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A REPORT ON ANANTNAG EARTHQUAKE OF FEBRUARY 20, 1967

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Abstract

The damage to buildings that occurred during the Anantnag earthquake in Kashmir on Feb. 20, 1967 is reported. An isoseismal map of the affected area is presented using Modified Mercalli Scale of Intensities. The weaknesses in different types of construction leading to the damages have been reasoned out and recommendations are made for improvement of earthquake resistance of the various construction methods.

Past Earthquakes in Kashmir Valley

Kashmir valley has been shaken up convulsively by many earthquakes in the past. It has been postulated that the high seismic activity in this region is on account of the criss-cross faults oriented in the N. E. and N. W. directions[1]. The earliest known evidence of an earthquake in Kashmir is from Princep's Tables which mentions a shock that occurred in the year 1552 ; no other particulars or description is given about this. However, it is recorded that a latter earthquake which occured on June 22, 1669, was very violent and felt all over Kashmir ; it lasted all night. The earthquake of 1780 also has been described as severe. Perhaps, the June 6, 1828 earthquake was the severest. About 1200 houses collapsed and about a 1000 people lost their lives The shock was strong enough to create fissures in the ground. The after shocks lasted for about two months and there were about 100 to 200 shocks in a day, each accompanied by an explosion[2]. The earthquake of May 30, 1885 claimed a heavier toll of property and life—there were about 3000 casualties. This seismic paroxysm had its epicentre a few miles west of Srinagar and was felt over an area of 28000 sq kms. The main shock was preceded by a fore-shock on May 29, 1885 but the after-shocks continued for a considerable length of time ; the last shock was reported on August 16, 1885. This shock also was accompanied by a sound of a "hundred canons going off at once". The area over which the shock was sufficiently severe to do serious damage to buildings extended from the "neighbourhood of Srinagar on the south-east, round a little north of Sopur, and Baramula down the Jhelum Valley as far as the Fort of Chikar near Garhi ; the country south of Sopur also suffered as far as Magam (or Margaon) on the road from Srinagar to Gulmarg"[3].

From 1923 to 1952, Srinagar felt in all 176 shocks usually of slight intensity[4]. Only a few of them caused some damage in the form of cracks in the walls of old "kutcha" buildings. Earthquakes of moderate intensity have been felt on very few occasions.

On September 2, 1963, the Kashmir valley was shaken up vigorously by an earthquake of magnitude 5.5 which was felt over an area of approximately 100,000 sq.kms. On account of the shallow focal depth (44km.), the shaking was less intense but it was strong enough to collapse 2000 village houses mostly of mud construction. About 5000 houses suffered partial damage. Since the shock occurred during the day time, the loss of life was not high—only sixty five deaths were reported. The villages worst affected by this earthquake are situated in Badgam Tehsil, about 15 to 30 km. from Srinagar. There was no significant fissuring of the ground or landslides during the earthquake though isolated failures of potentially unstable slopes were noted. Isoseismals of the 1885 and 1963 earthquakes are shown in Fig. 1.

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Earthquake of February 20, 1967

The most recent shock occured on February 20, 1967 which shook the entire district of Anantnag situated in the south eastern portion of the Kashmir valley. The shock was also felt in the south-eastern section of Srinagar district. As in the earlier shocks, this quake was also accompanied by a deep rumbling sound which was described as the pealing of thunder by the local pupulace.

The newspaper report from Srinagar, February 20, 1967 as given by P.T.I. in the Hindustan Times of February 21, 1967 stated that "the Kashmir valley was rocked by an earthquake of medium intensity tonight. It was felt here at about 8.50 p.m. The quake was followed by a rumbling noise, lasting about 25 seconds......In all about three tremors were felt at short intervals". It was also reported that quake of mild intensity rocked Kapurthala and the Northern region of Jammu at 8.40 p.m. the same day (Statesman, February 21, 1967) The Indian Express of February 22, 1967 carried the news of February 21, 1967 from Srinagar which mentioned that "the Kashmir valley was rocked by another earthquake of mild intensity today, the second since yesterday. In Srinagar, the earthquake was felt at 6.17 p.m. and lasted about 20 seconds. Similar reports have been received from other parts also. In last night's earthquake, two houses collapsed in a village in Anantnag District, about 32 miles from here. Some houses, in Anantnag town also suffered cracks. No loss of life has been reported so far".

The after-shocks continued and the National Herald of February 25, 1967 reported the news issued from Srinagar on February 22, 1967 that "over fifty houses collapsed and another fifty were damaged in the Anantnag District in the Kashmir valley, which was rocked by earth tremors during the last 38 hours ending at ten this morning, according to official reports received here to day. The reports said that one person was killed and another was seriously injured in the house collapses. Over 300 persons, whose houses had collapsed, are being accommodated in tents".

The seismological data for the main shock as given by the Indian Meteorological Department are given below :

No.	Station	Origin Time G.M.T.			Epicentre	Magnitude (USCGS)	Focal Depth (USCGS)
		h	m	s			
1.	New Delhi	15	18	42	33.5°N 75.5°E	5.3	24 km.
2.	Bombay	15	18	39.9	33.7°N 75.5°E	5·7	24 km.

According to the information received from the Deputy Commissioner, Anantnag(5), 458 villages in the district have been affected. 786 houses have been totally damaged or are likely to collapse having loss more than Rs. 1000.00 each. The number of houses which have been partially damaged are 24,974. The total amount of cash relief disbursed as per standing damage list is about Rs. 27 lakhs. Total value of the loss of property is presumably much more than the amount disbursed for relief measures*.

*This information is not final since evaluation is still going on in the earthquake affected area.

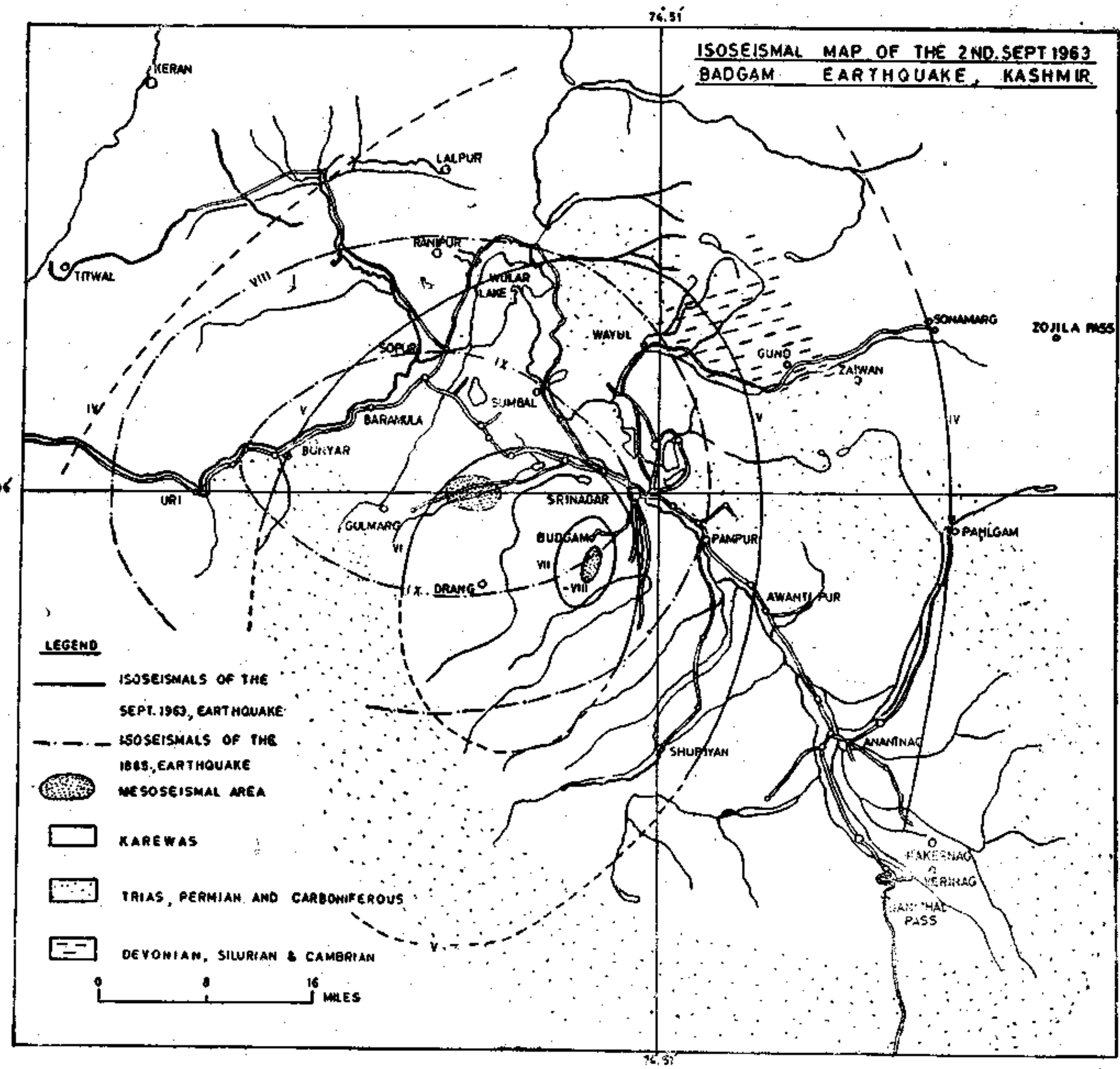


Fig. 1. Isoseismals of the Kashmir Earthquake of 1885 and Badgam Earthquake of 1963

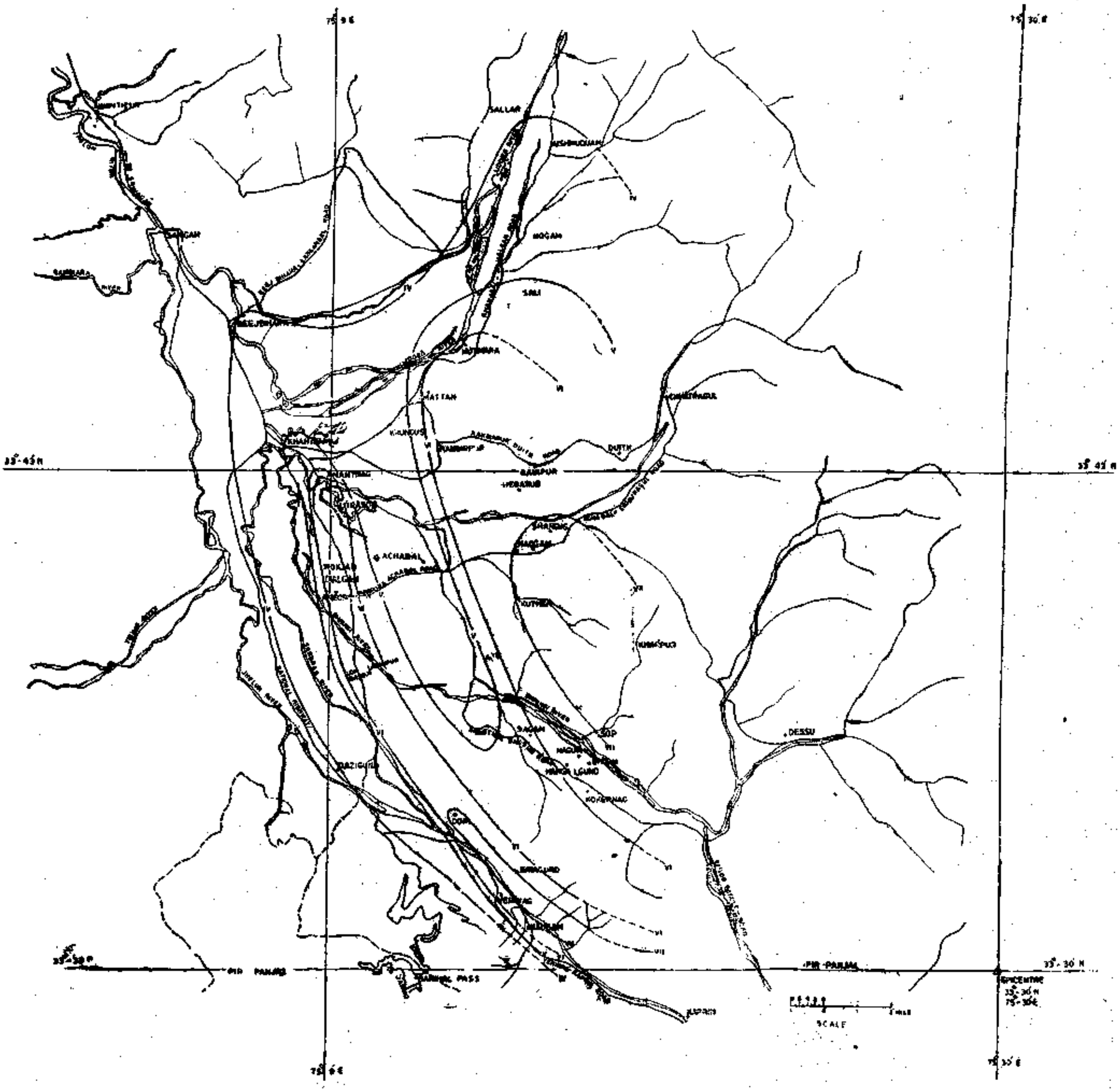


Fig. 2: Isoseismals of the Anantnag Earthquake of February 20, 1967.

