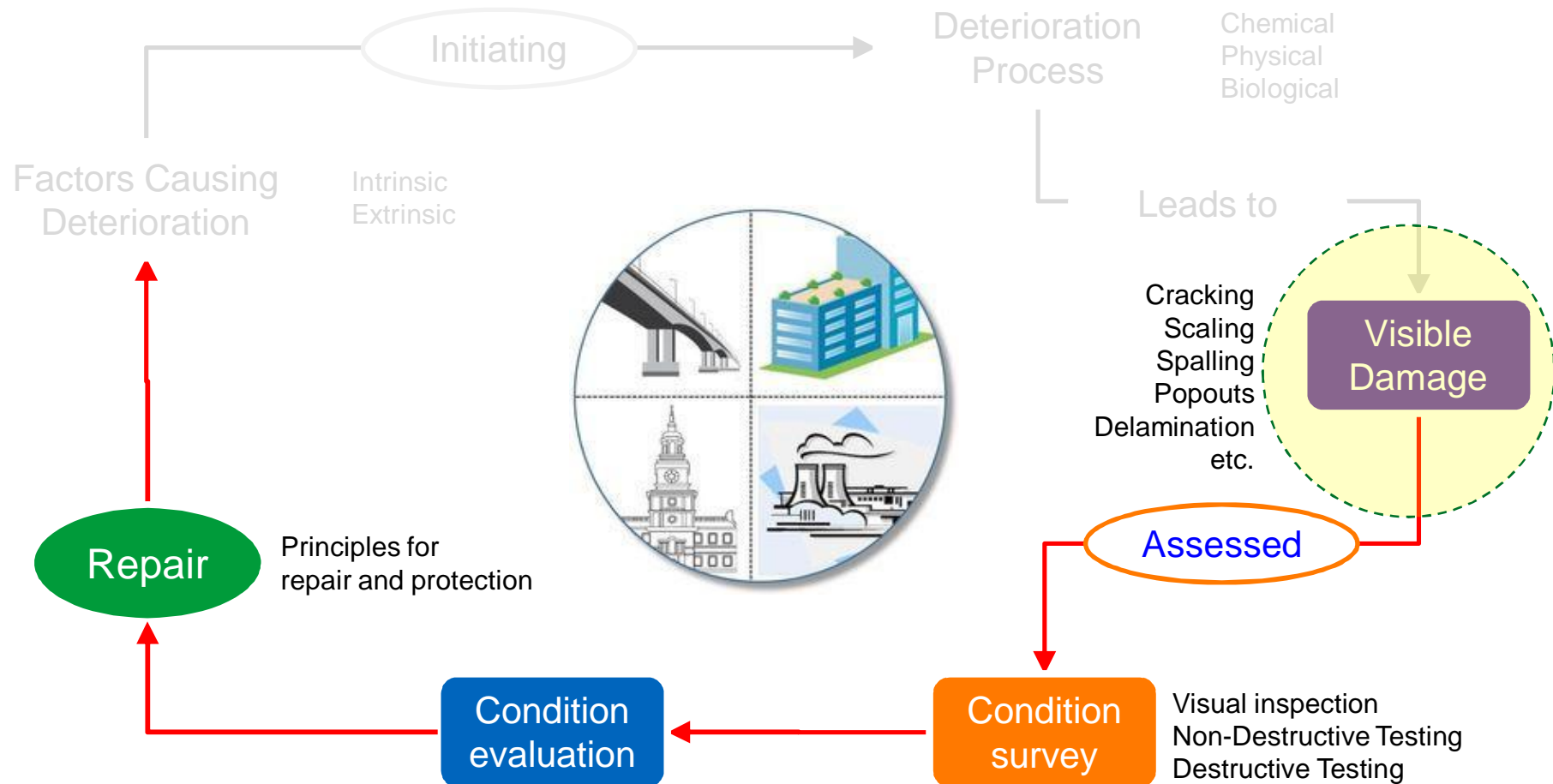




Defects and damage in structures

19.09.2016

Course outline



Outlines

- Concrete Defects and Damage
- Concrete Damage due to Reinforcement Corrosion
- Typical times of appearance of defects
- Recognizing defects and probable causes
 - Defects due to construction
 - Load-induced Defects
 - Defects related environmental factors and material properties
 - Other defects (ASR – DEF – Fire – Masonry and rendering defects)

Concrete Defects and Damage

Mechanical	Chemical	Physical
<ul style="list-style-type: none"> • Impact. • Overloading. • Movement (settlement). • Vibration. • Earthquake. • Explosion. 	<ul style="list-style-type: none"> • Alkali aggregate reaction. • Aggressive chemical agents exposure i.e. sulphates, nitrates and other salts, soft water (acidic/low pH). • Bacterial or other biological action. • Efflorescence/leaching. 	<ul style="list-style-type: none"> • Freeze/thaw action. • Thermal movement. • Salt crystal expansion. • Shrinkage. • Erosion. • Abrasion and wear.
Example: Cracking caused by incorrect handling or fixing of precast panels.	Example: Chemical attack from aggressive gases (and subsequent reinforcement corrosion) on the top of chimneys or the soffits of a factory roof.	Example: Freeze/thaw effects with progressive scaling on the soffits of a parking structure.

