COMMENTARY TO AMERICAN SOCIETY OF CIVIL ENGINEERS/STRUCTURAL ENGINEERING INSTITUTE STANDARD 7-05

This commentary is not a part of the ASCE Standard *Minimum Design Loads for Buildings and Other Structures*. It is included for information purposes.

This commentary consists of explanatory and supplementary material designed to assist local building code committees and regulatory authorities in applying the recommended requirements. In some cases it will be necessary to adjust specific values in the standard to local conditions. In others, a considerable amount of detailed information is needed to put the provisions into effect. This commentary provides a place for supplying material that can be used in these situations and is intended to create a better understanding of the recommended requirements through brief explanations of the reasoning employed in arriving at them.

The sections of the commentary are numbered to correspond to the sections of the standard to which they refer. Because it is not necessary to have supplementary material for every section in the standard, there are gaps in the numbering in the commentary.

Chapter C1
GENERAL

C1.1 SCOPE

The minimum load requirements contained in this standard are derived from research and service performance of buildings and other structures. The user of this standard, however, must exercise judgment when applying the requirements to "other structures." Loads for some structures other than buildings may be found in this standard and additional guidance may be found in the commentary.

Both loads and load combinations are set forth in this document with the intent that they be used together. If one were to use loads from some other source with the load combinations set forth herein or vice versa, the reliability of the resulting design may be affected.

Earthquake loads contained herein are developed for structures that possess certain qualities of ductility and postelastic energy dissipation capability. For this reason, provisions for design, detailing, and construction are provided in Appendix A. In some cases, these provisions modify or add to provisions contained in design specifications.

C1.3 BASIC REQUIREMENTS

C1.3.1 Strength. Buildings and other structures must satisfy strength limit states in which members are proportioned to carry the design loads safely to resist buckling, yielding, fracture, and so forth. It is expected that other standards produced under consensus procedures and intended for use in connection with building code requirements will contain recommendations for resistance factors for strength design methods or allowable stresses (or safety factors) for allowable stress design methods.

C1.3.2 Serviceability. In addition to strength limit states, buildings and other structures must also satisfy serviceability limit states that define functional performance and behavior under load and include such items as deflection and vibration. In the United States, strength limit states have traditionally been specified in building codes because they control the safety of the structure. Serviceability limit states, on the other hand, are usually noncatastrophic, define a level of quality of the structure or element, and are a matter of judgment as to their application. Serviceability limit states involve the perceptions and expectations of the owner or user and are a contractual matter between the owner or user and the designer and builder. It is for these reasons, and because the benefits are often subjective and difficult to define or quantify, that serviceability limit states for the most part are not included within the model United States Building Codes. The fact that serviceability limit states are usually not codified should not diminish their importance. Exceeding a serviceability limit state in a building or other structure usually means that its function is disrupted or impaired because of local minor damage or deterioration or because of occupant discomfort or annoyance.

C1.3.3 Self-Straining Forces. Constrained structures that experience dimensional changes develop self-straining forces. Examples include moments in rigid frames that undergo differential foundation settlements and shears in bearing walls that support concrete slabs that shrink. Unless provisions are made for self-straining forces, stresses in structural elements, either alone or in combination with stresses from external loads, can be high enough to cause structural distress.

In many cases, the magnitude of self-straining forces can be anticipated by analyses of expected shrinkage, temperature fluctuations, foundation movement, and so forth. However, it is not always practical to calculate the magnitude of self-straining forces. Designers often provide for self-straining forces by specifying relief joints, suitable framing systems, or other details to minimize the effects of self-straining forces.

This section of the standard is not intended to require the designer to provide for self-straining forces that cannot be anticipated during design. An example is settlement resulting from future adjacent excavation.

C1.4 GENERAL STRUCTURAL INTEGRITY

Through accident, misuse, or sabotage, properly designed structures may be subject to conditions that could lead to either general or local collapse. Except for specially designed protective systems, it is usually impractical for a structure to be designed to resist general collapse caused by gross misuse of a large part of the system or severe abnormal loads acting directly on a large portion of it. However, precautions can be taken in the design of structures to limit the effects of local collapse, and to prevent or minimize progressive collapse. Progressive collapse is defined as the spread of an initial local failure from element to element resulting, eventually, in the collapse of an entire structure or a disproportionately large part of it.

Some authors have defined resistance to progressive collapse to be the ability of a structure to accommodate, with only local failure, the notional removal of any single structural member. Aside from the possibility of further damage that uncontrolled debris from the failed member may cause, it appears prudent to consider whether the abnormal event will fail only a single member.