M.M. Intensity Isoseismals

The places worst affected by the earthquake and their intensity rating based on the Modified Mercalli Intensity Scale are :—

Place	Intensity (M. M. S.)	Approximate Distance from Epicentre (Km.)
1. Shangus	VII	30.3
2. Sop	VII	22.6
3. Doru	VII	27.4
4. Hutmara	VI	39.5
5. Mattan	VI	39.1
6. Anantnag	VI	40.3
7. Batagund	VI	23.8

The plot of the isoseismals as shown in Fig. 2 is based on field data and on the spot questioning of the local people after the earthquake. Out of the worst affected places, Shangus, Hutmara and Mattan lie close to the left bank of the Lidder River; Sop lies on the right bank of the Bringi River and Doru on the right bank of the River Sandran, a few kilometres east of the confluence of this river and River Jhelum. Anantnag itself is just a few kilometres away from the right bank of River Jhelum. The damage in these places may be due to their situation on alluvium beds. Achabal, though it is situated within the triangle formed by joining Sop, Doru and Anantnag, and is only 34.1 Km. from the Epicentre, escaped vigorous shaking and had very minor damage. The Modified Mercalli Intensity value that could be assigned to this place is V. It is thus seen that the isoseismals plotted are neither circular nor elliptical—they appear to have been greatly influenced by the geological and soil conditions. Moreover, the instrumental epicentre, 33.5 °N, 75.5°E (approximately 41 Km. S.E. from Anantnag town) being near the Marbul Pass in the Pir Panjal Range of mountains, is a very sparsely populated area with practically no habitation. The absence of dwelling houses and buildings in the epicentral region thus leaves a void in the isoseismal study. It was fortunate that the epicentral tract was in the desolate mountains otherwise the damage would have been more itense and the toll of life would have been larger. This earthquake and the Badgam earthquake of 1962 both were of magnitude 5 5. Anantnag shock had a focal depth of 44 Km. However, larger number of lives were lost then—only one death (in Sop) has been confirmed for this earthquake. Reports of large scale slumping and fissuring of the earth have not been received, nor were such phenomena observed in the villages (and their neighbourhood) which suffered the maximum damage. There was, however, one instance in which an almost spherical boulder, 2.0 metres in diameter, rolled down a hillside in the precincts of the temple at Mattan. The boulder crashed into the rear wall of the temple "dharamshala" (Fig. 3) from a point on a hillside about 15 metres away inclined at about 20° to the horizontal (Fig. 4).

Geology of Anantnag District

The Kashmir valley is a tectonic depression filled up with Karewa formations of Pleistocene to Recent age. These were formed in a sinking lake between two slowly rising mountains on either side. The Karewa beds, 1500 metres in thickness, consist of fine grained sand, loam, sandy clay and gravely conglomerate, with few lignite horizons. The Karewas, forming flat topped hillocks, plateaus, and terraces, are mostly horizontal and occur with low dips of 2° to 5°. On the flanks of Pir Panjal, where they are found at an elevation of about 3450 metres, these rocks are tilted and their dips vary from 2° to 20° away from the mountains. Dips of over 40° with some folding have also been reported recently[6].

Srivastava and others[7] are tentatively of the opinion that Kashmir valley, which appears to be a subsided block, has criss-cross faults along N. E. and N. N. W. directions. These faults appear to be still active and are responsible for the occasional earthquake shocks in the area.

Damage to Buildings

The inherent weaknesses in the buildings and their damage due to the shock will be better comprehended if an account of the construction practices in vogue is given: It was reported by Jones[8] after the Kashmir earthquake of May 30, 1885, that "structures in Kashmir are not of a nature to successfully withstand earthquake shocks, even when not of any great degree of intensity. In a very considerable number of cases in which huts were damaged, the supports of the roof had given way leaving only a mass of rubbish to indicate where the house had stood".

Anantnag district is mainly rural and farming is the main occupation. Since there has not been a marked improvement in the economic condition of the peasants, in general, the style of buildings in the villages still remains almost the same and they are as susceptible to mild shocks now as they were in 1885. This is the observation made in the damage survey after the Anantnag earthquake of February 20, 1967, eighty two years since then. A description of the numerous buildings in Anantnag district and their behaviour during the earthquake will be a rather formidable task. A large number of the buildings now existing can, however, be classified into five groups.

A. Traditional Kashmiri Village Hut or "Dhajji-Diwari" construction.

B. Rubble Masonry Structures.

C. Tall Structures.

D. Brick-Nogged and Wooden Structures.

E. Modern Construction.

It must be remembered that steel and cement were not easily available in the olden days, especially so in Kashmir. Even now, they are not within easy reach of the villagers on account of their high cost. In Kashmir, lime is also a rare and an expensive building material which the majority of the villagers cannot afford. Brick kilns are scarce too, and as a result, burnt brick houses are rather uncommon. Thus, the use of the above mentioned building materials is extremely restricted on account of their high cost, non-availability, and the indigent condition of the local populace itself. Houses

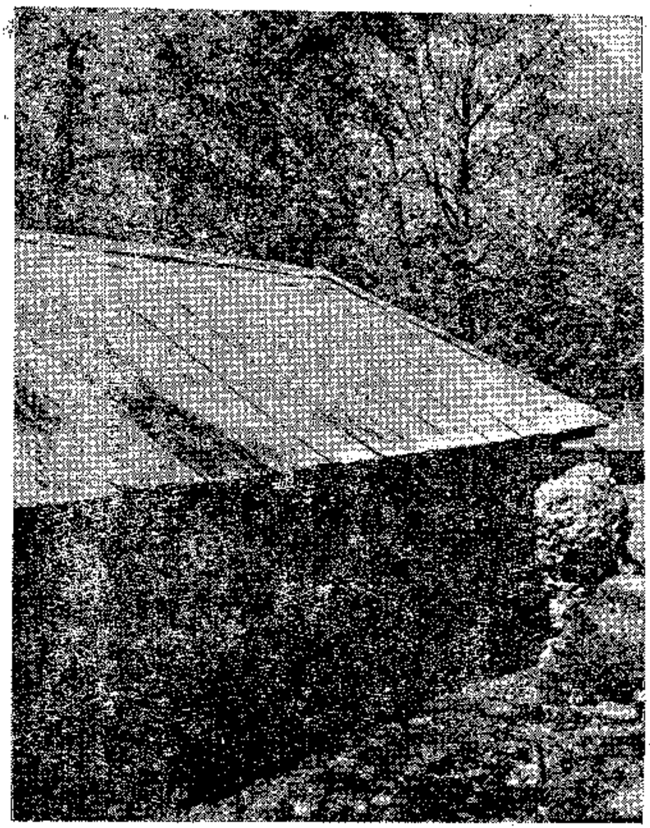


Fig. 3 Rolled Boulder which crashed into Dharam Shala in Mattan.

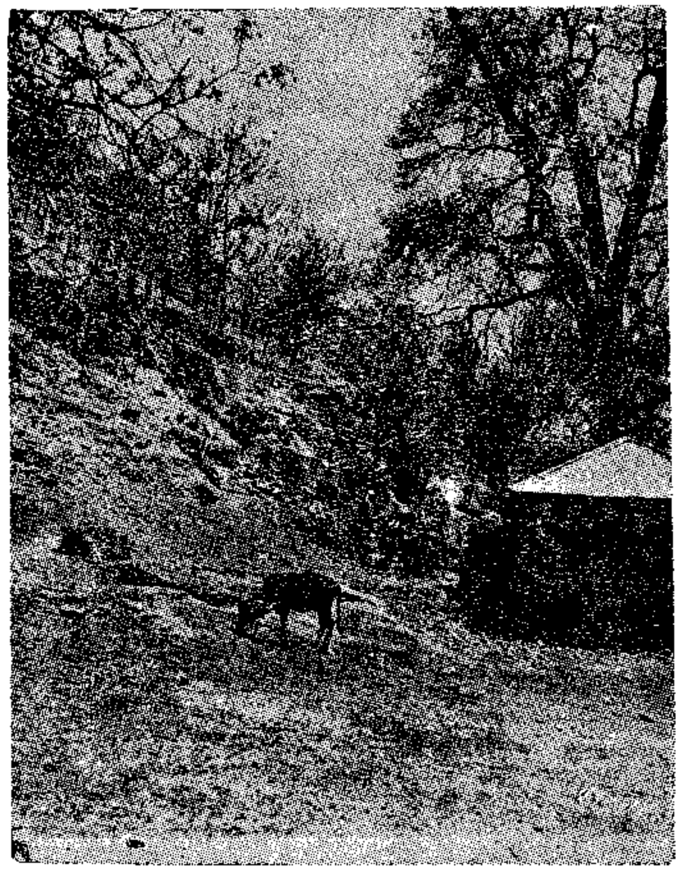


Fig. 4. View of the Hillside from where Boulder Rolled Down.

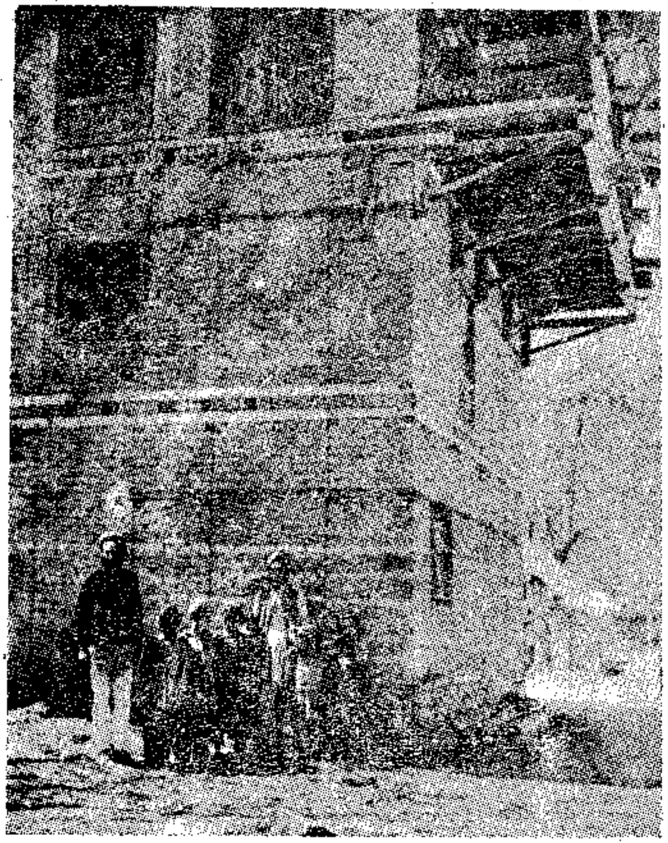


Fig. 5 "Dhajji-Diwari" Construction showing the Piers and the Infill. (Not the absence of bond between the two).

