299 | 16.8 | 0.25968 | | | 15.12443 | 0.29258 |
| 14.79564 | 0.33046 | | | 19.42618 | 0.34046 | 16.9 | 0.29416 | | | 15.33162 | 0.31339 |
| 15.201 | 0.35109 | | | 19.9584 | 0.38109 | 17.5 | 0.33244 | | | 15.74598 | 0.35761 |
| 15.30234 | 0.36254 | | | 20.09146 | 0.42254 | 18.6 | 0.37841 | | | 16.7819 | 0.42113 |
| 17.43048 | 0.51805 | | | 22.88563 | 0.4838 | 20.8 | 0.44269 | | | 18.23219 | 0.50978 |
| 18.2412 | 0.56402 | | | 23.95008 | 0.55402 | 21.7 | 0.51569 | | | 21.65073 | 0.73472 |
| 19.65996 | 0.64192 | | | 25.81286 | 0.64192 | 22.6 | 0.59815 | | | 24.86208 | 0.88877 |
| 23.3082 | 0.8484 | | | 30.60288 | 0.7884 | 29.8 | 0.78719 | | | 27 | 1 |
| 27 | 1 | | | 34.59456 | 1 | 31 | 1 | | | | |

Field experiments

| Filed1 - sur | | | | | | Filed1 - cps | | | | | |
|--------------|-----------|-------------|-----------|---------------|-----------|--------------|-----------|-------------|-----------|---------------|-----------|
| laser-point | | water-tank | | laser-scanner | | laser-point | | water-tank | | laser-scanner | |
| diameter/cm | passing/% | diameter/cm | passing/% | diameter/cm | passing/% | diameter/cm | passing/% | diameter/cm | passing/% | diameter/cm | passing/% |
| 12.4 | 6.15E-04 | 13.64 | 0.00195 | 12.4 | 0.00205 | 12.4 | 6.15E-04 | 13.64 | 0.00195 | 13.9624 | 0.00207 |
| 13.2 | 0.00136 | 15.24 | 0.00625 | 13 | 0.00507 | 13.2 | 0.00136 | 15.24 | 0.00625 | 14.638 | 0.00445 |
| 14.1 | 0.00226 | 20.45 | 0.01876 | 13.5 | 0.00878 | 14.1 | 0.00226 | 20.45 | 0.01876 | 15.201 | 0.00711 |
| 14.8 | 0.00331 | 25.82 | 0.04691 | 13.85 | 0.01302 | 14.8 | 0.00331 | 25.82 | 0.04691 | 15.5951 | 0.00999 |
| 14.8 | 0.00436 | 29.27 | 0.14072 | 14.275 | 0.01777 | 14.8 | 0.00436 | 29.27 | 0.14072 | 16.07365 | 0.01315 |
| 15.8 | 0.00563 | 33.73 | 0.35179 | 14.675 | 0.02297 | 15.8 | 0.00563 | 33.73 | 0.35179 | 16.52405 | 0.01657 |
| 15.9 | 0.00693 | 38.21 | 0.52768 | 17.26625 | 0.02851 | 15.9 | 0.00693 | 38.21 | 0.52768 | 19.4418 | 0.02215 |
| 16.3 | 0.00832 | 46.07 | 0.63322 | 17.64625 | 0.03443 | 16.3 | 0.00832 | 46.07 | 0.63322 | 19.86968 | 0.0281 |
| 16.8 | 0.00985 | 52.85 | 0.75986 | 18.02625 | 0.04074 | 16.8 | 0.00985 | 52.85 | 0.75986 | 20.29756 | 0.03445 |
| 16.9 | 0.01141 | 58.91 | 0.91183 | 18.02625 | 0.04704 | 16.9 | 0.01141 | 58.91 | 0.91183 | 20.29756 | 0.0408 |
| 16.9 | 0.01297 | 63.52 | 1 | 18.40625 | 0.05376 | 16.9 | 0.01297 | 63.52 | 1 | 20.72544 | 0.04756 |
