How to build the perfect sandcastle

Natural Sciences[1]
Natural Sciences[1]Chemistry [2]Energy [3]Geology [4]Physics [5]Denmark [6]Videnskab.dk [7]
Scientists have come up with a formula that makes it possible to build spectacular sandcastles.

We all love sandcastles, and every summer children of all ages try to outdo each other in building bigger, taller and more spectacular castles.

But sandcastle building is not only for kids. There is some rather complex science behind this seemingly simple form of beach fun.

The castle's gate opening, the jellyfish-filled moat and its clam-clad princess tower all contain physical characteristics which determine how high the castle can rise.

The moisture of the sand is of great importance when building a sandcastle. If it's too dry, the castle's sand grains will fall apart and your castle-building adventure will be over. And if the sand is too wet, the castle will buckle under its own weight.

One bucket of water per 50 buckets of sand

Fortunately for all amateur sandcastle engineers, scientists have now completed a study of the physical properties behind 'the perfect sandcastle'.

They have come up with an answer to how much water and how much sand you actually need.

"The optimal amount of water is one bucket per 50 buckets of sand – that's a volume percentage of two," says Peder Møller, a Danish PhD, whose thesis at Laboratoire de Physique Statistique de ENS, France, formed part of an international research project.

The findings have just been published in the journal *Scientific Reports*.

High-rise sandcastles

In their efforts to find the optimal water content in sandcastles, the team built cylinders out of sand and checked how tall they could make them, using sand with water contents ranging from 0.1 to 30 percent.

"With water content of between 0.5 and 15 percent, you can construct something that looks like a sandcastle, although the extremities are far from optimal," says Møller.

Using the optimal water content of two percent, however, they managed to construct a cylindrical sand tower, only 2 cm wide but which rose 25 cm up in the air. With a cylinder width of 16 cm, the tower rose an impressive 100 cm from the laboratory floor.

"In theory, with water content of two percent it's possible to build a sand tower that's 2 cm wide and 30 cm

tall, or 16 cm wide and 120 cm tall.”

The physics behind sandcastles

Behind the playful appearance of the scientists’ work lies basic research which will increase our understanding of the physical properties that make the sand grains stick together – the so-called capillary bridges.

“Water molecules 'want' to stick together. That's why vapour in the air clusters into drops that fall to earth as rain,” he says.

“But the water molecules also 'want' to coat the sand grains. These coated grains then stick together via the capillary bridges the water forms - in exactly the same way as your hairs cling together when wet.
And exactly like with your hairs, too little water or too much – when you are under water – destroys the bridges."

You can conduct your own little experiment by putting a little water on your fingers. When you move your index fingers towards each other, the drops coalesce to form a small water bridge between your fingers. That’s a capillary bridge.

However, the water will continue to hold onto your fingers while it finishes its task of forming a drop that will fall to earth when the drop is big enough.

This is the same process as when water forms capillary bridges between the sand grains and draws them together. That’s why sand sticks to your body when you lie down in the sand after a swim. Once your body is dry and you get up again, the sand grains fall off your body, since the water, and thus also the capillary bridges, are gone.

New findings useful for engineers

The new knowledge about the influence that water content has on capillary bridges is not only intended to be of use to children on the beach:

“Ten percent of the world’s energy consumption is used for transporting and handling granular materials such as sand,” says the researcher.

“Here, capillary bridges could be of great importance to the material’s transport properties. Consider for example the difference between pouring wet and dry sand into a sand mill in the sandbox.”

Møller is keen to point out that although the study bears the mark of basic research, he hopes the new findings will eventually be used for something more than just constructing sandcastles.

The findings can for instance be useful for engineers trying to assess the stability of the subsurface. This stability also depends on the capillary bridges in the soil.

Read the Danish version of this article on videnskab.dk [8]

Sand is an excellent building material for making castles and sculptures. Scientists have now found that water content of two percent makes sand optimally suitable for building large structures. This picture was taken at the sand sculpture festival in the Danish town of Søndervig earlier this year. (Photo: Steen Holm)

[9]
You?re not limited to building castles when you?re playing with sand. The picture was taken at the sand sculpture festival in the Danish town of Søndervig earlier this year. (Photo: Steen Holm) [10]
sandcastle.jpg [11]

Fact box

It’s not only the water content that determines how tall your sandcastle can get. The strength of the sand is also influenced by how compressed the sand is and how large the grains are.

The more compressed the sand and the smaller the grains, the taller the castles can get.

If the sand is highly compressed, it can get around 30 percent more strength, increasing its ability to stick together even under pressure from large amounts of overlying sand.

In theory, with water content of two percent it?s possible to build a sand tower that?s 2 cm wide and 30 cm tall, or 16 cm wide and 120 cm tall.
Peder Møller

The Worldwide Sculpture Orgnisation [12] Peder Møller's profile (LinkedIn) [13]
How to construct the perfect sandcastle, Scientific Reports, DOI: 10.1038/srep00549 [14]

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August 3, 2012 - 07:02
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