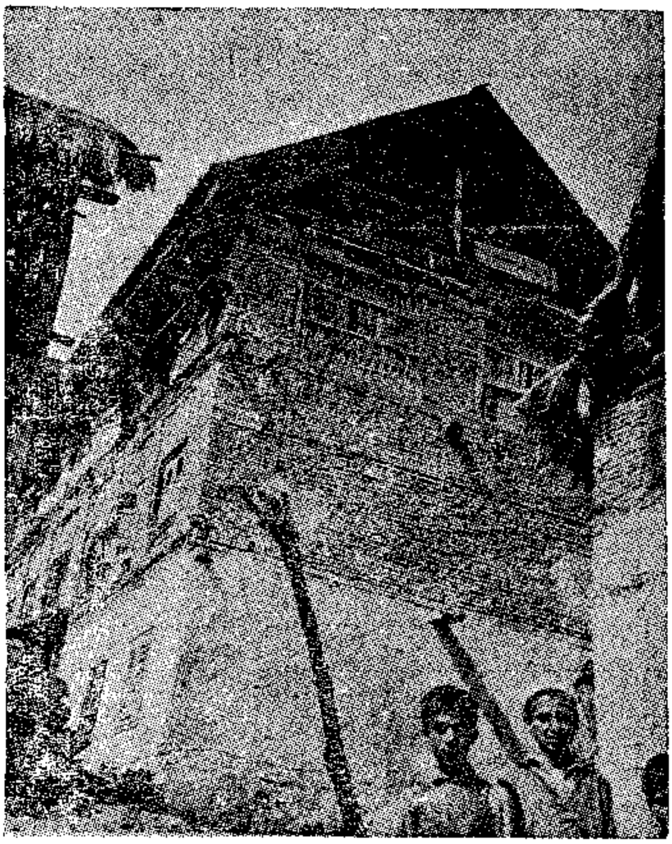


Fig. 6 Shoddy appearance of the Adobe Walls in Mud plaster

Fig. 7. Timber Rakers supporting out of Plumb Walls

Fig. 8. Close-up of the Damaged Wall shown in Fig. 7

Fig. 9. Longitudinal Scction of an Adcbe Pier

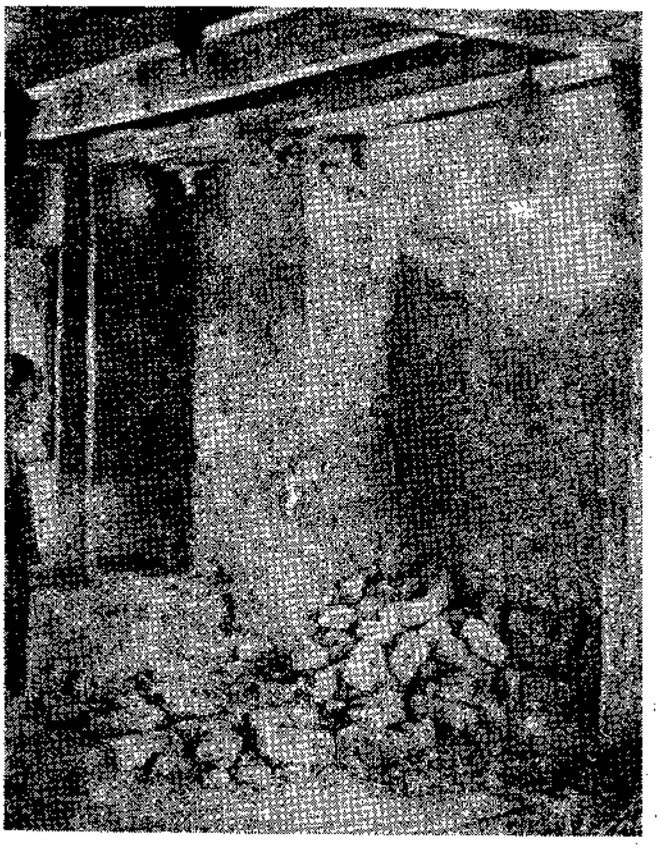


Fig. 10. Damage of Upper Storey Adobe Pier and Panel

are, therefore, constructed mainly of sun-dried bricks (adobe), stone and timber ("kail", "walnut", "budloo", "deodar", "sal")†

(A) "Dhajji-Diwari" Construction :

The traditional Kashmiri house is either single or double storeyed construction usually with an attic. The distinguishable feature in this is the trabeated structural system comprising of adobe piers and timber beams. The size of the pier varies, depending upon the situation; the piers in the corners and in the centre of the gable ends are usually about 600 × 600 mm whereas those at intermediate points are about 450 mm × 450 mm. The centre to centre distance of the piers varies from 1 metre to about 2 metres. These piers usually rise from shallow foundations made of rubble masonry bonded with lime mortar. Mud mortar is used for the rest of the pier. The space between the piers is built up with sun-dried bricks bonded with mud mortar and the thickness of such infills may vary from one brick to two and a half bricks. The upper storey (or the attic) walls are usually thinner than the ground floor walls.

The most disappointing characteristic feature of such construction is that no attempt is made to have a bond between the pier and infill and both are entirely independent units This is seen clearly in Fig. 5.

No particular bond is adopted for the masonry work. The majority of the houses have walls made monotonously of stretchers (stretcher bond) the headers being provided at the plinth or lintel level Sometimes there is a course of headers after every five or six courses of stretchers (English garden bond). Such bonds are normally recommended for half or one brick thick walls but are used by the villagers for thicker walls as well. Consequently the keying of their inner and outer surfaces is usually ignored.

The thickness of the joint varies from 18 mm to 25 mm. In the course of time, the exposed mud gets washed away by the rain, and wall gives a shoddy appearance as in Fig. 6. The piers also have a similar construction.

Thus the construction appears to be such that a shock of intensity VI or even V (MMS) is sufficient to throw the wall out of plumb and even to cause damage beyond repair. Fig. 7 shows out-of-plumb walls supported by timber rakers. Fig. 8 is a close-up of the "dhajji-diwari" house shown in Fig. 7. The dressed exterior surface of the panel is separated both from the corner pier and remainder of the wall for lack of proper bond between themselves. The longitudinal section of an adobe pier is seen in Fig. 9. Absence of key stones is very conspicuous, both between the front and rear half of the pier and between the pier and the wall that has fallen apart altogether. Fig. 10 shows the damage of an upper storey wall and an adjacent pier. The mud-mortar which merely peeled off by the shock is seen lying on the floor. Fig. 11 shows the damage of a ground floor wall, and reveals the muck that is used for constructing such walls. Diagonal cracks may also develop in adobe walls bonded with mud mortar as in the case of the interior walls of the residence of the doctors of the Missionary Hospital in Anantnag (Fig. 12).

† **Kail** (Pinus Excelsa) Moderately durable, easily treatable under open tank process. Fairly good for permanent structures.

Walnut (Juglens) Non-durable and non-treatable wood suitable only for temporary structures.

Budloo Ordinary local wood.

Deodar (Cedrus deodara) Naturally durable soft timber, good permanent construction.

Sal (Shorea robusta) Naturally durable hard and strong timber, first choice for permanent structures.

The partition walls are usually brick-nogged, the timber framework consisting of vertical studs usually 1 to 1.5 metres and horizontal timbers spaced 1 to 2 metres centre to centre. The cross sectional dimensions of these timbers vary, but are usually 75×40, 75×75, 75×100 mm. The partitions are usually half brick thick and laid in a stretching bond. No particular care or precaution is taken to prevent them from getting loose in case there is a mild tremor. Besides earthquakes, even the constant banging of the doors in the house is liable to shake the bricks loose and make the partition shaky since a proper bond between timber and brick is not easily achieved. Fig. 13 shows the brick infill shaken loose from the timber framework.

In "dhajji diwari" construction the storey height usually adopted is about 2.5 metres to 3.0 metres. The ground floor roof is normally of timber planks carried by timber joists and borne by main timber beams as shown in Fig. 14. The roof is invariably pitched on account of the heavy snow fall and rains experienced by the valley. Besides thatch, birch bark was also used as a roofing material. Fig. 15 shows a single storeyed "dhajji-diwari" hut with roof coverd with birch bark, a material which has now become obsolete. Timber tiles are also frequently used and these provide a good architectural finish. These are, however, expensive and are used in government buildings or in houses of those who are well off. Those who can afford, now use corrugated galvanised iron sheets as a roof covering material. The roof may have two types of supporting system :—

(i) It may simply have a timber log at the ridge running the entire length of the house. The two ends of the log rest on adobe piers as shown in Fig. 16. Depending upon the width of the building, there may be more timber logs between the ridge and the eaves, and each is supported on piers as shown in Figs. 17 and 18. The gables thus present a pigeon-hole type appearance.

(ii) The other is a simple truss system having a collar roof, a double strut roof or a king-post truss. Figs. 19 and 20 show the arrangement of such trusses and Figs. 6 and 21 show the gables of houses having such a roofing system.

The trusses are simply nailed on the timber wall plates running over the long walls. In places where the wall is thin, the wall plates span over the adobe piers. In either case the wall plates are just held in place by mud mortar. In certain instances it was noted that there is absolutely no connection between the wall plates in the long and short directions (Fig. 22). This lapse in construction could prove (as it did in Anantnag earthquake) to be very costly since the various parts of the attic would vibrate independently rather than as a single unit in the event of an earthquake shock. Such a behaviour could lead to collapse of the roof and endanger the safety of the entire structure. The various elements of the truss are simply nailed apparently to reduce cost, and none of the better well known types of joints are adopted.

It was observed that "dhajji-diwaris" having roofing system of type (i) proved more hazardous than a trussed roof. This would appear to be obvious since the timber logs at ridge and eaves are supported on isolated adobe piers which experience vigorous shaking during earthquakes. Their strength in the lateral direction is almost negligibe and these are liable to collapse first, bringing down the whole roof along with them. Fig. 23 shows the collapse of such a house in Batagund (Isoseismal VI).

The most singular noteworthy feature of a "dhajji-diwari" is the embodiment of timber runners around the entire house, usually at the plinth and roof levels. These are known as "dassa" in the vernacular language, and provide a means of safety for the structure subjected

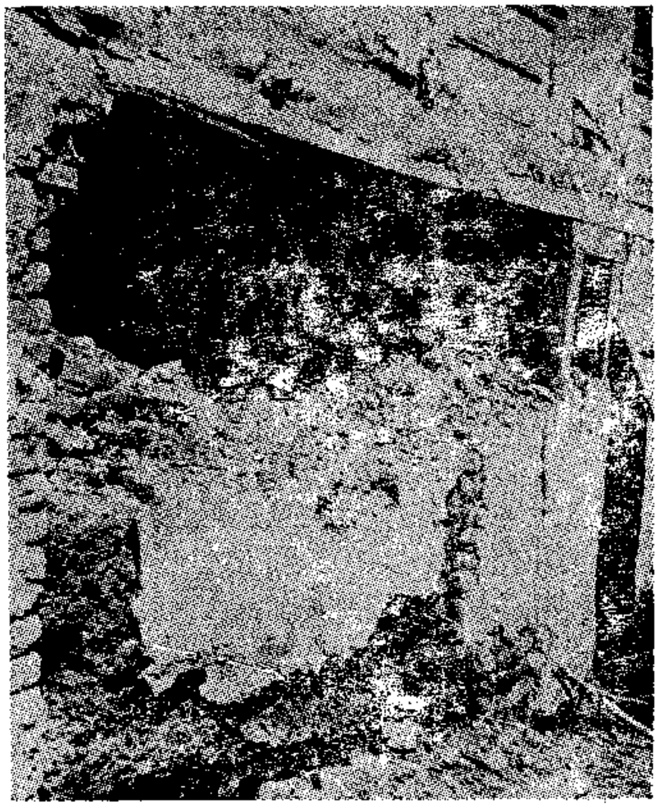


Fig. 11. Damage of Ground Floor Wall made of Adobe, Mud and Muck

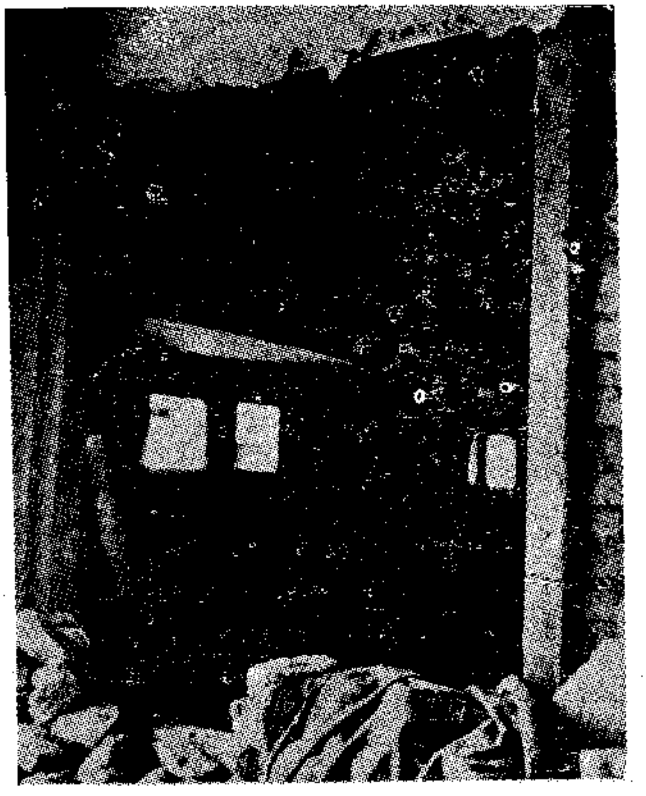


Fig. 12. Collapse of Partition Walls of House in Hutmara

Fig. 13. Common Roofing System in a "Dhajji-Diwari"

