WINDOWS AND BOMB 'BLAST'

THE Research and Experiments Department of the Ministry of Home Security has issued two memoranda dealing with the protection of plate glass windows and other large sheets of glass from the effects of bombing. The following points have been extracted from the bulletins.

EFFECTS OF BLAST

Bulletin No. C.9 is concerned with vertical windows, fixed or made to open, fitted with plate glass $\frac{3}{16}$ in. thick or more. Such windows are common in shop fronts, restaurants and hotels, in internal display cabinets inside or outside buildings. The protection of the interior lit by the window is also considered.

Shop windows are prone to damage by blast because of their large areas. Small panes of plate glass are relatively strong but may fail by the frame breaking. When a bomb explodes the direct blast pressure may force in the window, or the suction following the pressure pulse may pull it outwards. At greater distances reflections of the shock-wave may start strong vibrations in a window which happens to have the same natural frequency. Such a window may break when others close by are unharmed.

The minimum distance from an explosion at which plate glass will escape damage cannot be predicted, but within 200 ft. its chance of survival is small. Beyond that distance the chance depends on factors which include size and thickness of pane, frame fixing, size of bomb and method of detonation and, in particular, the reflection of the blast wave from adjacent buildings. The last factor is chiefly responsible for the apparently freakish fracture of windows. Panes facing the ends of streets leading towards the explosion often break while adjacent windows escape. Where blast travels along a street, the side panes (at shop entrances, etc.) may be broken and the larger front panes escape; elsewhere the reverse may happen.

When a pane breaks under severe blast, pieces may be scattered violently. It is not possible to foretell whether the pieces will fly inwards or outwards. When a pane breaks under distant blast, pieces generally fall inside and outside within a few feet.

Plate glass in internal partitions, show cases, etc., is almost as liable to fracture and to dangerous scattering as glass in external windows. Plate glass in doors, and in sliding or hinged windows, is somewhat less vulnerable. It is desirable to fasten doors wide open during air raids and generally to open windows.

There is no method of preventing the fracture of glass under blast, nor has any method yet been discovered of materially increasing the resistance of glass to blast while retaining its transparency.

Various forms of bracing and damping devices have been investigated but none has been found which can be relied on to strengthen the resistance of the glass. In certain circumstances a bracing device may increase the liability of the pane to fracture. The behaviour of braced windows in air raids has confirmed the investigations. An important objection to such devices is that it may give the occupier of the building a false sense of security, blinding him to the need for providing against the danger of flying glass.

The possibility of increasing the resistance of large sheets of plate glass is being investigated. Research, however, does not at present indicate more than that it is useful to provide a flexible setting for the glass.

MINIMIZING THE RESULTS OF FRACTURE

Since it is not practicable to prevent the fracture of plate glass windows, while retaining their transparency, efforts should be directed towards minimizing the results of breakage. Such results include injury from flying glass, damage to stock or other contents of the building from flying glass and from exposure to weather and, in shops, pilfering of stock and loss of trade.

Shop windows may be covered externally with boarding on stout framing, securely fixed, and provided with hinged shutters over openings exhibiting the display space. Such boarding only gives a slight degree of protection. Rolling shutters of steel or wood give less protection than boarding. Under severe blast they may be dislodged from their guides. Internal damage can be much reduced if a solid brick wall or substantial panelling is built at the back of the window display space.

Wire netting of $\frac{1}{2}$ in. mesh will stop all but the smallest fragments of broken glass; these, except under very severe blast, are not likely to fly far. There is no need to use two layers of netting. The netting should be as close to the glass as possible, preferably touching it. Netting of larger mesh than $\frac{1}{2}$ in. has much less effect in arresting flying glass fragments. A mesh larger than 1 in. may pass dangerous fragments of glass.

Blinds and curtains, particularly if heavy and thick, give a moderate degree of protection against flying glass fragments, except under intense blast.

An adhesive treatment does not make the breakage of glass less likely but, if appropriate to the weight and size of glass, it affords a useful measure of protection against the scattering of fragments. The following "anti-scatter" adhesive treatment is suitable for plate glass $\frac{3}{16}$ in. or $\frac{1}{4}$ in. thick, though it reduces the transparency. A full coat of varnish is brushed on the glass and when it has become tacky a sheet of fabric or strong textile netting is pressed into the varnish so that the whole glass area is covered. When the material is thoroughly set a full coat of varnish is brushed over the whole. Where considerable transparency is required (for example, in display windows) textile strips can be used, though this treatment is not so efficient as a close mesh netting all over the glass. Interspaces between strips should not be more than 6 in. each way. The stronger the textile and adhesive, the better the result. Transparent film of "Cellophane" type pressed into and afterwards coated with varnish is a useful alternative to the fabric or textile netting treatment. Liquid coatings and paper strip are not recommended for plate glass.

© 1940 Nature Publishing Group

GLASS SUBSTITUTES

Bulletin No. C.10 deals with flexible substitutes for glass.

