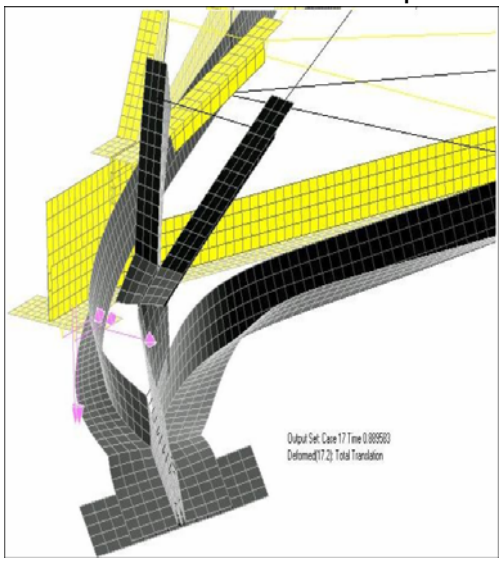
Civil Case Study (Structural Engineering Research Center, India – Transmission Line Towers)

TEST – Failure of Cross Arm Tip



FEM Analysis – Cross Arm Tip

The Tower Testing and Research Station (TTRS), Structural Engineering Research Center (www.sercm.org) of Chennai, India, conducted 105 full-scale tower tests and out of these, 28 towers had premature failures. The wide discrepancy between the test results and those obtained using current design codes clearly revealed that the behavior of transmission towers under complex loading conditions could not be consistently predicted using the present day analytical techniques and design methodology. In order to study the problem in depth, nonlinear finite element analysis using NEi Nastran was carried out.

The cross arm failures in four towers tested at TTRS were investigated. The nonlinear finite element analysis capability of NEi Nastran was used to model the elasto-plastic behavior of the cross arms. In the case of tower 3, the failure of the cross arm was due to local buckling of the bottom main compression member, as shown in the first picture (TEST). Both legs of the angle section of the bottom main members were modeled using plate elements. Top tie members were modeled using plate elements to some length and beam elements for the remaining length, as shown in the second picture (FEM Analysis). At the transition between the beam and plate elements, a rigid element was used to connect the beam elements node with the nodes of the angle section modeled with plates. This enabled modeling of the progressive yielding at the point of plastic hinge formation and subsequent failure by local buckling of the elements. The effect of an eccentric bolted connection between the members was modeled by using a beam element.

It was found that the local buckling of members at tip of cross arm was mainly due to the loading eccentricity and the bending stress was exceeding its capacity. This also confirmed that the full scale testing of tower provides an insight into the actual stress distribution of the configuration tested.

NEi Nastran results show that in case idealized cross arm patterns cannot be provided due to difficulties in detailing/fabrication leading to eccentricities, a detailed nonlinear finite element analysis is needed to obtained correct estimates of failure loads and patterns. Strengthening can be resorted to if necessary so that premature failures are avoided during testing. NEi Nastran delivered a precise, accurate, and cost-effective solution to this critical design challenge.

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