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Preventive measures for cracks in buildings

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Factors influencing occurrence of cracks in different types of building have been identified in the paper to suggest suitable preventive measures adopting appropriate techniques in new building constructions.

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 soon after the construction. Different causes may sometimes produce same type of cracks, and vice-versa. Cracks whether visible from outside or inside, more often than not gives rise to psychological fear, over and above being eye sore to the viewers, even if it is not harmful structurally.

A large number of buildings have been surveyed in various parts of the country and it has been found that the form taken by the cracks is greatly influenced by types, location, length and height of the building, soil conditions and types of foundation, location of openings and other points of weakness, flooring/roofing system, strength of materials and components, variations in atmospheric temperature and any other restraints operating on the building. Factors responsible for cracks and their remedial measures have been dealt elsewhere by the author[1].

The cracking and repair of buildings is a perpetual problem, involving considerable cost and inconvenience to building industry as well as to the public. The problem can be tackled in two ways : adopting preventive measures, or by repairing. Prevention being better than cure, designer and builders would prefer to reduce the formation of cracks by adopting appropriate materials, and design and construction techniques suitable for exposed conditions at site. Detailing the structure in a systematic manner also prevents the occurrence of serious cracking, at least for the assumed service life of the building.

The paper gives an account of the preventive measures for cracks in different types of buildings in detail with a view to minimise the development of cracks in new constructions, from planning and designing stage to actual execution at site.

Soil and foundation movement

Cracking due to soil and foundation movement is mainly dependent upon the nature and response of the foundations to such external influences as heat, moisture and loadings imposed upon them. Cracks are usually diagonal or vertical which originate from corners or weak sections and are wider at one end.

Prevention : (*i*) Selection of proper foundation—For all buildings, the design of the foundation should aim at keeping differences in settlements within limits as given in *Indian Standard Code of practice for structural safety of buildings : shallow foundations*, IS : 1904-1978, that the superstructure can stand without serious distortion[2]. At the same time either the total settlements should be so restricted, or special arrangement made, as to ensure that connections to the buildings such as drains are not damaged. The type of foundation chosen should be one that will keep the movements as small as possible. If a certain amount of differential movement of the ground cannot be avoided, the foundations taken together with the building should be made sufficiently rigid to redistribute the load and also to keep the relative settlements of the building small.

Construction on filled up ground—Filled up ground should not be used for building purposes unless it has been properly filled, consolidated and sufficient time has passed after the filling. The time required for a fill to reach a sufficient degree of natural consolidation to make it suitable as foundation depends upon the nature of the material comprising the fill, the natural ground and the drainange conditions.

Use of long buildings should be avoided, or where possible, they should be divided into small lengths to account for unequal settlement. On most fills, ordinary strip footings will rarely be adequate and usually raft or pile foundations are recommended.

Placing a building partly on the natural ground and partly on fill should be avoided as far as possible and the foundations should be taken down to the natural ground by piers or piles.

Construction on shrinkable clay—In such areas, foundation should be taken down to a depth where no ground movement occur and use of short bored piles or under-reamed pile foundation with plinth beams will prove more economical and quicker in construction.

Proper care should be taken to avoid the footing trenches or bored holes being exposed to either wet or very dry weather and trenches/holes should be covered or filled with concrete as soon as they are excavated to the required depth.

Flexible impervious apron should be provided around the building to prevent seepage of water to foundation.

(*ii*) Construction of building on ground that has been cleared of trees should be avoided till an appreciable time, atleast a year, is elapsed. The foundation should always be taken below the level of the dry clay.

(*iii*) Stagnation of water around the building should be avoided by providing adequate drainage system.

(*iv*) Plantation of creepers and fast growing trees in the immediate vicinity of building should be avoided

(*v*) Dynamic movements in buildings; *i.e.*, vibrating effects should be controlled either by reduction or isolation at source or by reducing the response of the building with damping materials like rubber, bitumen, air gap, etc. in the soil around the building.