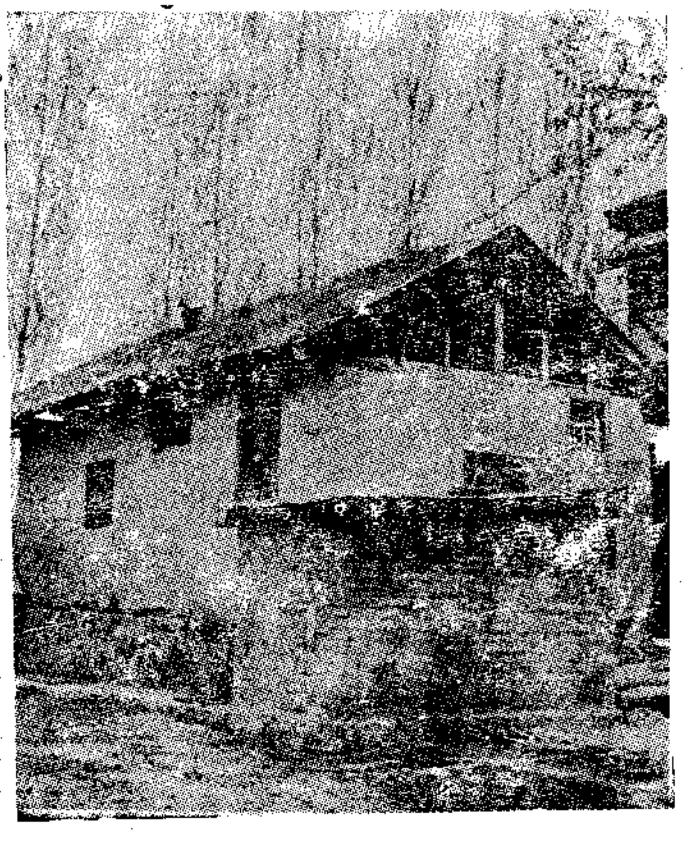


Fig. 14. "Dhajji-Diwari" with a Birch Bark Roof

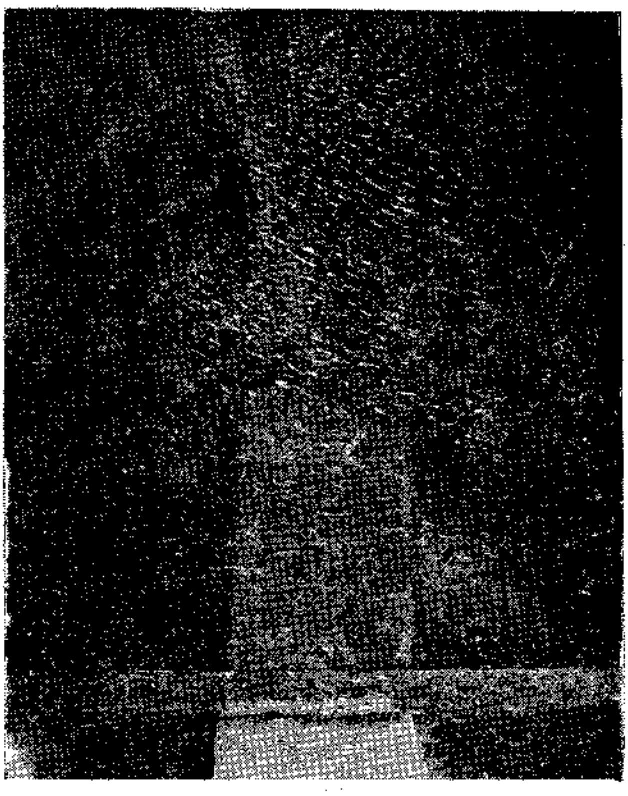


Fig. 15. Timber Ridge Piece resting on Adobe Pier at the Gable End

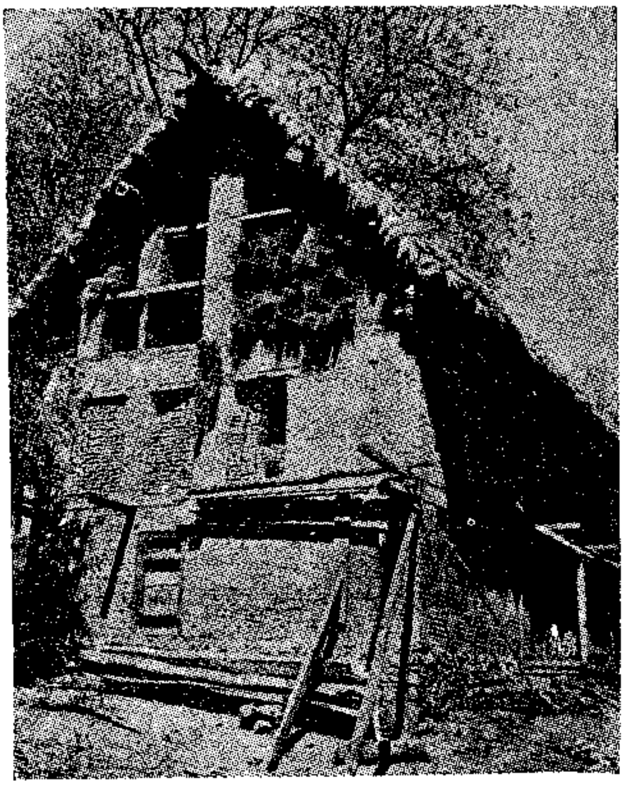


Fig. 16. Gable End of a Traditional Kashmiri "Dhajji-Diwari"

Fig. 17. Gable End of a Traditional Kashmiri "Dhajji-Diwari"

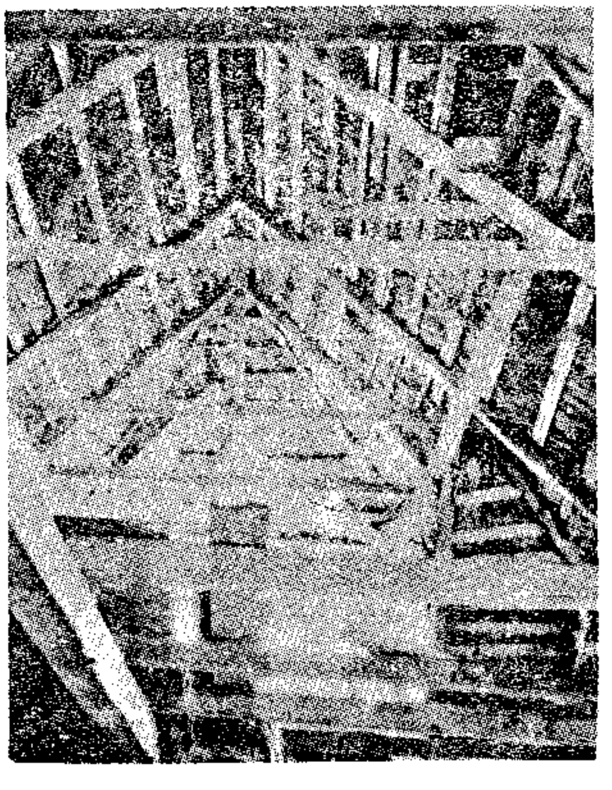


Fig. 18. Collar Roof Truss

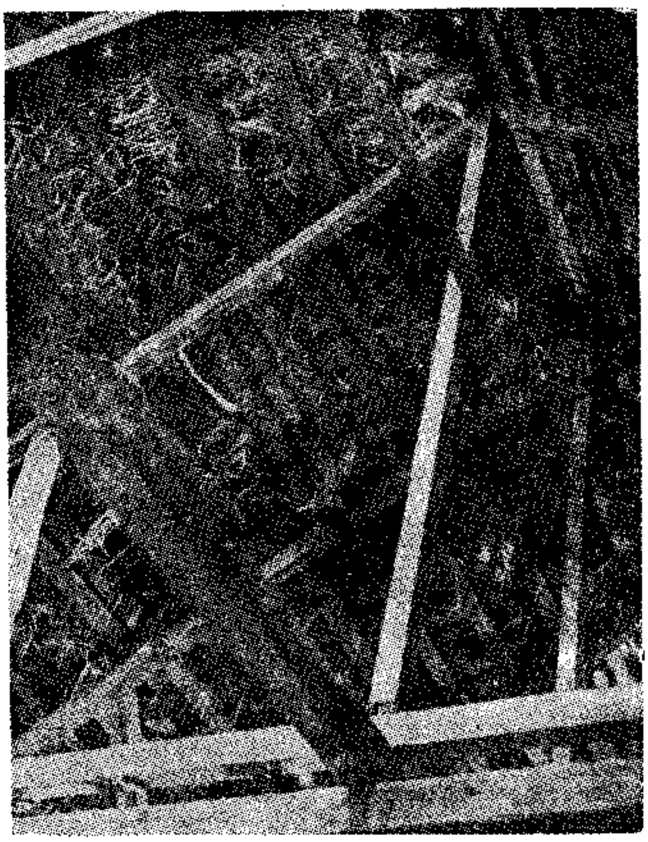


Fig. 19. Strutted Roof Truss

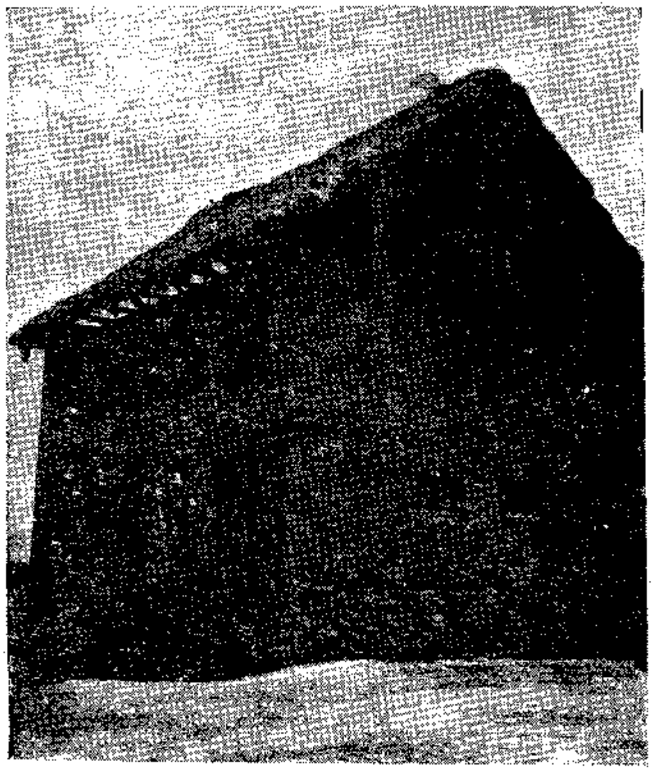


Fig. 20. King post Roof Truss of a "Dhajji-Diwari"