Because accidents, misuse, and sabotage are normally unforeseeable events, they cannot be defined precisely. Likewise, general structural integrity is a quality that cannot be stated in simple terms. It is the purpose of Section 1.4 and the commentary to direct attention to the problem of local collapse, present guidelines for handling it that will aid the design engineer, and promote consistency of treatment in all types of structures and in all construction materials. ASCE does not intend, at this time, for this standard to establish specific events to be considered during design, or for this standard to provide specific design criteria to minimize the risk of progressive collapse.

Accidents, Misuse, Sabotage, and Their Consequences. In addition to unintentional or willful misuse, some of the incidents that may cause local collapse are [Ref. C1-1]: explosions due to ignition of gas or industrial liquids; boiler failures; vehicle impact; impact of falling objects; effects of adjacent excavations; gross construction errors; very high winds such as tornadoes; and sabotage. Generally, such abnormal events would not be a part of normal design considerations. The distinction between general collapse and limited local collapse can best be made by example as follows.

General Collapse. The immediate, deliberate demolition of an entire structure by phased explosives is an obvious instance of general collapse. Also, the failure of one column in a one-, two-, three-, or possibly even four-column structure could precipitate general collapse, because the local failed column is a significant part of the total structural system at that level. Similarly, the failure of a major bearing element in the bottom story of a two- or three-story structure might cause general collapse of the whole structure. Such collapses are beyond the scope of the provisions discussed herein. There have been numerous instances of general collapse that have occurred as the result of such events as bombing, landslides, and floods.

Limited Local Collapse. An example of limited local collapse would be the containment of damage to adjacent bays and stories following the destruction of one or two neighboring columns in a multibay structure. The restriction of damage to portions of two or three stories of a higher structure following the failure of a section of bearing wall in one story is another example.

Examples of General Collapse.

Ronan Point. A prominent case of local collapse that progressed to a disproportionate part of the whole building (and is thus an example of the type of failure of concern here) was the Ronan Point disaster, which brought the attention of the profession to the matter of general structural integrity in buildings. Ronan Point was 22-story apartment building of large, precast-concrete, load-bearing panels in Canning Town, England. In March 1968, a gas explosion in an 18-story apartment blew out a living room wall. The loss of the wall led to the collapse of the whole corner of the building. The apartments above the 18th story, suddenly losing support from below and being insufficiently tied and reinforced, collapsed one after the other. The falling debris ruptured successive floors and walls below the 18th story, and the failure progressed to the ground. Better continuity and ductility might have reduced the amount of damage at Ronan Point.

Another example is the failure of a one-story parking garage reported in [Ref. C1-2]. Collapse of one transverse frame under a concentration of snow led to the later progressive collapse of the whole roof, which was supported by 20 transverse frames of the same type. Similar progressive collapses are mentioned in [Ref. C1-3].

Alfred P. Murrah Federal Building. [Refs. C1-4 through C1-7] On April 19, 1995 a truck containing approximately 4,000 lb of fertilizer-based explosive (ANFO) was parked near the sidewalk next to the nine-story reinforced concrete office building. The side facing the blast had corner columns and four other perimeter columns. The blast shock wave disintegrated one of the 20 × 36 in. perimeter columns and caused brittle failures of two others. The transfer girder at the third level above these columns failed, and the upper-story floors collapsed in a progressive fashion. Approximately 70 percent of the building experienced dramatic collapse. One hundred sixty-eight people died, many of them as a direct result of progressive collapse. Damage might have been less had this structure not relied on transfer girders for support of upper floors, if there had been better detailing for ductility and greater redundancy, and if there had been better resistance for uplift loads on floor slabs.

There are a number of factors that contribute to the risk of damage propagation in modern structures [Ref. C1-8]. Among them:

1. There is an apparent lack of general awareness among engineers that structural integrity against collapse is important enough to be regularly considered in design.
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 [Refs. C1-8, C1-9].

Design Alternatives. There are a number of ways to obtain resistance to progressive collapse. In [Ref. C1-10], 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 in order for the structure as a whole to develop alternate paths. Specific suggestions for the implementation of each of the defined methods are contained in [Ref. C1-10].