[https://www.concretereairsite.co.uk/DamageNProblems.html](https://www.concreterepairsite.co.uk/DamageNProblems.html)

Concrete Damage due to Reinforcement Corrosion

Carbonation	Stray / Electrical Current	Corrosive Contaminants e.g. Chlorides
<ul style="list-style-type: none"> Carbon dioxide (CO₂) in the atmosphere reacting with calcium hydroxide in the concrete pore liquid. CO₂ + Ca(OH)₂ → CaCO₃ + H₂O Soluble and strongly alkaline pH 12-13 → almost insoluble and much less alkaline pH 9. Steel passivated → steel unprotected. 	<ul style="list-style-type: none"> Metals of different electro potential are connected to each other in the concrete and corrosion occurs. Corrosion can also be due to stray electrical currents from power supply and transmission networks. 	<ul style="list-style-type: none"> Chlorides accelerate the corrosion process At above 0.2-0.4% concentration in the concrete they can break down the passive oxide protective layer on the steel surface. Chlorides are typically from marine/salt water exposure or the use of de-icing salts.
<p>Example: Reinforcement corrosion following reduction of the passivating concrete alkalinity, by natural atmospheric carbonation.</p>	<p>Example: Reinforcement corrosion evident as rust staining from cracks, after galvanised steel supports for parapet railings were fixed in direct contact with the embedded steel reinforcement.</p>	<p>Example: Steel corrosion accelerated by chloride ingress from de-icing salts used on a bridge and penetrating, particularly through the joints over the support piers.</p>

Recognizing defects and probable causes

- Many factors may contribute to or cause the deterioration of concrete structures
- These factors may be broadly summarized as follows:
 - Errors in the design assumptions or the design process
 - Specification or use of inappropriate materials
 - Poor workmanship
 - Environmental effects
 - Overloading, due to under-design or change of use
 - Accidental effects such as fire
 - Inappropriate repairs

Appearance of defects

1. Cracking
2. Scaling
3. Delamination
4. Spalling
5. Popouts
6. Efflorescence
7. Construction defects
8. Other damage
9.

http://ntl.bts.gov/lib/44000/44500/44562/State_Study_169_-_Diagnostic_Evaluation_and_Repair_of_Deteriorated_Concrete_Bridges.pdf

Typical times of appearance of defects

Type of Cracking	Form of Crack	Primary Cause	Time of Appearance
Plastic settlement	Above and aligned with steel reinforcement	Subsidence around rebar; excessive water in the mix.	10 minutes to three hours
Plastic shrinkage	Diagonal or random	Excessive early evaporation	30 minutes to six hours
Thermal expansion and contraction	Transverse (example: across the pavement)	Excessive heat generation or temperature gradients	One day to two or three weeks
Drying shrinkage	Transverse or pattern	Excessive water in the mix; poor joint placement; joints over-spaced	Weeks to months
Freezing and thawing	Parallel to the concrete surface	Inadequate air entrainment; non-durable coarse aggregate	After one or more winters

Continue

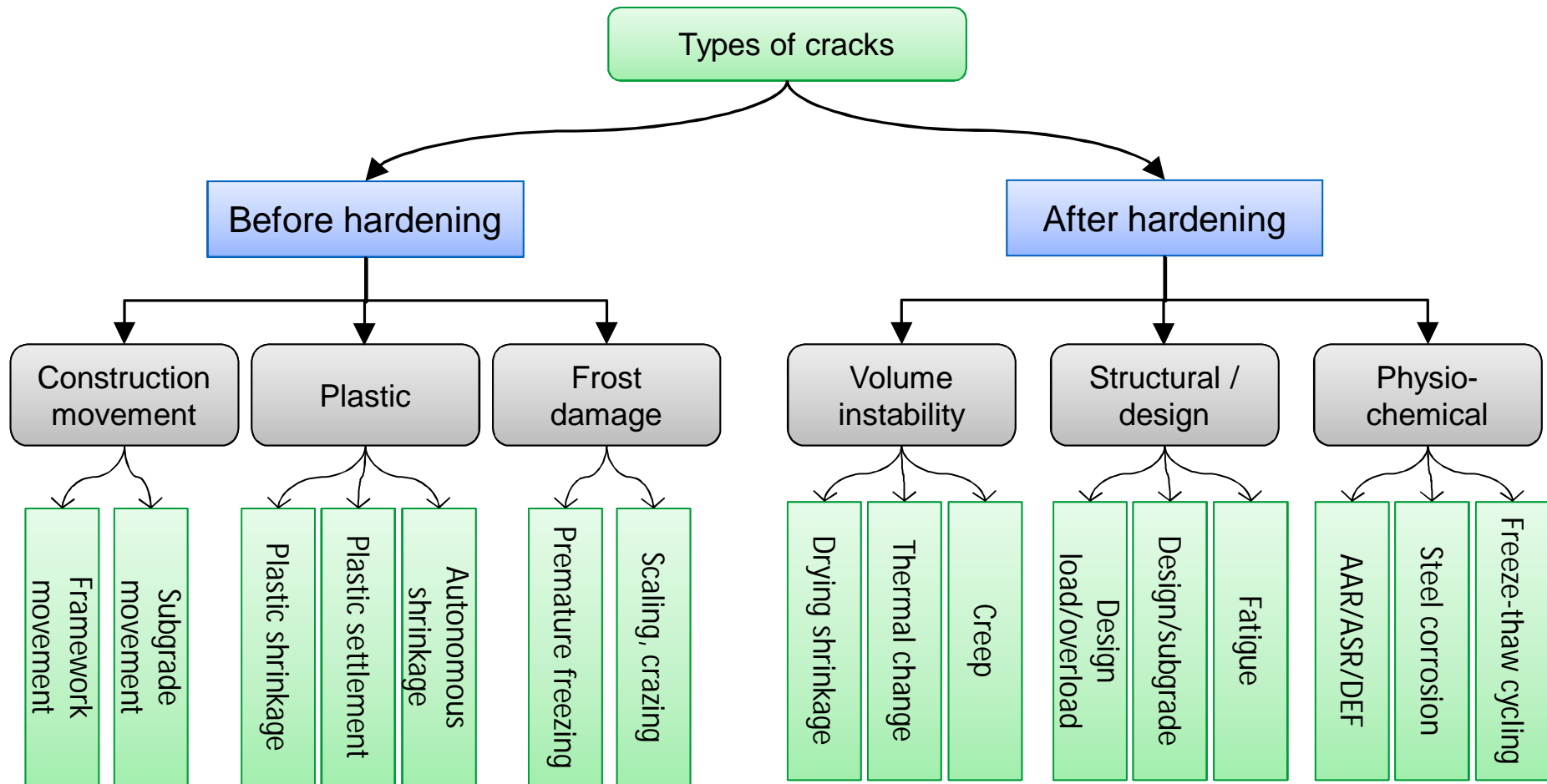
<http://www.nachi.org/visual-inspection-concrete.htm>

