Cracks in building and their remedial measures

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Development of cracks in buildings results in loss of strength and stability, causes rain penetration, decreases sound insulation and affects aesthetics and overall effeciency. The paper addresses itself to the task of detecting causes of cracks and suggests remedial measures to combat the situation. Methods of repair and precautions to be taken while repairing the cracks have also been described in detail.

The formation of cracks in buildings is a common phenomenon and almost all buildings are associated with it in some form or the other. Most of the buildings develop cracks in their fabric, usually soon after the construction. Superficial cracks are easily repairable and unlikely to recur to any great extent, whereas structural cracks in buildings result in loss of strength and stability, cause rain-penetration, decrease sound insulation and affect aesthetics and overall efficiency.

The approach of an engineer to a problem of cracks in buildings should be identical to that of a doctor to his patient. An engineer should have a sound knowledge of the behaviour of building materials and methods of construction, various types of cracks likely to occur, their causes and respective remedial measures. In brief, it involves detection, diagnosis and remedy. Before remedies are sought, correct diagnosis will decide whether satisfactory repair is possible, economical and worthwhile. Factors responsible for cracks, in load bearing walls, framed structures with flat or pitched roofs for isolated buildings and row housing have been studied in detail with a view to suggesting suitable remedial measures described in the present paper.

Investigation of cracks

The cracks may take place in vertical, horizontal, stepped, diagonal, or a combination of any of these forms as depicted in *Fig* 1. Cracks in buildings are classified as (*i*) active cracks, where the movement is observed to continue; and, (*ii*) dormant cracks where no further movement occurs.

The detection of cracks should be accomplished after thorough investigations on the number, width, depth, length, location and direction of cracks. The investigator should discard any preconceived ideas about the causes of crack and start with unbiased mind and investigate the following aspects:

(*i*) whether the crack is new or old looking

(*ii*) whether it appears on the opposite face of the member also

(*iii*) is the crack active or dormant

(*iv*) whether cracks form random or in a definite pattern

(*v*) formation of similar cracks in buildings in the same locality

(*vi*) season of the year during which the building is constructed

(*vii*) the soil condition, type of foundation used and movement of ground, if any

(*viii*) drawings, specifications, methods of construction and test results of site, if any

Besides, discussions with the persons responsible for the design, construction, maintenance and occupants of the building should be held.

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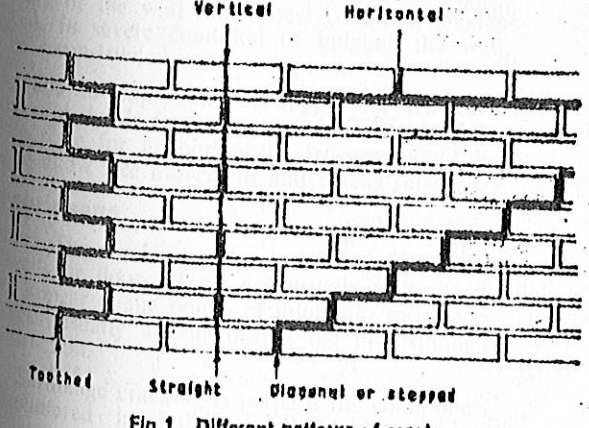

Fig 1 Different patterns of cracks

Causes of cracks

Cracking in buildings is a complex phenomenon. Different causes may sometimes produce same type of crack, and vice versa. It has been observed that old constructions generally show less cracks and are less susceptible to damage. Modern constructions, however, are in many important respects radically different from those of the past and generally lead to greater problems of crack because of allowance for less factor of safety; larger spans with slender members; use of weak and under-developed soil for mass construction, without adopting suitable foundation techniques; use of newly developed building materials and construction techniques; without adequate knowledge about their limitations; speedy construction and over-emphasis on economy.

A large number of buildings have been surveyed in various parts of the country and it was found that the form taken by the crack is greatly influenced by the relative strength of the components, location of openings and other points of weakness, flooring or roofing system and any other restraint operating on the building[1]. The main causes of cracks follow in detail alongwith respective possible remedial measures.

Movements of the ground

Symptoms: Cracking in wall due to movement of ground takes either diagonal/vertical form which originates from corners of openings. These cracks are usually wider at one end.

