PAPER No. 262

AIR RAID PROTECTION FOR BUILDINGS, ETC.

By N. B. Shroff., f. r. i. b. a.

1. Modern warfare has necessitated considerations for adequate protection of buildings from air attacks. The destructive effects of bombing and the damage it can cause to both life and property are tremendous. Apart from military defence, various methods to meet this emergency as far as possible, are needed for civic defence. Provisions have to be made for the protection of life and property from the blast and splinters of high explosive bombs, and from fires caused by incendiary bombs. Shelters of heavy and light protection, refuge rooms and trenches have to be provided for the masses in schools, offices and factories, for the floating population and for individual residences. Important targets of attacks are factories, aerodromes, railway stations, vital services centres, hospitals, military camps, etc. Indiscriminate bombing of civilian population of towns also takes place. Attempts are made to make the targets less recognisable and visible, by means of camouflaging and black-outs.

In order to provide adequate protection, it is necessary to study the force and effects of bombing. Various types of bombs are devised and used for attacks and these may mainly be classed as incendiary bombs, high explosive bombs and gas bombs.

Incendiary Bombs

2. It is easy to set large and crowded cities ablaze by means of incendiary bombs and with them many fires could be started at the same time. In London, in 1940, fires were started by the 2½ lbs Magnesium bombs and over Singapore and Rangoon, the Japanese have used the 120 lbs Phosphorus bombs. Magnesium bombs on bursting, produce intense heat, which is even capable of melting thin iron sheets. The Phosphorus bomb scatters hundreds of bits of flaming stuff all round. The heavy type is likely to fall through the top floor. It may explode when it strikes or after it has pierced some distance.

High Explosive Bombs

3. High explosive bombs are of different types, varying in weight from 50 lbs to 4,000 lbs and even more and are

intended to produce different effects. The heavy armour piercing bombs are designed for deep penetration and are used for demolishing factories and other heavily protected centres. The medium weight general purpose bombs are designed for maximum destruction in built up areas by intense blast and splinter effect. The delayed action ones can penetrate some distance into resisting-materials before exploding, and can perforate several concrete floors in multi-storeyed buildings. The lighter anti-personnel bombs are intended to cause injury to persons in the open by fragmentation and are fused to fire on impact.

Effect of Explosion

4. High explosive bombs make large craters in the ground and on bursting, cause an earthquake impulse in the near vicinity which also causes damage to structures. The blast or air pressure generated by the explosion is of considerable magnitude but of very short duration and is followed by a suction wave which often does more damage. This suction wave is due to the wave of emptiness following immediately on the wave of compression. The result of this on a building is that in the first instance, it is compressed but then immediately afterwards it bursts outwards and collapses. The effect of explosion is greater in a confined space like a street or building than in an open space.

Bombs are likely to strike the sides of a building as well as the roof because the angle of approach of the bomb when it strikes the target is between 15 to 35 degrees from the vertical, the angle and the striking velocity depending upon the height and speed of the aircraft and weight of the bomb.

Blast effect is greater when a bomb touches a hard surface than when it penetrates soft earth; therefore shelters, where possible, are covered with earth, and soft earth round a building is preferable. A bomb bursting in soft ground will have its splinter effect considerably reduced and there will be a tendency for its blast effect to go upwards, whereas if it bursts on a hard surface, the blast and splinter effect are more horizontal and more damaging to buildings.

Gas Bombs

5. Gas bombs are also of various types. Chemical substances in liquid or gas form are used to produce poisonous or irritant effects on the human body. They are either dropped in bombs or sprayed directly from aeroplanes Effects of gas are most distressing. Buildings, roads and other surfaces which come in contact with gas make them dangerous for use until they are properly decontaminated. Food, clothes and

unprotected parts of the human body also get contaminated. In absorbent surfaces, they penetrate more and take longer to evaporate naturally or to become neutralised artificially. Tarred road surfaces, bricks, stone and concrete also absorb gases.

Protection Work

6. To protect against incendiary bombs, resistance against penetration and fire should be provided. Six inches thick reinforced cement concrete slab is necessary for the roof.

