2. To have more flexibility in floor plans and to keep costs down, interior walls and partitions are often non-load-bearing and hence may be unable to assist in containing damage.
3. In attempting to achieve economy in structure through greater speed of erection and less site labor, systems may be built with minimum continuity, ties between elements, and joint rigidity.
4. Unreinforced or lightly reinforced load-bearing walls in multistory structures may also have inadequate continuity, ties, and joint rigidity.
5. In roof trusses and arches there may not be sufficient strength to carry the extra loads or sufficient diaphragm action to maintain lateral stability of the adjacent members if one collapses.
6. In eliminating excessively large safety factors, code changes over the past several decades have reduced the large margin of safety inherent in many older structures. The use of higher-strength materials permitting more slender sections compounds the problem in that modern structures may be more flexible and sensitive to load variations and, in addition, may be more sensitive to construction errors.

Experience has demonstrated that the principle of taking precautions in design to limit the effects of local collapse is realistic and can be satisfied economically. From a public-safety viewpoint it is reasonable to expect all multistory structures to possess general structural integrity comparable to that of properly designed, conventional framed structures (Breen 1976 and Burnett 1975).

Design Alternatives. There are a number of ways to obtain resistance to progressive collapse. In Ellingwood and Leyendecker (1978), a distinction is made between direct and indirect design, and the following approaches are defined:

Direct Design: Explicit consideration of resistance to progressive collapse during the design process through either

Alternate Path Method: A method that allows local failure to occur but seeks to provide alternate load paths so that the damage is absorbed and major collapse is averted.

Specific Local Resistance Method: A method that seeks to provide sufficient strength to resist failure from accidents or misuse.

Indirect Design: Implicit consideration of resistance to progressive collapse during the design process through the provision of minimum levels of strength, continuity, and ductility.

The general structural integrity of a structure may be tested by analysis to ascertain whether alternate paths around hypothetically collapsed regions exist. Alternatively, alternate path studies may be used as guides for developing rules for the minimum levels of continuity and ductility needed to apply the indirect design approach to enhance general structural integrity. Specific local resistance may be provided in regions of high risk because it may be necessary for some element to have sufficient strength to resist abnormal loads for the structure as a whole to develop alternate paths. Specific suggestions for the implementation of each of the defined methods are contained in Ellingwood and Leyendecker (1978).

Guidelines for the Provision of General Structural Integrity. Generally, connections between structural components should be ductile and have a capacity for relatively large deformations and energy absorption under the effect of abnormal conditions. This criterion is met in many different ways, depending on the structural system used. Details that are appropriate for resistance to moderate wind loads and seismic loads often provide sufficient ductility. In 1999, ASCE issued a state of practice report that is a good introduction to the complex field of blast resistant design ASCE (1999).

Work with large precast panel structures (Schultz et al. 1977, PCI Committee on Precast Bearing Walls 1976, and Fintel and Schultz (1979) provides an example of how to cope with the problem of general structural integrity in a building system that is inherently discontinuous. The provision of ties combined with careful detailing of connections can overcome difficulties associated with such a system. The same kind of methodology and design philosophy can be applied to other systems (Fintel and Annamalai 1979). The ACI *Building Code Requirements for Structural Concrete* (ACI 2002) includes such requirements in Section 7.13.

There are a number of ways of designing for the required integrity to carry loads around severely damaged walls, trusses, beams, columns, and floors. A few examples of design concepts and details are

1. Good Plan Layout. An important factor in achieving integrity is the proper plan layout of walls and columns. In bearing-wall structures, there should be an arrangement of interior longitudinal walls to support and reduce the span of long sections of crosswall, thus enhancing the stability of individual walls and of the structures as a whole. In the case of local failure, this will also decrease the length of wall likely to be affected.