It is pointed out that glass damage from a bomb explosion is always much more widespread than its other effects. The breaking of glass and the violent scattering of its fragments under the blast of high-explosive bombs cause a fair proportion of air raid casualties, and serious inconvenience from exposure to weather. Several 'anti-scatter' treatments to prevent the flying of glass fragments have been recommended in Ministry of Home Security publications, but though such treatments may hold fractured panes together, they neither reduce the risk of breakage nor prevent the pane being wholly dislodged if the blast is violent enough. It appears unwise to replace broken glass with new glass, in view of the risk of repeated attack and because new glass would in turn require protective treatment. Further, supplies of materials for protective treatments can be expected to serve only a fraction of the glass at present in use. The utility of a flexible substitute for glass, that can be harmlessly dislodged by blast and readily replaced, is therefore obvious.

Flexible substitutes may be either translucent or, where permanent obscuration is required, opaque. Most translucent substitutes are at present made of synthetic resins or cellulose substances reinforced with metal or textile mesh. Alternatively, cotton or linen textiles may be used ; these are not ordinarily windproof or rainproof, but may be obtained suitably treated with cellulose lacquer or with boiled linseed oil, or alternatively, may be treated in position at the window opening.

Only the stiffer materials, that is, those reinforced with metal mesh, are likely to be suitable for use in roof glazing bars. They should probably be supported below at 2 ft. intervals, as recommended for roof glass in R. and E. Department Bulletin C. 7. No tests have yet been carried out.

For vertical glazing, preliminary blast tests show that if flexible glass substitutes are fixed with nails or staples, the material when displaced is usually torn at the edges. Also where edge fixing is too strong the material may be burst in the centre. Fixing with a soft non-setting putty or mastic, fastening the edges with adhesive tape, fixing by ordinary wood glazing beads in the glass rebates, fixing on the face of the frame by plasterer's lath or similar wood strip, and holding the edges of the material in strip rubber channelling are being tested. It is important that the material should not be wrapped around beads or laths, and nails used to fix such beads should not perforate the edge of the material.

Where permanent obscuration is required galvanized flat sheet steel, composite sheets of asbestos and steel, hard wallboards are suggested for roof glazing. These will stand up to blast pressures considerably greater than those that fracture roof glass. When displaced they can usually be replaced undamaged. They can be fixed in the same way as roof glass. Thinner and more flexible opaque materials such as combinations of wire mesh and bituminous sheeting, soft wallboards, etc., will probably require support from beneath. Experiments have shown that flat asbestos-cement sheeting, including the newer 'flexible' type, is readily fractured by blast ; there is, therefore, little to be gained by using it as a glass substitute in roof glazing bars, since it is likely to be fractured before it is displaced, though, when fractured, it is not so dangerous as glass. Wall-boards require painting or impregnation with preservative to give protection against weather.

For vertical glazing, the same materials can be used, and also bituminous sheeting, plywood and plasterboard can be used. The two latter should be painted on the face and on the edges to prevent the soaking in of moisture. A plasterboard faced with bituminous sheet is obtainable.

As with translucent materials, firm fixing, as by nailing, is undesirable.

There are many substitute materials on the market, and a list of twenty-six known to the Department, with names and addresses of manufacturers, is given. The inclusion of a name in the list neither gives nor implies any guarantee by the Ministry of Home Security of the reliability at any time of the price or quality or of the availability of the materials.

BRACING SYSTEMS

Bulletin No. B. 6, issued by the Research and Experiments Department of the Ministry of Home Security, discusses bracing systems for large sheets of glass. The static strength of a sheet of glass, assumed to be subjected to a uniformly distributed load over its whole surface, is increased if a brace is fitted which provides a single central rigid support having an area greater than $A_c = 1/16$ (length of the sheet $\times$ breadth of the sheet). If the area of the central rigid support is less than A_c, the strength of the pane is decreased, since the more concentrated forces at the support induce high stresses at that point. If the support is not rigid the strengthening effect is diminished, and so also is the concentration of stress.

If the brace restrains movement at the centre of the pane, the glass between the centre and the edges acquires a natural frequency of vibration higher than that of the pane without the brace. Consequently the equivalent static pressure exerted by the blast on the braced pane is increased. It has been calculated that if the natural frequency of the pane, without a brace, is 10 cycles per second, as with a sheet of plate glass $\frac{1}{4}$ in. thick and 9 ft. square, the effect of fitting a rigid central brace is to increase the equivalent static load exerted by the blast about $3\frac{1}{2}$ times.

In practice, the brace will not act as a rigid support but will always allow some movement of the pane, depending on the tension of the stay wires and their inclination to the pane. The fundamental frequency of the unbraced pane will thus not be entirely eliminated by the fitting of the brace, though vibration of the pane at this frequency will be greatly restrained.

It follows that fitting a more or less rigid support at the centre of a sheet of glass always increases the effective pressure and suction forces exerted by the blast wave, and may or may not increase the strength of the pane. Consequently the effective resistance which the glass can offer to the incident blast wave may or may not be increased. The two effects are opposing and either may predominate, but in no case is the effect likely to be great ; in other words, the brace may make the conditions worse or better, but it is not likely to have much effect either way. A brace will not prevent flying splinters of glass after a break occurs.

© 1940 Nature Publishing Group