In existing buildings, arrangements should be made to provide proper fire escapes. Combustible materials should not be kept or stored round the staircase or lift shafts, in enclosed courtyards, and near the outer exits. A building should not become a fire-trap when it blazes up, reducing the chances of rescue

Normally, it is not practicable to provide effective protection against direct hits of large high-explosive bombs in ordinary buildings, due to its heavy cost. It needs about six feet thick concrete roof to make it bomb proof. It may be pointed out that in any case, this protection against direct hits of modern heavy explosive bombs should be considered as partial unless the shelter is very many feet underground. Therefore normally, protection against damage by blast and splinters from high explosive bombs, exploding more than 50 feet away, should be aimed at. This could be provided by making the shelter preferably underground, with thick protective walls and sufficiently thick floor with supports for taking the load of falling debris of the structure above.

Though thick walls are necessary for a ground floor structure to afford protection against splinter and blast, but in order to minimise the destructive effect of blast pressure upon multi-storeyed buildings, framed structures, with thin walls which would yield to blast pressure without transmitting damaging stresses to the structural framework, would be preferable.

Screen or Baffle Walls

7. Any one within 100 yards' radius of a hit is likely to be killed or badly hurt, unless he is behind a wall of proper thickness. Ordinary doors and windows even with wooden shutters will not keep out bomb splinters, which travel at twice the speed of a rifle bullet, nor will they give protection from machine-gunning. Best of all for ordinary purposes, is a wall of brick in 1 : 3 cement mortar, 13½ inches thick built up to a height of six feet above the top of the plinth, in front of the

openings. The distance between the blast wall and building should be about 4 feet. The end of the walls should cover the opening at an angle of 45 degrees. The common faults which should be guarded against are that the walls should not be built unnecessarily high, otherwise they become a source of danger unless they are buttressed to resist over-turning. Walls over 8 feet high should usually be reinforced. The walls should also be of sufficient lengths to protect the danger angles at each end.

Cover walls built of sandbags give equally good protection. These will be tapering and about 2'-6" wide at the top. The height and length will be the same as that of brick walls.

Protection to main walls of structures could also be given by building a baffle wall round the structure, about 6 feet to 8 feet away. This will resist the blast and may even fall down in case of heavy blast, saving the protected structure.

Protection for Statues, etc.

8. As protection against direct hits is not practicable; and as direct hits are rare, it is not necessary to cover completely any statues, etc., of importance, but they could be protected against blast and splinters by walls, sandbags or any other means, erected about 6 to 8 feet height.

Shelters

9. To meet the different needs and purposes, various types of shelters are devised. They are either light or with heavy protection. These could be within a building or outside and independent, either under or over ground. In existing buildings, suitable places could be strengthened and converted into shelters.

Lateral and overhead protection should be considered. For General purposes, 13½ inches walls in cement with six inches R. C. C. roof slab, will afford protection from blast and splinters of medium weight bombs falling 50 feet away. Small ventilators fitted with plugs may be provided. For gas protection, a lobby at the entrance to form a pocket for air lock, with double doors, is essential. A blanket or carpet weighed down with a long wooden strip should be provided of which one foot should be left trailing on the floor, over the side frames of the doors. Emergency exits are also necessary in large shelters.

In shelters with heavy protection, not only the top and the sides have to be heavily protected but also the bottom to resist deflected bombs which may penetrate under the shelter. To make an underground shelter bomb proof, it will be necessary

to provide about 6 feet thick concrete for the roof and the side walls and about 4 feet of concrete for the floor near the walls and reduced to 2 feet for the middle portion.

A shelter could be designed with double protection by providing a corridor all round, to isolate the protected unit from the shock waves transmitted through the surrounding earth.

Refuge Room

10. A refuge room should be selected in a suitable place in existing buildings, either in the basement or on the ground floor. It should also be free from the danger of flooding if a nearby water main bursts. A small room like a store, pantry or dressing room, with proper accesses, will be suitable. The walls, if thin, should be thickened and the roof strutted up. The window openings should be protected or closed. The rooms could be equipped with food, water and other essential necessities.