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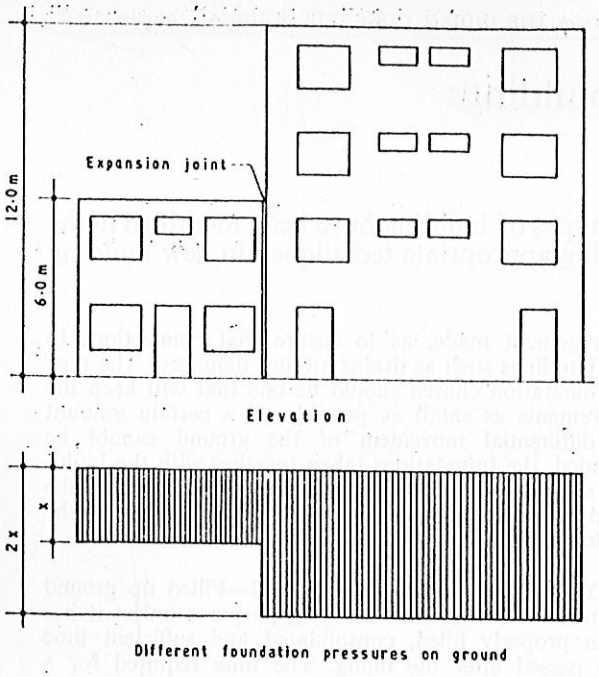

Fig 1 Differential settlement

(*vi*) Expansion joint—Vertical movement joints as given in *Indian Standard Code of practice for design and installation of joints in buildings*, IS : 3414-1968[4], should be provided at changes in the height of the building where differential settlements are likely to occur as a result of unequal ground pressures, *Fig* 1.

Thermal movement

All building materials expand and contract to varying extent with the change in temperature. In majority cases, building elements are wholly or partially restrained and change in temperature induces stresses in them which may be quite considerable, leading to formation of cracks. The width of the cracks usually vary with the temperature.

Prevention : Planning—Proper orientation, shading, insulation treatment on roof and white or light colouring on walls/roofs help in reducing the cracks in building.

(*ii*) Expansion joint—Expansion joints according to IS : 3414-1968 should be provided wherever there is change of direction in the shape of building structure, such as connecting passages joining the two large blocks of buildings, or at places where two wings of building meet in different directions, to allow for their independent movement. Staggering of joints should be avoided as far as possible. Joints should be efficient and completely cleared of unwanted mortar.

Reinforced cement concrete roof slabs should have expansion joints at intervals of about 12m to 15m. This can be achieved by providing a joint in the slab or by providing twin beams at the joint. In the former case, slab should be designed considering the edge at the joints free, while in later case, the beam should be designed as two separate L-beams which is normally adopted. Adequate concrete bed blocks should be provided under the beams for proper distribution of load.

For beam portion and slab embedded in masonry at floor level, provisions should be made for smooth bearing on the wall with 6-mm thick cement plaster 1 : 3 (cement: sand) finished with a layer of kraft paper. In case of roof slab, two layers of bitumenous paper, or kraft paper should be provided in between the slab and the wall bearing after rendering it smooth with 6-mm thick cement plaster, whereas on the sides of beams at roof level, kraft paper or bitumenous tarfelt should be used. A gap of 12mm should be left at the ends of beams and between the edges of the slab and the masonry which is filled with bitumenous filler (80kg hot bitumen : 1kg cement : 0.25m^3 coarse sand) or very weak mortar.

The jointing material should be of high ductility and low stiffness. Proper care should be taken so that penetration of water and dampness through joints are prevented.

In long brick walls, expansion joints should be provided at short distances of 12.0 to 15.0m from the corners and 20.0 to 30.0m in the centre as the movement is greater at the ends and less towards the centre. For wide temperature fluctuations and in uninsulated walls the spacing of joints should be decreased in accordance with coefficient of thermal expansion.

