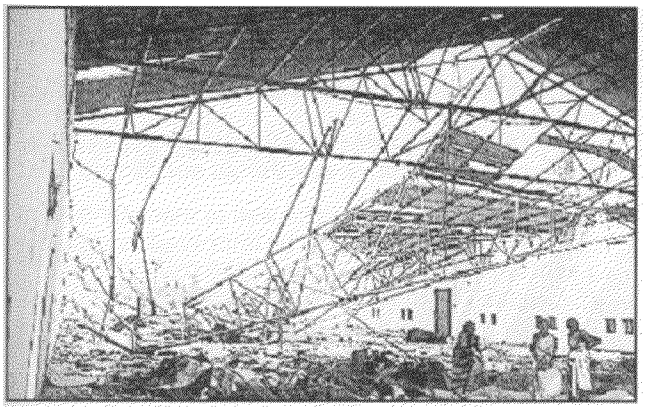

Fig 4 : Damage to a Storage Godown

these openings into the "near empty" godowns has given rise to the build-up of uplift and nigh unprecedented internal pressure, which caused the collapse of the gable end wall including its RCC columns and roof truss system including its cladding (Fig 4). Openings in the wall, allowing the gusty wind to enter, insufficient cover to reinforcement in the columns of the gable wall, main rods in the columns placed in the normal to wind direction and lapping of more than 50 per cent of rods at the same point are some of the reasons for the failure of the building.

Industrial Structures

Most of the industrial structures are provided with A.C sheet roofing and also failure of such roofs are very common during cyclones, due to their inadequate strength to resist uplift force and to debris attack, poor connection details and also due to their low fatigue strength owing to their material brittleness. The complete A.C. Sheet roof cladding of a big industry shed of size 80m x 160m had failed due to the debris impact on north light glass, thus leading to increased internal pressure, and hence failure of total roof system (Fig 5).

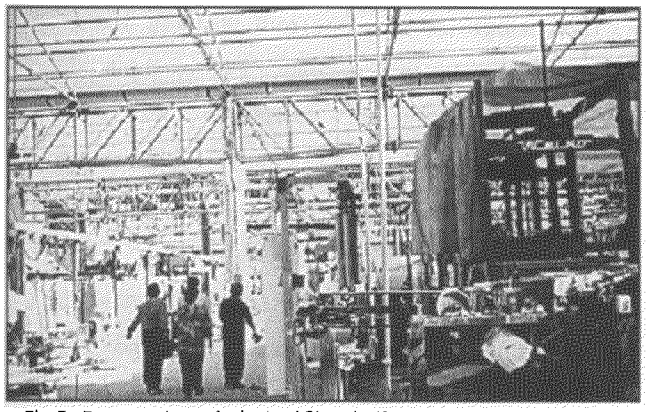

Fig 5 Damage to an Industrial Structure

It is recommended to provide toughened glass to the north light covering to resist the debris impact and to provide 'U' bolts (4 Nos. for each sheet) in place of 'J' bolts, to have better connection system and number of support points to resist cyclonic forces.

Poultry Sheds

This region has got lot of poultry sheds. These structures are two/three storeyed building of size 40 x 16m with slender columns The eaves level is 5m above ground level The roof is AC sheets, and there is no wall in between the columns Since there is no lateral resistance to the cyclonic wind by this slender, two storeyed structure, there were complete failures of the poultry sheds in these areas Almost all the poultry sheds have lost their AC roof and some of the sheds have lost the column framework also.

Gujarat Cyclone

Residential Dwellings

The damage to housing sector due to this cyclone in the surveyed area is less when compared to the previous cyclones. This may be due to the less number of thatched houses in this area. The walls of the most of the residential houses were with brick / stone blocks which are somewhat stronger to resist lateral wind forces The roof of most of the houses is either with RCC or tiles. Of course the tiled houses were damaged due to blowing away of tiles. The tents and hutments of thousands of salt workers who were living in the creek surrounding the Kandla Port area were literally washed away due to the continued action of tidal + storm surge forces which was reported to be over 5 to 8 metres in some places.