Slit Trenches

11. The cheapest and the quickest method of protection is open or covered trenches. This however should not be taken as a very effective measure. The slit trenches may be dug in zig-zag shape, at least 2′-6″ wide at the top and 2′-0″ at the bottom, and at least 4′-6″ deep. Each side should not be less than 5 feet and not more than 25 feet long. About 2 feet length should be provided for each person using the trench. The trenches should be located far away from the buildings and at least, at a distance of half the height of the buildings. They may be under trees if possible. If more than one shelter is needed, trenches should be 25 feet to 50 feet apart. A drainage sump about 2 feet deep and 2 feet diameter may be dug at each corner if required. The trenches could be strutted, if necessary.

Flying Glass

12. In case of blast from explosive bombs, there is great danger to life from the flying glass of windows. Glass is most likely to fly at right-angles to its frame. It is a mistake to keep the glass windows shut to resist blast. It is advisable to keep them open to permit free passage for blast. Openings in buildings are preferable in a way that they will reduce the chances of house collapse due to a suction wave. The panelled shutters may be closed to give protection against splinters.

Glass in all cases must be reinforced by sticking something unbreakable to it. If light is to be permitted through it, some protection could be obtained by sticking strips of strong paper

or cotton cloth at right angles to each other and not more than 4 inches apart, over the glass and the frame. Wired glass gives good resistance.

Factory Designs

13. Factory designs need special considerations. They must be practicable in view of the present labour and materials available, and must permit ultra-rapid construction. Safety of plant and process if attacked, and also the safety of the workers must be provided. They should also meet the requirements of the industries they serve.

Devices for black-out arrangements for the glazed portions, and light-locks for entrances should be provided. The North-lights should be designed so that the glazed portion is sloping inwards from the apex, instead of the usual straight or sloping outwards surfaces. This avoids glitter in day-light as well as moon-light, makes black-out and camouflage easy and gives safety from falling glass.

These days, windowless factories are designed which permit of two or three shifts of production. Open web trusses of large spans of treated timber are also used to meet the scarcity of steel.

The lay-out of factory buildings, and similar important structures for service centres or hangers for aerodromes, etc., is important, so that they could be so planned so as to cause least damage to the other surrounding structures in case of a hit to one of them.

Shelters located in factories should be such that they are not under overhead water tanks or with heavy machinery on upper floors. They should be away from columns in exposed position supporting heavy loads, and also from water reservoirs. Their location should not be close to high or heavy chimney stacks.

Black-out

14. Arrangements for black-out in all buildings are necessary, instructions for which are notified by local authorities. The main object is to cover all lights in such a way that no direct light is thrown upwards, nor any bright light thrown out or reflected from walls or floors.

Camouflaging

15. Camouflaging is done to make the targets less recognisable in day-time, from the air. The object should be made to merge in the surroundings. Effect could be obtained by

skilful application of imitative patches and patterns of harmonious colours, so as to break the outline and shape of the object. A good example of camouflaging in nature is in wild animals, like the stripes on a tiger matching the surroundings in which he moves. Covering by nets is also applied. Study of shadows and silhouettes should be given careful consideration.

Aesthetics

16. In an attempt to provide bare protection against air raids, in existing or new structures it is very likely to make them hideous in appearance. This is bound to create a very adverse psychological effect of horror on human minds. It is therefore necessary to provide security combined with pleasant surroundings. This creates problems which require special treatment. Better planning and proper arrangement of equipment, etc., adds to the efficiency and comforts of the occupants. Glass shop-fronts protected with wooden planks may be painted over artistically which will make them look more interesting and pleasant and will also add to the publicity of the shop. Protection to buildings of architectural importance could be provided, without materially impairing their appearance, if done in a proper manner.

Changing Conditions

17. Adequate protection has to be provided to meet the different conditions, and these conditions are changing rapidly. The incendiary bombs used over London were light in weight while the Japanese incendiary bombs used in Burma were of medium weight. Smaller towns may need light shelters while larger cities with thick population, factories and other service centres, need better arrangements as attacks are likely to be heavier at such places. It is difficult to determine any future conditions in the Province, and probably light temporary shelters will be suitable. Anderson shelters, which are light shelters of circular steel corrugated sheets covered with earth, were found to be unsuitable in places in England where sustained attacks continued throughout the day or night and were intended to provide shelter for short periods only. Need for heavily protected shelters, where people could really sleep and rest, free from the nerve-racking sounds of the bursting of high explosive bombs, was felt. Such conditions are however not likely to arise in the Punjab, but with the growing defence of India, better arrangements for the protection of the masses are necessary.