| 17.4 | 0.01467 | -- | -- | 18.77675 | 0.06088 | 17.4 | 0.01467 | -- | -- | 21.14262 | 0.05473 |
| 17.4 | 0.01637 | -- | -- | 19.13775 | 0.06843 | 17.4 | 0.01637 | -- | -- | 21.54911 | 0.06233 |
| 17.5 | 0.0181 | -- | -- | 19.48925 | 0.0764 | 17.5 | 0.0181 | -- | -- | 21.9449 | 0.07035 |
| 17.5 | 0.01983 | -- | -- | 19.84075 | 0.08481 | 17.5 | 0.01983 | -- | -- | 22.34068 | 0.07882 |
| 17.6 | 0.02159 | -- | -- | 20.12575 | 0.09359 | 17.6 | 0.02159 | -- | -- | 22.66159 | 0.08765 |
| 18.6 | 0.02367 | -- | -- | 20.49625 | 0.10286 | 18.6 | 0.02367 | -- | -- | 23.07878 | 0.09698 |
| 19.3 | 0.02599 | -- | -- | 20.87625 | 0.11265 | 19.3 | 0.02599 | -- | -- | 23.50666 | 0.10684 |
| 19.7 | 0.02846 | -- | -- | 21.28 | 0.12303 | 19.7 | 0.02846 | -- | -- | 23.96128 | 0.11728 |
| 20.5 | 0.03124 | -- | -- | 21.66 | 0.13397 | 20.5 | 0.03124 | -- | -- | 24.38916 | 0.1283 |
| 20.6 | 0.03406 | -- | -- | 22.04 | 0.1455 | 20.6 | 0.03406 | -- | -- | 24.81704 | 0.1399 |
| 20.9 | 0.037 | -- | -- | 22.42 | 0.15763 | 20.9 | 0.037 | -- | -- | 25.24492 | 0.15211 |
| 21.3 | 0.04012 | -- | -- | 22.4295 | 0.16978 | 21.3 | 0.04012 | -- | -- | 25.25562 | 0.16434 |
| 21.4 | 0.04329 | -- | -- | 22.819 | 0.18257 | 21.4 | 0.04329 | -- | -- | 25.69419 | 0.17722 |
| 21.4 | 0.04645 | -- | -- | 23.2085 | 0.19603 | 21.4 | 0.04645 | -- | -- | 26.13277 | 0.19077 |
| 21.4 | 0.04961 | -- | -- | 23.5885 | 0.21017 | 21.4 | 0.04961 | -- | -- | 26.56065 | 0.20499 |
| 21.6 | 0.05287 | -- | -- | 23.978 | 0.22501 | 21.6 | 0.05287 | -- | -- | 26.99923 | 0.21993 |
| 22.68 | 0.05663 | -- | -- | 24.377 | 0.24061 | 22.68 | 0.05663 | -- | -- | 27.4485 | 0.23563 |
| 22.785 | 0.06045 | -- | -- | 24.776 | 0.25698 | 22.785 | 0.06045 | -- | -- | 27.89778 | 0.25211 |
| 22.995 | 0.06437 | -- | -- | 25.1655 | 0.27414 | 22.995 | 0.06437 | -- | -- | 28.33635 | 0.26938 |
| 22.995 | 0.0683 | -- | -- | 25.5455 | 0.29209 | 22.995 | 0.0683 | -- | -- | 28.76423 | 0.28745 |
| 22.995 | 0.07222 | -- | -- | 25.9255 | 0.31085 | 22.995 | 0.07222 | -- | -- | 29.19211 | 0.30634 |
| 23.205 | 0.07626 | -- | -- | 26.296 | 0.33043 | 23.205 | 0.07626 | -- | -- | 29.6093 | 0.32604 |
| 23.625 | 0.08051 | -- | -- | 26.676 | 0.35087 | 23.625 | 0.08051 | -- | -- | 30.03718 | 0.34661 |
| 23.625 | 0.08477 | -- | -- | 26.9382 | 0.37191 | 23.625 | 0.08477 | -- | -- | 30.33241 | 0.3678 |