Typical times of appearance of defects

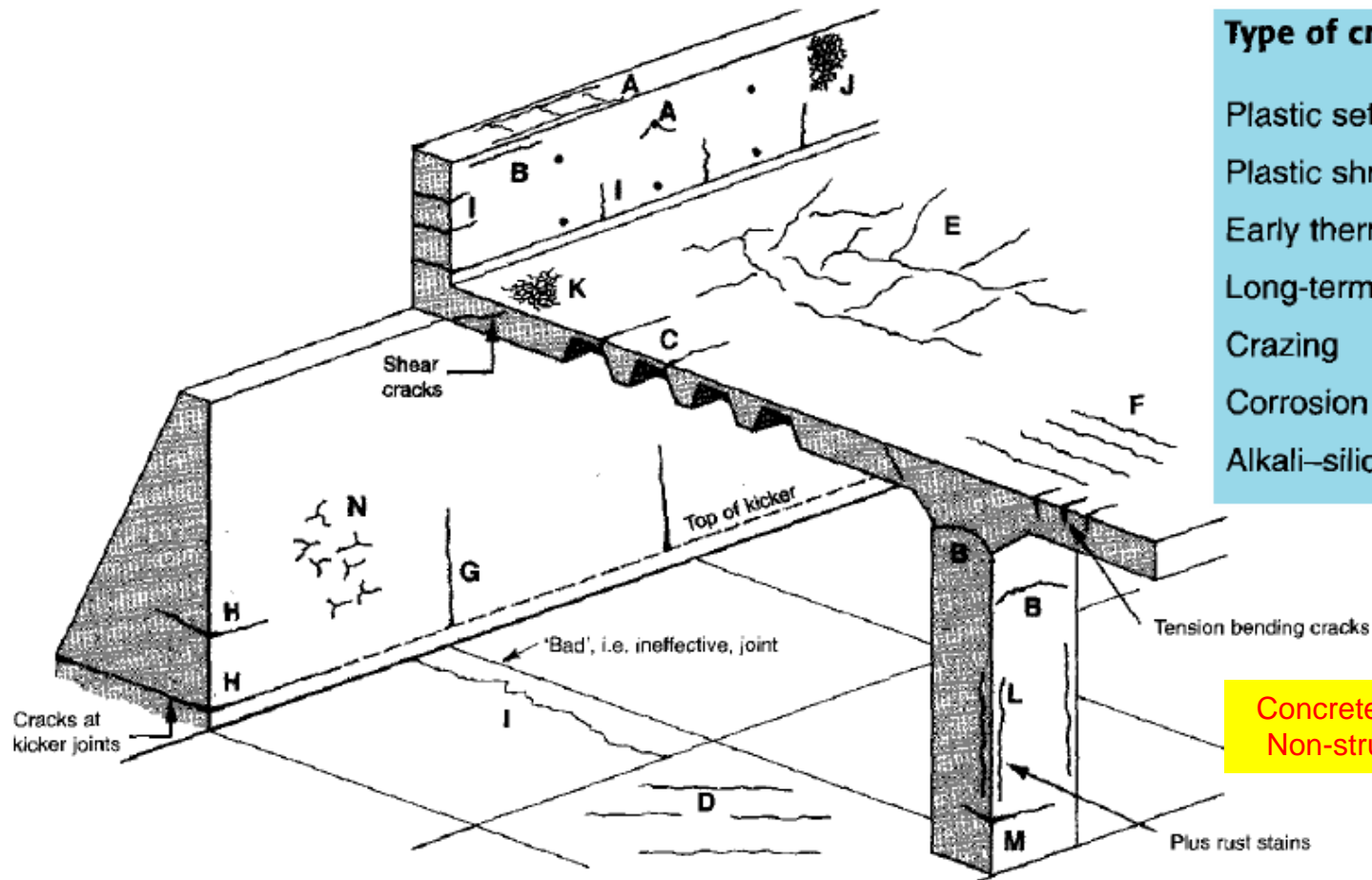
Type of Cracking	Form of Crack	Primary Cause	Time of Appearance
Corrosion of reinforcement	Above reinforcement	Inadequate concrete cover; ingress of moisture or chloride	More than two years
Alkali-aggregate reaction	Pattern cracks; cracks parallel to joints or edges	Reactive aggregate plus moisture	Typically, over five years, but may be much sooner with highly reactive aggregate
Sulfate attack	Pattern cracks	External or internal sulfates promoting the formation of ettringite	One to five years