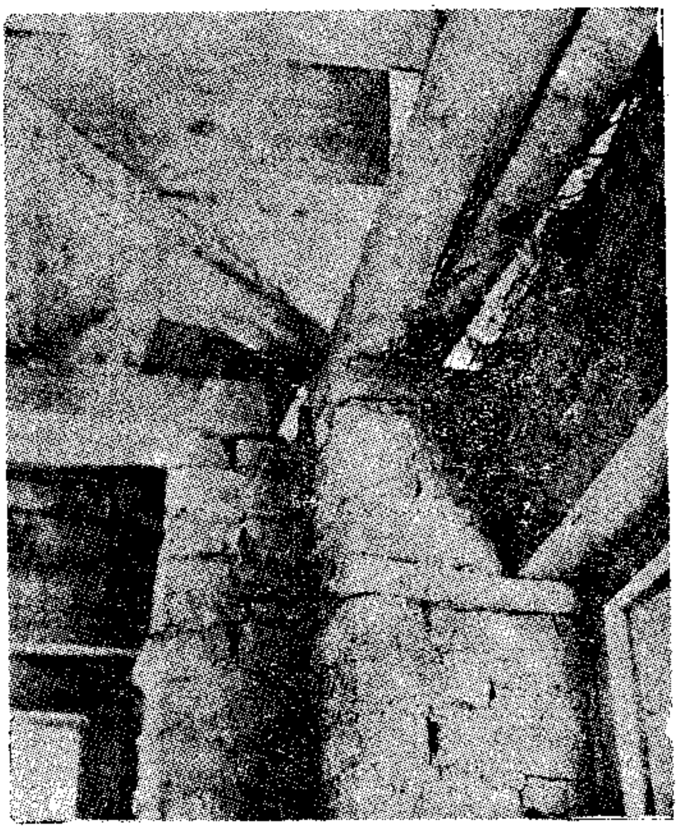


Fig. 21. Wall Plates of Short and Long Walls (Note the absence of connection between the two)

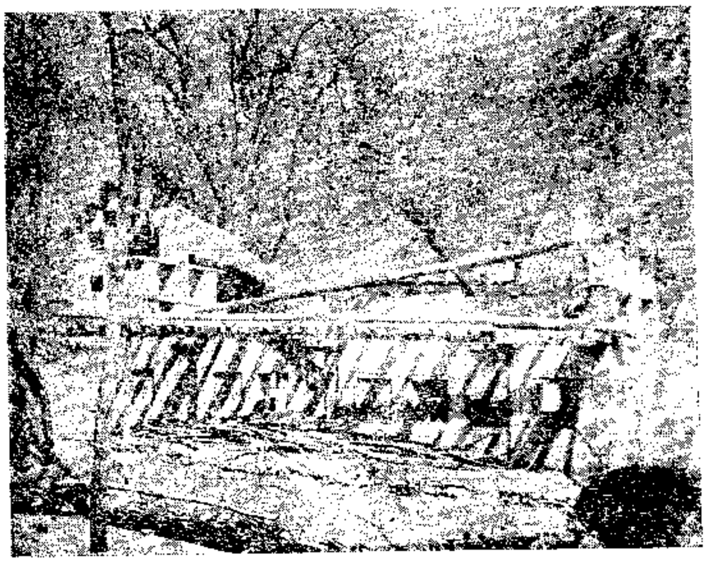


Fig. 22. Collapse of a "Dhajji-Diwari" in Batagund with pigeonhole type Gable

Fin. 23. "Dhajji-Diwari" construction having Double Timber Runners at the Roof levels.

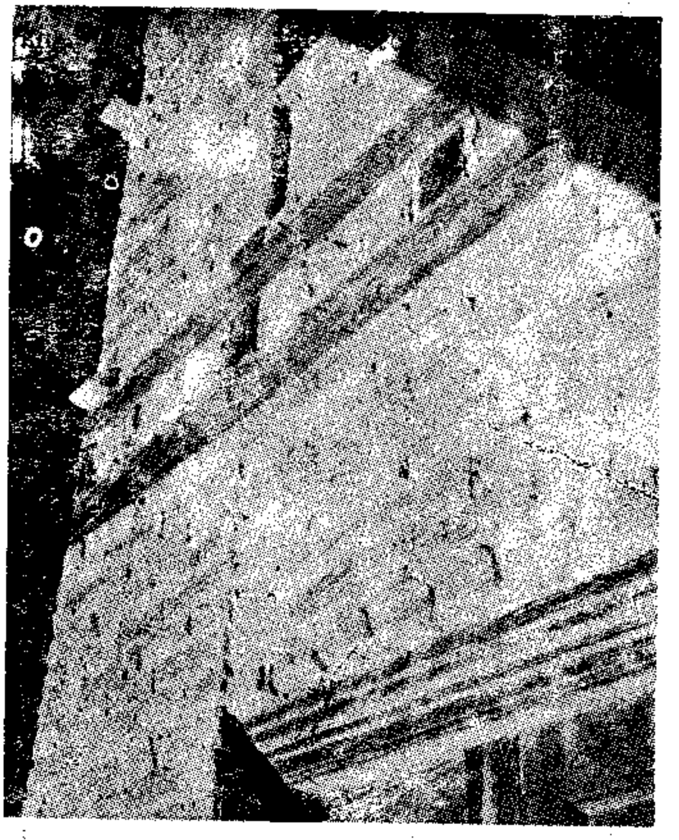


Fig. 24. Metal Straps connecting the Long and Short Wall Timber Runners at the Corner.

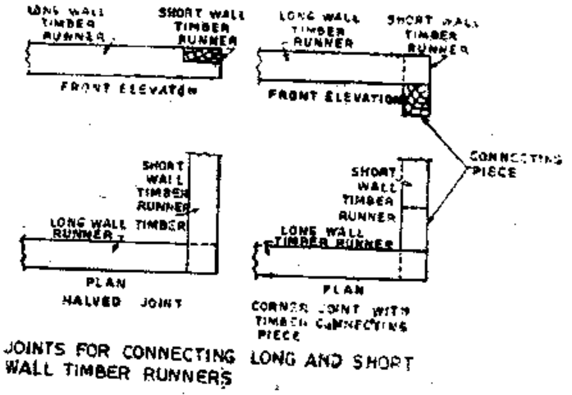


Fig. 25.

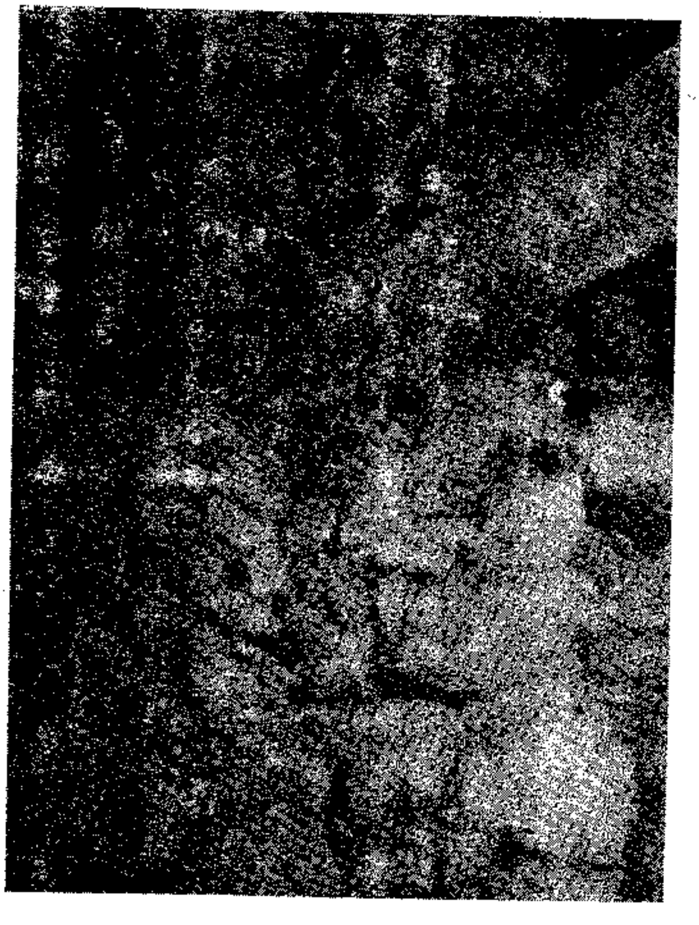
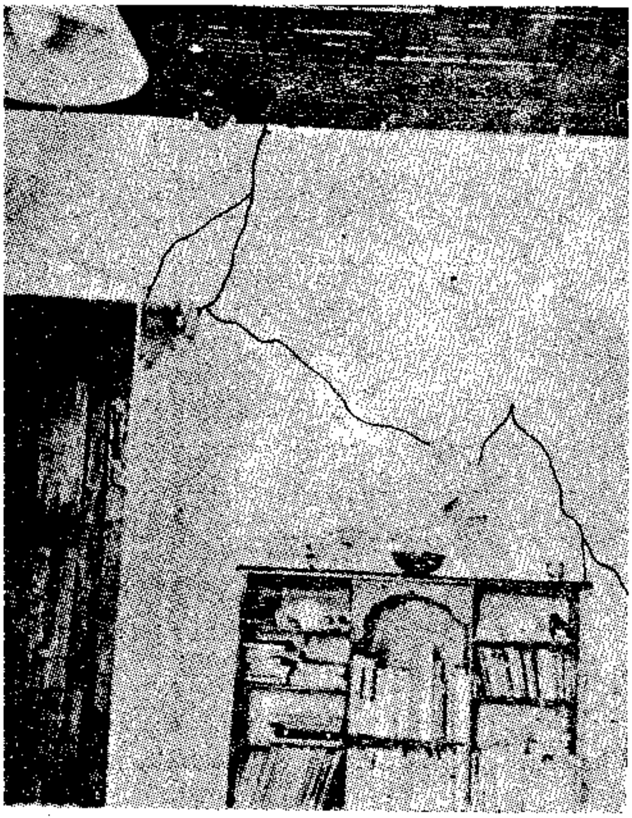
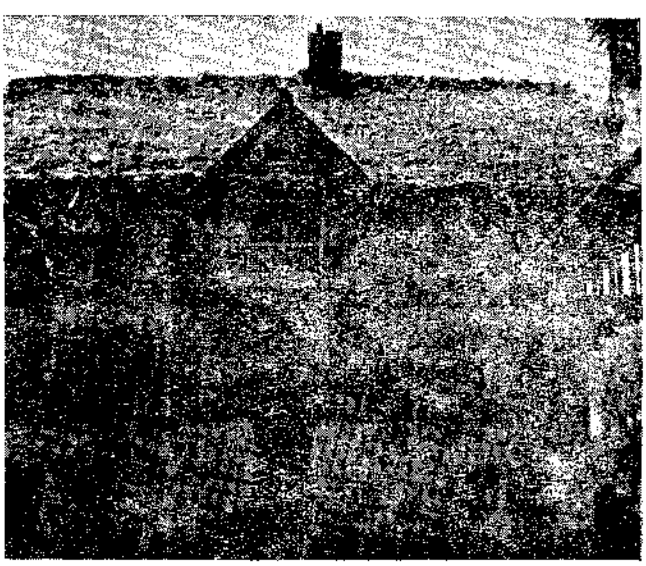


Fig. 26. Plinth Level Timber Runner encased in the Wall.



:. 27. Diagonal cracking of interior Sun Dried Brick Masonry Wall in Mission Hospital, Anantnag.

Fig. 28. Undamaged School Building in Batagund in which a large volume of Timber has beed used.



. 29. Undamaged "Dhajji-Diwari" house in Sop. (Note the large volume of timber used in the construction).