| | | | | | | | | | |
|--------|---------|----|----|---------|---------|--------|---------|----------|---------|
| 23.625 | 0.08902 | -- | -- | 27.265 | 0.39374 | 23.625 | 0.08902 | 30.70039 | 0.38976 |
| 23.73 | 0.09334 | -- | -- | 27.5975 | 0.41637 | 23.73 | 0.09334 | 31.07478 | 0.41254 |
| 23.73 | 0.09765 | -- | -- | 27.93 | 0.43983 | 23.73 | 0.09765 | 31.44918 | 0.43616 |
| 23.835 | 0.10202 | -- | -- | 28.272 | 0.46416 | 23.835 | 0.10202 | 31.83427 | 0.46065 |
| 23.94 | 0.10645 | -- | -- | 28.614 | 0.48938 | 23.94 | 0.10645 | 32.21936 | 0.48604 |
| 23.94 | 0.11088 | -- | -- | 28.9655 | 0.51555 | 23.94 | 0.11088 | 32.61515 | 0.51237 |
| 23.94 | 0.11531 | -- | -- | 29.336 | 0.54273 | 23.94 | 0.11531 | 33.03234 | 0.53973 |
| 24.045 | 0.11979 | -- | -- | 29.725 | 0.57101 | 24.045 | 0.11979 | 33.47035 | 0.5682 |
| 24.255 | 0.1244 | -- | -- | 30.195 | 0.60065 | 24.255 | 0.1244 | 33.99957 | 0.59803 |
| 24.255 | 0.129 | -- | -- | 31.06 | 0.63291 | 24.255 | 0.129 | 34.97356 | 0.63051 |
| 24.57 | 0.13379 | -- | -- | 31.965 | 0.66808 | 24.57 | 0.13379 | 35.99259 | 0.6659 |
| 24.675 | 0.13864 | -- | -- | 33.025 | 0.70686 | 24.675 | 0.13864 | 37.18615 | 0.70494 |
| 24.675 | 0.14349 | -- | -- | 34.155 | 0.74976 | 24.675 | 0.14349 | 38.45853 | 0.74812 |
| 24.78 | 0.1484 | -- | -- | 35.58 | 0.79825 | 24.78 | 0.1484 | 40.06308 | 0.79693 |
| 24.78 | 0.15331 | -- | -- | 36.9888 | 0.85274 | 24.78 | 0.15331 | 41.64939 | 0.85178 |
| 24.78 | 0.15822 | -- | -- | 38.8296 | 0.91577 | 24.78 | 0.15822 | 43.72213 | 0.91522 |
| 24.78 | 0.16314 | -- | -- | 42.768 | 1 | 24.78 | 0.16314 | 48.15677 | 1 |
| 24.885 | 0.16811 | -- | -- | -- | -- | 24.885 | 0.16811 | | |
| 24.99 | 0.17315 | -- | -- | -- | -- | 24.99 | 0.17315 | | |
| 25.095 | 0.17825 | -- | -- | -- | -- | 25.095 | 0.17825 | | |
| 25.095 | 0.18335 | -- | -- | -- | -- | 25.095 | 0.18335 | | |
| 25.515 | 0.18871 | -- | -- | -- | -- | 25.515 | 0.18871 | | |
| 25.725 | 0.1942 | -- | -- | -- | -- | 25.725 | 0.1942 | | |
| 25.725 | 0.1997 | -- | -- | -- | -- | 25.725 | 0.1997 | | |
| 25.83 | 0.20526 | -- | -- | -- | -- | 25.83 | 0.20526 | | |
| 25.83 | 0.21082 | -- | -- | -- | -- | 25.83 | 0.21082 | | |
| 25.83 | 0.21639 | -- | -- | -- | -- | 25.83 | 0.21639 | | |
| 25.935 | 0.22202 | -- | -- | -- | -- | 25.935 | 0.22202 | | |
| 26.04 | 0.22772 | -- | -- | -- | -- | 26.04 | 0.22772 | | |
| 26.145 | 0.23349 | -- | -- | -- | -- | 26.145 | 0.23349 | | |
| 26.25 | 0.23932 | -- | -- | -- | -- | 26.25 | 0.23932 | | |
| 26.46 | 0.2453 | -- | -- | -- | -- | 26.46 | 0.2453 | | |
| 26.565 | 0.25135 | -- | -- | -- | -- | 26.565 | 0.25135 | | |
| 26.67 | 0.25748 | -- | -- | -- | -- | 26.67 | 0.25748 | | |
| 26.88 | 0.26375 | -- | -- | -- | -- | 26.88 | 0.26375 | | |
| 26.985 | 0.27009 | -- | -- | -- | -- | 26.985 | 0.27009 | | |
| 27.195 | 0.27658 | -- | -- | -- | -- | 27.195 | 0.27658 | | |
| 27.195 | 0.28307 | -- | -- | -- | -- | 27.195 | 0.28307 | | |
| 27.195 | 0.28956 | -- | -- | -- | -- | 27.195 | 0.28956 | | |

