explosion is of a dynamic nature, it is general practice to assume that it is static, and design checks are normally carried out on this basis.

Accidental impact loads can arise from highway vehicles or construction equipment. A motor vehicle could collide with a wall or column of a multi-storey building or a crane load accidentally impact against a wall at any level. Both of these could cause collapse of a similar nature to those considered under explosive loading, but the method of dealing with the two types of loading may be different, as shown in section 9.4.

The risk of occurrence of an accidental load is obviously of importance in that certain risks, such as the risk of being struck by lightning, are acceptable whilst others are not. Designing for accidental damage adds to the overall cost of the building, and it is necessary to consider the degree of risk versus the increase in cost for proposed design methods to become acceptable.

The risks which society is prepared to accept can be compared numerically by considering the probability of death per person per annum for a series of types of accident. It is obvious that such estimates would vary with both time and geographical location, but values published for the United States based on accidental death statistics for the year 1966 are shown in Table 9.1.

It has also been shown that the risk for accidental damage is similar to that for fire and, since in the case of fire, design criteria are introduced, there is a similar justification for adopting criteria to deal with accidental loading. The estimates for accidental damage were based on a study of the occurrence of abnormal loadings in the United States, and Table 9.2 shows a lower bound to the number of abnormal loadings per annum.

9.3 LIKELIHOOD OF OCCURRENCE OF PROGRESSIVE COLLAPSE

Accepting that accidental loading will occur it is necessary to consider the likelihood of such loading leading to progressive collapse.

Table 9.1 Accidental death statistics for USA, 1966

Cause	*Risk, per person per annum*
Motor vehicle	2.7×10^{-4}
Falling	1.0×10^{-4}
Fire	4.0×10^{-5}
Drowning	2.8×10^{-5}
Firearms	1.3×10^{-5}
Poisoning	1.1×10^{-5}
Earthquake	8.0×10^{-7}
Lightning	5.5×10^{-7}

Table 9.2 Numbers of abnormal loadings for USA, 1966 (lower bounds)

Type	*Number, per annum*
Explosive bombing	204
Gas explosions	131
Explosion of hazardous materials	177
Highway vehicle impact	190
Total/annum	702

A range of loadbearing masonry buildings have been analysed, and basically there are three types of construction which required investigation in relation to accidental damage:

- *Case A,* where there is an outside wall without returns or only one internal return (Fig. 9.1). Removal of a panel would leave the remaining section suspended on the floor slabs above.
- *Case B,* where there is an internal wall without return (Fig. 9.2). The walls above the damaged wall will have to be carried by the floor slab.
- *Case C,* where the removal of a section of a wall imposes high local bearing stresses on a return wall or walls (Fig. 9.3). Remaining masonry is carried by return wall.

An examination of a number of both high-rise (greater than six storeys) and low-rise structures for the possible occurrence of one of the above cases, followed by the removal of a panel and analysis of the remaining structure using the yield-line theory, has shown that there would be little difficulty in designing masonry buildings to satisfy the requirements in regard to partial collapse.

In addition, experimental tests have been conducted on a section of a five-storey brickwork cross-wall structure in which sections of the main cross-walls of the ground floor were removed with a view to testing the stability of the structure in a damaged condition. The structure had not been specially designed to withstand such treatment but it remained stable throughout the tests, and it was concluded that there would be no difficulty in designing a masonry structure to provide 'alternative paths' in the case of accidental damage. In fact, in many cases there would seem to be no necessity for additional elements to secure the safety of the structure.

The likelihood of occurrence of progressive collapse in buildings similar to Ronan Point has been considered, and it is estimated that the possibility of collapse is 0.045%, i.e. 1 in every 2000 of such blocks is likely to collapse in a life of 60 years.