<http://www.nachi.org/visual-inspection-concrete.htm>

Common causes of cracking in concrete structures



Intrinsic cracks in hypothetical structure

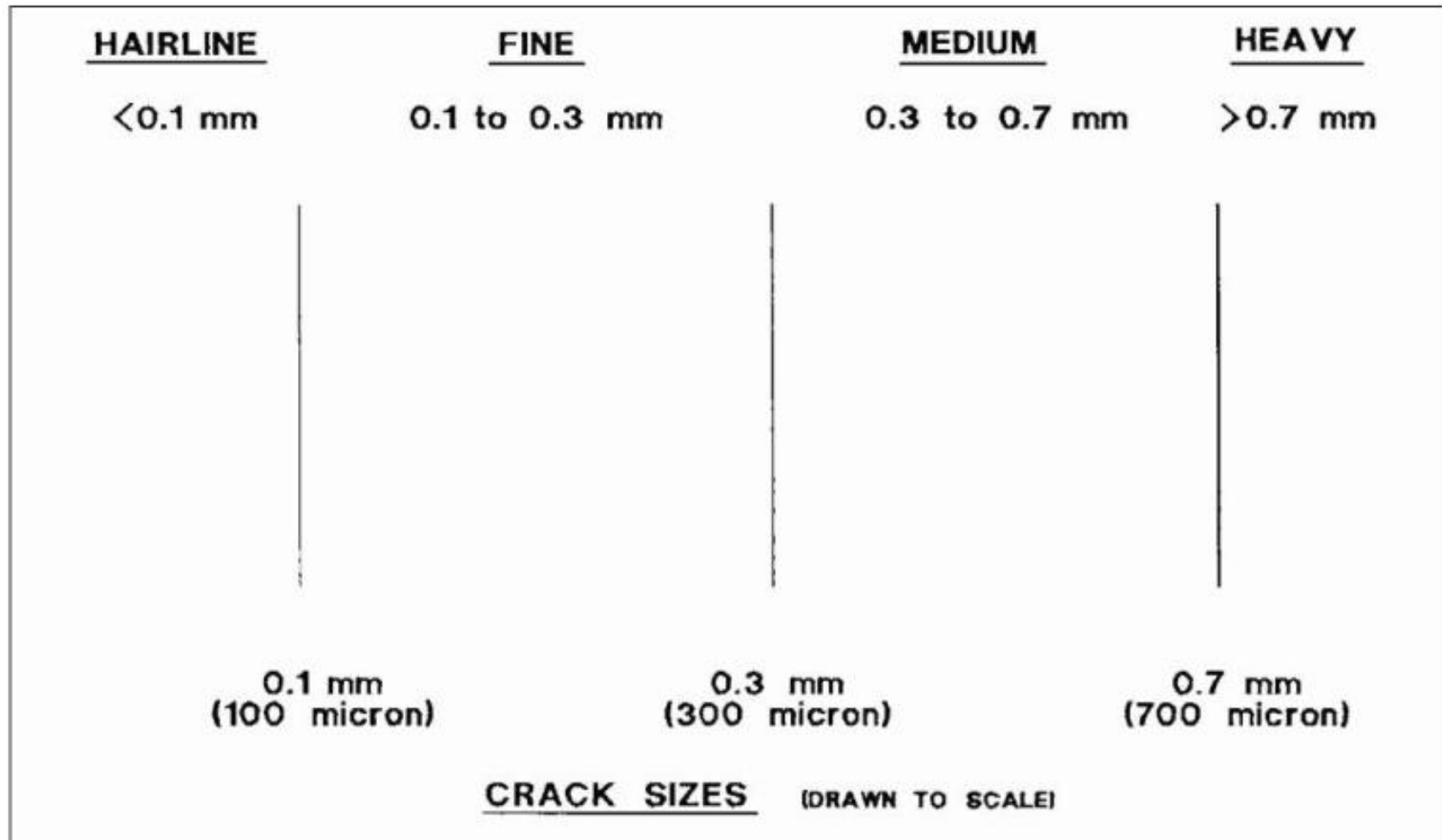


Type of cracking

Plastic settlement	A, B, C
Plastic shrinkage	D, E, F
Early thermal contraction	G, H
Long-term drying shrinkage	I
Crazing	J, K
Corrosion of reinforcement	L, M
Alkali-silica reaction	N

Concrete society technical report 22
Non-structural cracks on concrete.

Crack sizes



Defects due to construction

Construction defects

WHY Do construction defects Occur?

- **Honeycomb and rock pockets** appear on the concrete surface where voids are left due to failure of cement mortar to fill spaces around and among coarse aggregates. This happens due to:
 - poor quality control during mixing, transporting or placing of concrete
 - under or over-compaction of concrete, low cement content or improper mix design



- **Dimensional errors** in concrete structure result due to poor centering of structural member as per drawing or error in detailing.
- **Finishing errors** in concrete structures can involve over-finishing of the concrete surface or addition of more water or cement to the surface during finishing of the concrete.
- This results in the porous surface which make the concrete permeable resulting in less durable concrete.
- Poor finishing of concrete results in the spalling of concrete from surface early in their service life.

[http://ntl.bts.gov/lib/44000/44500/44562/State_Study_169 -
_Diagnostic_Evaluation_and_Repair_of_Deteriorated_Concrete_Bridges.pdf](http://ntl.bts.gov/lib/44000/44500/44562/State_Study_169_-_Diagnostic_Evaluation_and_Repair_of_Deteriorated_Concrete_Bridges.pdf)

Construction defects

- Another source of construction defects is related to insufficient concrete cover which may be caused by shift or cage shift, improper fabrication of steel, or improper placement of forms.
- Basic Categories of Construction Defects
 - Site Defects
 - Building Envelope Defects
 - Structural Defects
 - Heating, Ventilating, and Air Conditioning Defects
 - Electrical and Plumbing Defects
 - Fire/Life Safety System Defects



Example of construction defects
(insufficient concrete cover)

http://ntl.bts.gov/lib/44000/44500/44562/State_Study_169_-_Diagnostic_Evaluation_and_Repair_of_Deteriorated_Concrete_Bridges.pdf

Construction defects

Definition:

- Defects in concrete structures can be due to poor construction practices i.e. poor construction quality control at site or due to poor structural design and detailing.
- After construction at site, the common types of defects in concrete structures are:
 - Honeycombing and rock pockets,
 - form failure or misalignment of formwork,
 - dimensional errors,
 - rock pockets and finishing errors.

<http://theconstructor.org/concrete/construction-defects-in-concrete-structures/8472/>



Examples of construction defects

Plastic Shrinkage

- Plastic shrinkage is caused by excessively high rates of evaporation from the surface of the concrete before it has hardened.
- Drying does not take place at an even rate throughout the concrete matrix. It happens most rapidly at the upper surface through evaporation and more slowly at the bottom through absorption.
- The rate at which the sub-grade absorbs water will depend on its absorbent properties, including its porosity, moisture content, and even its electro-chemical properties.



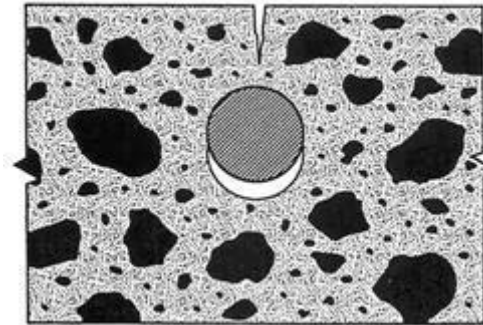
Cause:

- This condition occurs as a result of very rapid evaporation of the concrete while it is still in a plastic state.
- Hot, dry, and windy environmental conditions and lack of countermeasures employed.