(*iii*) *Reinforcement*—In the bed joints of brickwork above and below the openings, or at the weak sections, *i.e.*, door and window openings, reinforcement of 1 to 6-mm diameter and 600-mm long mild steel bars should be provided, along the diagonals of opening, in every fourth brick course. Care should also be taken that reinforcement should be covered with mortar and kept as far away as possible from the face exposed. Reinforcement does not itself prevent the formation of cracks, but helps to restrict them from becoming wider and unsightly.

Adequate temperature reinforcement should be provided as given in *Indian Standard Code of practice for plain and reinforced concrete*, IS : 456-1978[5], which reduces the effect of the volume changes by

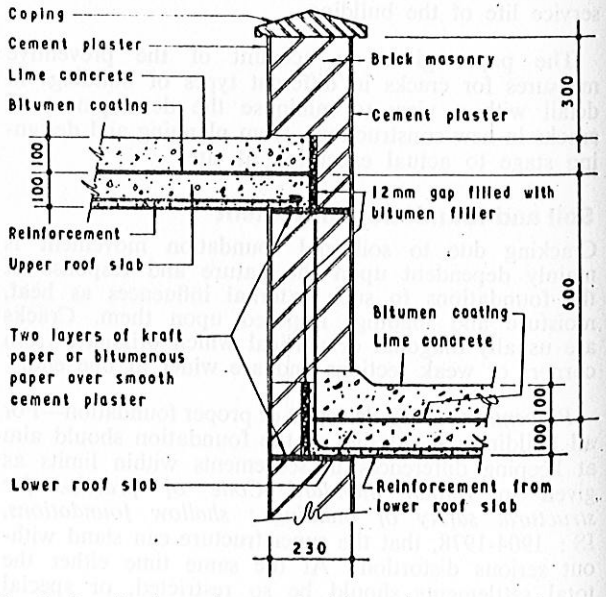

Fig 2 Details of two long roof slabs resting on a wall at different levels

imparting restraining force on the member and thus minimises the width of crack.

(*iv*) Free movement of the roof slab—This is achieved by reducing the forces transmitted from the roof to the wall through interposition of low-friction horizontal joint. Low-friction horizontal joint between slab and wall can be provided as described above.

(*v*) Reinforced concrete roofs at different levels—Cracks have been observed in walls, where long roofs at different levels and over a wall, due to expansion of each slab in opposite directions. To prevent such cracks the wall should be anchored with the lower slab by providing suitable reinforcement. The upper slab should be absolutely free to move on the top of the wall *Fig* 2.

(*vi*) Pitched roof—In case of large steel trusses provision should be made for their free movement, due to temperature variation, by making slotted holes in the saddle plate for anchor bolts. Similar provision should also be made in purlins at their joints for free-movement.

(*vii*) Wall and roof junction—The temperature drop in the wall immediately below roof is steep and no increase is reported at a depth of about 350-mm below the roof slab[6]. Vertical and horizontal reinforced concrete ties or bands in the plane of the wall are to be provided. The vertical ties together with foundation divide the wall surface into number of panels of masonry and thus reducing both horizontal and vertical deformation.

Drying shrinkage

Building materials usually absorb moisture during building construction operations and dry out slowly. These cracks are of uniform width and appear at the points of minimum resistance.

Prevention: (*i*) Brickwork—Bricks should never be saturated with water (particularly more absorbent types of bricks). Bricks are generally wetted to reduce the suction and facilitate proper laying and bedding.

Mortar used should be of relatively weaker type than the bricks. Leaner mix of 1 : 2 : 9 (cement : lime : sand) by volume is ideally suitable, otherwise mix should be designed according to strength requirements. Where rich mortar is to be used for some reasons, bricks of very low drying shrinkage should be adopted.

The long and continuous walls should be divided into small lengths or panels free from any restraints at the ends.

Bricks/units with the low shrinkage value should be selected.