DISCUSSION

The Author in introducing his Paper said that in the present days, the subject of A. R. P. had become of great interest to all. It was so wide that one could even write a volume about it, and much could be discussed. He said that in this paper attempt had been made to cover the subject in a few pages, giving a summary of the points of interest, which might be helpful in forming a general idea of the subject to those who might he called upon to do the work in an emergency.

The co-operation and understanding of the public, in the matter, was necessary, and the Paper was written in simple language so that it could even be understood by laymen, creating interest in them for taking up the work, if and when necessity arose.

In the beginning of the Paper, the various kinds of bombs and their effects were given. He mentioned that in the recent bombing of Calcutta only anti-personal bombs were used and consequently the damage done was very little. Further in the Paper the different kinds of protections were dealt with, touching various points such as baffle walls, light and heavy shelters, factory designs, camouflaging, etc.

With regard to the protection or baffle walls, he added that they could also be of sundried bricks and mud. These would be cheaper and good for absorbing the intensity of blast.

Due to the changed situation of the war, the danger of attack on this part of India was much reduced, and the Government were thinking of not going further with their A. R. P. programme, but it was necessary to study the subject and keep prepared to meet emergency of any sort. In the end he hoped that no such damage would befall on us.

Mr. R. Trevor Jones said that Mr. Shroff's Paper was very interesting and he was prompted to ask a few questions which possibly he may find difficult to answer. He would particularly like to comment on his remarks on the effect of aesthetics of existing and new building structures in providing protection against air raids. This leads one to think a lot. After this war it must be considered that we may be afflicted from time to time by air attacks and that as we are doing to-day or have done for many years to protect our buildings and engineering works against earthquakes and floods, must these buildings be so designed as to provide protection against the aerial bombs? No doubt this question is and has been considered by many post-war planning authorities but it is rather a perturbing thought. Does it mean that we are to

revert to troglodyte life ? The engineer and the geologist to build the tunnel and the cave and the architect to plan and beautify the interior—how we shall !

Or does it mean that as we have to be covered by 6 feet of concrete to be High Explosive bomb proof, complete protection can never be afforded and we must be satisfied with the "hit and miss" methods which we are forced to adopt in this country largely owing to shortage of supplies of all sorts—to rely on the slit trench, the blast wall and the blocked opening. But anyway whatever we have to design in future, aerial warfare teaches us that congestion and overcrowding is more than ever to be forbidden. We want more room to expand, more open space, more land in which to obtain recreation and in war time somewhere to go to ground.

Mr. C. H. Mckenna said that the author of this Paper is to be complimented on his dealing with a subject which, fortunately for the Punjab, has not been tried out. Even though under recent orders from the Government of India the Punjab has now been classified as being out of range of hostile aircraft for the present, nevertheless, engineers may be sent to any part of India which may be under attack and therefore a study of this Paper by engineers may be of vital importance.

The author cannot be expected to cover every item in connection with structural protection for buildings and he may be pardoned if he gave a few details of up to date information in connection therewith.

Recent report regarding incendiary bombs used by Germans over Great Britain show that in many cases these weigh 5 lbs. and are composed of two parts—the top part being the usual magnesium electron incendiary bomb and the bottom half an explosive portion weighing about 3 lbs which on impact falls away allowing the bomb to split up; the incendiary portion ignites but the detonation of the explosive portion is delayed some minutes after the fire bomb itself has ignited. This new type of bomb would penetrate most roofs and the previous standard of 5—6 inches reinforced concrete roof will not suffice. According to experiments carried out in the Ministry of Home Security, Experimental School, it would require cover of about 5 feet of earth to afford protection against this type.

The reasons, the Germans are using this new type of explosive incendiary bomb, is because women and even small boys are able to deal with the ordinary 2 lbs bomb. Another type of bomb which is used against certain targets like Aerodromes, Warehouses, etc., is the oil bomb which weighs about 200 lb.

and requires special technique, *e.g.*, from appliances to deal with the burning oil.

