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Study on Causes and Prevention of Cracks in Building

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Abstract*: Building cracks are most common type of problem in any type of building. So, it is important to understand the cause and the measures to be taken for prevention. Some faulty steps during construction and some unavoidable reasons different type of cracks starts to appear on various structural and non- structural parts of the building. So, timely identification of such cracks and adopting preventive measure are essential. Though cracks in concrete cannot be prevented entirely but they can be controlled by using adequate material and technique of construction and considering design criteria. Structural cracks are the one whose inherent cause lies in either in incorrect design, or faulty construction or overloading and are the one which can endanger the safety of a given structure. On the other hand, the non-structural cracks are the one which have the underlying origin due to moisture or thermal fluctuations, elastic deformation, creep, chemical reaction, or reason related to the foundation soil such as it movement or settlement or unhindered vegetation. Non-structural cracks are mostly due to internally induced stresses in building materials and these generally do not directly result in structural weakening. In this paper, we will discuss about types of cracks, causes of cracking and preventive measures to be taken along with the techniques for treatment of cracks.
***Keywords*: Crack categorization, Causes of cracking, Prevention, Techniques, measurement of cracks**

I. INTRODUCTION

Cracks in a building are of common occurrence. The first and most common reason of crack development is the stress component exceeding its strength component which can be associated to the externally applied loads (forces) such as dead, live, wind or seismic loads, or foundation settlement or stresses developed internally due to thermal movements, moisture changes and/or chemical action, etc.

Most buildings crack at some time during their service life. The appearance of cracks is a symptom of distress within the structure of the building. Often the cracking is of little consequence and once it is established as static, simple repair by filling or re-pointing is all that is required. However a crack maybe the first sign of a serious defect which may affect the serviceability or the stability of the building. Modern structures are comparatively tall and slender, have thin walls, are designed for higher stresses and are constructed speedily. These structures are, therefore, more liable to cracks as compared with old structures which used to be low, had thick walls, were lightly stressed and were built at a slow pace.

II. CRACK CATEGORIZATION

Cracks develop due to deterioration of concrete or corrosion or reinforcement bars due to poor construction or inappropriate selection of constituent material and by temperature and shrinkage effects. Internally induced stresses in building components lead to dimensional changes and whenever there is a restraint to movement as is generally the case cracking occurs. Depending on width of crack, these are classified as follows:

Table I
CLASSIFICATION OF CRACKS BASED ON WIDTH

Classification	Crack width
Thin	<1mm
Medium	1mm to 2mm
Wide	> 2mm wide

According to IS: 456 2000, the surface width of crack should not exceed 0.3mm in members where cracking is not harmful and does not have any serious adverse effects upon the preservation of reinforcing steel, nor upon the durability of the structures .In the members where cracking in tensile zone is harmful either because they are exposed to moisture or in contact of soil or ground water,

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an upper limit of 0.2mm is suggested for maximum width of crack. For particularly aggressive environment such as the 'severe' category, the assessed surface width of crack should not in generally exceed 0.1mm.
Cracking in reinforced concrete structures of various types can be divided into two main groups:

A. Non-structural Cracks

These type of crack occur mostly due to internally induced stresses in building material and normally do not endanger safety but may look unsightly, create impression of faulty work or give feeling of instability. Crack on wall, parapet wall, driveway are called non-structural cracks.

B. Structural Cracks

Structural cracks results from incorrect design, faulty construction or overloading and may endanger the safety of a building. The cracks in beam, column, slab and footing are considered as structural cracks.

III.CAUSES OF CRACKS

A. Moisture Movement

Most of the building materials having pores in their structure in the form of intermolecular (ex concrete, mortar, bricks etc) expand on absorbing moisture and shrink on drying. These movements are reversible. Initial shrinkage is partly irreversible and occurs in all building materials which are cement/lime based e.g. concrete, mortar, masonry etc. Some of the building materials absorb moisture from environment and undergo gradual expansion (Initial expansion), bulk of which is irreversible. For the bricks, this entire expansion takes place in first 3 months once they are removed from kilns. Cracks due to shrinkage affect mainly the appearance and finish and the structural stability is not impaired. These cracks generally get localized near door and window openings or stair case walls. In external walls they run downward from window sill to plinth level or to the lintel of lower story.