Fig. 30. Block Development Office, Larkipura.

Fig. 31. Damage of Random Rubble Masonry Walls around Windows in B. D. O., Shangus.

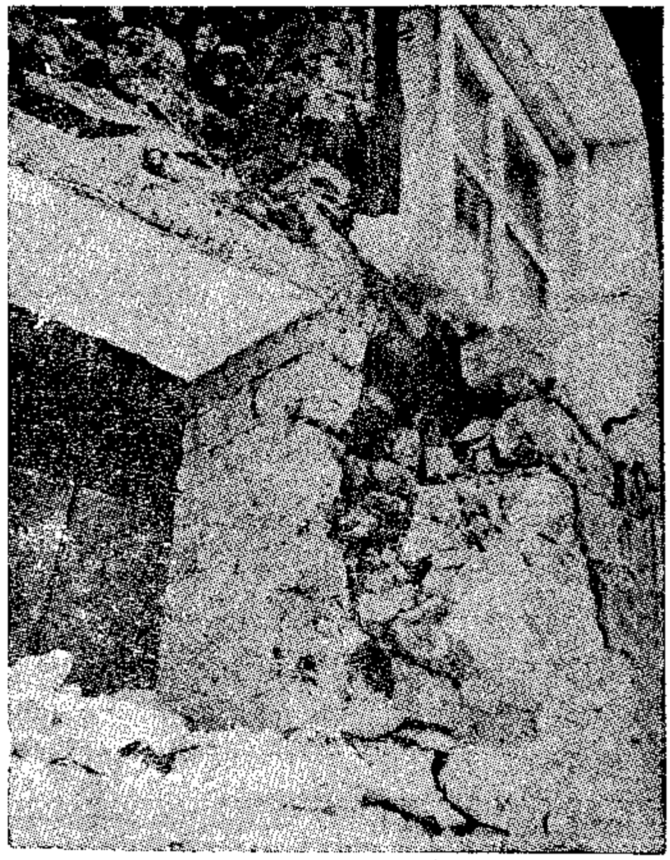
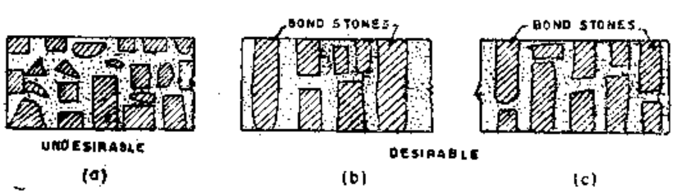


Fig. 32. Close-up of the Damaged Wall near Corner of Window seen in Fig. 31.



CROSS SECTION OF DESIRABLE AND UNDESIRABLE RANDOM RUBBLE MASONRY WALLS

FIG. 33

Fig, 34. Verandah of the B.D.O. at Shangus after the Earthquake.

to an earthquake shock. Figs. 5, 6, 7, and 24 show these runners. The long and short-wall timber runners may be either connected through a metal strap as shown in Fig. 25 or they may have joints as shown in Fig. 26.

Joints in which a metal strap is used in conjunction with a timber connection piece is obviously a better joint. Cogging the timber connecting piece with the runner will also be an improvement. Occasionally, two parallel rows of runners are used at a particular level and at times an additional runner is provided at the lintel level. Sometimes the runners may be encased within the wall (Fig. 27). This photograph also serves the purpose of showing the cross section of the wall which can be seen to consist of brickbats and rubble, packed between the dressed exterior and interior surfaces with very little mortar to hold them together. The random rubble portion upto the plinth is also similarly constructed. No key-stones are provided between the exterior and interior surfaces. The timber runner is placed over the first course of masonry work which is usually of brick on edge.

It has been observed by Jai Krishna and Arya[6] that plinth bands offer very little help in the resistance of earthquake force. Plinth bands become more a part of the plinth rather than the wall itself particularly at the most critical points i.e. the corner of the door openings. The timber runners, never-the-less, tie the short wall to the long wall and also bind the pier and the infill to some extent. Perhaps the greatest advantage gained from such runners is that they impart ductility to an otherwise very brittle structure. An increase in ductility augments the energy absorbing capacity of the structure, thereby increasing its chances of survival during the course of an earthquake shock. This was substantiated by the observation that "dhajji-diwaris" in which a larger volume of timber was used (Figs. 28 and 29) were comparatively safer. Fig. 28 shows a school building in Batagund with a larger number of windows. The timber framework of the windows and the timber runners appear to have provided the necessary ductility to the structure since it showed no external signs of distress. Some partition walls inside were, however, shaken loose.

(B) Rubble Masonry Construction :

There is no dearth of good building stone in Kashmir. However, on account of the expenditure involved, this has not been exploited fully. Anantnag district has some stone quarries near Anantnag town itself. A comparatively higher cost discourages the villagers from using rubble masonry except for the foundation and plinth, and in certain instances for the ground floor as well. Governmental bodies have used rubble masonry rather extensively. It was, however, disappointing to note that in majority of the cases, it is used rather unwisely. The Block Development offices in various places in the district have an almost similar construction. The rear view of the Larkipura Block Development Office is given in Fig. 30. It is a random rubble construction in mud-mortar, the joints being flush pointed with lime mortar. Larkipura had an intensity VI and as a result the damage was only slight in this structure, confined mainly to minor cracking of masonry walls mostly near corners of openings. The Block Development Office at Shangus (Isoseismal VII) was however damaged beyond repair. The inherent weakness of the masonry wall around and between openings is clearly highlighted by Fig. 31. A close-up of the damaged portion near the window is shown in Fig. 32. The interior of the wall is seen to be built up of odd shaped stones and chips with large voids between them. Even the mud matrix used could hardly be considered adequate. The face stones were found to be placed mostly on edge rather than on their widest bed. The elementary precaution for random rubble work is to provide bond stones from facing to the backing or to see that the face stones tail back sufficiently into the hearting so as to create a good bond between the facing, hearting and backing. Sketches giving the desirable and undesirable types of random rubble masonry work are given in Fig. 33.

The verandah and the interior walls were plastered by lime plaster about 25 mm thick. This peeled off almost completely in the entire buiding. Fig. 34 shows the condition of the verandah of the Shangus Block Development Office.

The office building of the Range Officer, Lower Range, at Mattan was also badly affected and declared unsafe. It has a random rubble construction similar to the masonry work of Block Development Offices. The walls in this structure also were shattered beyond repair. At many places they bulged out due to lack of bond between the facing, hearting and backing. From Fig. 35 it is to be noted that on account of bulging, there is a difference of about 25 mm between the jamb and the window frame.

The desirability of siting the window sufficiently away from the edge, the necessity of strengthening the wall around the opening and having a certain prescribed distance between two adjacent openings, and the indispensability of a lintel band to inhibit the development of diagonal cracks, may be seen rather clearly in the cracking pattern of a single storeyed random rubble masonry building in Mattan (Fig. 36). The separation of the brick masonry pier at the corner from the wall of the building (Fig. 37) of the Social Education Centre at Mattan, again emphasises the importance of having a bond or a tie between the various elements of a structure. In contradistinction, a coursed rubble masonry construction with a timber runner at a level slightly above the lintel level (Fig. 38) situated at Mir Maidan remained unscathed. The P. W D. overseer's house at Verinag (Isoseismal VI) which is a random rubble masonry structure with a reinforced cement concrete lintel band (Fig. 39), sustained the shock admirably. However, the upper storey of the double storeyed Tourists' Department Dak Bungalow about 20 metres away was considerably damaged, so much so, that the gable end towards the staircase had to be rebuilt. The triangular space of the gable of the Government College building at Khanabal was also excessively damaged. The coursed rubble facing toppled down, exposing an interesting feature used in the construction of walls about sixty to seventy years back (Fig. 40). Horizontally laid timber boards about 20 mm thick can be seen after every course. The use of these boards in the construction of walls is not understandable since they apparently have no structural function for they cannot strengthen the walls if arranged as seen in the figure. Damage of the gables in this earthquake again affirmed their weakness in withstanding an earthquake shock. It was observed in this as well as in the past earthquakes that roofs with hipped ends were better and should be preferred over gable ends for houses in seismic zones[9].

As in other earthquakes, Anantnag earthquake also damaged numerous chimneys and produced wide cracks in many arched openings.

(C) Tall Structures :

These are made of burnt bricks or have ashlar, coursed or random rubble masonry walls in lime mortar and have three or more than three storeys Such structures are to be seen in Anantnag town only. Fig. 41 shows the shop cum residences in Lal Chowk, the new commercial centre of Anantnag town. The various buildings butt against each other and are usually three storeys high. A four storey building situated a little distance away from Lal Chowk, has the ground floor made of ashlar masonry borded with lime mortar and flush cement pointing, and the upper storeys made of first class burnt bricks in lime mortar. Fig. 42 shows the timber runners and tying of the long and short masonry walls by corner

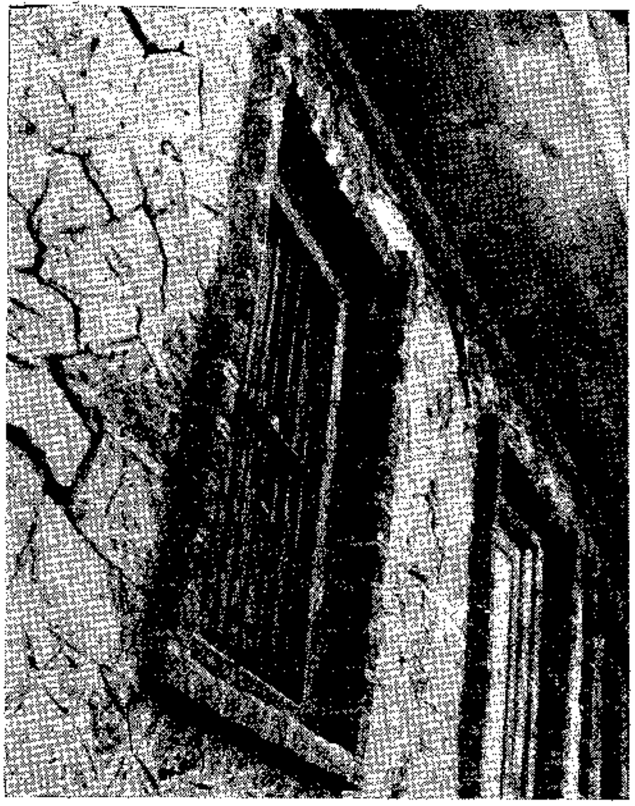


Fig. 35. Bulging of Random Rubble Masonry Walls of the Office of the Range Officer, Mattan. (Note the difference between window frame and jamb).

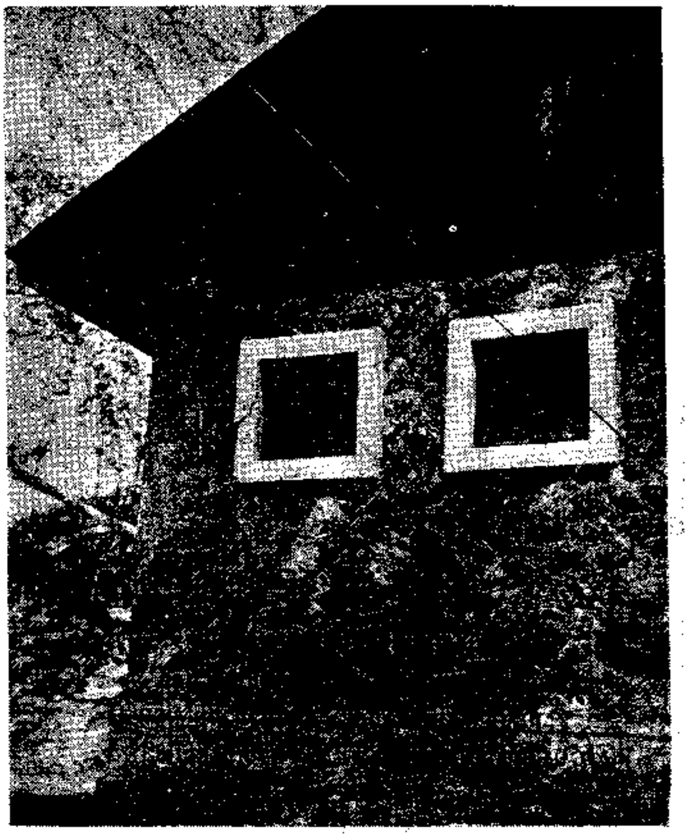


Fig. 36. Diagonal Cracking of Rubble Masonry Walls and Damage around Window opening of a House in Mattan.