In the paragraph dealing with high explosive bombs, the author has omitted the parachute mine. This bomb is between 6—8 feet long and is let down on a parachute 27 feet diameter falling at about 40 miles per hour. On impact it does not penetrate the ground surface very much and thus causes the maximum damage to surrounding buildings and personnel. Large areas of devastation in London have been caused by these parachute mines. Accurate aim cannot be taken when releasing such mines but in conjested areas it does not matter where they drop as great havoc will be caused. In dealing with the effects of the explosion of high explosive bombs an earth tremor it transmitted which effects the foundation of buildings and one of the means of detecting an unexploded bomb is to look for cracks and settlement in the foundations of nearby buildings. Blasts exerts a positive pressure followed immediately by a negative or suction pressure and it is considered that this latter negative pressure is what causes the main damage to buildings. Engineers might be interested to know that in the new extensions being made in the Central Workshops, Amritsar, the roof trusses are carried on independent columns and the panelling in between is independent of these columns so that if high explosive bombs drops nearby, these panels will or may collapse whereas the roof and side stanchions remain intact.

Should the enemy ever decide to use gas, it is likely that he will resort to liquid gas either Mustard or Lewisite variety; as these gases, being in liquid form, or not volatile to any great extent. One of the means of attack is by spraying liquid gas from the air on workers leaving a factory during the meal hour interval and thereby holding up production in a factory for a matter of 4 or 5 months.

Many people and even engineers are under the impression that bomb proof buildings are practical proposition. In Great Britain use has been made of deep tube railway stations and in Ramsgate tunnels were excavated in the chalk cliffs. In either case Government was very much against the principle of congregating people in underground tunnels as the effect on their morale was very distressing. The standard to be aimed at when fixing protection by screen walls, is that required to prevent bomb splinters penetrating a 13½ inches brick wall in 1·3 cement mortar from a 500 lbs. high explosive bomb dropping not nearer than 50 feet. Any bomb within 50 feet of an object is considered to be a technical direct hit and no protection can be guaranteed against such. In the Punjab owing to the scarcity of cement and bricks which were monopolised for

Aerodrome construction, resort has been made to the construction of protective walls in sundried bricks in mud mortar. The minimum thickness required for these walls at any section is 30 inches but different thicknesses are required for walls of different heights for stability. It has been found by experiment that such mud walls have stood up very well to the effect of 500 lbs high explosive bombs.

Sand bags are only used for temporary protection of gun posts, etc., as it has been found that sand bags rot after few months exposure due to weather. Their use has largely been discontinued in Great Britain.

Very few Statues in London have been protected and the only ones I have seen are "Eros Statue" in Piccadilly Circus and "The Gunners Memorial" near Hyde Park Corner. The Cenotaph in Whitehall is not protected. Many of the statues have been scarred by bomb splinters but this has probably enhanced their value as a memorial.

Street shelters are not a practical proposition in Indian cities owing to lack of space and therefore the selection of a refuge room on the ground floor or basement is to be preferred. The ideal in selection of such a room should be one with a small span containing an entrance and an exit, which has as little glass as possible and facing soft ground as opposed to a hardmetalled road. Six square feet floor space should be allowed for each person sheltering in such a room but this will vary with the season and in the very hot summer some type of exhaust fan is to be preferred. However in the Punjab, constant air attack, as has taken place in cities in the Great Britain, is not likely and any raids would be of the hit and run variety and the length of time which personnel may have to spend in a refuge room would not therefore, be very long.

As the author is an Architect and is therefore, very keen on the appearance of a building, we can understand his note on aesthetics in connection with structural precautions. In London many of the buildings with plate glass shop fronts have had the glass removed and substituted by tastily painted woodwork with a small opening about 3 feet square through which passers-by can examine the wares displayed. Otherwise in Great Britain there has been very little attempt to provide any decorative effect in protective work against air raids.

Mr. G. R. Sawhney said that the Author deserves our thanks for writing this very instructive Paper on a very important subject, which deals with measures to be adopted for the safety of personnel and property in towns which are vulnerable to bombing from aircraft.