Causes : Movement of ground is dependent upon nature and the response of the foundations to such external influences as heat, moisture and loadings upon them. Soil beneath the foundation of walls which is exposed to the sun, tend to dry out to a greater extent than the soil beneath the foundation of walls under shade. Sometimes, excessive watering of gardens or leakage from drainage and water pipes at isolated points causes different moisture contents in the soil resulting in the movement of ground. Crack that vary in width with the seasons are normally indicative of movement resulting from shrinkable clay subsoils.

Unequal settlement of foundation may result in shear failure of buildings which occurs when part of foundation is overloaded. The soil slips in a complete downward, sideward or upward direction and allows the footing to settle as a result of the displacement of the bearing material. Shear failure is predominant in made-up ground. The other causes may be geological faults, vibrations from traffic, machinery, seismic tremors, etc.

Remedies : If movement has ceased or become negligible, simple patching of the cracks, by method of 'routing and sealing' as described in the paper, should be done. Hair cracks are usually filled up with whitewash.

Where movement is active and cracks are serious, the following measures are to be taken before repairing of the cracks :

(*i*) providing an impermeable ground cover (flexible apron) around the building[2].

(*ii*) prevention of water stagnation around the building by providing adequate drainage system.

(*iii*) plantation of creepers and fast growing tree, in the immediate vicinity of building should be avoided.

(*iv*) underpinning of the footing or restraining the lateral flow of foundation by sheet piling.

(*v*) the bearing capacity of the soil beneath and adjacent to the footing, can be improved by stabilization process[3].

Thermal movement

Symptoms : In external walls, horizontal cracks usually occur at or near roof level, and at top or bottom of window openings. Diagonal cracks appear at the corners and nearly vertical cracks in the middle portion of the building as shown in *Fig.* 2. Cracks are most likely to occur near openings or at the points of minimum resistance and the width of crack vary with the atmospheric temperature.

Causes : All building materials expand and contract to greater or lesser extent with the change in atmospheric temperature. In majority cases, building elements are wholly or partially restrained and change in temperature induce stresses in them which may be quite considerable.

In modern construction, cement concrete or steel are very much in use and their co-efficients of expansion are about twice as large as that of brick or stone. The contraction and expansion in masonry would be taken off to a large extent by the compression and opening of joints, whereas such behaviour is not possible in concrete. In large buildings the movements due to temperature variations are restricted to a large extent by cross and end walls. Brick work is also affected if large areas are exposed to direct sun, giving rise to internal stress causing cracks, *Fig.* 3. The thermal movement of flat reinforced concrete roofs result in cracks due to non-provision of free movement conditions of the slab over walls. In tall buildings, depending upon the nature of construction, one or two upper most storeys are subjected to relatively more thermal variation in comparison to the storeys underneath. This also induces variable thermal stresses leading to formation of cracks.

Remedies : Horizontal crack at or near the roof slab and wall : the wall plaster upto 10 cm. above and below the crack should be removed forming a V-groove and filled with sealant grout. Alternatively, although more difficult, the roof slab should be temporarily supported on rolled steel joists or ballies and planks, the mortar joint immediately below the bearing portion of the slab cleared off and replaced by a bitumastic sealant joint. Subsequently the top and bottom portion

of the crack should be replastered and made a V-groove along the crack.

Cracks in long reinforced concrete slabs—cracks should be enlarged in the form of a V-groove and treated with sealant. After repairing, 2 to 3 cm thick bitumen based sealing mortar/concrete should be placed over the crack in the form of hump over which tarfelt or waterproofing course should be laid. Further, the roof surface should be white-washed or thermally insulated to minimise heat absorption and consequent movement. However, the crack of ceiling should be finished in the form of a V-groove along the crack which usually appear at regular intervals.

Cracks due to bulging of wall—tie rods are to be provided near roof or floor level anchoring the suspect wall to another wall or structural member which is sound, or tending to move in the opposite direction. The other alternative may be build buttresses, keyed into the suspect wall, carried to a stable base, and firmly secured, to ensure that the buttress actually resists against the wall in the direction intended, *Fig* 4. The stability of the wall under new condition should be checked. In severe condition of bulging, the wall should be reconstructed.

Cracks due to expansion of supporting trusses—all mortar and debris from the oval hole provided in the saddle plate for anchoring the trusses should be removed to allow free movement and cracks repaired.

Drying shrinkage

Symptoms : The cracks usually start from the middle of long walls or floors. They are usually of uniform width and appear at the points of minimum resistance. These cracks usually appear during the first summer after construction.