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 [Ref. C1-11]

Work with large precast panel structures [Refs. C1-12 through C1-14] 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 [Ref. C1-15]. The ACI Building Code Requirements for Structural Concrete [Ref. C1-16] 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.
2. Provide an integrated system of ties among the principal elements of the structural system. These ties may be designed specifically as components of secondary load-carrying systems, which often must sustain very large deformations during catastrophic events.
3. Returns on Walls. Returns on interior and exterior walls will make them more stable.
4. Changing Directions of Span of Floor Slab. Where a one-way floor slab is reinforced to span, with a low safety factor, in its secondary direction if a load-bearing wall is removed, the collapse of the slab will be prevented and the debris loading of other parts of the structure will be minimized. Often, shrinkage and temperature steel will be enough to enable the slab to span in a new direction.
5. Load-Bearing Interior Partitions. The interior walls must be capable of carrying enough load to achieve the change of span direction in the floor slabs.
6. Catenary Action of Floor Slab. Where the slab cannot change span direction, the span will increase if an intermediate supporting wall is removed. In this case, if there is enough reinforcement throughout the slab and enough continuity and restraint, the slab may be capable of carrying the loads by catenary action, though very large deflections will result.
7. Beam Action of Walls. Walls may be assumed to be capable of spanning an opening if sufficient tying steel at the top and bottom of the walls allows them to act as the web of a beam with the slabs above and below acting as flanges [Ref. C1-12].
8. Redundant Structural Systems. Provide a secondary load path (e.g., an upper-level truss or transfer girder system that allows the lower floors of a multistory building to hang from the upper floors in an emergency) that allows framing to survive removal of key support elements.
9. Ductile Detailing. Avoid low-ductility detailing in elements that might be subject to dynamic loads or very large distortions during localized failures (e.g., consider the implications of shear failures in beams or supported slabs under the influence of building weights falling from above).
10. Provide additional reinforcement to resist blast and load reversal when blast loads are considered in design [Ref. C1-17].
11. Consider the use of compartmentalized construction in combination with special moment resisting frames [as defined in Ref. C1-18] in the design of new buildings when considering blast protection.

While not directly adding structural integrity for the prevention of progressive collapse, the use of special, nonfrangible glass for fenestration can greatly reduce risk to occupants during exterior blasts [Ref. C1-17]. To the extent that nonfrangible glass isolates a building's interior from blast shock waves, it can also reduce damage to interior framing elements (e.g., supported floor slabs could be made to be less likely to fail due to uplift forces) for exterior blasts.

C1.5 CLASSIFICATION OF BUILDINGS AND OTHER STRUCTURES

C1.5.1 Nature of Occupancy. The occupancy categories in Table 1-1 are used to relate the criteria for maximum environmental loads or distortions specified in this standard to the consequence of the loads being exceeded for the structure and its occupants. The occupancy category numbering is unchanged from that in the previous edition of the standard (ASCE 7-98). Classification continues to reflect a progression of the anticipated seriousness of the consequence of failure from lowest hazard to human life (Occupancy Category I) to highest (Occupancy Category IV).

In Chapters 6, 7, 10, and 11, importance factors are presented for the four occupancy categories identified. The specific importance factors differ according to the statistical characteristics of the environmental loads and the manner in which the structure responds to the loads. The principle of requiring more stringent loading criteria for situations in which the consequence of failure may be severe has been recognized in previous versions of this standard by the specification of mean recurrence interval maps for wind speed and ground snow load.

This section now recognizes that there may be situations when it is acceptable to assign multiple occupancy categories to a structure based on use and the type of load condition being evaluated. For instance, there are circumstances when a structure should appropriately be designed for wind loads with importance factors greater than one, but would be penalized unnecessarily if designed for seismic loads with importance factors greater than one. An example would be a hurricane shelter in a low seismic area. The structure would be classified in Occupancy Category IV for wind design and in Occupancy Category II for seismic design.

Occupancy Category I contains buildings and other structures that represent a low hazard to human life in the event of failure either because they have a small number of occupants or have a limited period of exposure to extreme environmental loadings. Examples of agricultural structures that fall under Occupancy Category I are farm storage structures used exclusively for the storage of farm machinery and equipment, grain bins, corn cribs, and general purpose barns for the temporary feeding of livestock [Ref. C1-19]. Occupancy Category II contains all occupancies other than those in Occupancy Categories I, III, and IV and are sometimes referred to as "ordinary" for the purpose of risk exposure. Occupancy Category III contains those buildings and other structures that have large numbers of occupants, are designed for public assembly, or in which physical restraint or other incapacity of occupants hinders their movement or evacuation. Buildings and other structures in Occupancy Category III, therefore, represent a substantial hazard to human life in the event of failure.