The Paper reads as if the author had the protection of the buildings more in his thoughts than the personnel who may be living or may have to take shelter in them.

As the previous speakers have covered most of the ground already he would confine his remarks to a few general points.

The author seems to have based his ideas more on what we can gather from various A. R. P. Pamphlets; as applicable to conditions in England, and seems to have overlooked the fact that local conditions need different treatment in many ways.

It is the way an artist would look at this subject and not an engineer.

Walls built of sand bags do not give just as good a protection as those built in burnt brick in cement or sundried bricks in mud.

The bags are likely to get deteriorated by weather and hence these walls should not, as a rule, be made of these bags for such protection purposes. The distance between the protection wall and the building should vary from 2½ feet and 5 feet, depending on weather the doors or openings it has to protect are to be used by men for walking in and out or also for the man on structures to be carried in.

In case of openings for Engine Rooms, etc., for which heavy machinery may have to be taken out, a far bigger distance than 5 feet space have to be provided for, as extra length of the wall on either side of the opening will increase considerably with increase in the distance from building to wall. The wall should as a rule be placed at only 2½ feet for ordinary buildings, offices, etc.

The height of the wall for the protection of statues would depend on the height of the statue to be protected.

Shelters are not much use in this country where space can be found for silt trenches. Even purely good refuge internal rooms can generally be found in most of the single storey houses while in congested part of an old city the short narrow lanes make quite good shelters.

A very big percentage of the injuries is caused by flying glass of windows and doors, hence such door must, as far as possible, be kept open during raids. As this cannot be possible at all times the next best thing to do is to treat glass panes.

Cheapest and effective method to do so is to paste muslin cloth with gum or varnish replacing the glass by " vimlite " or protecting the panes by means of wire gauze or other wire mesh screens. There are other methods as well but they are

very expensive and also materials are not available in the open market.

Underground shelters and covered trenches are not suitable to our conditions and should be avoided to be built in this country.

The height of a wall should be fixed with reference to the floor of a room or part of the building to be protected against splinters and blast and not its plinth. Even cellars may have to be protected, in which case the walls built 6 to 8 feet above plinth would look rediculous.

Mr. D. A. Howell said that the author was to be complimented on producing a Paper on a subject of almost universal importance in these days. Fortunately in the Punjab, the threat of war and of air attack was receding for the time being but it was impossible to foretell when it might approach again.

There was a great deal of useful and comprehensive literature available on the subject of A. R. P. Protection. Practically the whole of this had originated in Great Britain mainly produced by the Government Departments responsible for advising on and carrying out A. R. P. measures during the present war.

The problems of A. R. P. generally were ample and straightforward from an engineering point of view ; it was mainly a question of what degree of protection could be afforded—the cost entered into everything more so than in the case of peacetime engineering works because of the feeling that much protection works would only be needed so long as the threat of an attack persisted.

The factor of excessive cost had generally precluded higher scale of protection, at any rate for civil defence buildings in Northern India, than the lowest laid down, *viz.*, against blast and splinters from high explosive bombs falling more than 50 feet away.

Generally, the only protection proposed was lateral, as the cost of dealing with roof of buildings, even to resist the light kilo incendiary bombs would be prohibitive.

The standard types of walls for lateral protection consisted of burnt brickwork 13½" thick, laid in 1 : 3 cement-sand mortar; cement concrete 15" thick ; R. C. concrete 10" to 12" thick ; sand or earth revetments 30" thick, etc. etc., the normal height being 5½ to 6 feet above the ground floor level so as to protect personnel sheltering inside the rooms. In the case of walls exceeding about 7 or 7½ feet in height, buttressing was required in order to counteract overturning effect by blast.

The experts considered that the usually accepted valve of blast effect on the whole area of a wall was on the neighbourhood of one lb per square inch but that this could be reduced to 50 per cent., allowing for the inertia of the mass of the wall. A further reduction to 60 lbs per square inch was obtained by assuming that the wall and its footing embedded in the ground, acted as a cantilever.

The buttresses was arranged to divide the walls into panels each not exceeding one hundred square feet, in area. These principles originally applied to cases of 500 lbs high explosive bombs falling more than 50 feet away. Since then the weight of bombs had increased and we heard of 2,000 lb bombs, 4,000 lb bombs and still heavier bombs. The blast effected from these was obviously much greater than that defined above and it could safely be said without fear of contradiction that standard types of walls already described were not fully blast-proof.