Causes : Shrinkage cracking is perhaps the commonest form encountered in buildings. Building materials usually absorb moisture during building construction operations and dry out slowly. Shrinkage affects many building materials such as sand, lime bricks, lightweight concrete products, cement renderings, etc. Dense concrete has less shrinkage than lightweight concrete. Shrinkage increases with the increase in the water-cement ratio and cement content. Wide cracks passing through the masonry units occur when the mortar used is strong *Fig* 5. It is worthwhile to mention that rendering over brickwork is liable to shrink because of their disparity in coefficients of expansion and a shearing stress of 'crawling' effect takes place in the plane of contact between the two materials causing formation of cracks at random fashion.

Remedies : Hair cracks in rendering or concrete may be left untreated. If the cracks are confined to the mortar joints the front portion of the joint should be raked out, and repointed with composite mortar. If the cracks pass through alternate courses of brick/blocks, the cracked bricks should be replaced and matched to the wall. Vertical cracks at the junction of the main wall or below column and infilling panel should be repaired as described using sealants with V-groove pointing in rendering along the crack recommended.

It is also advisable that straight wide cracks after repairing should be covered with strips which would allow movement to take place behind them.

Weathering and chemical action

Symptoms : Horizontal cracks in the rendering on brickwork corresponding to the mortar joints, deterioration of mortar, poor adhesion of rendering to the brickwork. This can be detected from the hollow sound when tapped and spalling of rendering and edges of individual units. Rusting of reinforcement results in brown stains on the surface and splitting cracks along the reinforcement or in its vicinity.

Causes : Cracks in building generally develop due to sodium, magnesium, calcium and organic compounds present in the brickwork, and the aluminate constituents of the cement or hydraulic lime result in the formation of new compound with an appreciable increase in volume. The mortar expands, deteriorates and the edges of the units spall leading to the formation of cracks.

Unprotected reinforcement will corrode in the presence of moisture and air, but the rate of corrosion is more rapid in the presence of corrossive agents; *e.g.* acids, sulphates and chlorides which are present in the surroundings of industrial atmosphere. Rusting greatly increases the volume of the steel, produces a pressure which is relieved by the bursting of the affected material and causes local displacement/spalling in its vicinity.

Remedies: To prevent the cracks widening further and to maintain the structural stability of the building the source of moisture should be located and measures taken to eliminate it.

All cracked, non-adherent rendering and efflorescence should be removed by brushing, allowed to dry, and a bonding agent applied on the surface prior to re-rendering with leaner mix of 1:2:9 (preferably sulphate-resisting cement : lime : sand). Spalling of the bricks usually affects a small proportion of wall. The damaged bricks should be replaced preferably with low sulphate content bricks using the above-mentioned mortar.

When the corrosion of reinforcement is detected, the reinforcement should be exposed by removing all unsound, damaged, porous or undesirable concrete or mortar. Existing reinforcement should be brushed free of rust by a wire brush; preferably by sand blasting. Treatment with special rust-inhibitive primer should be applied on the derusted surface and finished with concrete or mortar to ensure adequate cover to the reinforcement.

Improper design and detailing

Symptom: Cracks are usually large and well defined extending across the surface.

Causes: Cracks in building may sometimes develop due to overloading of its components which are not anticipated in the design and construction stages, abrupt changes in sections, use of long walls and slabs and construction of long blocks without any expansion joint at their junctions, *Fig* 6. Far too often the cracks occur because the designer has not conceived that changes can take place in the construction or in the materials used resulting in overstressing or cracking of the building element. Sometimes the cracks are attributed to the choice of inferior materials selected from cost considerations. But, almost any material can be used satisfactorily, if their limitations are taken into account in the design. Use of modern techniques without adequate knowledge, improper detailing of the drawing due to incompetence and carelessness at the planning stage lead to development of cracks, *Fig* 7.

Remedies: Cracks due to overloading of masonry piers/columns/walls—they should be strengthen by addition of extra cross section to withstand the load, or the load is to be distributed to the construction nearby. Alternatively, masonry should be strengthened by steel joists or reinforced concrete members and cracks repaired suitably.

Cracks due to bulging of cladding panels in framed buildings—mortar joint immediately below or to the side of the structural member (beam or column) should be removed and rebuilt using suitable sealant leaving a gap of 6mm and finished with a V-groove pointing along the joint.

Cracks due to non-provision of insulation treatment on roof—Remedial measures have been already suggested earlier under thermal treatment.

