ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Study on Different Types of Cracks in Plain and Reinforced Concrete

Nagipogu Prem Kumar
Post Graduate Student,
Department of Civil Engineering,
Annamacharya Institute of Technology and Sciences,
Kadapa.

Dr. P. Sri Chandana, Ph.D
HoD,
Department of Civil Engineering,
Annamacharya institute of Technology and Sciences,
Kadapa.

Abstract:

Cracks in plain and reinforced concrete posses a challenging to civil engineers from the six decades. An attempt has been need in this thesis to understand the various types of cracks occurring in concrete and quantification of crack width where as such origin is available. The understanding of various types of cracks is sustainable with the case studies are presented in this paper.

1. INTRODUCTION

Cracks in concrete are extremely common and difficult to understand. When crack in the slab or wall, especially if the concrete is relatively new, he automatically assumes there's something wrong. This is not always the case. Some types of cracks are inevitable. The best that a contractor can do is to try to control the cracking. Concrete cracks may occur in concrete construction for a variety of reasons. Cracking in concrete construction is almost inevitable because concrete, like most other building materials, moves with changes in its moisture content. Specifically, it shrinks as it loses moisture. Being a brittle material it is liable to crack as it shrinks unless appropriate measures are taken to prevent this, e.g. by the provision of control joints.

1.1SOME TYPES AND CAUSES

In most cases where cracks appear in concrete the crack can be identified and the cause of cracking established. An extensive survey carried out revealed that concrete cracking can be attributed to the following:

- Construction and supervision problems
- Design defects
- Ambient conditions (temperature, humidity, etc.)
- Quality of materials

2. IN ADDITION ALL CRACKS CAN BE GROUPED INTO TWO BROAD CATEGORIES:

2.1 Cracks occurring before and during hardening.

These cracks are occurred before or during hardening of freshly placed concrete these type of cracks occurred in between 2-3hrs of placing of placing of concrete and these are easily identified by good observation some crack types are listed below

1. Plastic shrinkage
2. Plastic settlement
3. Construction Movement

2.2 Cracks occurring after hardening of concrete

This category covers the performance of concrete whose shape can no longer be altered without damage it includes cracks caused by drying shrinkage, as well as those which result from the temperature movements which take place in all materials exposed to the elements. Unless the structure concerned permits movements of its members without development of excessive stresses, extensive cracking often may occur.

1. Physical cracks
i) Drying shrinkage
ii) Crazing
2. Chemical Action
i)Sulphate attack
ii) Cracks due to corrosion
3. Cracks Due to thermal movement
4. Cracks due to Settlement

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

5. Cracks Due To Creep.

2.3 Identification of Settlement cracks

The most common restraint in slabs is from the reinforcement. The cracks occur on the top surface and usually follow the line of the uppermost bars, giving a series of parallel cracks; there may also be shorter cracks at right angles over the bars running in the opposite direction. Cracks are typically 1 mm wide and usually run from the surface to the bars. The settlement may also result in visible undulations on the concrete surface, with the high points over the top reinforcing bars.

In some cases where the bars in the top layer of reinforcement are close together, the whole surface layer of the concrete may be 'suspended' on the reinforcement while the concrete below settles. This can lead to a horizontal discontinuity beneath the bars, resulting in a loss of bond and with time delimitation of concrete cover that protects the reinforcing steel against corrosion.

Fine cracks can occur in relatively narrow formed surfaces such as columns. The concrete may arch between the containing form faces. Settlement below the restrained concrete results in a crack being formed, generally coinciding with the links. It is sometimes possible for plastic settlement cracks to form on a vertical face where reinforcement has restricted the free flow of concrete within the formwork. In such cases it is possible that the cracks are formed between the lines of the reinforcement.

3. CRACKS IN CONCRETE DUE TO PLASTIC SETTLEMENT

VISUAL INSPECTION (CASE STUDY)

- The cracks are appeared24 hrs after placing of concrete
- These cracks are reflects the location of the reinforcement inside concrete slab
- See below figure which shows the pattern of cracking

Fig 1: Cracks in concrete due to plastic settlement

Causes

- The cause of plastic settlement is related to bleeding of fresh concrete. Bleeding refers to the migration of water to the top of concrete and the movement of solid particles to the bottom of fresh concrete.
- The expulsion of water during bleeding results in the reduction of the volume of fresh concrete. This induces a downward movement of wet concrete.
- If such movement is hindered by the presence of obstacles like steel reinforcement, cracks will be formed.