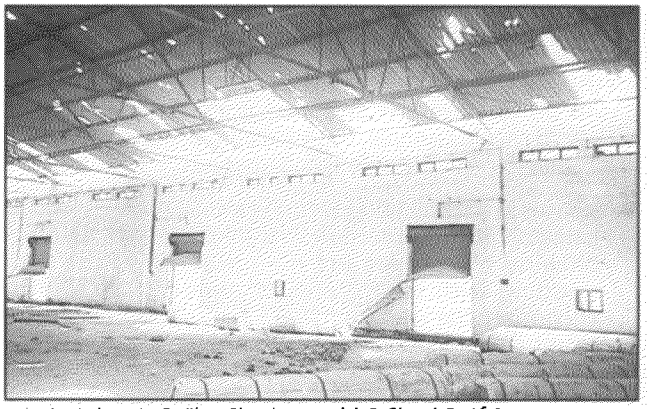

Fig 6 : Failure to Rolling Shutters and A C Sheet Roofing

Storage Godowns

Being one of the major national ports for handling both solid and liquid cargo, the surroundings of the Kandla Port area, there were number of storage godowns. The storage godowns have been typical with number of rolling shutters and AC sheet roofing on steel trusses of 15 to 30m span **The failure initiation has been due to twisting and tearing of rolling shutters due to sudden impact of the storm surge on rolling shutters and besides direct wind force, wind gushing through these openings cause increased internal pressure leading to the roofing damage** (Fig. 6). Further 11 storage godowns inside the Kantla Port with sizes vary from 60m to 192m length and with span of 22 5m have been damaged either to the failure of A/C sheet roofing or to the truss system In some of the sheds, the supporting columns have failed at the ground level.

As observed by SERC, many of the AC sheet roofing failures at 'J' bolts were due to dynamic action of wind, flattening of the 'J' bolt and thus ineffectiveness of the connections.

Industrial Structures

Since Kutch area is the major salt producing place in India, there is lots of industrial structures for salt industry Invariably almost all the industries have their roof trusses with tubular members, roof with asbestos sheets and they were connected by means of 'J' bolts to the purlin As

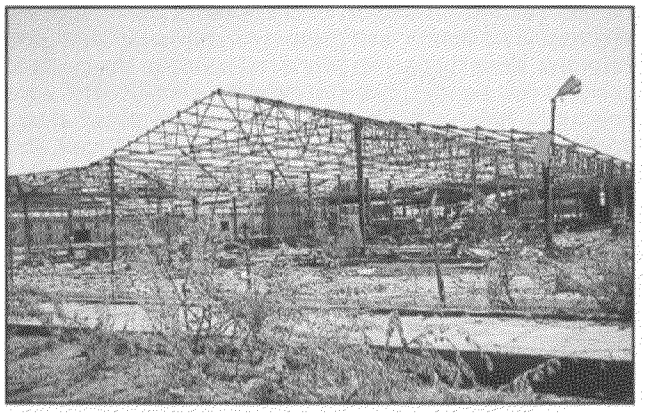

Fig 7 · Roof cladding damage of an industrial structure

the common failure during cyclones, all the asbestos sheet roofing had failed either completely or partially (Fig. 7).

Guidelines for Cyclone Resistant Construction of Buildings

Conventionally evolved non-engineered and semi-engineered buildings suffer moderate to very severe damage which depends on the design, construction and maintenance of buildings. The type of materials used and methods of construction adopted play an important role. Based on the present and past post-disaster damage surveys by SERC, Chennai, the following general guidelines are suggested to mitigate the damage to buildings.

- Houses with thatched roofs and mud walls, extensively being constructed in coastal regions, the thatched roof blowing off can be prevented by tying the roof cladding with rope, wires or metal straps and by anchoring the posts with proper transverse anchor members into the ground
- In the case of roof with tiled cladding, it is preferable to provide concrete restraining strips over tiles, at a spacing of not greater than 1.5m centres and these strips can be anchored to the main rafters suitably.
- Hipped roofs are better than gable roofs to resist cyclonic wind forces. There is evidence that the highest local suction pressures on the gable roof can be roughly 50 per cent higher than those on hipped roof
- It is advantageous to use galvanisd 'U' bolts of 6mm dia in industrial structures for AC cladding roof instead of 'J' bolts, since these 'J' bolts tend to flatten out, weakening the strength of the connection between the cladding and the purlins / rafters during cyclones
- The masonry walls are required to be designed to have adequate lateral strength, in addition to having strength to resist vertically acting dead and live loads. The unsupported brick-wall should not exceed 3.5m.
- The lateral resistance of the wall in many of the low-rise industrial buildings can be improved by providing a continuous RC bond beam at the top. Provision of RC columns to support the roof trusses (instead of brick pilasters) with infilled brick work will help in preventing the progressive collapse of the roof truss system in the even of a cyclone.
- It is desirable to provide suitable roof bracing to increase the integrity of the structure in resisting the cyclonic forces
- Anchorage, bracing and continuity are the prime factors influencing the structural integrity and increasing the resistance to withstand cyclonic wind forces

By adopting these measures, even though it is not possible to prevent the occurrences of a cyclone, it is possible to mitigate the extent of damage to a great extent, caused to buildings and structures

Acknowledgements

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