Cracks of reinforced concrete slab/beam—Before repairing of the cracks deflection recovery test should be done as per IS: 456. If it satisfies the requirements remedial measures are to be adopted as described in Bonding with epoxy or grouting methods of repair. Alternatively span may be reduced, concrete elements post tensioned or any other suitable strengthening method adopted.

Inadequate quality control

Symptoms: Any type of crack may occur.

Causes: Cracks in building generally develop due to inadequate quality control at site such as use of unsound and inferior materials; careless workmanship, ignorance, incompetance and poor supervision at site; *i.e.* noncompliance with the instructions given in the specification, early removal of temporary supports and over loading with materials during the building process.

Remedies: Adequate quality control should be achieved by constructing the building with good workmanship and standard practices specified.

Unforeseen and accidental forces

Symptoms: Random cracking.

Causes: Building components are heterogeneous in nature and susceptible to cracks when subject to earthquake or similar natural calamities or vibrations from machinery, traffic, sonic booms, etc. Since the earthquake force is a function of mass, massive buildings cause more cracking than the buildings lighter in weight.

Remedies: Strengthening measures are to be taken depending upon the type and nature of cracks[6].

General methods of repair

Repairing of the cracks should be accomplished as discussed below:

Routing and sealing: This is the simplest method for repairing the cracks. It involves enlarging the crack along its exposed face, filling it with suitable materials. For dormant cracks, repairing is to be done with mortar, whereas, sealants should be used for active cracks. Care should be taken in the selection of type and grade of sealant to suit local atmospheric conditions. During routing operation the cracks shall be raked in the form of a V-groove to a depth of 10 to 15mm with minimum surface width of 15mm. It should be completely cleaned with water, and dust removed and filled with composite 1 : 2 : 9 cement : lime : sand mortar. However, in case of sealant the portion should be completely dried before its application. For repairing of crack in brick masonry, the following procedure may be adopted depending upon the width of crack:

Cracks upto 5mm in width—In case of weak mortar joints, the joints are to be raked deeply for subsequent filling and pointing with composite mortar not richer than 1 : 1 : 6. With stronger mortar joints, the bricks adjacent to the crack are either cut out and rebonded using 1 : 1 : 6, filled with grout and pointed. To promote good adhesion, the brickwork should be wetted before the mortar is applied.

Cracks above 5mm in width—cracks should be properly cut and cleaned. Precast reinforced concrete tiles of the size of a brick, made up of M150 cement concrete and having one 8-mm diameter bar placed in centre along the length shall be placed, after removing one brick from the position of the crack, at right angles to the direction of cracks after every fourth or fifth course and toothed matching to the surface. Cracks above door and window openings may also be treated similarly.

Bonding with epoxies: Epoxy resins are organic compounds having excellent adhesive properties. Once hardened, the compound does not melt, flow or bleed. Fine cracks, are enlarged in the form of a V-groove, are cleaned, dried and filled with epoxy resin mixed with approved hardener in the proportion of 1 : 6 (resin-cum-hardener : sand) before it starts hardening.

Large cracks should be bonded by drilling along the length of crack at several locations, injecting water or solvent to flush out the loose material and allowing the surface to dry. Sealing is then to be continued until epoxy either flows out of the adjacent sections at the crack or begins to bulge out the surface seals.

Grouting: Grouting of the cracks is also performed in the same manner as the injection of an epoxy. This method is applicable where the cracks run in a reasonably straight line and are accessible at one end. It consists of cleaning the crack and sealing it with high early strength cement grout.

Stitching: Strength of the cracked portion can be restored by providing stitching-dogs of variable lengths on both sides of the section which spread out the tensile force over a considerable area. Sealing of the crack should be done before stitching. Further, the stitches should also be sealed. In addition, a hole at each end of the crack should be made to blunt and relieve the concentration of stress.

Precautions

The following precautions should be taken before repairing any structure:

(*i*) restraints causing the cracks should be relieved

(*ii*) flexible sealant materials should be used to seal an active crack instead of using rich mortar and rigid material

(*iii*) cracks over corroded reinforcement should be sealed after removing the rust

(*iv*) movement joints should be completely cleared of unwanted mortar

(*v*) cracks should be repaired during the summer months when the width of crack is maximum.

Conclusion

Factors responsible for the development of cracks in building have been identified in an attempt to suggest suitable remedial measures. Effective methods of repair have also been brought out with a view to helping the maintenance engineers tackling the problem with confidence.

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