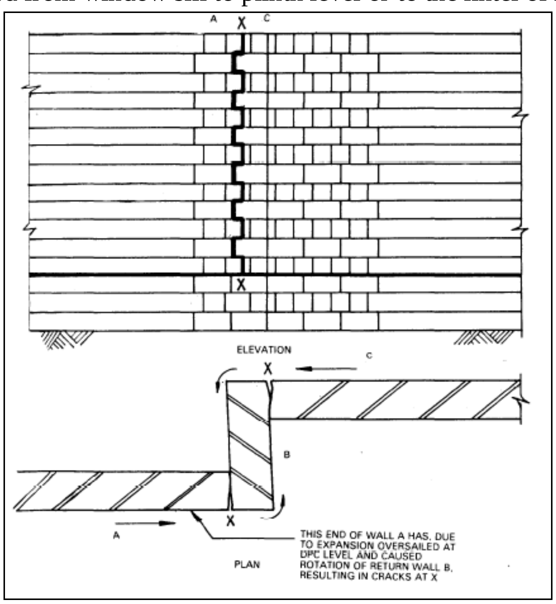

Fig. 1 Cracks due to expansion of brickwork

B. Thermal Movement

Due to variation in atmospheric temperature, there will be thermal movement in building components. When there is some restraint to movement of building component, internal stresses are generated resulting in cracks due to tensile or shear stresses. Cracks due to thermal movement could be distinguished from those due to shrinkage or other causes from the criterion that the former open and close alternately with changes in temperature while the latter are not affected by such changes. Thermal movement depends on colour and surface characteristics of exposed bonding surfaces. Dark coloured and rough textured materials have lower reflectivity and hence rise in temperature is more for these surfaces. In case of concrete roof slabs, as the material has low conductivity, thermal gradient is quite appreciable and that causes the slab to arch up and also to move outward due to heat from the sun. This result in cracks in external walls which support the slab and in the internal walls that are built up to the soffit of the slab. In case of framed-structures, roof slab, beams and columns move jointly causing diagonal cracks in walls which are located parallel to the movement, and horizontal cracks below beams in walls which are at right angle to the movement.