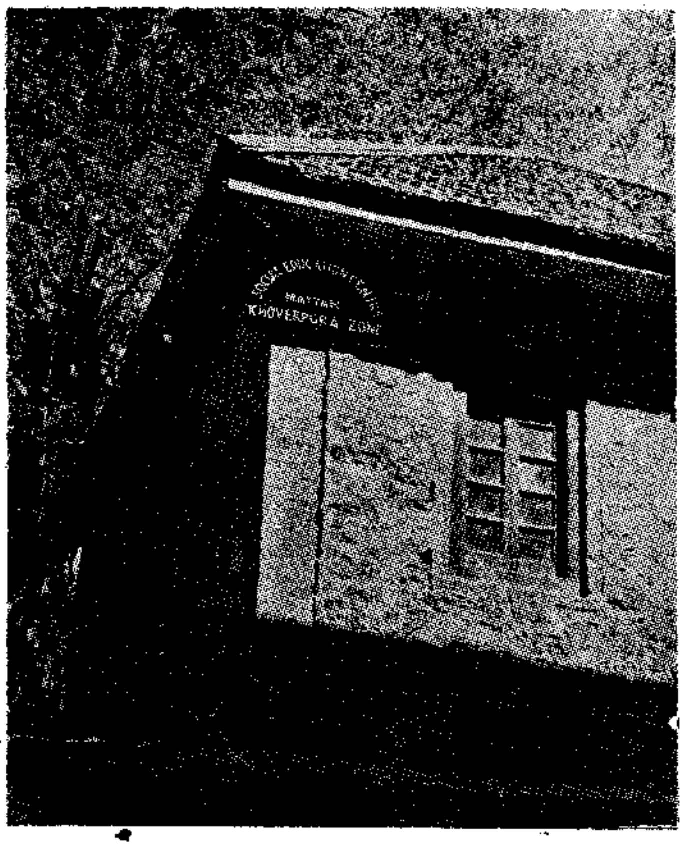


Fig. 37. Separation of the Brick Masonry Corner Pier from the Rubble wall.

Fig. 38. Undamaged Coursed Rubble Masonry Construction with a Timber Runner at Lintel level in Mir Maidan.

Fig. 39. Undamaged Random Rubble Masonry House in Verinag with a Lintel Band

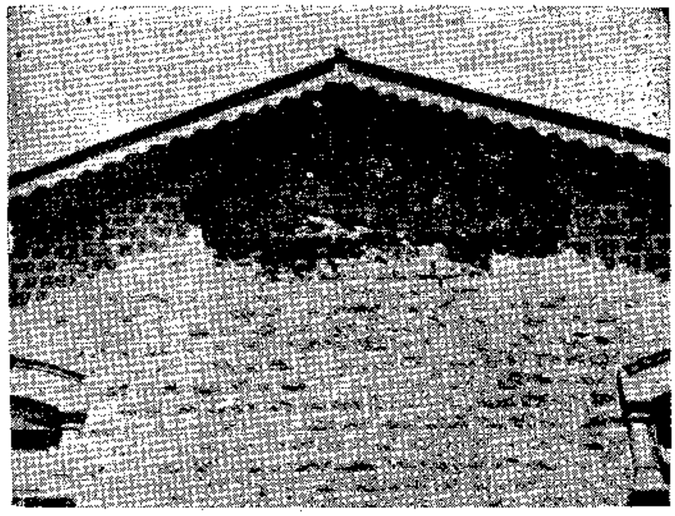


Fig. 40. Damaged Gable End of the Government College Building in Khanabal, showing the use of Horizontal Timber Planks in the Walls.

Fig. 41. Buildings in Lal Chowk, Anantnag, which were unaffected by the Earthquake.

Fig. 42. Undamaged Four Storey Building in Anantnag,

stones: A seven storey structure with hipped roof covered with corrugated galvanised iron sheeting, and a three storeyed building with a birch bark roof are seen in Fig. 43. All these structures are seen to have the horizontal timber runners well connected at ends, and behaved admirably during the earthquake having very insignificant damage. This good behaviour may be attributed to better construction features and also due to the fact that they are situated in the outer northwestern section of the town which had a lower intensity.

(D) Brick-Nogged and Wooden Structures :

Since a larger volume of timber has to be used in order to make the wooden framework for a brick-nogged structure, these turn out to be more expensive than the "dhajji-diwari" or the rubble masonry construction having timber in the form of runners only. As such, they have not been used much by the people of Anantnag district. These turned out to have better performance during earthquakes. A double storey brick-nogged house at Mattan, Fig. 44, was quite safe even though the walls were of adobe. In the old section of the Anantnag town, a brick-nogged mosque (Fig. 45) proved to be invulnerable. The library building of the Government College at Khanabal which has brick nogged gable in the first storey (Fig. 46) was also unaffected. The timber beam supporting the balcony of the first floor traverses over masonry piers having wooden pieces embedded at the top of the piers. The beam is nailed on to these timber pieces as shown in Fig. 47.

A building (in Mattan) having timber framework and wooden panelled walls, shown in Fig. 48, is earthquake resistant on account of its flexibility and ductility. Such structures are, however, recommended only with trepidation since there is always a danger of fire following the earthquake. The diagonally arranged wooden planks in the panels increase the strength of the walls in the horizontal direction.

(E) Modern Construction :

The spiralling cost of timber has had a marked effect in the building practices in Kashmir. Besides this, improvement of communications and availability of other building materials like burnt bricks, lime, cement and steel have also influenced the style of modern construction. Cement and steel are, however, still expensive. Thus the majority of the private houses now being constructed have burnt brick masonry walls in lime mortar. The absence of the timber runners at various levels is very conspicuous. In the new construction, timber is only used for the trusses. Corrugated galvanised iron sheets are also replacing the conventional thatch roof. A large number of houses in 'Nai Basti" (New Settlement) in Khanabal are of the type shown in Fig. 49. Probably since these structures were new and Khanabal had only an intensity V, they were not damaged significantly. A similar new house in Mir Maidan had diagonal cracks as seen in Fig. 50. The walls became shaky and were thrown out of plumb. How much damage a future shock will do is rather conjectural, but it can be put down categorically that such structures are unsafe in an area which is known to have a high seismic activity. It has been pointed out by Jai Krishna and Arya[8] and also by Jai Krishna and Brijesh Chandra[10] that in order to make such masonry structures aseismic, it becomes necessary to strengthen them with a judicious combination of vertical steel in corners, steel around openings and reinforced cement concrete bands at the roof and lintel levels. Such a practice has recently been adopted to a large extent in the seismic zones of north Bengal and Assam[11].

The proposed plans and specifications of Club Building at Anantnag indicate that the timber runners have been omitted in this public building also. Its specifications in brief, are as follows :

(i) The foundation will be of stone masonry in lime mortar over a bed of lime concrete.

(ii) The masonry work upto the plinth will be of stone bonded with lime mortar, duly dressed and cement pointed. A layer of 50 mm thick cement concrete (1 : 2 : 4) will be laid over the floor to act as damp proof course.

(iii) The superstructure will be of brick masonry in lime mortar.

(iv) The roof will have corrugated galvanised iron sheeting over 12 mm thick "budloo" wood nailed to "kail" wooden trusses.

The absence of timber runners or any other bonding arrangement* makes the proposed construction inadequate for earthquake resistance.

Fig. 51 shows a partially covered timber roof truss of a building under construction in the newly established Industrial Estate in Anantnag. This is a purlin-rafter construction in which the common rafter is omitted and the roof covering rests directly on the purlins. The bolted metal strip covers used in conjuction with the splayed joint strengthens the main tie beam considerably. U-shaed metal straps connect the lower end of the vertical strut to tie-beam and the upper end to the principal rafter. Such straps prevent the loosening of the joints and tie the various members efficiently. Joints and connections of this type, although reasonably good for timber trusses in seismic zones, are rather expensive and cannot be adopted by the majority of the private house builders of rural Kashmir. Under such circumstances, nailed, bolted, or disc-dowel joints may be employed effectively and economically[12].

Bond between Old and New Construction

It is necessary that where some alterations have to be done in the existing structure, a proper bond should be provided between the old and new construction. This will ensure that the latter built up portion does not fall apart as it did in the altered arched opening in the High School building at Mattan (Fig. 52). An arched opening in the Mission Hospital at Anantnag which was subsequently provided with a lintel also suffered the same fate.

Conclusions and Recommendations

Seismic history and geotectonics of Kashmir valley indicate that earthquakes will occur there in the future also. Thus it is necessary to bring about certain improvements in the construction of various types of buildings.

(A) Dhajji-Diwari Construction :

(i) The sun-dried bricks used in the traditional Kashmiri village hut needs to be replaced by burnt bricks. Instead of mud-mortar, better quality mortar such as lime mortar or 1 : 6 cement-mortar should be used. If it is not economically possible to adopt the better quality mortar for the entire construction, the corners and jambs must be bonded in better quality mortar and the rest of the masonry work may be in mud mortar. In such a composite construction, the more critical points in a building will be strengthened.

* For recommendations for construction of buildings in seismic areas, reference may be made to I. S. Code of Practice for Earthquake Resistance Building Construction (Under publication).

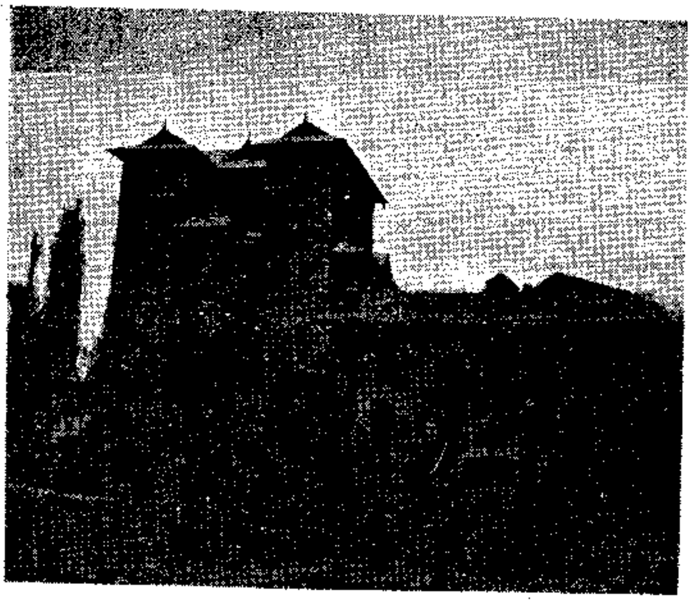


Fig. 43. Undamged Seven Storey Building in Anantnag.

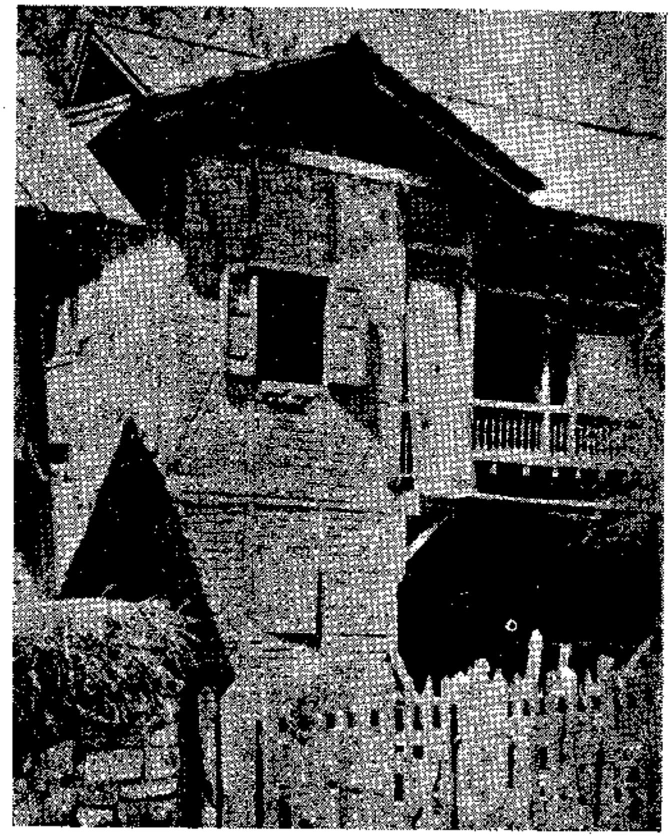


Fig. 44. Undamaged Brick-Nogged Structure in Mattan.