Rendering work on walls should be deferred as longer as possible so as to allow for maximum shrinkage before rendering.

New brickwork should be kept wet minimum for seven days after it has hardened to increase the strength of masonry. It is also advisable to protect from direct exposure to the sun or drying winds.

Reinforcement in the bed joints should be provided as described under thermal movement. In important buildings, where bricks of poor strength or high shrinkage value have been used, a reinforced cement concrete band as given in *Indian Standard Code of practice for earthquake resistant construction of buildings*, IS : 4326-1976[7] should be provide above openings at lintel level.

In case of constructions with sand-lime bricks, lightweight concrete components, hollow concrete blocks, etc. vertical movement joints at closer spacings of 6.0 to 8.0m should be provided. Use of weak mortar is recommended in such cases. During wet weather, the unfinished work should be covered and the units stored under shade before use.

Use of dense rendering with smooth finish should be avoided.

(*ii*) Concrete work—Stiffer concrete mix, *i.e.* concrete with low water/cement ratio should be used. Richer mix of concrete should be avoided as far as possible.

Proper curing should be done (alternate wetting and drying cycle should be avoided).

Cement grout and excessive trowelling to the surface should be avoided.

Smooth surface of the form work for concreting should be avoided.

Graded and dense aggregate should be used for preparing concrete.

Adequate reinforcement should be provided considering the combined effect of temperature and shrinkage.

Concrete floor should be laid in panels by providing glass/aluminium strips in between, or in alternate bays. Similar strips should be provided in skirting/dado also.

(*iii*) Framed buildings—Vertical joints between columns and brick wall panels should be made with resilient weather proof material (bitumenous filler).

Compression joints should be provided between the top of each cladding panel and the beam.

As much time as can conveniently be allowed should elapse between casting the frame and providing the cladding.

(*iv*) Timber work—Well seasoned timber frames for doors and windows should be used after applying bitumenous paint along the sides of the frames in contact with masonry and more positige (rigid) fixing arrangement to the wall are to be adopted.

Weathering and chemical action

Chemical action due to presence of chloride and sulphates of sodium, magnesium and calcium in brickwork, subsoil water and the surrounding atmosphere of the industrial area leads to poor adhesion resulting in splitting cracks which can be detected from the hollow sound when tapped followed by spalling of renderings and edges of individual units with time.

Prevention: (*i*) Brickwork—In brickwork below damp-proof course level where wet conditions are expected, bricks having low sulphate content should be used.

Brickwork exposed to sea or other salt bearing water should preferably be built with dense bricks and sulphate resistant cement mortar.

Rich cement rendering should not be applied to bricks containing large amounts of sulphates because such renderings tend to form shrinkage cracks through which water enters the brickwork but cannot readily evaporate, resulting in dampness.

Gypsum should never be added to mortars containing portland cement or hydraulic lime.

The use of dense stone or bricks as a facing to porous brickwork should be avoided otherwise it would create problem of dampness.

Bricks containing high soluble salts should not be used in exposed conditions.

The brickwork should be guarded against coming in contact with salt-bearing materials during building operations.

The subsoil should be checked for sulphate content. If sulphates are present in the soil or in the ground water, sulphate resisting cement should be used for the concrete as well as mortar.

(*ii*) Cement—Buildings in areas where sulphate attack is anticipated should be constructed with sulphate resistant cement.

(*iii*) Steel—Steel members enclosed in brick work/concrete should be covered on all faces with dense cement mortar/concrete and kept as far away as possible from the face exposed.

Partially embedded steel or iron members should be surrounded with bitumenous compound at point of entry to brick work.

Special rust-inhibitive paint should be applied to the reinforcement before use where soluble salts are expected in construction materials as well as water.

(*iv*) Water used for mixing and curing operations should be clean and free from injurious salts and other substances that may be deleterious to concrete, mortar and steel. Potable water is considered satisfactory for construction works.