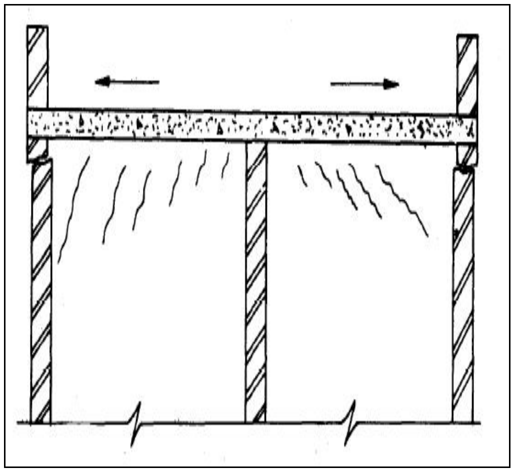

Fig. 2 (a) Cracking in Top Most Storey of a Load Bearing Structure

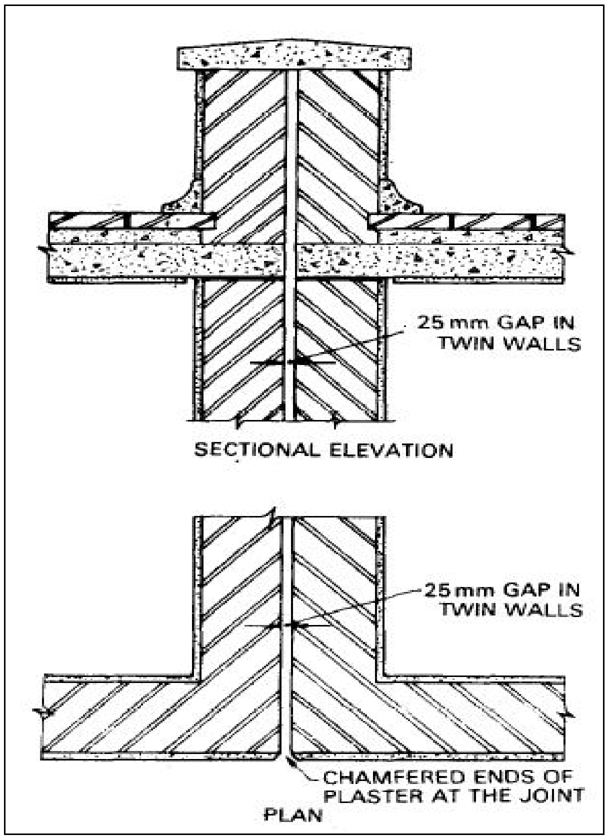

Fig. 2 (b) Expansion Joints in Slabs Supported on Twin Walls

C. Elastic Deformation

Structural components of a building such as walls, columns, beams and slabs, generally consisting of materials like masonry, concrete, steel etc, undergo elastic deformation due to load in accordance with Hook's law, the amount of deformation depending upon elastic modulus of the materials, magnitude of loading and dimensions of the components. If RCC slabs, RCC lintels over openings and masonry in plinth and foundation have good shear resistance, cracking in question would not be very significant.

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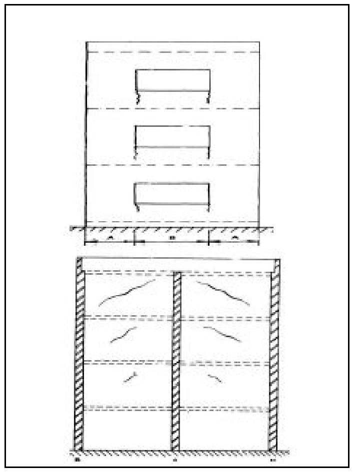

Fig. 3 Vertical Cracks and Diagonal Cracks

D. Movement due to Creep

In concrete, extent of creep depends on a number of factors, such as water and cement content, water cement ratio, temperature, humidity, use of admixtures and pozzolanas, age of concrete at the time of loading and size and shape of the component. Creep increases with increase in water and cement content, water cement ratio, and temperature; it decreases with increase in humidity of the surrounding atmosphere and age of material at the time of loading. In case of brickwork, amount of creep depends on stress/strength ratio and, therefore, creep in brickwork with weak mortar, which generally has higher stress/strength ratio, is more. Another reason for greater creep in case of brickwork with weak mortar is that weak mortar has greater viscous flow than a strong mortar. In brick work, creep may cease after 4 months while in concrete it may continue up to about a year or so. However, in concrete, extent of creep is related to the process of hardening and thus most of the creep takes place in the first month and after that its pace slows down. That means creep strain can be reduced by deferring removal of centering and application of external load.

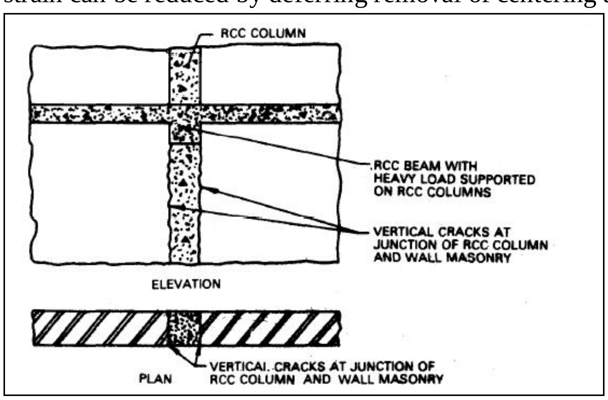

Fig. 4 Vertical Cracks at Junction of RCC Column and Wall Masonry in a Load Bearing Structure

E. Movement Due to Chemical Reaction

Chemical reactions may occur due to the materials used to make the concrete or materials that come into contact with the concrete after it has hardened. Concrete may crack with time as the result of slowly developing expansive reactions between aggregate containing active silica and alkalis derived from cement hydration, admixtures or external sources. Certain chemical reactions in building materials result in appreciable increase in volume of materials, and internal stresses are set up which may result in outward thrust and formation of cracks. The materials involved in reaction also get weakened in strength. Commonly occurring instances of this phenomenon are: sulphare attack on cement products, carbonation in cement based materials, corrosion of reinforcement in concrete and brickwork, and alkali-aggregate reaction.