Nevertheless, these walls did fulfil a very important function of intercepting splinters and stopping a great deal of blast effect and they were probably the best protection that could be provided with the money. It was highly important in the opinion of the speaker that no matter what they were made of, the walls should be of homogeneous construction, so far as practicable; for example, cement concrete, sand or earth, shingle or ballast.

In the case of a brick wall, the same condition was obtained by using a rich mortar (1 : 3) which would have a strength almost equal to that of the bricks themselves.

The reason for insisting on homogeneous construction was that a wall formed of blocks or lumps cemented together with weaker mortar, if struck by blast, might be demolished in such a manner, that the strong blocks or lumps would become detached and move forward as projectiles.

A common effect of blast was to cause " spalling " on the opposite side of the wall whereby lenticular shapped pieces of the wall got broken off.

For the reasons above discussed, walls should not be constructed of burnt brick in mud mortar, burnt brick in weak cement or lime mortar, etc. The same objections applied to all forms of katcha-pakka work, walls of cement concrete faced with brickwork and other non-homogeneous types of construction.

The specifications of walls described in official A. R. P. hand-books in India were mainly based on British practice.

The speaker, however, had proposed for adoption in the dry climate of the Punjab, protection walls not less than 30 inches in thickness, built of sundried bricks laid in mud mortar, covered with a cheap plaster intended to reduce damage by rain in the monsoon. As an alternative again, *pise* walls could be used of the same thickness. Both of these types were practically homogeneous in construction and they possessed various advantages over burnt brick work laid in 1 : 3 cement, sand mortar.

Due to their thickness and weight, they had a very much higher resistance to factor, bearing in mind that blast effect of the large high explosive bombs now in use was very much greater than of the 500 lbs high explosive bombs on which these blast protection walls had been originally designed.

Moreover, the mud or *pise* walls had very considerable resiliency and would absorb the "shock" of blast much better than brick. There would thus be much less risk of "spallings."

The speaker suggested that everybody would agree, if there were a choice between being hit on the head by a piece of mud or by the piece of burnt brick, it would be in favour of the mud every time.

Other advantages were lower cost, the materials were in general use all over the country and were obtainable almost everywhere.

The speaker thought that the problem of affording lateral protection to ground floor rooms by the provision of these so-called blast and splinter proof walls was comparatively simple, but undoubtedly such walls had the effect of making rooms dark and also made them warmer and comfortable in the hot season. If it were contemplated to so design buildings as to facilitate lateral blast and splinter proof protection in the future, he suggested that the following points should be observed :—

(*a*) All walls to be built at least 13½" thick of B. B. in cement mortar (1 : 3) at least up to 6 feet above the ground floor level;

(*b*) Efforts should be made to keep window sills at not less than 6 feet above ground floor level; if this were not practicable, the window sills should be kept as high as possible;

(*c*) Doorway openings wherever possible, should be so arranged, as to be masked by other walls or parts of the building, against blast and splinters from any high explosive bomb falling more than 50 feet away.

In regard to roofs and ceilings, the speaker considered that reinforced brickwork construction, jack arches and also first and second class mudroofs with tiles were unsuitable and not desirable in view of A. R. P. requirements.

The best that roofs and floors consisted of R. C. C. slabs about 6 inches thick, while in the hills, pentroofs covered by galvanised sheeting were suitable.

The Author in replying to Mr. Trevor Jone's observations regarding aesthetics said that it was necessary to relieve the psychological effect of strain on human minds whether in peace time or war time, as such, consideration to aesthetics was desirable. It was not possible to say at present whether all buildings in future would have to be provided with air-raid protection, but perhaps some provision would have to be made which might be used in emergency with sense of security and also could be used in peace time with convenience.

Further in reply to the other speakers he said that the subject had been treated in outline to suit different local conditions. In concluding he remarked that it was not possible to lay down any hard and fast rules in the matter but they had to be flexible to satisfy many and varied individual circumstances, which were bound to arise in an emergency.