Section 3
Commentaries

The commentaries in the following subsections were provided by committee members with expertise in particular technical disciplines. The titles and authors of each subsection are as follows:

- 3.1 **Geotechnical and Seismological Aspects** by Klaus Jacob
- 3.2 **Loads and Load Procedures** by Joseph Kelly
- 3.3 **Seismic Design of Nonstructural Components, Elements of Structures and Non-Building Structures** by Leo E. Argiris
- 3.4 **Application to Building Additions and Alterations** by Ramon Gilsanz
- 3.5 **Economic Impact Study** by Irwin Cantor

3.1 Geotechnical and Seismological Aspects

New York City is not free from earthquakes. It is located in a zone of moderate seismicity. For instance, since 1884 the entire state of New York has experienced four damaging earthquakes with magnitudes between about M~5 and M~5.5 and many smaller earthquakes are recorded every year. The greater New York City area alone can expect on average one magnitude M~5 earthquake about once every 100 to 200 years (the last such damaging event with magnitude M~5.2 occurred in 1884). Based on geological arguments and comparison to geologically similar regions elsewhere, the possibility cannot be excluded that magnitudes as high as M~7 may occur near New York City, including adjacent offshore areas on the Atlantic coastal shelf. This possibility for M > 6 earthquakes exists despite the fact that in the short historic record (about 300 years), no larger earthquakes than M=5.2 have been observed near New York City. But during historic time much larger (M = 7 ± .5) and quite damaging events have occurred elsewhere along the Atlantic coast of eastern North America.

The ground motions associated with earthquakes in the eastern United States differ distinctly from ground motions in the western U.S. in several important ways. Eastern earthquakes are reported to have released higher rock stresses compared to their western counterparts, thereby causing the ground motions to contain more high-frequency energy. The ground motion shaking is more intensely felt to larger distances because the Earth's crust and its rocks in the eastern U.S. transmit seismic waves more efficiently, especially at the higher frequencies of engineering interest. This stronger shaking, especially at shorter building periods and to larger distances, is caused by the fact that the crustal rocks in the eastern U.S. tend to be older, more competent, and less riddled with seismically active faults, compared to generally younger California rocks along the tectonically very active San Andreas fault system.

Other differences relate to the geological near-surface conditions: very competent, hard rocks are exposed at the surface in many portions of New York City (e.g. Bronx and Manhattan) ever since the glaciers retreated from the area about 10,000 years ago. Along the Hudson, Harlem and East River, along the water front in the New York Harbor estuary, and in other low-lying lands and former marshes (e.g. Flushing Meadow), very soft sediments have been deposited since glacial times, sometimes almost directly onto the exposed, hard bedrock formations. Land has been reclaimed by filling in marshland or along the waterfront. The contrasts in stiffness between the soft soils and underlying hard rocks create often extreme conditions for frequency-selective amplification of ground motions. On sites with deep soft soils, ground motions with periods shorter than 0.3 seconds tend to be attenuated (diminished in amplitude), and those with longer periods (> 0.3 sec) are often amplified, sometimes by factors up to 5 or 8, compared to those observed on adjacent hard-rock sites. Moreover, liquefaction of cohesionless soils, such as sands and silts, can be expected for smaller earthquakes and to larger distances in the eastern U.S. than in the western U.S. Soil liquefaction is caused by pore pressure built-up in water-saturated unconsolidated, cohesionless soils. Soil liquefaction often results in considerable loss of bearing strength when the soils liquefy during prolonged shaking. Liquefaction also can cause lateral spreads and settlement of soils.

Although the New York City Seismic Building Code became effective as late as 1996, most of the technical seismological content of the code provisions was drafted in the late 1980's. It was based on the combined seismic, geotechnical and strong ground motion information then available. This information was taken into account when reviewing whether the seismic provisions of the Uniform Building Code (UBC), used as the primary reference code, needed any modifications when applied to New York City. The original UBC seismic provisions had been largely based on California or other west-coast seismic data and experiences, which rarely apply to New York City's geologic conditions without sometimes considerable modifications. The seismic information available in the 1980's for the eastern U.S. and New York City affected the seismic load factors, seismic design-spectral shapes, spectral site coefficients for amplification of ground motions on soil sites, and the inferred liquefaction potential of soil sites. Accordingly, some of the seismic loads and soil parameters had to be modified from those quoted in the referenced Uniform Building Code.

