SIEMENS

Machinery

Femto Engineering

FEA sheds light on fatal accident

Products

Femap, NX

Business challenges

Increasingly complex crane designs

Accident had no apparent cause

Need to prevent future incidents

Keys to success

Fast, accurate finite element modeling using beam elements

Analysis work done in the Windows environment

Rapid nonlinear simulations of multiple scenarios

Variety of postprocessing options including animation

Results

Static overloading ruled out as cause

FEA results steered investigation toward trolley movement

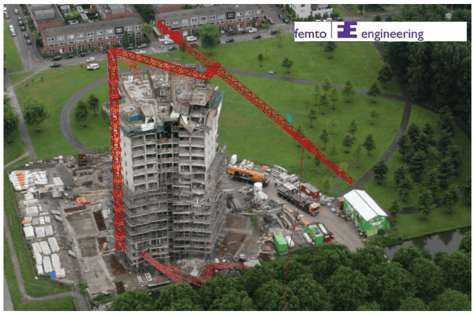
Dynamic forces due to trolley motion identified as cause

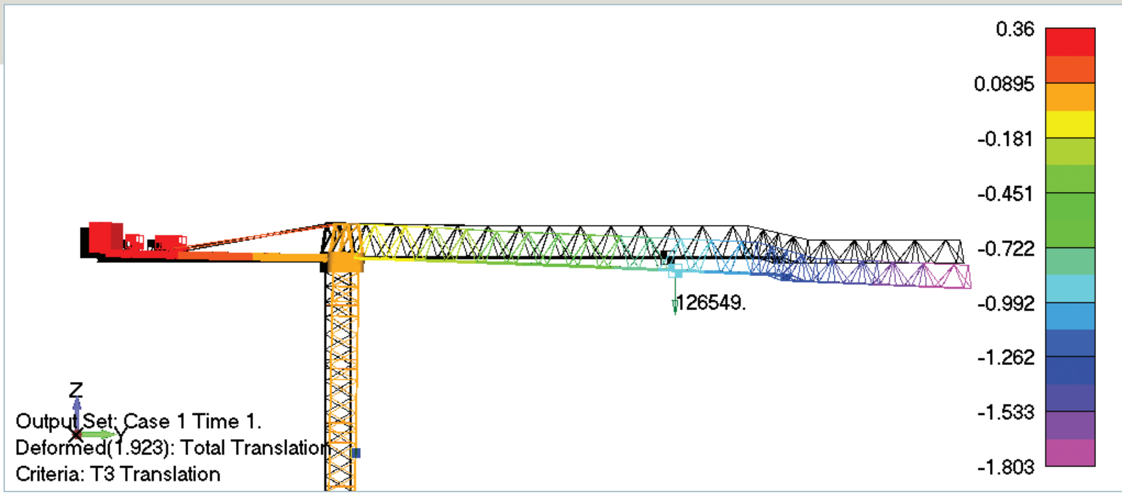
Femap and NX Nastran helped determine the cause of a crane collapse in the Netherlands

Fatality triggers formal investigation

In Rotterdam in 2008, a crane being used in the construction of a high-rise apartment building collapsed for no apparent reason. The crane operator, who was working 315 feet (96 meters) above ground in the crane's trolley, was killed. There was also extensive damage to the construction site. The accident could have been even worse because the crane's operating radius covered a nearby footpath and children's play area. The fatality triggered the involvement of the Dutch Safety Board, which began its investigation immediately.

The collapse involved a tower crane, a type of crane that is built at the construction site and consists of a mast topped by a horizontal jib. The operator of a tower crane sits high above the ground in a trolley that runs along the jib. The operator moves the trolley back and forth along the jib to position the hoist cable at the correct radius. Tower crane designs have become increasingly complex in recent years due to the incorporation of new electronic and control technologies. "As such, it becomes increasingly difficult to keep track of the consequences of assembling elements into a single tower crane," states the Dutch Safety Board's report, which is available in Dutch, German and English and can be read at www.onderzoeksraad.nl.





"I prefer Femap because it is the easiest to use…due to Femap working in the Windows environment and also to the strong modeling functionality of the software."

Alexander Naatje
Project Engineer
Femto Engineering

Was overload the cause?