Fig. 45. Undamaged Brick-Nogged Mosque in Anantnag.

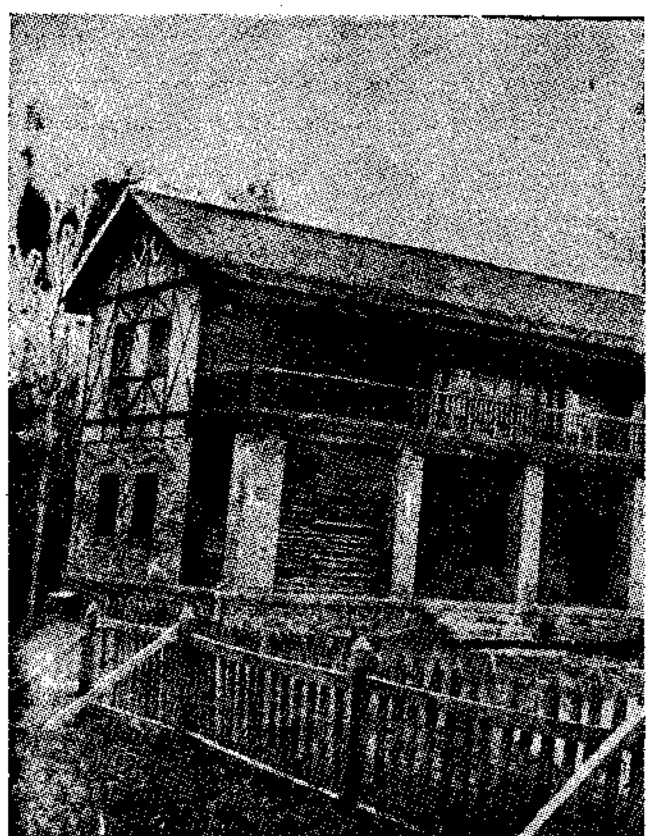


Fig. 46. Undamged Library Building, Government College, Khanabal.

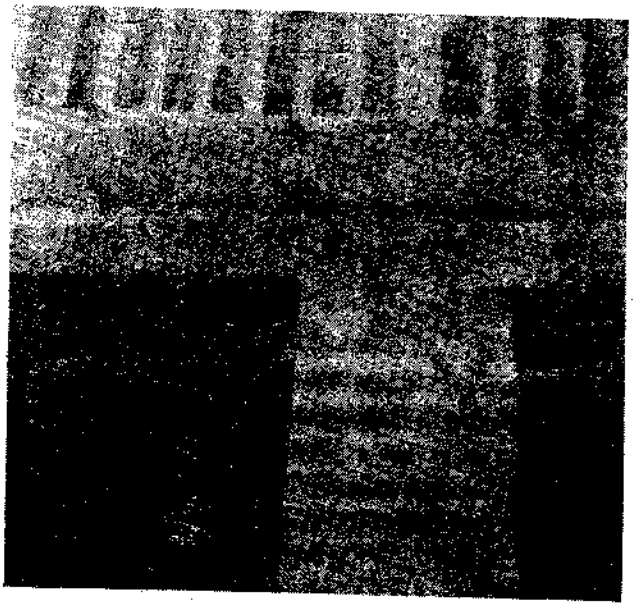


Fig. 47. Connection between Timber Beam and Masonry Column.

Fig. 48. Building in Mattan having Timber Panelled walls.

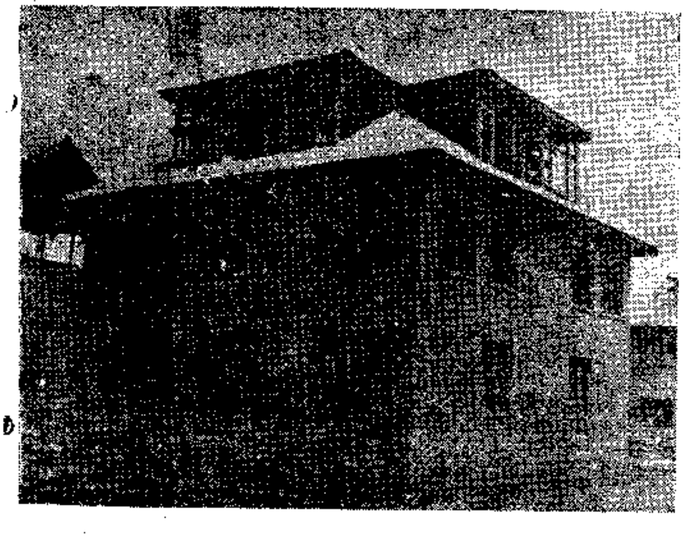


Fig. 49. New Brick Masonry Costruction.

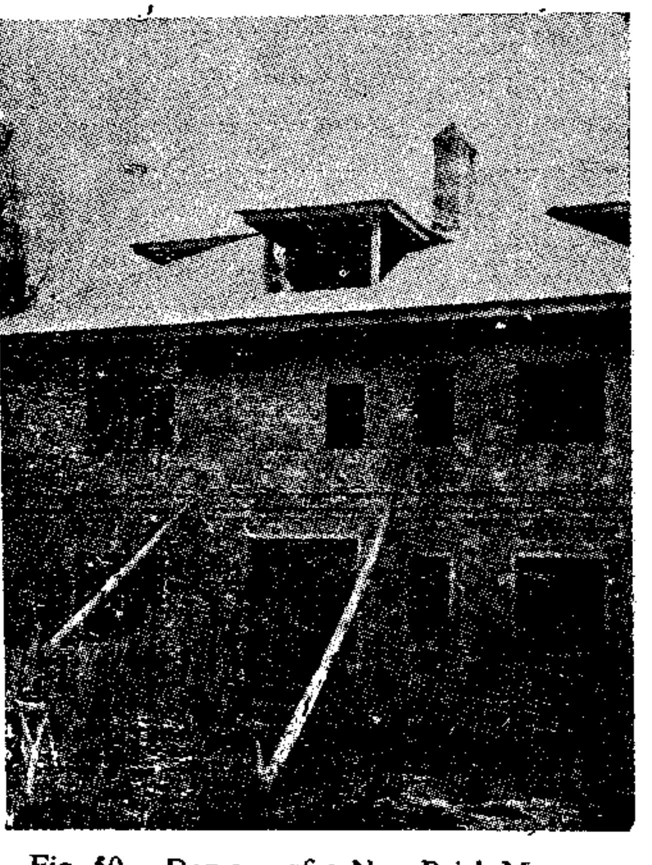


Fig 50. Damage of a New Brick Masonry Building in Mir Maidan.

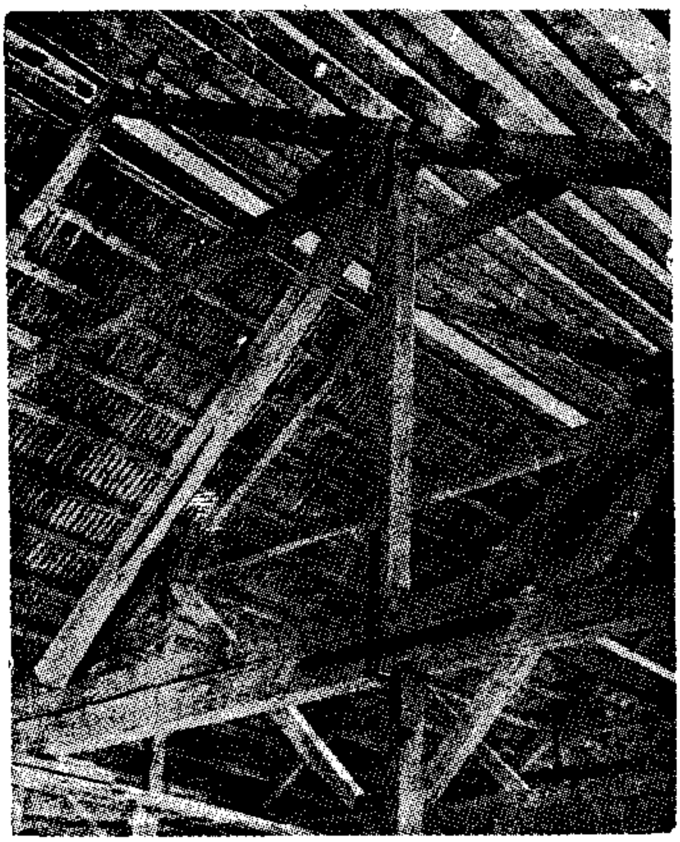


Fig. 51. Timber Roof Truss showing Main Tie-beam, Diagonal and Vertical Struct.

Fig. 52. Damage of the improperly bonded New and Old Construction

(ii) Since the infills were observed to separate out during earthquakes, care should be taken in "tying" the piers to the infill between them.

(iii) The usual English or Flemish bond may be introduced for brick masonry work instead of the bond comprising of stretchers only. This will ensure that there is propoer keying of the facing and backing. To save the inmates from cold during winters, instead of constructing thicker walls by filling the space between facing and backing by brick-bats, stones, mud and rubbish, it will be desirable to construct cavity walls which will be light and more effective against cold.

(iv) The vertical studs and the horizontal brick nogging partition walls should be bounded together so that brick nogging may not come off. This should be done by means of timber battens, say 25 mm × 10 mm nailed to the vertical timbers on the inside of the panels or by wire nails (6 gauge 15 cm long) half inside timber and half inside brickwork.

(v) Roofs with pigeon-hole type gables should be discouraged. The alternative would be a simple truss system with nailed, bolted or dowelled joints.

(vi) The timber lintel bands in the long and cross walls should be connected through metal straps at corners or by means of joints as shown in Fig. 25.

(vii) For "Dhajji-Diwari" construction, the number of storeys should not exceed one storey and the attic floor.

(B) Rubble Masonry Construction :

(i) Rubble masonry also requires better bonding material. Mud-mortar should be discarded and lime-mortar or cement mortar used.

(ii) Cross-section of a rubble masonry wall as shown in Fig. 33 (a) is undesirable, and should be avoided. The desirable cross-section is as shown in Fig. 33 (b) in which bond stones are provided from facing to backing. If stones of length equal to the thickness of the walls are not available, then the bond stones may be two-thirds the thickness of the wall and a lap provided as shown in Fig. 33 (c). Such stones when provided every metre apart vertically and horizontally will ensure a good bond between the facing, hearting and backing.

(iii) The long and cross walls should be "tied" together by interlacing the storeys at the corner. If there is a pier at the corner, the two walls should be tied to the pier to ensure integral action of long and cross walls. A band of reinforced cement concrete may be provided all around at the lintel level.

(iv) Vertical steel reinforcement may be provided at the junctions and corners of the load bearing walls. This greatly adds to the resistance against earthquakes.

(C) Modern Brick Construction :

Absence of horizontal timber runners appears to be a serious omission in modern construction of burnt brick and rubble masonry. Such houses will have inadequate strength against earthquakes. Experimental studies and observed behaviour have shown that lintel bands of either timber or reinforced cement concrete add considerable strength to the buildings. If economically feasible, vertical steel may be introduced at the corners and junctions of load bearing walls.

For detailed specifications for reconstruction of masonry and timber buildings, reference may be made to Indian Standard Code of Practice for Earthquake Resistance Building Construction (Under publication, 1967).

Acknowledgements

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