

on the floors where the fires led to the onset of the collapse. The photographic evidence showed no signs of column bowing or a floor collapse.

6.6 THE BUILDING STRUCTURAL MODELS

6.6.1 Computer Simulation Software

Structural modeling of each tower was required in order to:

- Establish the capability of the building, as designed, to support the gravity loads and to resist wind forces;
- Simulate the effects of the aircraft impacts; and
- Reconstruct the mechanics of the aircraft impact damage, fire-induced heating, and the progression of local failures that led to the building collapse.

The varied demands made different models necessary, and different software packages were used for each of these three functions. The reason for the choice in each case is presented in the next three sections of the report.

6.6.2 The Reference Models

Under contract to NIST, Leslie E. Robertson Associates (LERA) constructed a global reference model of each tower using the SAP2000, version 8, software. SAP2000 is a software package for performing finite element calculations for the analysis and design of building structures. These global, three-dimensional models encompassed the 110 stories above grade and the six subterranean levels. The models included primary structural components in the towers, resulting in tens of thousands of computational elements. The data for these elements came from the original structural drawing books for the towers. These had been updated through the completion of the buildings and also included most of the subsequent, significant alterations by both tenants and The Port Authority. LERA also developed reference models of a truss-framed floor, typical of those in the tenant spaces of the impact and fire regions of the buildings, and of a beam-framed floor, typical of the mechanical floors.

LERA's work was reviewed by independent experts in light of the firm's earlier involvement in the WTC design. It was that earlier work, in fact, that made LERA the only source that had the detailed knowledge of the design, construction, and intended behavior of the towers over their entire 38-year life span. The accuracy of the four models was checked in two ways:

- The two global models were checked by Skidmore, Owings & Merrill (SOM), also under contract to NIST, and by NIST staff. This entailed ensuring consistency of the models with the design documents, and testing the models, for example, to ensure that the response of the models to gravity and wind loads was as intended and that the calculated stresses and deformations under these loads were reasonable.
- The global model of WTC 1 was used to calculate the natural vibration periods of the tower. These values were then compared to measurements from the tower on eight dates of winds