Occupancy Category III also contains important infrastructure structures that serve broad groups of civilians. While the failures of these structures do not always create unusual life-safety risks, such structures are included under the requirements of this occupancy category because their failures can cause substantial economic impact and/or mass disruption of day-to-day civilian life. Examples of conditions that justify classification as Occupancy Category III follow.

Failures of power plants that supply electricity on the national grid can cause substantial economic losses and disruption to civilian life when their failures can trigger other plants to go offline in succession. The result can be massive and potentially extended power outage/shortage that leads to huge economic losses because of idled industries and a serious disruption of civilian life because of inoperable subways, road traffic signals, and so forth. One such event occurred in parts of Canada and the northeastern United States in August 2003.

Failures of water and sewage treatment facilities can cause disruption to civilian life because these failures can cause large-scale (but mostly non-life-threatening) public health risks caused by the inability to treat sewage and to provide drinking water.

Failures of major telecommunication centers can cause disruption to civilian life by depriving users of access to important emergency information (using radio, television, and phone communication) and by causing substantial economic losses associated with widespread interruption of business.

Occupancy Category IV contains buildings and other structures that are designated as essential facilities and are intended to remain operational in the event of extreme environmental loadings. Such occupancies include, but are not limited to, hospitals, fire, rescue, and other emergency response facilities. Ancillary structures required for the operation of Occupancy Category IV facilities during an emergency also are included in this occupancy category. When deciding whether an ancillary structure or a structure that supports such functions as fire suppression is Occupancy Category IV, the design professional must decide whether failure of the subject structure will adversely affect the essential function of the facility. In addition to essential facilities, buildings and other structures containing extremely hazardous materials have been added to Occupancy Category IV to recognize the potential devastating effect a release of extremely hazardous materials may have on a population.

C1.5.2 Toxic, Highly Toxic, and Explosive Substances. A common method of categorizing structures storing toxic, highly toxic, or explosive substances is by the use of a table of exempt amounts of these materials [Refs. C1-20, C1-21]. These references, and others, are sources of guidance on the identification of materials of these general classifications. A drawback to the use of tables of exempt amounts is the fact that the method cannot handle the interaction of multiple materials. Two materials may be exempt because neither pose a risk to the public by themselves but may form a deadly combination if combined in a release. Therefore, an alternate and superior method of evaluating the risk to the public of a release of a material is by a hazard assessment as part of an overall Risk Management Plan (RMP).

Buildings and other structures containing toxic, highly toxic, or explosive substances may be classified as Occupancy Category II structures if it can be demonstrated that the risk to the public from a release of these materials is minimal. Companies that operate industrial facilities typically perform Hazard and Operability (HAZOP) studies, conduct quantitative risk assessments, and develop risk management and emergency response plans. Federal regulations and local laws mandate many of these studies and plans [Ref. C1-22]. Additionally, many industrial facilities are located in areas remote from the public and have restricted access, which further reduces the risk to the public.

The intent of Section 1.5.2 is for the RMP and the facility's design features that are critical to the effective implementation of the RMP to be maintained for the life of the facility. The RMP and its associated critical design features must be reviewed on a regular basis to ensure that the actual condition of the facility is consistent with the plan. The RMP also should be reviewed whenever consideration is given to the alteration of facility features that are critical to the effective implementation of the RMP.

The RMP generally deals with mitigating the risk to the general public. Risk to individuals outside the facility storing toxic, highly toxic, or explosive substances is emphasized because plant personnel are not placed at as high a risk as the general public due to the plant personnel's training in the handling of the toxic, highly toxic, or explosive substances and due to the safety procedures implemented inside the facilities. When these elements (trained personnel and safety procedures) are not present in a facility, then the RMP must mitigate the risk to the plant personnel in the same manner as it mitigates the risk to the general public.

As the result of the prevention program portion of a RMP, buildings and other structures normally falling into Occupancy Category III may be classified into Occupancy Category II if means (e.g., secondary containment) are provided to contain the toxic, highly toxic, or explosive substances in the case of a release. To qualify, secondary containment systems must be designed, installed, and operated to prevent migration of harmful quantities of toxic, highly toxic, or explosive substances out of the system to the air, soil, ground water, or surface water at any time during the use of the structure. This requirement is not to be construed as requiring a secondary containment system to prevent a release of any toxic, highly toxic, or explosive substance into the air. By recognizing that secondary containment shall not allow releases of "harmful" quantities of contaminants, this standard acknowledges that there are substances that might contaminate ground water but do not produce a sufficient concentration of toxic, highly toxic, or explosive substances during a vapor release to constitute a health or safety risk to the public. Because it represents the "last line of defense," secondary containment does not qualify for the reduced classification.