Plastic Settlement

<http://www.nachi.org/visual-inspection-concrete.htm>

- Plastic settlement can be caused by subsidence around rebar.
- This is sometimes related to excessive water in the mix.
- As soon as concrete is placed, it begins to consolidate, and as bleed water rises to the surface, cement particles consolidate and the concrete settles.
- The settling process is restrained by reinforcement steel and, under certain circumstances, cracks will develop directly above the steel.
- Plastic settlement cracks can be caused by:
 - inadequate concrete cover of the steel;
 - excessive water in the concrete;
 - form movement or blowout; or
 - poor consolidation practices.



Repeating pattern of cracks where rebar cross-members connect longitudinal rebar

Autogenous Shrinkage

- Plastic shrinkage is shrinkage caused by the loss of water to the atmosphere.
- Autogenous shrinkage is shrinkage that takes place with no loss of water to the atmosphere.
- Autogenous shrinkage is caused by internal drying, with water being absorbed by the constituent materials in the concrete.
- Absorption of water from the pores also causes shrinkage.
- Since there is no loss of water to one exposed surface, autogenous shrinkage is more uniform than plastic shrinkage.

<http://www.nachi.org/visual-inspection-concrete.htm>

- However, tensile stresses still develop, and embedded steel can cause anomalies in an area of concrete with relatively uniform stress.
- These anomalies can cause variations in stress within the concrete that are relieved by cracking. Autogenous shrinkage cracking will be shallow and is not a structural issue.

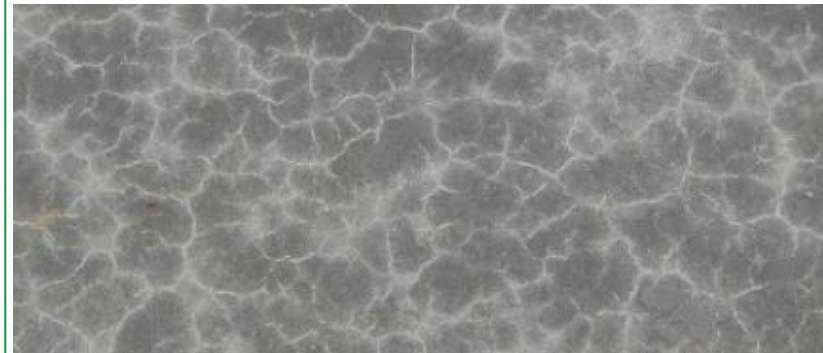


Outside corners are also high-stress points.

Crazing

Definition:

- Pattern cracking, also called map cracking and craze cracking, appears as a network of random cracking on the concrete's surface.
- The cracking is usually shallow (less than 3 mm deep) and not a structural issue.
- It's seldom a durability problem but more of a cosmetic one.
- The area enclosed by pattern cracking may be anywhere from 1.25 cm to 20 cm across.



Crazing cracks caused by premature drying

<http://www.nachi.org/visual-inspection-concrete.htm>

Crazing

WHY do crazing cracks occur?

- poor curing practices
- Environmental conditions such as low humidity, high outside temperatures, direct sunlight, and wind can create high rates of evaporation from the surface layer of concrete
- Resistance to shrinkage from the underlying concrete causes stress that is relieved by craze cracking
- excessive water in the mix
- over-vibration of the concrete, causing coarse aggregate to settle and cement paste to concentrate at the surface

<http://www.nachi.org/visual-inspection-concrete.htm>

- over-working the surface with a steel trowel during finishing
- performing finishing operations while bleed water is still on the surface
- sprinkling cement dust on the surface to soak up bleed water.



Drying Shrinkage

- Drying shrinkage is shrinkage that takes place after the concrete has hardened and some degree of bonding has developed between the cement paste and the aggregate.
- As concrete continues to dry, it will continue to shrink.
- Drying shrinkage includes both shrinkage that takes place while losing moisture to the air and autogenous shrinking
- The cracks will look similar to those formed during plastic shrinkage
- Drying shrinkage cracks may be the propagation of cracks that initially developed during plastic shrinkage.

<http://www.nachi.org/visual-inspection-concrete.htm>



A typical interruption in a shrinkage crack



A re-entrant corner crack

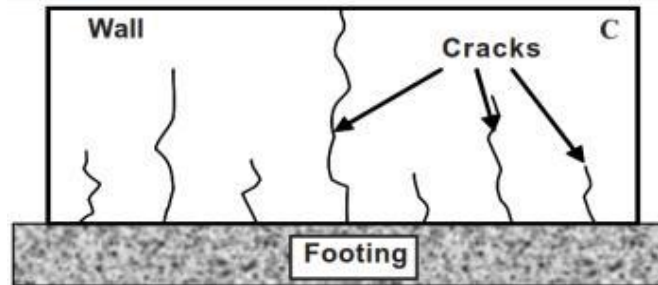
Cracking examples



Cracks due to unsuitable jointing



Settlement cracks



Cracks due to continuous external restraint (example: cast-in-place wall restrained along bottom edge of footing)



Cracks due to lack of isolation joints

<http://www.nrmca.org/aboutconcrete/cips/04p.pdf>

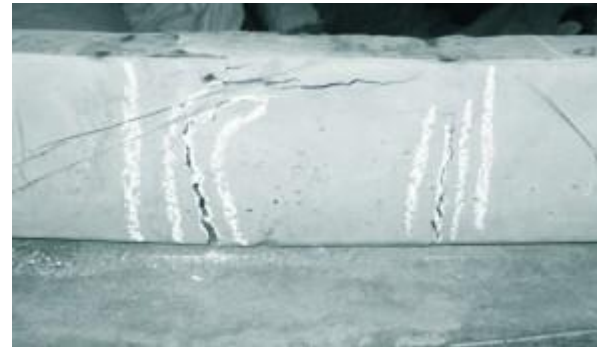
Load-induced Defects

Structural cracks

Structural cracks

- are caused by both dead and live load stresses, which can lead to eventual failure of the structure.
- Flexure structural cracks are vertical and begin in areas of maximum tension or moment.
- Shear structural cracks are diagonal and are usually found in the web of a member. They may begin at the bottom and move diagonally toward the center of the member.