3.1 Prevention of plastic settlement cracking

Plastic settlement cracks may be prevented or closed, by reverberating the concrete after settlement is virtually complete, and it has begun to set e.g. after half an hour to one hour. Revibration closes the cracks and enhances the surface finish and other properties of the concrete. Careful timing is essential to ensure that the concrete reliquaries under the action of the vibrator and that the cracks close fully. Applying vibration before the concrete has begun to stiffen may allow the cracks to reopen. Applying it too late, i.e. after the concrete has begun to harden, may damage the bond with reinforcement or reduce its ultimate strength.

Other procedures which may help reduce plastic settlement cracking include:

- Using lower slump mixes;

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

- Using more cohesive mixes;
- Using an air entertainer to improve cohesiveness and reduce bleeding; and
- Increasing cover to top bars.

Where there is a significant change in section, the method of placing may be adjusted to compensate for the different amounts of settlement. If the deep section is poured first to the underside of the shallow section, this concrete can be allowed to settle before the rest of the concrete is placed. However the top layer must be well vibrated into the bottom layer.

3.2 Cracks Occurring After Hardening

Cracks occur in hardened concrete for two principal reasons:

- Volume changes in the concrete and
- Chemical reactions within the body of the concrete which cause expansion and subsequent cracking of the concrete.

Volumetric movement in concrete cannot be prevented. It occurs whenever concrete gains or losses moisture (drying shrinkage) or whenever it's temperature changes (thermal movement). If such movements are excessive, or if adequate measures have not been taken to control their effects, the concrete will crack. Chemical reactions within the body of the concrete, which can cause it to expand and crack, include reinforcement corrosion and sulphate attack, and alkali-aggregate reaction. Provided adequate care is taken in the selection of materials and good quality concrete is properly placed, compacted and cured, these reactions should not occur except in extreme environmental conditions.

4. PHYSICAL CRACKS

4.1. Drying shrinkage

Drying shrinkage occurs after the setting-process, when the concrete is hardening. This type ofshrinkage is most effective when the concrete is young and decreases as the concrete gets older.This is very dependent on external conditions, e.g. relative humidity, temperature and wind. Ifthe concrete is located were the relative humidity is less in the environment than in the concreteitself, it dries out and water dissipate from the porous veins in the concrete. This lowers thepressure in the pores and the concrete shrinks. Drying shrinkage often creates subtle network ofcracks on the surface of the concrete.

When water evaporates from hardened concrete stored in unsaturated air it causes drying shrinkage. Some part of this shrinkage is irreversible and has to be distinguished from the reversible part which is moisture movement. The left part in Figure 22 shows how a sample thathas been drying in unsaturated conditions is put into water, and shows the swelling when cementabsorbs water. When it is then made to dry again the drying shrinkage begins once more, this canbe done repeatedly and then the recovery of shrinkage will become increasingly less.

When concrete is exposed to its service environment it tends to reach equilibrium with that environment.
Shrinkage cracks, as opposed to flexuralcracks, are parallel sided and in the case of slabs usually extend right through the slab thickness.Such cracks can cause water penetration/leakage and ultimately impair the durability of the concrete element.

