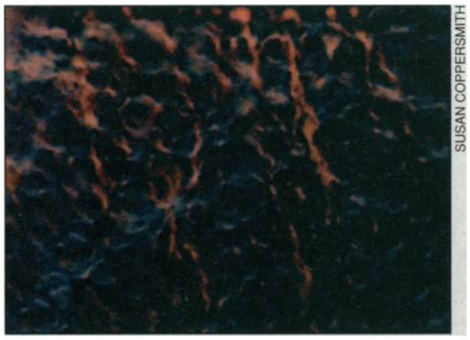
PHYSICS

A Fine-Grained Look at Forces in Sand

KANSAS CITY, MISSOURI—Next time you stand on a sandy beach gazing out over the ocean, you may be intrigued to know that some surprising physics is taking place right under your feet. At an American Physical Society meeting here last month, Susan Coppersmith, of the University of Chicago, described a set of experiments that have begun to piece together just how weight gets divvied up and passed downward in granular materials such as sand and beads. It turns out that the forces are not distributed evenly among the grains, as you might expect. Instead, like a human pyramid in which some of the tumblers are doing more than their fair share of the work, the weight gets transmitted downward from grain to grain in jagged "force chains."



Force chains. Beads that change polarization under stress show uneven force distribution.

Coppersmith's group—using devices ranging from high-tech optics to low-tech carbon paper—has provided the first three-dimensional views of these chains. And colleagues such as James Kakalios, a physicist at the University of Minnesota, agree that the experiments are "rather clever." Understanding such measurements, he says, "is very interesting and important, because forces in granular materials do not get transmitted in the same way they would in a fluid." This penchant for pushing in directions other than straight down, says Kakalios, is important in everything from grain silos, the sides of which may suddenly rupture, to the steady, unfluidlike flow of sand in an hourglass.

Coppersmith's group includes researchers at the University of Chicago; the Xerox Corp.; the University of California, San Diego, and Santa Cruz; and the Tata Institute of Fundamental Research in India. The team used a simple image to convey the topic under study: "a foot on the beach in Aruba." Coppersmith described two sets of experiments to examine the way grains under the hypothetical foot might be affected. In the high-tech version, researchers used clamps to apply pressure to a 10-centimeter-tall container filled with half-millimeter beads made of a special material, the light-transmitting quality of which changes under pressure, exhibiting "stress-induced birefringence." As stress increases, this material rotates the polarization of light. Coppersmith's group shone a light through a polarizing filter, then through the beads, and finally through a second filter at right angles to the first. Only light rotated by beads under stress could get through, producing an illuminated map of stress lines.

To learn how the weight is distributed quantitatively, the group went low-tech. They discovered that when the bottom of the stack of beads rested on a piece of carbon paper placed facedown on a clean sheet of paper, the sizes of the resulting smudges were proportional to the weight on a given bead. "The idea that you can get real, quantitative data from carbon paper blows my mind," says Sidney Nagel, a Chicago team member.

The carbon paper not only produced useful results, but those results agreed reasonably well with a quantitative model the group had developed. This model, based on observations of the force chains and computer simulations, assumes that a given bead divides the weight randomly among the three beads on which it rests. This approach leads to sharper spatial concentrations of weight than would be predicted by standard "bell curve" statistics. But the approach keeps the weight more evenly distributed than does "fractal statistics," used to describe some gases and liquids. "It's quite amazing that you can do so well with such a simple model," says Coppersmith. She now aims to apply concepts gleaned from this work to phenomena such as shear motion—which occurs as sand or mud begins to avalanche.

In order to tackle more realistic problems involving piles of grain, says Pierre-Gilles de Gennes of the École Supérieure de Physique et de Chimie Industrielles in Paris, researchers will need to refine the principles they have extracted from this weight-distribution research. For example, he points out, the Chicago model ignores the role of arches of grains that can spontaneously form and direct weight toward the edges of the container. Other groups, especially that of Jean-Philippe Bouchaud at the Atomic Energy Agency's Centre d'Études de Saclay and Michael Cates at the University of Edinburgh in the U.K., are looking into that issue. The curious physics of sandpiles should keep these researchers occupied for years to come.

–James Glanz

SCIENCE PUBLISHING

Fermilab Group Tries Plain English

Leonardo da Vinci composed his notebooks in mirror-image script, in part to make them incomprehensible to prying competitors. A casual reader of today's physics journals, packed with jargon and unwieldy diction, might conclude that modern savants have discovered how to achieve the same goal in standard, left-to-right prose. Now, however, a major research group in one of the field's most intimidating enclaves—particle physics—has decided it cares enough about its readers to post, on the World Wide Web, a "plain English" version of every technical paper it publishes. The seemingly revolutionary experiment aims to bring particle physics to a wider audience and ease the job of scientists trying to stay abreast of specialties outside their own.

The philosophy is simple, says John Womersley, a physicist in a collaboration known as D0, at the Fermi National Accelerator Laboratory (Fermilab), just west of Chicago. "We really feel that if we can't explain what we're doing, then we shouldn't be doing it," says Womersley, who wrote the first of three D0 group reports now available on Fermilab's Web site.*

Early reviews of the Web products' accessibility have been decidedly mixed, but at least one other group has plans to begin a similar program, and some observers predict that more will be forced to follow suit. "D0's 'plain English' is a first, very important step" toward better public communication, says Petra Folkerts, a press and information officer at the Deutsches Elektronen-Synchrotron in Hamburg, Germany.

Members of the D0 group, the name of which is derived from the huge D0 particle detector hunched over Fermilab's Tevatron accelerator, concede that generating publicity was at least part of the motivation for starting the project. "We know there is going to be a lot of pressure on science in the future to justify its existence," says Harry Weerts, a D0 spokesperson at Michigan State University. "We shouldn't forget where the funding is coming from, right?" Taxpayers, who foot the bills, are on D0's readership wish list. But the physicists say they don't want to create just another type of press release; instead, they hope to educate the public about the way scientific research is usually done—not in big jumps, but in many small steps. That way, says Womersley, "we don't have to worry so much about writing a punchy story that will get us above Michael Jackson's baby" in the daily newspapers. The reports, he says,

* http://d0sgi0.fnal.gov/public/pubs/d0_physics_summaries.html