The seismic-geotechnical features of the New York City seismic code provisions as drafted on the basis of the seismological information available in the late 1980's can be summarized as follows:

- The design ground motions were intended to represent ground motions expected to have a 90% probability of not being exceeded in 50 years, corresponding to an average recurrence period of about 500 years. Of course this implies a 10% chance that the motions (and corresponding seismic loads) may be exceeded in 50 years. These values are only estimated targets that unintentionally can vary somewhat between soil and rock sites, and also with the natural building period (i.e. building height). With the occurrence of future seismic events and with the development of new seismic hazard mapping procedures, new information will come to light that may require that these estimates be updated periodically. These changes may increase or decrease the specified seismic loads depending on site conditions and building type and period. Since the code only represents minimum requirements, some building owners may opt to seek greater protection by choosing design options capable of resisting ground motions and design forces that are higher than those outlined in the current code. This aspect is further commented on below.

- The seismic code provisions allow design ground motions either from code-prescribed design spectra, or those based on site-specific investigations.

- New York City belongs to a single seismic zone with a seismic zone factor Z=0.15. The seismic zone factor relates numerically (but is not identical) to peak ground acceleration when measured in units of g, the gravitational acceleration at the Earth's surface.

- Five rock and soil classes, S_0 to S_4, apply that can be determined using standard New York City material classifications, in conjunction with standard penetration test (SPT) blow counts and shear wave velocities for rock. The soil/rock profiles need to be defined from geotechnical information generally to depths of 100 feet or less, below grade.

- The five classes of rock and soil profiles used in the New York City code are associated with five site coefficients that vary from S_0=0.67 for hard rock, to S_4=2.5 for the softest soils; thus the code allows for a maximum site amplification of S_4/S_0=3.75 between soft soils and hard rock. This is a higher ratio than used in all U.S. seismic codes of pre-1994 vintage. These national codes generally failed to realistically quantify the observed differences in ground motions between soft-soil and hard-rock sites. The site factors adopted for the New York City site classes thus reduce the code-prescribed seismic loads for structures founded on the hardest rocks, and introduce load penalties for structures founded on the softest soil sites, in accordance with site-dependent damage patterns observed globally during many past earthquakes.

- A liquefaction screening test has been included for sites containing water-saturated non-cohesive soils in the upper 50 feet. These soil profiles are identified based on geotechnical borings that measure standard penetration test (SPT) blow counts. Two separate criteria for liquefaction screening are used; one applies to buildings that belong to ordinary occupancy categories, and a more stringent one for more important buildings in special occupancy categories.

The geotechnical/seismic data and other types of information that were used to modify the UBC code provisions and seismic loads were believed to reflect the then current level of knowledge of seismic and geotechnical processes in the eastern U.S. in general, and for New York City in detail. Nevertheless, it must be kept in mind that the information used was based on a limited number of observations and inferences. Also, there is no guarantee that the past limited seismic experience can be used as an unequivocal guide to the future behavior of earthquakes in this region. The resulting design motions and seismic loads were believed to be adequately representative of the seismic and geotechnical conditions characteristic for New York City, and for the targeted ground motion recurrence period of about 500 years. Therefore, the design motions were intended to provide a nearly uniform and balanced level of protection between the different soil and rock conditions, and for the different building periods that exist in New York City.

Available seismic information does change with time. Also one must keep in mind that the code provisions are intended to represent minimum requirements aimed primarily at preventing catastrophic structural collapse and related loss of lives, rather than losses from non-life-threatening damage and/or business interruptions. Owners and developers interested in added seismic protection for their structures are not prevented from adopting more severe ground motions than those specified as minimum conditions in the code. As a guide, one can estimate that the doubling of the code-specified ground motions raises their average recurrence period by a factor of five, from about 500 years to about 2,500 years, and lowers the corresponding exceedance probability to one fifth, from about 10% in 50 years to about 2% in 50 years.