Design and quality control

Cracks in building sometimes develop due to various reasons which are not anticipated at the planning, design and construction stages such as poor selection of site, lack of knowledge about the behaviour of new building materials and their limitations, improper detailing, poor workmanship and inadequate quality control at site, non-compliance with the instructions given in the specification etc.

Prevention: (*i*) Design—At the planning stage proper attention should be given to ensure conditions that might occur during construction, or at a later stage on occupation of the building.

The structural members of the building should be designed, for structural safety and functional requirements, in a systematic manner based on relevant building codes. Full account should be taken of the dead, live and wind loads, forces caused by earthquake, and effects due to shrinkage, creep, temperature, etc., whichever applicable.

Suitable materials should be selected for the construction of buildings. Over-emphasis on economy should not be considered by selecting inferior and unsound materials.

Movement joints (expansion joints) at suitable places should be incorporated as described earlier under thermal movement.

Brick and stone walls should be designed considering use of relatively weak composite mortar.

The design of foundation should be accomplished as discussed earlier under soil and foundation movement.

(*ii*) Detailing—Drawings should be complete with sufficient details so that no misinterpretation is made. Detailing which are inclined to cause cracking should be avoided.

In detailing of continuous floor/roofs adequate reinforcement over the supports should be provided to resist negative moment.

(*iii*) Quality control—Adequate quality control should be achieved by constructing the building with good workmanship and standard practices specified.

Construction sequence should be rigidly followed in framed buildings.

In in-fill wall panels of framed buildings, the top of the panel should be filled with resilient (bitumenised) material and the vertical joints against the columns should be made with compressible water-light material finished with V-pointing along the joints so that cracks, if at all, occur appear within the groove and are not visible from outside face.

Roofs at different levels and pitched roof—Preventive measures have already been suggested earlier under thermal treatment.

Roof slab should preferably be projected out from the wall face by at least 150-mm instead of constructing a parapet which often leads to crack at the junction of wall and roof slab. Proper drip course in the projected slab portion should also be provided.

Unforeseen and seismic forces

Building components are heterogeneous in nature and susceptible to cracks when subject to earthquake, wind, moving traffic or explosions, etc. This is due to different transmission rates at which the waves pass through the different materials. Wind and earthquake forces are the most important factors and very tall and massive buildings can produce random cracking.

Prevention: (*i*) Buildings should be designed and strengthened according to IS: 4326-1976[7], with due regards for adequate structural safety and functional requirements. The parts of the buildings should be tied together in such a manner that the building acts as a single unit.

(*ii*) Adequate reinforcement according to IS : 4326-1976 and crushed (angular) aggregate in concrete should be used to improve the shock resistance of the building.

(*iii*) Materials such as rubber, bitumenised compound or air-gap as internal damping in the soil around the building should be used where buildings are subjected to moving traffic or explosion.

Conclusion

Factors responsible for the development of cracks in different type of buildings have been identified and suitable preventive measures for cracks, from planning and designing stages to actual construction sites, have been suggested in detail, with a view to minimising development of serious cracking.

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References

1. CHAND, SURESH. Cracks in building and their remedial measures. *The Indian Concrete Journal*, October 1979. Vol. 53, pp. 268-272.

2. ———*Code of practice for structural safety of buildings: shallow foundations*, IS: 1904-1978. Indian Standards Institution, New Delhi.

3. ———*Remedial measures for cracked buildings*. Digest no 9. Central Building Research Institute, Roorkee.

4. ———*Code of practice for design and installation of joints in buildings*, IS:3414-1968. Indian Standards Institution, New Delhi.

5. ———*Code of practice for plain and reinforced concrete*, IS:456-1978. Indian Standards Institution, New Delhi.

6. ROSENHANPT, S. A study of thermal cracks in masonry walls. *CIB Bulletin, no 3. 1961*.

7. ———*Code of practice for earthquake resistant construction of buildings*, IS:4326-1976. Indian Standards Institution, New Delhi.