[http://ntl.bts.gov/lib/44000/44500/44562/State_Study_169 - Diagnostic Evaluation and Repair of Deteriorated Concrete Bridges.pdf](http://ntl.bts.gov/lib/44000/44500/44562/State_Study_169_-_Diagnostic_Evaluation_and_Repair_of_Deteriorated_Concrete_Bridges.pdf)

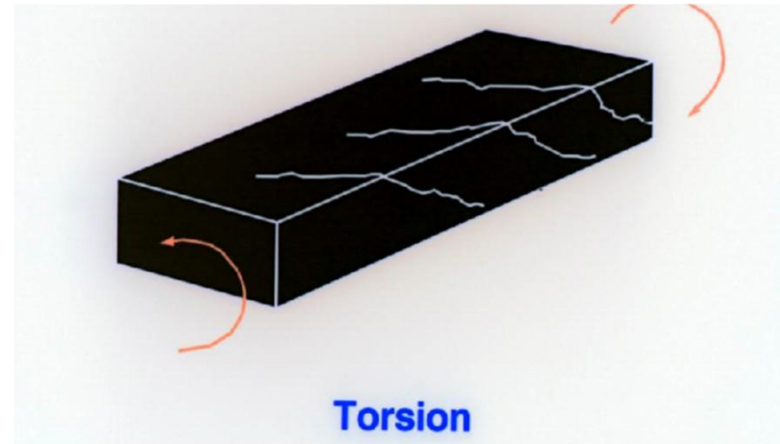
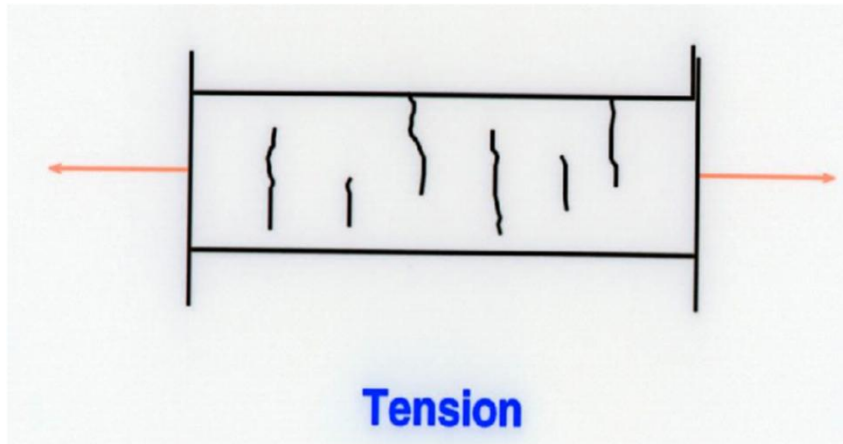
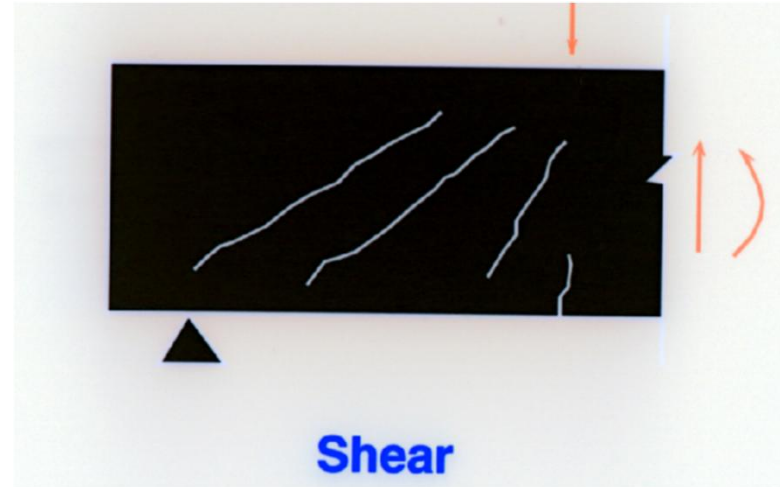
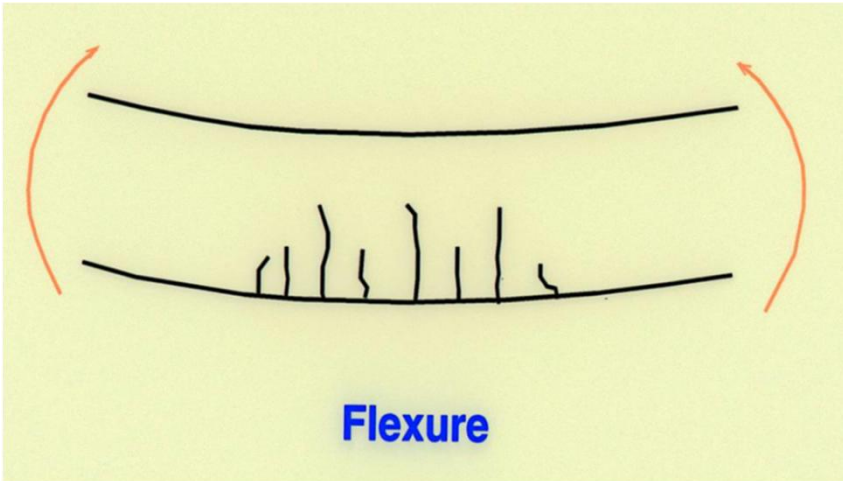


Flexure structural cracks



Shear structural cracks

Structural cracks



Fatigue

- Concrete fatigue is long-term failure due to repeated loading (cycles).
 - Loads may be applied in tension, compression, torsion (twisting), bending, or a combination of these actions.
 - In fatigue, each individual load is less than a single static or unchanging load that would exceed the strength of the concrete.
 - Fatigue has to do with the development and propagation or growth of cracks and micro-cracks, and the failure of the bond between the cement paste and aggregate.
- Crack development and bond failure worsen slowly over time and are influenced by a number of variables.
 - Fatigue is not something most inspectors will be able to identify and is less common in residential construction than in commercial and especially industrial structures.