The Dutch Safety Board's investigation was designed to answer three questions. The first two were: Was the crane being used in a way that fell outside the conditions of use and parameters specified by the manufacturer? Did weaknesses in the steel cause the failure? Both of these investigations turned up negative. The third question looked at whether the crane was overloaded at the time of the collapse and included two lines of investigation: 1) finite element analysis (FEA) to evaluate the structural design of the crane, and 2) experiments to determine whether unintended movement of the trolley caused it to roll too far toward the outer end of the jib.

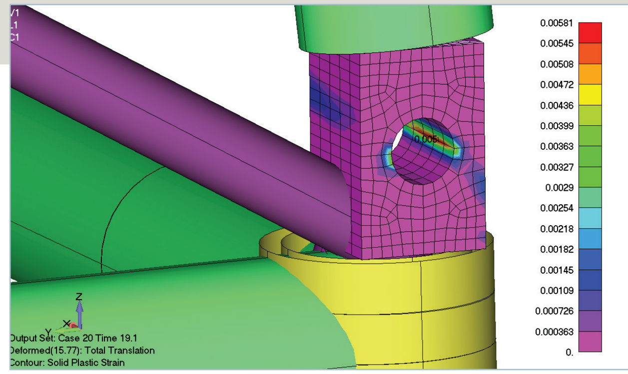
The finite element analysis was assigned to Femto Engineering, a Dutch engineering consultancy specializing in structural analysis. Alexander Naatje, a project engineer at Femto Engineering, performed the work. His choice of FEA pre- and post-processor for this project was Femap™ software from Siemens PLM Software. "We have other software but I prefer Femap because it is the easiest to use," he explains. "This is due to the ability to work in the Windows environment and also to the strong modeling functionality of the software."

Beam elements accelerated modeling

Naatje created his finite element model directly in Femap working from the crane manufacturer's drawings. "The model consisted mainly of one-dimensional beam elements so I was able to create it very quickly," Naatje explains. The alternative to using beam elements, which would have been necessary with some other pre-processors, was filling solid structures with solid elements. For slender structures such as those of this tower crane, this would have resulted in an impossibly large model. "One single beam element replaces hundreds of solid elements. This is a definite advantage of Femap," Naatje

"One single beam element replaces hundreds of solid elements. This is a definite advantage of Femap."

Alexander Naatje
Project Engineer
Femto Engineering



Solutions/Services

Femap
www.siemens.com/plm/femap

NX Nastran
www.siemens.com/nx

Customer's primary business

Femto Engineering is an engineering agency offering both consultancy and software for structural analysis.
www.femto.nl

Customer location

Delft
Netherlands

continues. "You can start your model from nodes and elements and not just from solid geometry."

Another strength of Femap, he notes, is that it allows a mixture of element types, which is useful when simulating details. For example, Naatje could create detailed solid elements for certain areas and then connect them to the beam elements in the global/ total model.

Simulating pre-crash events

Loading conditions and stiffness data were provided by the Dutch Safety Board, which recreated an identical crane as part of the investigation. The analysis solver used on the project was NX™ Nastran® software, also from Siemens. Naatje used the advanced nonlinear analysis functionality of Nastran, in particular the advanced nonlinear transient analysis function, to analyze the dynamic behavior of the crane and quickly run through multiple simulations of the events leading up to the collapse.

Naatje used Femap to create both still images and animations for the final report. A Femap animation of the collapse superimposed on an aerial photograph of the site provided an easily understood recreation of the event.

The work done by Naatje ruled out a static overload as the cause of the collapse. The analysis results showed that the collapse would have required a larger static load than what was being lifted at the time of the accident (13 tons). But it also showed that the flexibility of the crane was greater than what was assumed by the manufacturer. This flexibility caused the jib to bend 2.1 degrees below level while lifting the13-ton load. At this point the investigation turned to the trolley. Ultimately the board determined that dynamic forces caused by uncontrolled trolley motion as it rolled too far out toward the end of the jib caused the overloading that led to the collapse. The Dutch Safety Board used this information to make recommendations that it hopes will prevent future crane accidents.

Siemens PLM Software

Americas +1 314 264 8287
Europe +44 (0) 1276 413200
Asia-Pacific +852 2230 3308

www.siemens.com/plm