In buildings, the main components which are liable to sulphate attack are concrete and masonry in foundation and plinth, and masonry and plaster in superstructure. The chemical reaction proceeds very slowly and it may take about two or more years before the effect of this reaction becomes apparent. Sulphate attack on concrete and mortar of masonry in foundation and plinth would

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result in weakening of these components and may, in course of time, result in unequal settlement of foundation and cracks in the superstructure

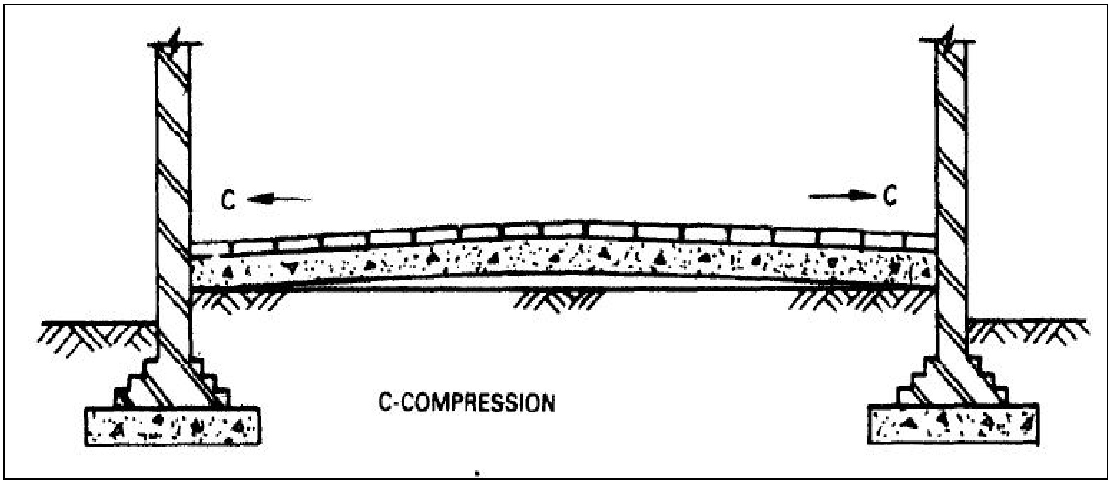


Fig. 5(a) Cracking and Upheaving of a, Tile Floor Due to Sulphate Action in Base Concrete

