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Blast Effects on Buildings
Third edition

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Figure 2.6 Widespread blast damage to conventional glazing

The primary purpose of blast-resistant glazing is to reduce the number of sharp-edged fragments that are created when ordinary annealed or toughened glass is subjected to blast loading. The elongated shards from annealed glass or smaller fragments of toughened glass, which are thrown at high speed, cause severe or lethal injuries to personnel. Elimination or minimisation of this hazard yields a significant protective benefit to building occupants. Furthermore, glass fragments damage fixtures and fittings and more delicate equipment such as computer hardware and are difficult and time-consuming to remove should they enter the air-conditioning system.

As well as incurring injury from glass fragments or other debris, occupants can suffer ear and lung injuries from blast overpressures that enter the building. Hence there are significant benefits to be gained in reducing hazards to occupants and minimising disruption to business by providing a façade that remains unbreached.

Figure 3.6 Bishopsgate crater generated by vehicle bomb

small charge) the lower limit of C_r is 2. When p_s is much greater than ambient pressure (e.g. at short range from a large charge), the upper limit for C_r using this Rankine–Hugoniot prediction is 8. However, because of gas dissociation effects at very close range, C_r can take a value of up to 12 or 13 (Figure 3.11). Figures 3.3 and 3.7 show reflected overpressure and impulse i_r for normally reflected blast wave parameters for spherical and hemispherical charges plotted against scaled distance Z.

Regular and Mach reflection

In consideration of reflection of a blast wave from a structure, the angle of incidence α of the blast wave on the surface of the target structure must be defined. By convention, α is defined as zero when the blast wave impinges normally upon the surface – that is, the direction of travel of the blast wave is perpendicular to the surface (sometimes called 'face-on' loading). When α is 90°, there is no reflection and the target surface is loaded by the incident overpressure, sometimes referred to as 'side-on' pressure. Regular reflection occurs between angles of incidence of 0° and approximately 40° in air, after which Mach reflection takes place.

Mach reflection is a complex process and is sometimes described as a 'spurt'-type effect where the incident wave 'skims' off the reflecting surface rather than 'bouncing' as is the case at lower values of α. The result of this process is that the reflected wave catches up with and fuses with the incident wave at some point above the reflecting surface to produce a third wavefront called the Mach stem. The point of coalescence of the three waves is the *triple point*. In the region behind the Mach stem and reflected waves is a

Table 9.2 Deformation limits

	Protection category			
	1		2	
	θ	μ	θ	μ
Steel–concrete–steel composite	2°	Not applicable	5°	Not applicable

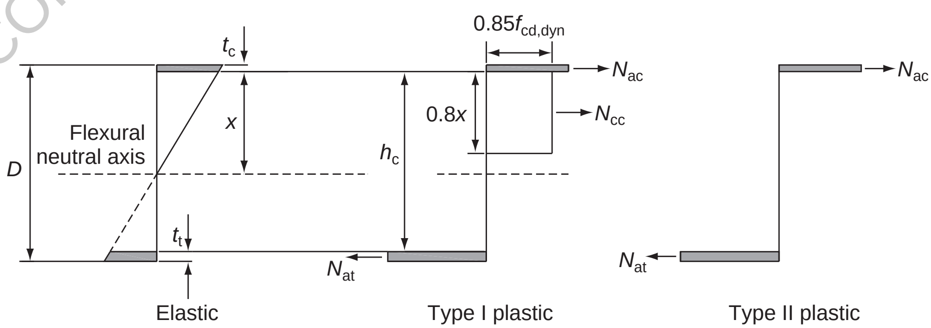
forces within the element and the dynamic reactions onto adjoining elements. Use of static increase factors to account for differences between nominal and actual yield strengths is common to steel and reinforced concrete design but is particularly important to SCS design which tends to be shear-sensitive.

Deformation limits and design cross-sections

As described in Chapter 7, the limiting factor in blast-resistant structural elements is normally a limit on deformation. Typically, limits will be defined in terms of permissible support rotations. For SCS composite materials, three protection categories are defined (Table 9.2). For protection category 1, the concrete contributes to the resistance of the section. This corresponds to protection category 1 for reinforced concrete. For protection category 2, the concrete is unable to contribute to the resistance of the section, and the moment capacity is based on the force couple of the steel plates.

Figure 9.1 illustrates the design cross-sections corresponding to the above protection categories. A type I plastic design cross-section is typically used for protection category 1 (up to 2° support rotation) where normal structural engineering assumptions such as plane sections remaining plane are valid and cracks are limited to below the neutral axis of the section. At larger support rotations, large cracks occur through the whole depth of the section. The loading is therefore resisted purely by the steel plates, and for protection category 2, the design cross-section is adjusted to reflect this (type II plastic).

Figure 9.1 Typical design cross-sections



Box 11.1 Ronan Point, London, 16 May 1968

A gas explosion in the kitchen on the 18th floor of a tower block at Ronan Point caused a progressive collapse of the corner of the building owing to the failure of the structural precast walls. The cladding was incapable of redistributing the gravity loads from the structure above after the blast loads caused failure of the cladding on the explosion floor. The inquiry into the collapse led to the 1970 revision of the Building Regulations and to the requirements for structures to be designed for notional column or transfer beam removal outlined above, and the minimum horizontal and vertical tying provisions. The value of 34 kPa (5 psi), which is the basis for key element design in subsequent revisions to the Building Regulations, was selected with reference to an estimated failure load of the load-bearing flank wall at Ronan Point, based on observational evidence. In practice, it is a notional load and does not specifically relate to the overpressure that would result from a gas explosion or the blast loads due to a high explosive detonation.

The difference in the approach to risk in different jurisdictions relates to tolerance of risk. As such, there need not be consensus between different jurisdictions about the level of risk deemed tolerable. Inasmuch as government (whether local, national or regional) is ultimately accountable for protecting the safety of the population (and therefore sets out the minimum measures it deems necessary based on the political accountability that it is prepared to shoulder), the government may be considered the ultimate ‘client’ for buildings under its responsibility. Differing approaches between different ‘clients’ as defined in this context are therefore to be expected, and, indeed, are the norm.

Figure 12.5 Example vehicle access control points. (a) Single line perimeter. (b) Interlock. (c) Final denial barrier