| | | | | | |
|--------|---------|----|----|----|----|
| 27.51 | 0.29628 | -- | -- | -- | -- |
| 27.615 | 0.30308 | -- | -- | -- | -- |
| 27.825 | 0.31003 | -- | -- | -- | -- |
| 28.035 | 0.31715 | -- | -- | -- | -- |
| 28.14 | 0.32434 | -- | -- | -- | -- |
| 28.14 | 0.33153 | -- | -- | -- | -- |
| 28.2 | 0.33877 | -- | -- | -- | -- |
| 28.3 | 0.34608 | -- | -- | -- | -- |
| 28.4 | 0.35348 | -- | -- | -- | -- |
| 28.6 | 0.36103 | -- | -- | -- | -- |
| 28.6 | 0.36858 | -- | -- | -- | -- |
| 28.665 | 0.37618 | -- | -- | -- | -- |
| 28.77 | 0.38387 | -- | -- | -- | -- |
| 28.77 | 0.39155 | -- | -- | -- | -- |
| 28.875 | 0.39932 | -- | -- | -- | -- |
| 29.1 | 0.40728 | -- | -- | -- | -- |
| 29.1 | 0.41523 | -- | -- | -- | -- |
| 29.505 | 0.42352 | -- | -- | -- | -- |
| 30.6 | 0.43277 | -- | -- | -- | -- |
| 31.7 | 0.44305 | -- | -- | -- | -- |
| 32 | 0.45363 | -- | -- | -- | -- |
| 32.5 | 0.46471 | -- | -- | -- | -- |
| 32.7 | 0.47599 | -- | -- | -- | -- |
| 32.7 | 0.48728 | -- | -- | -- | -- |
| 33.6 | 0.49952 | -- | -- | -- | -- |
| 33.8 | 0.51199 | -- | -- | -- | -- |
| 34 | 0.52467 | -- | -- | -- | -- |
| 34.1 | 0.53747 | -- | -- | -- | -- |
| 34.5 | 0.55073 | -- | -- | -- | -- |
| 34.6 | 0.5641 | -- | -- | -- | -- |
| 35.7 | 0.57878 | -- | -- | -- | -- |
| 36.5 | 0.59448 | -- | -- | -- | -- |
| 36.9 | 0.61069 | -- | -- | -- | -- |
| 36.9 | 0.62691 | -- | -- | -- | -- |
| 37.5 | 0.64393 | -- | -- | -- | -- |
| 38.1 | 0.66178 | -- | -- | -- | -- |
| 38.4 | 0.68006 | -- | -- | -- | -- |
| 38.6 | 0.69862 | -- | -- | -- | -- |
| 39.7 | 0.71882 | -- | -- | -- | -- |

| | |
|--------|---------|
| 27.51 | 0.29628 |
| 27.615 | 0.30308 |
| 27.825 | 0.31003 |
| 28.035 | 0.31715 |
| 28.14 | 0.32434 |
| 28.14 | 0.33153 |
| 28.2 | 0.33877 |
| 28.3 | 0.34608 |
| 28.4 | 0.35348 |
| 28.6 | 0.36103 |
| 28.6 | 0.36858 |
| 28.665 | 0.37618 |
| 28.77 | 0.38387 |
| 28.77 | 0.39155 |
| 28.875 | 0.39932 |
| 29.1 | 0.40728 |
| 29.1 | 0.41523 |
| 29.505 | 0.42352 |
| 30.6 | 0.43277 |
| 31.7 | 0.44305 |
| 32 | 0.45363 |
| 32.5 | 0.46471 |
| 32.7 | 0.47599 |
| 32.7 | 0.48728 |
| 33.6 | 0.49952 |
| 33.8 | 0.51199 |
| 34 | 0.52467 |
| 34.1 | 0.53747 |
| 34.5 | 0.55073 |
| 34.6 | 0.5641 |
| 35.7 | 0.57878 |
| 36.5 | 0.59448 |
| 36.9 | 0.61069 |
| 36.9 | 0.62691 |
| 37.5 | 0.64393 |
| 38.1 | 0.66178 |
| 38.4 | 0.68006 |
| 38.6 | 0.69862 |
| 39.7 | 0.71882 |

| | | | | | |
|------|---------|----|----|----|----|
| 40.7 | 0.74058 | -- | -- | -- | -- |
| 41.8 | 0.76415 | -- | -- | -- | -- |
| 42.6 | 0.7891 | -- | -- | -- | -- |
| 42.6 | 0.81406 | -- | -- | -- | -- |
| 43.9 | 0.84137 | -- | -- | -- | -- |
| 44.3 | 0.86943 | -- | -- | -- | -- |
| 44.9 | 0.89864 | -- | -- | -- | -- |
| 45.8 | 0.92965 | -- | -- | -- | -- |
| 46.9 | 0.96295 | -- | -- | -- | -- |
| 48.6 | 1 | -- | -- | -- | -- |

| | |
|------|---------|
| 40.7 | 0.74058 |
| 41.8 | 0.76415 |
| 42.6 | 0.7891 |
| 42.6 | 0.81406 |
| 43.9 | 0.84137 |
| 44.3 | 0.86943 |
| 44.9 | 0.89864 |
| 45.8 | 0.92965 |
| 46.9 | 0.96295 |
| 48.6 | 1 |

