

- The local environment was represented by a hot, soot-laden upper layer and a cooler, relatively clear lower layer.

FSI then calculated the radiative and convective heat transfer to each of these small sections using conventional physics. Finally, the temperature data were read into the ANSYS 8.0 finite element program, which applied the temperature distribution to the structural elements.

6.12.3 Thermal Insulation Properties

Equivalent Uniform Thickness of SFRM

Preliminary simulations with FSI explored the extent to which bare steel structural elements would heat more rapidly than the same elements would if they were well insulated. In one such calculation experiment, one of the largest columns in the tower structure was immersed in a furnace at 1,100 °C. Uninsulated, it took just 13 min for the steel surface temperatures to reach 600 °C, in the range where substantial loss of strength occurs. When insulated with 1 1/8 in. of SFRM, the same column had not reached that temperature in 10 hours. This established that the fires in WTC 1 and WTC 2 would not be able to significantly weaken the insulated core or perimeter columns within the 102 min and 56 min, respectively, after impact and prior to collapse. Thus, it was important to know whether the insulation was present or removed and much less important to know the exact thickness of the SFRM.

It was likely that the thinner steel bars and angles in the floor trusses would be more sensitive to the condition of the insulation. If the insulation were present, but too thin or imperfectly applied, these components might have been heated to failure in times on the order of an hour.

NIST performed additional simulations to probe the effect of gaps in the truss insulation and of variations in the thickness, similar to those observed in real SFRM application (Figure 5–6). It was evident that incorporation of these small-scale variations into the description of the structural members would have lengthened the FSI computations to an extreme. Furthermore, there was insufficient information to determine how the thickness varied over the length of the structural members. NIST combined the measured variations in the SFRM thickness (as described in Section 5.6.2) with simulations of the heat transfer through the uneven material. This led to the identification of a uniform thickness that provided the same insulation value as did the measured coatings. These values, shown in Table 5–3, were used in the thermal calculations. They were found to be greater than the specified thicknesses but slightly smaller than the average measured thicknesses, as they should be.

SFRM Thermophysical Properties

When the Investigation began, there were few published data on the insulating properties of SFRMs, especially at elevated temperatures. It was expected, and soon confirmed, that the fires could generate temperatures up to 1,100 °C. Therefore, NIST contracted for measurement of the key SFRM thermophysical properties that, along with coating thickness, determine the insulating effect of the coatings. These properties included thermal conductivity, specific heat capacity, and density. These were measured for each SFRM at temperatures up to 1,200 °C. Since there were no ASTM test methods developed specifically for characterizing the thermophysical properties of SFRMs as a function of temperature, ASTM test methods developed for other materials were used. Samples were prepared by the