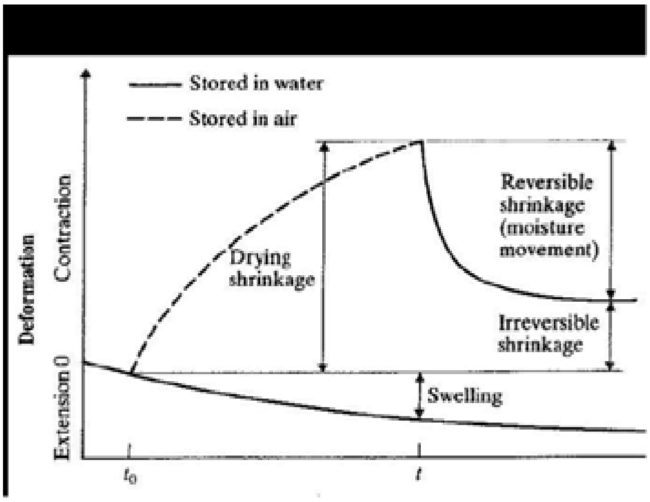

Fig2: Shrinkage Cracks

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

4.2. FACTORS AFFECTING DRYING SHRINKAGE

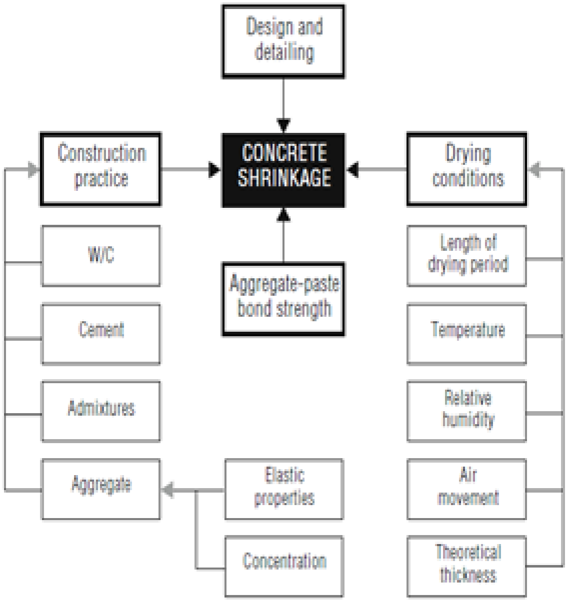

Fig-3 Factors affecting drying shrinkage

Fig 4 Cracks in concrete slab due to drying shrinkage

4.3 CRAZING

Crazing, a network pattern of fine cracks that do not penetrate much below the surface, is caused by minor surface shrinkage Crazing cracks are very fine and barely visible except when the concrete is drying after the surface has been wet. The cracks encompass small concrete areas less than 50 mm (2 in.) in dimension, forming a chicken-wire pattern. The term "map cracking" is often used to refer to cracks that are similar to crazing cracks only more visible and surrounding larger areas of concrete.

4.3.1 CAUSES OF CRAZING

a) Poor or inadequate curing
b) Too wet mix
c) Finishing operations
d) Sprinkling cement

4.3.2 VISUAL OBSERVATIONS (CASE STUDY)

- A network pattern of fine cracks that do not penetrate much below the surface.
- Very fine and barely visible except when the concrete is drying after the surface has been wet.
- The cracks encompass small concrete areas less than 50 mm (2 in.) in dimension, forming a chicken-wire pattern
- Cracks only more visible and surrounding larger areas of concrete.
- The term "map cracking" is often used to refer to cracks that are similar to crazing cracks only more visible and surrounding larger areas of concrete.

Fig.5 Cracks due to crazing

4.3.3 PREVENTION OF CRAZING

- Use lower slump concretes; do not add water to the mix adjust slump with admixtures instead Use concrete with minimal bleeding characteristics
- Do not finish the concrete until bleed water has disappeared or been removed.
- Do not overwork the surface to prevent excess fines from coming to the surface.
- Start curing immediately following the final finishing pass; cure continuously for 7 days

uninterrupted (intermittent wetting and drying increases risk for crazing)

- When appropriate, use broom finished to prevent overworking the surface
- Take extra care when using dry-shake colors. Overworking the dry-shake materials with a steel trowel can cause crazing
- Keep any combustion engine exhaust from venting onto the concrete surface. Carbonation

4.3.4 REASONS OF CORROSION

The two most common causes of reinforcement corrosion are

(i)localized breakdown of the passive film on the steel by chloride ions and

(ii)General breakdown of passivity by neutralization of the concrete, predominantly by reactionwith atmospheric carbon dioxide.

Sound concrete is an ideal environment for steel but the increased use of deicing salts and the increased concentration of carbon dioxide in modern environments principally due to industrial pollution, has resulted in corrosion of the rebar becoming the primary cause of failure of this material. Thescale of this problem has reached alarming proportions in various parts of theworld.

4.4 FACTORS LEADING TO CORROSION

1) Loss of Alkanity due to Carbonation
2) Loss of Alkanity due to Chlorides
3) Cracks due to Mechanical Loading
4) Moisture Pathways

4.4.1 CASE STUDY ON CRACKS DUE TO CORROSION OF REINFORCEMENT

Visual observations

i) Beams and arches

- The reinforced concrete beams and arches presented severe local damages due to corrosion, which led in the end to a significant reduction or loss of bearing capacity of some elements (figures 1 and 2). Mainly, these damages consist in:
- concrete cracking by corrosion under the action of chloride, especially at the bottom of the beams/arches, followed by sapling and corrosion destruction of the concrete cover and by uncovering of the reinforcements; local reduction of the elements cross-section due to corrosion of the concrete in its depth;