Field experiments

| Filed2-sur | | | | | | Filed2-cps | | | | | |
|-------------|-----------|-------------|-----------|---------------|-----------|-------------|-----------|-------------|-----------|---------------|-----------|
| laser-point | | water-tank | | laser-scanner | | laser-point | | water-tank | | laser-scanner | |
| diameter/cm | passing/% | diameter/cm | passing/% | diameter/cm | passing/% | diameter/cm | passing/% | diameter/cm | passing/% | diameter/cm | passing/% |
| 16.3 | 8.63E-04 | 14.5 | 0.00195 | 14.4 | 0.00164 | 16.3 | 8.63E-04 | 14.5 | 0.00195 | 16.3152 | 0.00164 |
| 16.8 | 0.00181 | 17.2 | 0.00625 | 14.4 | 0.00328 | 16.8 | 0.00181 | 17.2 | 0.00625 | 16.3152 | 0.00328 |
| 16.9 | 0.00277 | 23.2 | 0.01876 | 14.9 | 0.00509 | 16.9 | 0.00277 | 23.2 | 0.01876 | 16.8817 | 0.00509 |
| 17.2 | 0.00378 | 29.3 | 0.04691 | 15.3 | 0.00705 | 17.2 | 0.00378 | 29.3 | 0.04691 | 17.3349 | 0.00705 |
| 17.3 | 0.00482 | 33.2 | 0.07036 | 15.7 | 0.00918 | 17.3 | 0.00482 | 33.2 | 0.07036 | 17.7881 | 0.00918 |
| 17.4 | 0.00587 | 38.2 | 0.14072 | 16.2 | 0.01151 | 17.4 | 0.00587 | 38.2 | 0.14072 | 18.3546 | 0.01151 |
| 17.5 | 0.00694 | 43.3 | 0.28143 | 16.7 | 0.01406 | 17.5 | 0.00694 | 43.3 | 0.28143 | 18.9211 | 0.01406 |
| 17.6 | 0.00802 | 52.2 | 0.42214 | 17.1 | 0.01681 | 17.6 | 0.00802 | 52.2 | 0.42214 | 19.3743 | 0.01681 |
| 17.8 | 0.00915 | 59.9 | 0.52768 | 17.5 | 0.01975 | 17.8 | 0.00915 | 59.9 | 0.52768 | 19.8275 | 0.01975 |
| 18.6 | 0.01043 | 66.8 | 0.79152 | 17.9 | 0.02289 | 18.6 | 0.01043 | 66.8 | 0.79152 | 20.2807 | 0.02289 |
| 19.3 | 0.01186 | 72.3 | 0.87067 | 18.3 | 0.02625 | 19.3 | 0.01186 | 72.3 | 0.87067 | 20.7339 | 0.02625 |
| 19.7 | 0.01339 | 80.4 | 0.91421 | 18.7 | 0.02984 | 19.7 | 0.01339 | 80.4 | 0.91421 | 21.1871 | 0.02984 |
| 20.5 | 0.0151 | 86.8 | 0.95992 | 19.1 | 0.03366 | 20.5 | 0.0151 | 86.8 | 0.95992 | 21.6403 | 0.03366 |
| 20.6 | 0.01684 | 94.2 | 1 | 19.5 | 0.03773 | 20.6 | 0.01684 | 94.2 | 1 | 22.0935 | 0.03773 |
| 20.9 | 0.01866 | | | 19.9 | 0.04205 | 20.9 | 0.01866 | -- | -- | 22.5467 | 0.04205 |
| 21.4 | 0.02062 | | | 20.29756 | 0.04664 | 21.4 | 0.02062 | -- | -- | 22.99713 | 0.04664 |
| 21.5 | 0.0226 | | | 20.7 | 0.0515 | 21.5 | 0.0226 | -- | -- | 23.4531 | 0.0515 |
| 21.6 | 0.02461 | | | 21.1 | 0.05666 | 21.6 | 0.02461 | -- | -- | 23.9063 | 0.05666 |
| 22.4 | 0.02685 | | | 21.4 | 0.06203 | 22.4 | 0.02685 | -- | -- | 24.2462 | 0.06203 |
| 22.68 | 0.02917 | | | 21.8 | 0.06772 | 22.68 | 0.02917 | -- | -- | 24.6994 | 0.06772 |
| 22.785 | 0.03153 | | | 22.2 | 0.07372 | 22.785 | 0.03153 | -- | -- | 25.1526 | 0.07372 |
| 22.995 | 0.03395 | | | 22.6 | 0.08005 | 22.995 | 0.03395 | -- | -- | 25.6058 | 0.08005 |
| 23.5 | 0.03654 | | | 23 | 0.08672 | 23.5 | 0.03654 | -- | -- | 26.059 | 0.08672 |
| 23.625 | 0.03917 | | | 23.4 | 0.09375 | 23.625 | 0.03917 | -- | -- | 26.5122 | 0.09375 |
| 23.8 | 0.04186 | | | 23.8 | 0.10115 | 23.8 | 0.04186 | -- | -- | 26.9654 | 0.10115 |
| 23.835 | 0.04456 | | | 24.2 | 0.10892 | 23.835 | 0.04456 | -- | -- | 27.4186 | 0.10892 |
| 23.94 | 0.04729 | | | 24.5 | 0.11699 | 23.94 | 0.04729 | -- | -- | 27.7585 | 0.11699 |
| 24.045 | 0.05006 | | | 24.9 | 0.12545 | 24.045 | 0.05006 | -- | -- | 28.2117 | 0.12545 |
| 24.1 | 0.05285 | | | 25.3 | 0.13434 | 24.1 | 0.05285 | -- | -- | 28.6649 | 0.13434 |
| 24.255 | 0.0557 | | | 25.6 | 0.14354 | 24.255 | 0.0557 | -- | -- | 29.0048 | 0.14354 |
| 24.6 | 0.05866 | | | 26 | 0.15318 | 24.6 | 0.05866 | -- | -- | 29.458 | 0.15318 |
| 24.675 | 0.06166 | | | 26.3 | 0.16316 | 24.675 | 0.06166 | -- | -- | 29.7979 | 0.16316 |
| 24.78 | 0.06469 | | | 26.7 | 0.1736 | 24.78 | 0.06469 | -- | -- | 30.2511 | 0.1736 |
| 24.78 | 0.06772 | | | 27.1 | 0.18452 | 24.78 | 0.06772 | -- | -- | 30.7043 | 0.18452 |
| 24.885 | 0.0708 | | | 27.5 | 0.19592 | 24.885 | 0.0708 | -- | -- | 31.1575 | 0.19592 |