If the beneficial effect of secondary containment can be negated by external forces, such as the overtopping of dike walls by flood waters or the loss of liquid containment of an earthen dike due to excessive ground displacement during a seismic event, then the buildings or other structures in question may not be classified into Occupancy Category II. If the secondary containment is to contain a flammable substance, then implementation of a program of emergency response and preparedness combined with an appropriate fire suppression system would be a prudent action associated with an Occupancy Category II classification. In many jurisdictions, such actions are required by local fire codes.

Also as the result of the prevention program portion of an RMP, buildings and other structures containing toxic, highly toxic, or explosive substances also could be classified as Occupancy Category II for hurricane wind loads when mandatory procedures are used to reduce the risk of release of toxic, highly toxic, or explosive substances during and immediately after these predictable extreme loadings. Examples of such procedures include draining hazardous fluids from a tank when a hurricane is predicted or, conversely, filling a tank with fluid to increase its buckling and overturning resistance. As appropriate to minimize the risk of damage to structures containing toxic, highly toxic, or explosive substances, mandatory procedures necessary for the Occupancy Category II classification should include preventative measures, such as the removal of objects that might become airborne missiles in the vicinity of the structure.

In previous editions of ASCE 7, the definitions of "hazardous" and "extremely hazardous" materials were not provided. Therefore, the determination of the distinction between hazardous and extremely hazardous materials was left to the discretion of the authority having jurisdiction. The change to the use of the terms "toxic" and "highly toxic" based on definitions from Federal law (29 CFR 1910.1200 Appendix A with Amendments as of February 1, 2000) has corrected this problem.

Due to the highly quantitative nature of the definitions for toxic and highly toxic found in 29 CFR 1910.1200 Appendix A [Ref. C1-23], the General Provisions Task Committee felt that the definitions found in federal law should be directly referenced instead of repeated in the body of ASCE 7. The definitions found in 29 CFR 1910.1200 Appendix A are repeated in the following text for reference.

Highly Toxic. A chemical falling within any of the following categories:

1. A chemical that has a median lethal dose (LD[50]) of 50 mg or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 g each.
2. A chemical that has a median lethal dose (LD[50]) of 200 mg or less per kilogram of body weight when administered by continuous contact for 24 hr (or less if death occurs within 24 hr) with the bare skin of albino rabbits weighing between 2 and 3 kg each.
3. A chemical that has a median lethal concentration (LD[50]) in air of 200 parts per million by volume or less of gas or vapor, or 2 mg per liter or less of mist, fume, or dust, when administered by continuous inhalation for 1 hr (or less if death occurs within 1 hr) to albino rats weighing between 200 and 300 g each.

Toxic. A chemical falling within any of the following categories:

1. A chemical that has a median lethal dose (LD[50]) of more than 50 mg per kg, but not more than 500 mg per kg of body weight when administered orally to albino rats weighing between 200 and 300 g each.
2. A chemical that has a median lethal dose [LD(50)] of more than 200 mg per kilogram, but not more than 1,000 mg per kilogram of body weight when administered by continuous contact for 24 hr (or less if death occurs within 24 hr) with the bare skin of albino rabbits weighing between 2 and 3 kg each.
3. A chemical that has a median lethal concentration [LC(50)] in air of more than 200 parts per million but not more than 2,000 parts per million by volume of gas or vapor, or more than 2 mg per liter but not more than 20 mg per liter of mist, fume, or dust, when administered by continuous inhalation for 1 hr (or less if death occurs within 1 hr) to albino rats weighing between 200 and 300 g each.

C1.7 LOAD TESTS

No specific method of test for completed construction has been given in this standard, because it may be found advisable to vary the procedure according to conditions. Some codes require the construction to sustain a superimposed load equal to a stated multiple of the design load without evidence of serious damage. Others specify that the superimposed load shall be equal to a stated multiple of the live load plus a portion of the dead load. Limits are set on maximum deflection under load and after removal of the load. Recovery of at least three-quarters of the maximum deflection, within 24 hr after the load is removed, is a common requirement [Ref. C1-16].

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