Caterpillar Rolls to Success with FEA

Abaqus FEA accurately models the behavior of mobile compactors and landfill waste

View of a Cat® landfill compactor, showing the patented drum tip technology that offers greater compaction and traction.

Humans have been throwing things away since the dawn of history. As civilizations rose, so did trash heaps. These days the managing of waste isn't just a matter of collecting refuse—it's a high-volume, sophisticated business concerned with disposing of all that garbage in the safest and most efficient manner possible.

At the top of the heap is the issue of waste compaction in landfills. "Compaction is one of the most important processes in landfill operations," says Greg Zhang, engineering specialist in the Industrial & Waste Group at Caterpillar Inc. "It promotes waste density, prolongs the useful life of the land, and increases site profitability."

Caterpillar produces several models of landfill compactor—immense, multi-ton machines that look like the hybrid offspring of a steamroller and a bulldozer. These behemoths have massive steel drums with patented tip technology that provides greater compaction and traction and promotes ground-surface integrity.

Compactors need to fit the conditions of the sites in which they work, since not all waste is alike. In mainland China, for instance, landfill waste contains significantly more food and organic matter and higher water content than that of industrialized regions in North America and Western Europe. "Variations in waste make for important differences in compressibility and shear strength," Zhang says. "Often, that means we alter the drum and other features to suit the terrain."

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> **Greg Zhang**, Engineering Specialist, Industrial & Waste Group, Caterpillar

To better tailor compactor designs to individual environments, Caterpillar has been using Abaqus finite element analysis (FEA).

FEA hits the ground running

"Before Caterpillar started using FEA, their engineers basically created new model compactors by drawing on experience," says Liqun Chi, senior engineering specialist in the Product Development & Global Technology division of Caterpillar. "Within a certain range of parameters, that worked well, but outside of them—making bigger or smaller machines than the current product line—you could run into problems of scale." That could mean an expensive redesign after physical testing of the compactor, well into the product development cycle. "Analyzing designs at the concept stage instead made a lot of sense," Chi says.

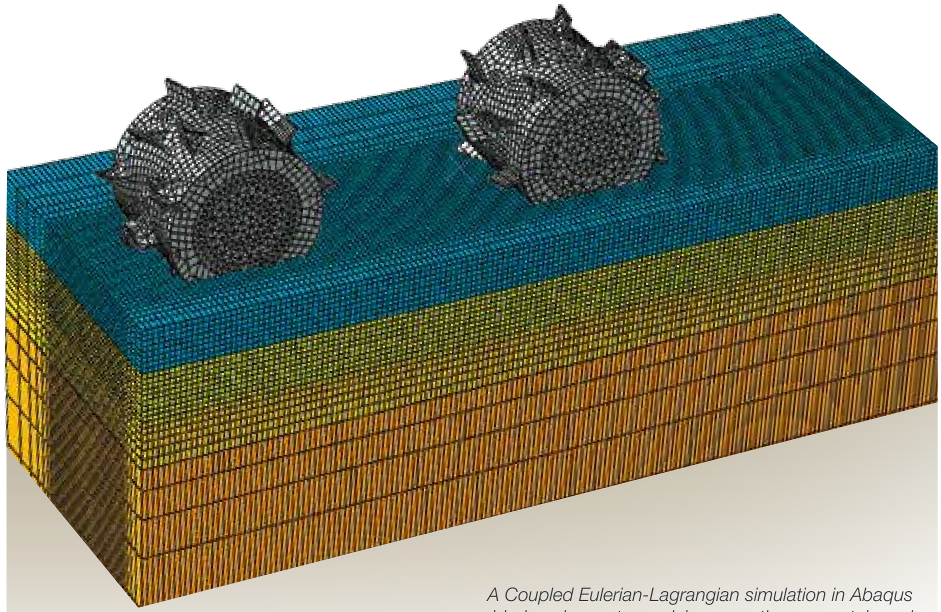
When the engineers first began employing simulation, their Abaqus models were quite simple: a featureless drum deforming a level landscape. A modified crushable foam model stood in for the loose waste material since it included elasto-plastic attributes with volumetric hardening and could capture both compaction and spring-back. The waste was modeled in multiple layers. The compactor drum made several passes (forward and reverse) over the waste, and the resulting compaction was compared to actual field data. The analysts also simulated the drum running on a typical slope.

The simulation data for compaction correlated well with field data—but the engineers also wanted to capture other information. "The smooth-drum model gave a lower figure for wheel torque than physical testing," Chi says. In addition, the analysis didn't consider the effects of detailed wheel design (tip shapes, number, and arrangement).