| | | | |
|--------|---------|----------|---------|
| 24.99 | 0.07391 | 27.8 | 0.20771 |
| 25.095 | 0.07706 | 28.2 | 0.22001 |
| 25.515 | 0.08037 | 28.5 | 0.23271 |
| 25.6 | 0.08371 | 28.9 | 0.24595 |
| 25.725 | 0.0871 | 29.3 | 0.25974 |
| 25.83 | 0.09054 | 29.8 | 0.27426 |
| 25.83 | 0.09397 | 30.33241 | 0.28957 |
| 25.935 | 0.09745 | 30.70039 | 0.30544 |
| 26.04 | 0.10097 | 31.07478 | 0.3219 |
| 26.145 | 0.10453 | 31.44918 | 0.33896 |
| 26.2 | 0.10812 | 31.83427 | 0.35666 |
| 26.25 | 0.11172 | 32.21936 | 0.375 |
| 26.46 | 0.11542 | 32.61515 | 0.39403 |
| 26.565 | 0.11915 | 33.03234 | 0.4138 |
| 26.67 | 0.12293 | 33.47035 | 0.43437 |
| 26.7 | 0.12673 | 33.99957 | 0.45593 |
| 26.8 | 0.13056 | 34.6 | 0.47865 |
| 26.88 | 0.13444 | 35.2 | 0.50257 |
| 26.985 | 0.13835 | 35.7 | 0.52753 |
| 27.195 | 0.14236 | 36.4 | 0.55398 |
| 27.195 | 0.14637 | 37.2 | 0.58222 |
| 27.195 | 0.15038 | 38 | 0.61232 |
| 27.3 | 0.15444 | 38.9 | 0.64461 |
| 27.615 | 0.15863 | 39.8 | 0.67919 |
| 28.035 | 0.16302 | 40.8 | 0.71644 |
| 28.1 | 0.16745 | 42 | 0.75708 |
| 28.2 | 0.17192 | 43.5 | 0.80223 |
| 28.6 | 0.17658 | 45.5 | 0.8539 |
| 28.665 | 0.18128 | 48.5 | 0.91648 |
| 28.77 | 0.18602 | 53.4 | 1 |
| 28.77 | 0.19077 | | |
| 29.1 | 0.19568 | | |
| 29.2 | 0.20064 | | |
| 29.505 | 0.20576 | | |
| 29.7 | 0.21098 | | |
| 30.6 | 0.2167 | | |
| 31.2 | 0.22275 | | |
| 31.6 | 0.22904 | | |
| 31.7 | 0.23539 | | |