Fig.6 Beam: corrosion destruction of concrete cover; due to the longitudinal and transversal steel reinforcements by chloride attack

Columns

- The reinforced concrete columns presented visibledamages by corrosion (fig. 3), which mainly consisted in the following:
- concrete cracking along the longitudinal steel reinforcements, more accentuated in the marginal area, due to the corrosion by expansion of the concrete under the action of nitrates; in a further phase, spalling of the concrete cover occurred and afterwards the in depth corrosion of the concrete

Fig.7 cracks in column due to corrosion of reinforcement in column

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Slabs

The reinforced concrete slabs presented severe localdamages by corrosion, mainly in the perforated areas and in the areas where the anticorrosive floor was damaged.The corrosion damages are similar to the ones described at the beams and, in certain areas, they led to an important reduction and loss of bearing capacity of slabs.

4.4 .2.Major causes of settlement

Following are the major causes of settlement:
(1) Changes in stress due to:
a. Applied structural load or excavations.
b. Movement of ground water table.
c. Glaciations; and.
d. Vibration due to machines and earthquake etc
(2) Desiccation due to surface drying and/or plant life.
(3) Changes due to structure of soil (secondary compression)
(4) Adjacent excavation
(5) Mining subsidence
(6) Swelling and Shrinkage
(7) Lateral expulsion of soils
(8) Landslides.

4.5 Cracks due to settlement of ground

Visual inspection (case study)

- A long horizontal crack is absorbed along the length of wall at plinth level.
- Crack width is initially less and more at the end.
- Crack is about greater than 2mm and depth about 1 inch
- Crack is propagating along the length of wall

Fig.8 Crack is structure due to non uniform settlement of ground

Remedial Measures

Philosophy of remedial measures is to
(a) Reduce or eliminate settlement
(b) Design structures to withstand the settlement

4.6 CRACKS DUE TO CREEP

Creep is the deformation of concrete over time under load, in other words it is the tendency ofthe concrete to slowly move (deform) under constant stress. The creep occurs as a result of long-term exposure to high load and is highly dependent on temperature. The rate of creep independent on the time of loading (the age of the concrete when load is first applied), material properties and the duration that the concrete has been under load. Long term effects of creep are large deformations that can result in structural failure.

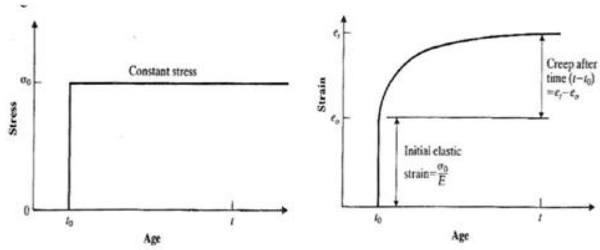

Figure 9: The graph to the left shows the stress over time for a concrete sample and the graph to right shows strain over time (both initial strain and creep strain)

4.6.1 FACTORS INFLUENCING CREEP

1. Influence of Aggregate
2. Influence of Mix Proportions:
3. Influence of Age:

5. CONCLUSIONS

Based on research following conclusions are drawn;
1. In a structure cracks are inevitable but not all those cracks are effects on the structure stability.
2. Plastic Shrinkage and settlement cracks are controlled by good workmanship.
3. Some cracks are repair easily in the beginning stage of propagation of crack.
4. Corrosion cracks are controlled by using anti corrosion treatments these are mostly occur in marine areas.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

5. Settlement cracks are controlled by using good soil compaction techniques based on soil conditions at foundation level stage.
6. Structural cracks may often by faulty design or by faulty construction.

6. REFERENCES

1. S. G. Mattar "shrinkage in concrete masonry walls: case study"

2. Nicholas J. Carino "Prediction of Cracking in Reinforced Concrete Structures"Building and Fire Research Laboratory, National Institute of Standards and Technology Gaithersburg, MD 20899
3. ACI committee 224 "Control of cracking in concrete structures" ACI- 224-R American concrete institute, Farmington hills MI, 2011

4. TUUTTI, K: "Corrosion of steel in concrete" Swedish Cement and Concrete Research Institute, Report 4-82, 1982, pp. 469. Ioan Pepenar "An overview of nitrates-induced corrosion of reinforced concrete structures"Civil and Environmental Research, Vol.5 2013.

Author Details

Nagipogu Prem Kumar
Post Graduate Student,
Department of Civil Engineering,
Annamacharya Institute of Technology and Sciences,
Kadapa.