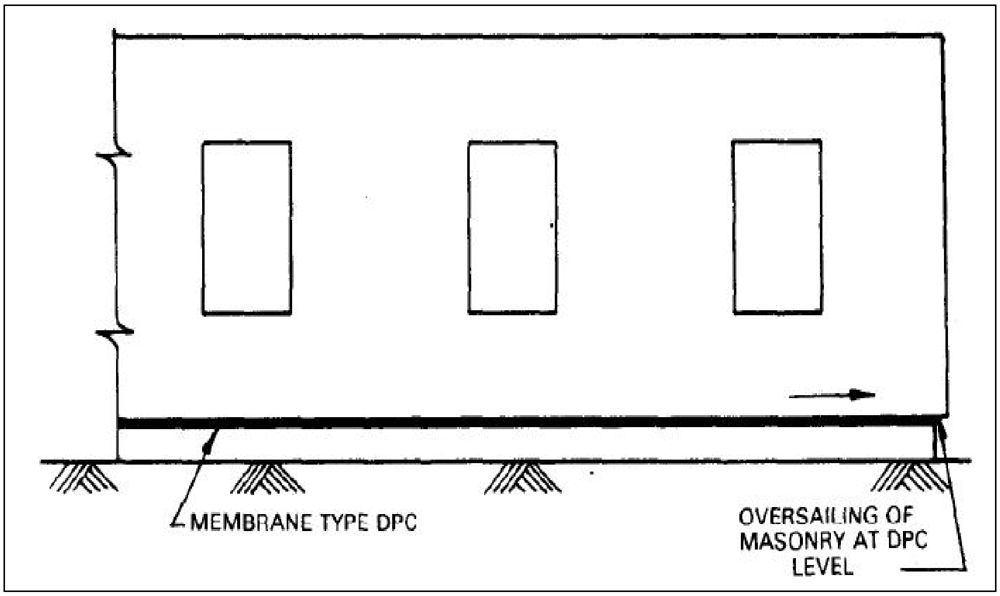


Fig. 5(b) Oversailing of Brick Masonry at DPC Level Due to Expansion

F. Foundation Movement and Settlement of Soil

Chemical reactions may occur due to the materials used to make the concrete or materials that come into contact with the concrete after it has hardened. Shear cracks may occur in the building due to large differential settlement of foundation and it may also occur due to unequal bearing pressure under different parts of the structure, or due to it excess the bearing strength of the soil, or due to minimum factor of safety used in the foundation…etc.

Cracks that occur due to foundation movement of a corner on an end of a building are usually diagonal in shape. These cracks are wide at top and decrease in width downward. These cracks thus can be easily distinguished from those due to thermal or moisture movements. In case of a building built on soil which is not very compact, sometimes settlement starts when water due to unusually heavy rains or unexpected floods gets into the foundation and causes settlement in the soil under load of the structure. Such a settlement generally not being uniform in different parts, results in cracking. Plinth protection around the building helps to some extent in preventing seepage of rain and surface water into the foundation, thereby obviating the possibility of settlement cracks.

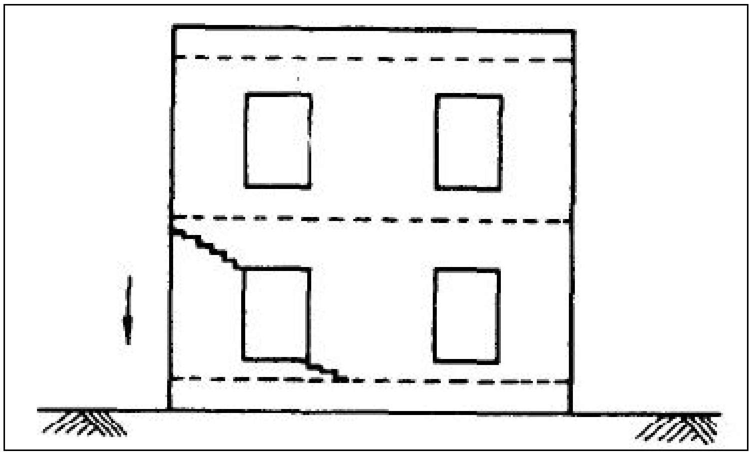


Fig. 6 Cracks at the Corner of a Building Due to Foundation Settlement

G. Cracking Due To Vegetation

Chemical reactions may occur due to the materials used to make the concrete or materials that come into contact with the concrete after it has hardened. Shear cracks may occur in the building due to large differential settlement of foundation and it may also occur due to unequal bearing pressure under different parts of the structure, or due to it excess the bearing strength of the soil, or due to minimum factor of safety used in the foundation…etc. Existence of vegetation, such as fast growing trees in the vicinity of compound walls can sometimes cause cracks in walls due to expansive action of roots growing under the foundation. Roots of a tree generally spread horizontally on all sides to the extent of height of the tree above the ground and when trees are located close to a wall; these should always be viewed with suspicion.

Sometimes plants take root and begin to grow in fissures of walls, because of seeds contained in bird droppings. If these plants are not removed well in time, these may in course of time develop and cause severe cracking of the wall in question.

When soil under the foundation of a building happens to be shrinkable clay, cracking in walls and floors of the building can occur either due to dehydrating action of growing roots on the soil which may shrink and cause foundation settlement, or due to upward thrust on a portion of the building, when old trees are cut off and the soil that had been dehydrated earlier by roots, swells up on getting moisture from some source, such as rain.