| | | | | | |
|--------|---------|----|----|----------|---------|
| 24.99 | 0.07391 | -- | -- | 31.4974 | 0.20771 |
| 25.095 | 0.07706 | -- | -- | 31.9506 | 0.22001 |
| 25.515 | 0.08037 | -- | -- | 32.2905 | 0.23271 |
| 25.6 | 0.08371 | -- | -- | 32.7437 | 0.24595 |
| 25.725 | 0.0871 | -- | -- | 33.1969 | 0.25974 |
| 25.83 | 0.09054 | -- | -- | 33.7634 | 0.27426 |
| 25.83 | 0.09397 | -- | -- | 34.36662 | 0.28957 |
| 25.935 | 0.09745 | -- | -- | 34.78354 | 0.30544 |
| 26.04 | 0.10097 | -- | -- | 35.20773 | 0.3219 |
| 26.145 | 0.10453 | -- | -- | 35.63192 | 0.33896 |
| 26.2 | 0.10812 | -- | -- | 36.06823 | 0.35666 |
| 26.25 | 0.11172 | -- | -- | 36.50454 | 0.375 |
| 26.46 | 0.11542 | -- | -- | 36.95297 | 0.39403 |
| 26.565 | 0.11915 | -- | -- | 37.42564 | 0.4138 |
| 26.67 | 0.12293 | -- | -- | 37.92191 | 0.43437 |
| 26.7 | 0.12673 | -- | -- | 38.52151 | 0.45593 |
| 26.8 | 0.13056 | -- | -- | 39.2018 | 0.47865 |
| 26.88 | 0.13444 | -- | -- | 39.8816 | 0.50257 |
| 26.985 | 0.13835 | -- | -- | 40.4481 | 0.52753 |
| 27.195 | 0.14236 | -- | -- | 41.2412 | 0.55398 |
| 27.195 | 0.14637 | -- | -- | 42.1476 | 0.58222 |
| 27.195 | 0.15038 | -- | -- | 43.054 | 0.61232 |
| 27.3 | 0.15444 | -- | -- | 44.0737 | 0.64461 |
| 27.615 | 0.15863 | -- | -- | 45.0934 | 0.67919 |
| 28.035 | 0.16302 | -- | -- | 46.2264 | 0.71644 |
| 28.1 | 0.16745 | -- | -- | 47.586 | 0.75708 |
| 28.2 | 0.17192 | -- | -- | 49.2855 | 0.80223 |
| 28.6 | 0.17658 | -- | -- | 51.5515 | 0.8539 |
| 28.665 | 0.18128 | -- | -- | 54.9505 | 0.91648 |
| 28.77 | 0.18602 | -- | -- | 60.5022 | 1 |
| 28.77 | 0.19077 | -- | -- | -- | -- |
| 29.1 | 0.19568 | -- | -- | -- | -- |
| 29.2 | 0.20064 | -- | -- | -- | -- |
| 29.505 | 0.20576 | -- | -- | -- | -- |
| 29.7 | 0.21098 | -- | -- | -- | -- |
| 30.6 | 0.2167 | -- | -- | -- | -- |
| 31.2 | 0.22275 | -- | -- | -- | -- |
| 31.6 | 0.22904 | -- | -- | -- | -- |
| 31.7 | 0.23539 | -- | -- | -- | -- |

| | |
|------|---------|
| 32 | 0.24192 |
| 32.5 | 0.24876 |
| 32.5 | 0.2556 |
| 32.7 | 0.26257 |
| 32.7 | 0.26954 |
| 33.4 | 0.27697 |
| 33.6 | 0.28453 |
| 33.8 | 0.29223 |
| 33.8 | 0.29992 |
| 34 | 0.30776 |
| 34.1 | 0.31566 |
| 34.5 | 0.32385 |
| 34.5 | 0.33203 |
| 34.6 | 0.34029 |
| 35.2 | 0.34898 |
| 35.7 | 0.35805 |
| 35.8 | 0.3672 |
| 36.4 | 0.37681 |
| 36.5 | 0.3865 |
| 36.9 | 0.39652 |
| 36.9 | 0.40653 |
| 37.1 | 0.41671 |
| 37.5 | 0.42722 |
| 38.1 | 0.43825 |
| 38.2 | 0.44936 |
| 38.4 | 0.46064 |
| 38.6 | 0.47211 |
| 39.4 | 0.4843 |
| 39.5 | 0.49658 |
| 39.7 | 0.50905 |
| 40.7 | 0.52249 |
| 41.8 | 0.53705 |
| 42.6 | 0.55246 |
| 43.9 | 0.56932 |
| 44.3 | 0.58665 |
| 45.3 | 0.60518 |
| 45.8 | 0.62433 |
| 46.3 | 0.64411 |
| 46.9 | 0.66468 |