Defects related environmental factors and material properties

Weathering

- Weathering is the effect of pollution and natural forces, such as frost, rain and sunlight, on a structure.
- With concrete, the main weathering problem is unexpected variations in the visual appearance of the structure.
- Dust in the atmosphere will be deposited on the facade. The flow of rainwater will tend to wash some areas preferentially, resulting in significant differences in colour between clean and dirty areas.
- This phenomenon is controlled by many factors, including the surface texture of the concrete, the architectural detailing and the orientation of the structure.



https://commons.wikimedia.org/wiki/File:Mechanical_weathering_of_a_cement_bollard_-_20110501.jpg

Mould and moisture damage

- <https://www.epa.gov/mold/basic-information>
- <https://www.epa.gov/sites/production/files/2014-08/documents/moldremediation.pdf>
- http://www.nj.gov/health/eohap/mold/documents/mold_guidelines.pdf

Definition of Mould

- Moulds are fungi which occur naturally in the environment.
- Many different species of mold exist.
- Moulds help break down dead materials and convert it back into organic matter which can be used by living organisms.

How Moulds Grow?

- Moulds grow by digesting and destroying the material they grow on.
- They can be found almost anywhere and can grow on just about any material as long as conditions are favorable.

- For favorable growing conditions, mold needs nutrients (oxygen and moisture) and a material to grow on.
- Moulds reproduce by making spores.
- These spores become airborne, both outside and inside of buildings.
- If spores land on suitable material and conditions are favorable, the mould will begin to grow.



Mould and moisture damage

- <https://www.epa.gov/mold/basic-information>
- <https://www.epa.gov/sites/production/files/2014-08/documents/moldremediation.pdf>
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Appearance of Mold

- Moulds grow in colonies and growth may take on different shapes and colors.
- Some moulds may appear circular in growth while others may grow and spread to cover an area.
- Moulds may appear brown, yellow, green or black in color.
- The appearance depends on the species of mold present.

Understanding Molds

- Even though moulds are everywhere, they may become a problem when they begin to grow inside homes and buildings.

- Many building materials such as drywall, ceiling tiles and wood framing contain cellulose, which is a material on which molds can grow.
- Moulds may grow unnoticed, above ceilings, behind walls, in attics and basements or in crawl spaces.
- Moulds can cause staining of walls and ceilings and can begin to break down the studs and joists of buildings causing extensive property damage.
- Excessive moisture is a key ingredient which causes molds to grow.
- Sources of excess moisture may be plumbing leaks, leaking roofs or windows, high humidity, flooding, or condensation inside walls due to poor insulation.

Mould and moisture damage

- <https://www.epa.gov/mold/basic-information>
- <https://www.epa.gov/sites/production/files/2014-08/documents/moldremediation.pdf>
- http://www.nj.gov/health/eohap/mold/documents/mold_guidelines.pdf

Common Health Effects Include:

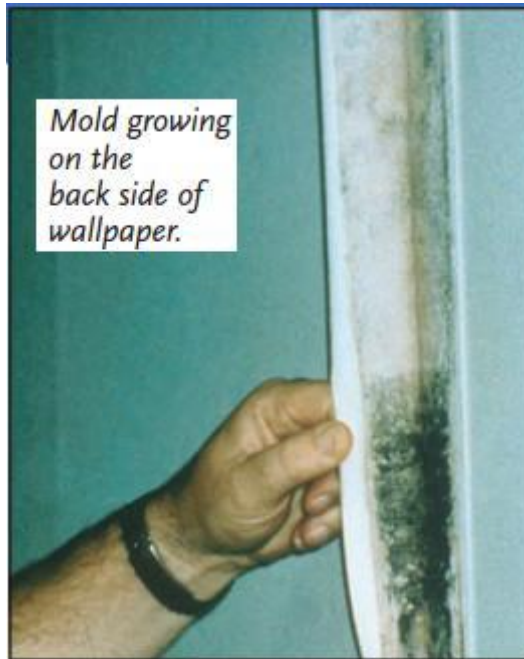
- Allergic reactions - sneezing, nasal congestion
- Irritation to the nose, throat, and respiratory tract
- Asthma attacks
- Hypersensitivity pneumonitis



Leaky window – mold is beginning to rot the wooden frame and windowsill.

Mold and moisture damage

- <https://www.epa.gov/mold/basic-information>
- <https://www.epa.gov/sites/production/files/2014-08/documents/moldremediation.pdf>
- http://www.nj.gov/health/eohap/mold/documents/mold_guidelines.pdf



Thermal expansion

- **Nonstructural cracks** can be caused by thermal expansion and contraction of concrete, contraction of the concrete during the curing process, or temperature gradients within massive sections of concrete.
- A blowup is a localized upward movement of a concrete curb or slab, usually at a joint or crack.
- The thermal expansion of concrete is $18 \dots 20 \cdot 10^{-6}/^{\circ}\text{C}$.
- Expansion joints are incorporated in designs to take up this linear dimensional change.

[http://ntl.bts.gov/lib/44000/44500/44562/State_Study_169 -
Diagnostic Evaluation and Repair of Deteriorated Concrete
Bridges.pdf](http://ntl.bts.gov/lib/44000/44500/44562/State_Study_169_-_Diagnostic_Evaluation_and_Repair_of_Deteriorated_Concrete_Bridges.pdf)

- The problem occurs when the movement is underestimated, not allowed for, or when correctly sized joints become contaminated with material that is not compressible.



Cracking from the straight plane of a concrete element due to forces imposed by **thermal expansion**.