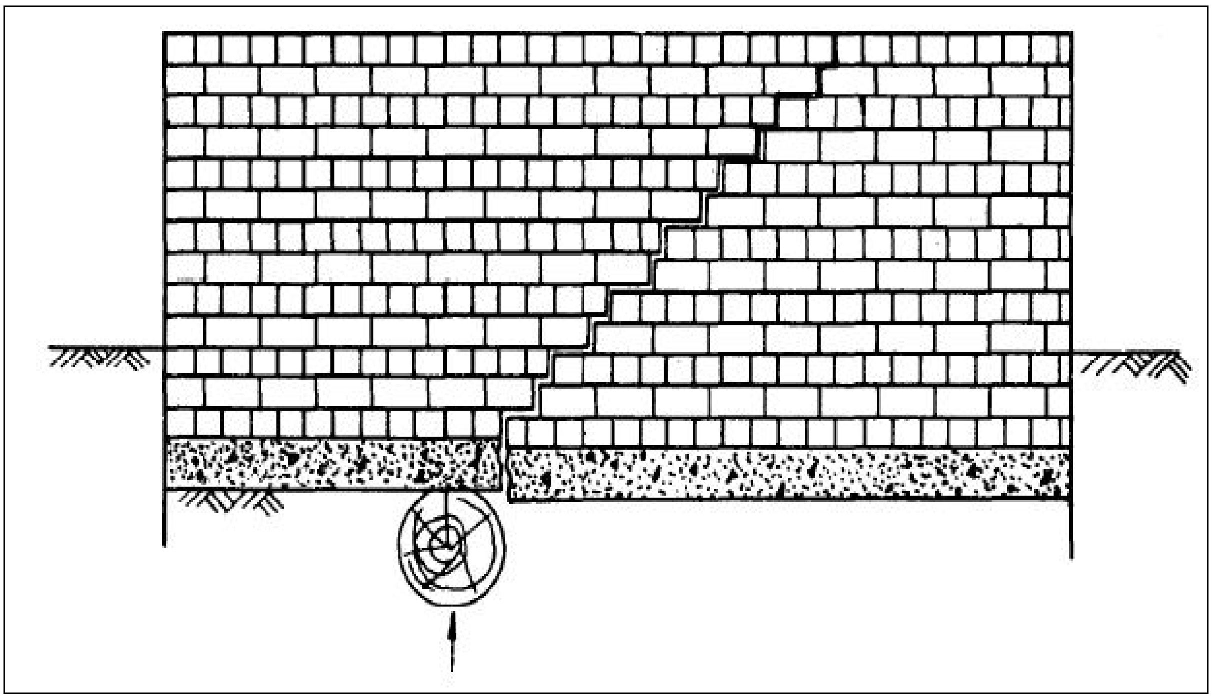
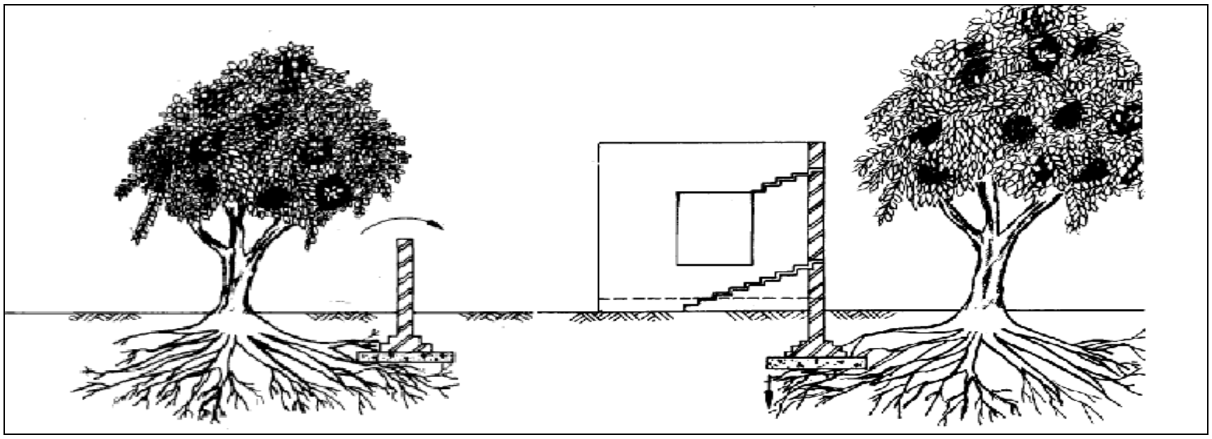


Fig. 7 (a) Cracking of a Compound Wall Due to Growing Roots Under the Foundation



7 (b) (i) 7 (b) (ii)