To add these features, the engineering team created a drum model with tips for an Asian-market SEM6020 compactor and tried a different method of analysis: arbitrary Lagrangian-Eulerian (ALE), a technique used to control distortion.

In this type of analysis, however, deformation of mesh elements remained a challenge. "We could accurately capture the behavior of a first pass of the drum," Zhang says, "but the deformation interfered with simulating subsequent passes. And it only worked well with gentle slopes and relatively small wheel slips." The analysts decided to explore another method.

Their final choice was a Coupled Eulerian-Lagrangian (CEL) analysis. This time, the engineers created two different simulation phases for each pass of the drum. In the Lagrangian phase, the elements were temporarily fixed within the compacting material, capturing its deformation. In the Eulerian phase, deformation was suspended and significantly deformed elements were re-meshed automatically. "Now we could accurately model multiple passes of the drum," Chi says.



A Coupled Eulerian-Lagrangian simulation in Abaqus enabled engineers to model compaction accurately and also helped them to determine wheel torque, traction coefficient, rolling radius, and rolling resistance.

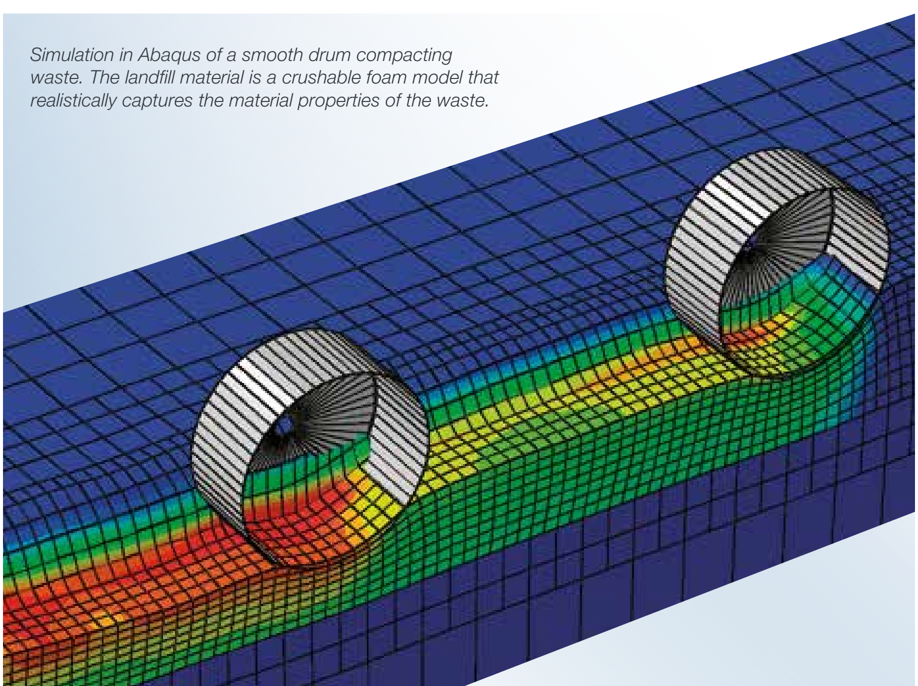
Rolling to results

The CEL method resolved the element distortion issues experienced with previous ALE compaction models. Now the team could simulate multiple passes for the compaction drums, even for drums with detailed tip shapes, accurately predicting the behavior of both drums and landfill waste compared to physical tests. "Abaqus is a powerful tool for simulating machine-ground interactions," Zhang says. "We were able to provide other product development teams—such as powertrain and wheel groups—with valuable torque, traction coefficient, rolling radius, and rolling resistance data."

The additional data ensures that every size compactor will perform as required, in whatever environment—improving metrics from productivity to fuel consumption.

"We now use CEL in Abaqus for all our multi-terrain loaders," Zhang says. "It helps us design the machinery as well as the drum tips." Analyses are currently being performed on a range of Chinese and U.S. landfill compactors, including the popular American model 836.

"We're also migrating the mesh from this model to the analysis of other rigs such as soil compactors, and even vibratory soil compactors, for construction," says Zhang. "Modeling these other types of equipment will require some finer mesh, but the analyses should provide us with performance benefits comparable to our landfill compactor simulations."



Simulation in Abaqus of a smooth drum compacting waste. The landfill material is a crushable foam model that realistically captures the material properties of the waste.

For More Information

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