| | | | | | |
|------|---------|----|----|----|----|
| 32 | 0.24192 | -- | -- | -- | -- |
| 32.5 | 0.24876 | -- | -- | -- | -- |
| 32.5 | 0.2556 | -- | -- | -- | -- |
| 32.7 | 0.26257 | -- | -- | -- | -- |
| 32.7 | 0.26954 | -- | -- | -- | -- |
| 33.4 | 0.27697 | -- | -- | -- | -- |
| 33.6 | 0.28453 | -- | -- | -- | -- |
| 33.8 | 0.29223 | -- | -- | -- | -- |
| 33.8 | 0.29992 | -- | -- | -- | -- |
| 34 | 0.30776 | -- | -- | -- | -- |
| 34.1 | 0.31566 | -- | -- | -- | -- |
| 34.5 | 0.32385 | -- | -- | -- | -- |
| 34.5 | 0.33203 | -- | -- | -- | -- |
| 34.6 | 0.34029 | -- | -- | -- | -- |
| 35.2 | 0.34898 | -- | -- | -- | -- |
| 35.7 | 0.35805 | -- | -- | -- | -- |
| 35.8 | 0.3672 | -- | -- | -- | -- |
| 36.4 | 0.37681 | -- | -- | -- | -- |
| 36.5 | 0.3865 | -- | -- | -- | -- |
| 36.9 | 0.39652 | -- | -- | -- | -- |
| 36.9 | 0.40653 | -- | -- | -- | -- |
| 37.1 | 0.41671 | -- | -- | -- | -- |
| 37.5 | 0.42722 | -- | -- | -- | -- |
| 38.1 | 0.43825 | -- | -- | -- | -- |
| 38.2 | 0.44936 | -- | -- | -- | -- |
| 38.4 | 0.46064 | -- | -- | -- | -- |
| 38.6 | 0.47211 | -- | -- | -- | -- |
| 39.4 | 0.4843 | -- | -- | -- | -- |
| 39.5 | 0.49658 | -- | -- | -- | -- |
| 39.7 | 0.50905 | -- | -- | -- | -- |
| 40.7 | 0.52249 | -- | -- | -- | -- |
| 41.8 | 0.53705 | -- | -- | -- | -- |
| 42.6 | 0.55246 | -- | -- | -- | -- |
| 43.9 | 0.56932 | -- | -- | -- | -- |
| 44.3 | 0.58665 | -- | -- | -- | -- |
| 45.3 | 0.60518 | -- | -- | -- | -- |
| 45.8 | 0.62433 | -- | -- | -- | -- |
| 46.3 | 0.64411 | -- | -- | -- | -- |
| 46.9 | 0.66468 | -- | -- | -- | -- |

| | |
|------|---------|
| 47.8 | 0.68645 |
| 48.4 | 0.70904 |
| 49.2 | 0.73278 |
| 50.1 | 0.75785 |
| 51 | 0.78429 |
| 52.1 | 0.81248 |
| 53.6 | 0.84317 |
| 55.8 | 0.8778 |
| 57.2 | 0.91511 |
| 58.7 | 0.95542 |
| 60.7 | 1 |

| | | | | | |
|------|---------|----|----|----|----|
| 47.8 | 0.68645 | -- | -- | -- | -- |
| 48.4 | 0.70904 | -- | -- | -- | -- |
| 49.2 | 0.73278 | -- | -- | -- | -- |
| 50.1 | 0.75785 | -- | -- | -- | -- |
| 51 | 0.78429 | -- | -- | -- | -- |
| 52.1 | 0.81248 | -- | -- | -- | -- |
| 53.6 | 0.84317 | -- | -- | -- | -- |
| 55.8 | 0.8778 | -- | -- | -- | -- |
| 57.2 | 0.91511 | -- | -- | -- | -- |
| 58.7 | 0.95542 | -- | -- | -- | -- |
| 60.7 | 1 | -- | -- | -- | -- |