Fig. 7 (b) (i) Roots of Fast Growing Tree under the Foundation of Compound Wall may Topple down the Wall (ii) Trees Growing Close to a Building on Shrinkable Soil may Cause Cracks in the walls

IV. PREVENTION OF CRACKS

A. To Prevent Cracks Due to Moisture Movement

1) Select materials having small moisture movement eg bricks, lime stones, marble etc
2) Plan for less richer cement content, larger size of aggregates and less water content.
3) Porus aggregates (from sand stone, clinker etc) prone for high shrinkage
4) Plan for offsets in walls for length of more than 600 mm
5) Use of of composite cement-lime mortar of 1:1:6 mix or weaker for plastering work
6) Plan for proper expansion/control/slip joints
7) For brick work 2weeks time in summer and 3 weeks time in winter should be allowed before using from the date of removal from kilns
8) Delay plastering work till masonry dried after proper curing
9) Proper curing immediately on initial setting brings down drying shrinkage

B. To prevent Cracks Due to Thermal Movement

1) Dark coloured and rough textured materials on exteriors have lower reflectitivity and react more for thermal expansions
2) Plan for a layer of adequate thickness of good reflective surface over concrete roof slabs to minimize these cracks
3) Slip joint should be introduced between slab and its supporting wall or the some length from the supporting wall or the slab should bear only on part width of the wall
4) Mortar for parapet masonry should be 1cement: 1 lime: 6 sand
5) Construction of masonry over the slab should be deferred as much as possible (at least one month) so that concrete undergoes some drying shrinkage prior to the construction of parapet.
6) Good bond should be ensured between parapet masonry and concrete slab
7) The bearing portion of the wall is rendered smooth with plaster, allowed to set and partly dry, and then given a thick coat of whitewash before casting the slab so that there is a minimum bond between the slab and the support. To ensure more efficient functioning of this joint, in place of whitewashing 2 or 3 layers of tarred paper are placed over the plastered surface to allow for easy sliding between RCC slab and the supporting masonry
8) To avoid cracks near door frames provide groove.

C. To Prevent Cracks Due to Elastic Deformations

1) When large spans cannot be avoided, deflection of slabs or beams could be reduced by increasing depth of slabs and beams so as to increase their stiffness.
2) Adoption of bearing arrangement and provision of a groove in plaster at the junction of wall and ceiling will be of some help in mitigating the cracks.
3) Allow adequate time lag between work of wall masonry and fixing of tiles.

D. To prevent Cracks due to Movements Due to Creep

1) Do not provide brickwork over a flexural RCC member (beam or slab) before removal of centering and allow a time interval of at least 2 weeks between removal of centering and construction of partition or panel wall over it.
2) When brick masonry is to be laid abutting an RCC column, defer brickwork as much as possible.
3) When RCC and brickwork occur in combination and are to be plastered over, allow sufficient time (at least one month) to RCC and brickwork to undergo initial shrinkage and creep before taking up plaster work.
4) A panel walls in RCC framed structures: (i) as far as possible, all framework should be completed before taking up masonry work of cladding and partitions which should be started from top storey downward. (ii) Provide horizontal movement joint between the top of brick panel and soffit of beams.
5) Partitions supported on floor slab or beam :(i) Provide upward camber in floor slab/beam so as to counteract deflection. (ii) Defer construction of partitions and plaster work as much as possible (iii) Provide horizontal expansion joints between the top of masonry and soffit of beam/slab, filling the gaps with some mastic compound.

E. To prevent Cracks due to Movement due to Chemical Reaction

1) For structural concrete in foundation, if sulphate content in soil exceeds 0.2 per cent or in groundwater exceed 300 ppm, use very dense concrete and either increase richness of mix to 1:1.5:3 or use sulphate resisting Portland cement/super-sulphated cement or adopt a combination of the two methods depending upon the sulphate content of the soil.
2) Cracking caused in concrete due to carbonation can be avoided or minimized by ensuing use of Exposed concrete items in thin sections, such as sunshades, fins and louvers of buildings, are with concrete of richer mix (say 1:1.5:3)

F. To Prevent crAcks due to Foundation Movement and Settlement of Soil

1) Plan for under-reamed piles in foundation for construction on shrinkable soils
2) Plan for plinth protection around the building
3) Slip / expansion joints to ensure that new construction is not bonded with the old construction and the two parts (Old and new) are separated right from bottom to the top. When plastering the new work a deep groove should be formed separating the new work from the old.
4) for filling deep - say exceeding 1.0m, Soil used for filling should be free from organic matter, brick-bats and debris filling should be done in layers not exceeding 25 cm in thickness and each layer should be watered and well rammed.
5) If filling is more than 1 meter in depth, process of flooding and compaction should be carried out after every meter of fill.

G. To Prevent Cracks Due to Cracking Due to Vegetation

1) Do not let trees grow too close to buildings, compound-walls, garden walls, etc, taking extra care if soil under the foundation happens to be shrinkable soil/ clay. If any saplings of trees start growing in fissures of walls, etc. remove them at the earliest opportunity.
2) If some large trees exist close to a building and these are not causing any problem, as far as possible, do not disturb these trees if soil under the foundation happens to be shrinkable clay.
3) If, from any site intended for new construction, vegetation including trees is removed and the soil is shrinkable clay, do not commence construction activity on that soil until it has undergone expansion after absorbing moisture and has stabilized.

V. TECHNIQUE FOR TREATMENT OF CRACKS

A. Surface Filling Method

For cracks of width of micro-cracks less than 0.2mm, it is the most simple technique used and to apply brush polymer or to apply elastomeric sealant on the surface in order to prevent moisture content, carbon dioxide and other harmful materials. But the main drawback is that it belongs to repair only shallow surfaces and not deep cracks and cracks not suitable to water pressure.

B. Cementitious Grouting Method:

It is used for repair of wide cracks. It is a mixture of cementitious material and water that is proportioned to produce a proper consistency. Cement-based grouts are available in a wide range of consistencies; therefore, the methods of application are different for different material. This type of material do not require skilled worker or special equipment to apply, safe to handle and economical. These materials tend to have similar properties to the parent concrete and mortar, and have the ability to undergo

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autogenously healing due to subsequent hydration of cementitious materials at fracture surfaces. The main disadvantage is that this material shrinks. These are not suitable for structural repairs of active cracks. For application of cementitious grouts generally, some form of routing and surface preparation, such as removal of loose debris are needed. Grouts are generally to be mixed to a proper consistency by using a drill and proper mixer, and the consistency may be adjusted thereafter. Application should be done by hand troweling or dry packing into vertical and overhead cracks to fill all pores and voids .Finally, a suitable coating to be applied on the repaired surfaces.

C. Epoxy Resin Grout

This is the most common polymer material used to fill gravity feed crack repairs. It should be formulated to very low viscosity and low surface tension and resins should be applied so that it can easily penetrate through cracks under the action of gravity. The material which is having viscosity below 200 centipoise should be preferred to a minimum content. While using this method cracks should be properly cleaned and should be free from dust. If required some routing techniques must be required to facilitate pouring of resins. While cleaning the surface which is having dust if water is applied for it then it should be properly dried for 24hr because the moisture if present in the crack it will obstruct the flow of resins. The pouring of resins should be continued till the cracks go in absorbing after which the excess resins may remove with the help of flat rubber squeeze.

D. Crack Stitching

Stitching involves drilling holes on both sides of the crack and grouting in U-shaped metal units with short legs (staples or stitching dogs) that span the crack. Stitching may be used when tensile strength must be reestablished across major cracks. The stitching procedure consists of drilling holes on both sides of the crack, cleaning the holes, and anchoring the legs of the staples in the holes, with either a non-shrink grout or an epoxy resin-based bonding system.

VI. CONCLUSION

This study gives insight to types of cracks, causes of cracks and prevention of cracks. Various techniques for treatment of cracks are discussed in this study. We can summarize that though it is not viable to assurance against cracking yet attempts can be made to minimize development of crack. And also, not all type of crack requires same level of consideration. The probable causes of crack can be controlled if proper consideration is given to construction material and technique to be used. In case of existing cracks, after detail study and analysis of crack parameters, most appropriate method of correction should be adopted for effective and efficient repair of crack.

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