Scaling

Definition:

- Scaling is flaking or peeling of a finished hardened concrete surface as a result of exposure to cycles of freezing and thawing.
- Generally it starts as localized small patches, which later may merge and extend to expose large areas.
- **Scaling is classified as:**
 - **Light scale** is the loss of surface mortar up to 6 mm deep exposing coarse aggregates.
 - **Medium scale** is the loss of surface mortar from 6 mm to 13 mm deep with mortar loss between the coarse aggregates.

- **Heavy scale** is the loss of surface mortar from 13 mm deep to 25 mm deep clearly exposing coarse aggregates.
- **Severe scale** is the loss of surface mortar greater than 25 mm deep where coarse aggregate particles are lost and reinforcing steel is exposed.



<http://www.armca.ca/uploads/files/Tech%20Tips/CTT2-Scaling%20Concrete%20Surfaces.pdf>

Scaling

WHY Do Concrete Surfaces Scale?

- A. The use of non-air-entrained concrete or too little entrained air.
- Adequate air entrained is required for protection against freezing and thawing damage.
- B. Application of excessive amounts of calcium or sodium chloride deicing salts on concrete.
- Chemicals such as ammonium sulphate or ammonium nitrate, which are components of most fertilizers, can cause scaling as well as induce severe chemical attack on the concrete surface.

<http://www.armca.ca/uploads/files/Tech%20Tips/CTT2-Scaling%20Concrete%20Surfaces.pdf>

- C. Any finishing operation performed while bleed water is on the surface.
- If bleed water is worked back into the top surface of the slab, a high water/cement ratio and, therefore, a low -strength surface layer is produced.
 - Overworking the surface during finishing will reduce the air content in the surface layer, making it susceptible to scaling in freezing conditions.
- D. Insufficient curing.
- This omission results in a weak surface skin, which will scale if it is exposed to freezing and thawing in the presence of moisture and deicing salts.

Popouts

Definition:

- A popout is a small fragment of concrete surface that broke away due to internal pressure, leaving a shallow, typically conical, depression.
- Popouts general vary size from 6 to 50 mm in diameter, but can be up to 300 mm in size.
- Usually fractured aggregate particle will be found at the bottom of the hole, with a part of the aggregate still bonded to the point of the popout cone.

WHY Do Popouts Occur?

- Popouts are usually caused by the expansion of porous aggregate particles having a high rate of absorption.

- As the aggregate absorbs moisture or freezes under moist conditions, its swelling creates internal pressures sufficient to scale the concrete surface.
- Ironstone, coal, shale and soft fine grained limestone are the commonly observed causes of popouts.



<http://www.armca.ca/uploads/files/Tech%20Tips/17%20Tip.pdf>

Delamination

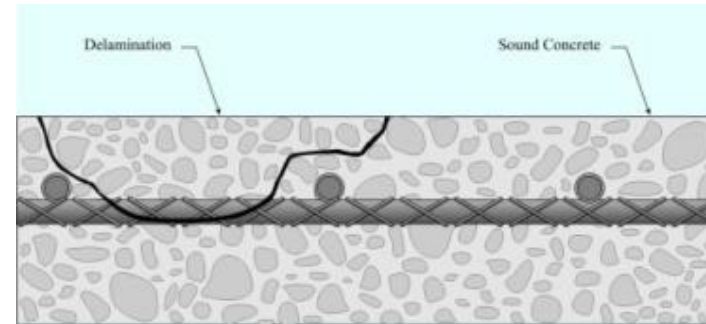
Definition:

- Delamination is the separating of concrete layers at or near the outermost layer of reinforcing steel.

WHY Does Delamination Occur?

- Delamination is caused by the expansion of corroding reinforcing steel and can lead to severe cracking.
- Rust can occupy up to ten times the volume of the corroded steel which it replaces.

[http://ntl.bts.gov/lib/44000/44500/44562/State_Study_169 - Diagnostic Evaluation and Repair of Deteriorated Concrete Bridges.pdf](http://ntl.bts.gov/lib/44000/44500/44562/State_Study_169_-_Diagnostic_Evaluation_and_Repair_of_Deteriorated_Concrete_Bridges.pdf)



Delaminations are separations in a slab, parallel to and generally near the upper surface

Spalling

- <http://www.sydneyengineers.com/articles/66-concrete-spalling>
- http://www.cement.org/docs/default-source/fc_concrete_technology/durability/is177-concrete-slab-surface-defects-causes-prevention-repair.pdf?sfvrsn=4

Definition:

- Spalling is a deep surface defect, often appearing as circular or oval depressions on surfaces or as elongated cavities along joints.
- Spalls may be 25 mm or more in depth and 150 mm or more in diameter, although smaller spalls also occur.

WHY Does Spalling Occur?

- Spalls are caused by pressure or expansion within the concrete, bond failure in two-course construction, impact loads, fire, or weathering.
- Improperly constructed joints and corroded reinforcing steel are two common causes of spalls



Spalling of Concrete slab due to corrosion

Efflorescence

http://ntl.bts.gov/lib/44000/44500/44562/State_Study_169_-_Diagnostic_Evaluation_and_Repair_of_Deteriorated_Concrete_Bridges.pdf

Definition:

- Efflorescence is a crystalline deposit on surfaces of masonry, stucco or concrete. It is whitish in appearance, and is sometimes referred to as "whiskers".

WHY Does Spalling Occur?

- Efflorescence is caused by vapor migrating through the structure bringing soluble salts to the surface
- Efflorescence requires the movement of moisture. Without moisture movement there would be no efflorescence on the surface to create the problem.



Brick
Efflorescence



Concrete Efflorescence

Steel Corrosion

- Corrosion of embedded steel is the most common cause of concrete problems.
- As steel corrodes, the corrosion product expands, and this expansion can crack concrete and cause sections to break loose in flakes.
- Inadequate cover due to control joints is also common in flatwork. Where control joints are installed perpendicular to embedded rebar, the areas at which the control joint crosses each bar may develop cracking and corrosion, and eventually spalling or flaking.

<http://www.nachi.org/visual-inspection-concrete.htm>



Corrosion typical of inadequate cover



Other defects

Alkali-silica reaction (ASR)

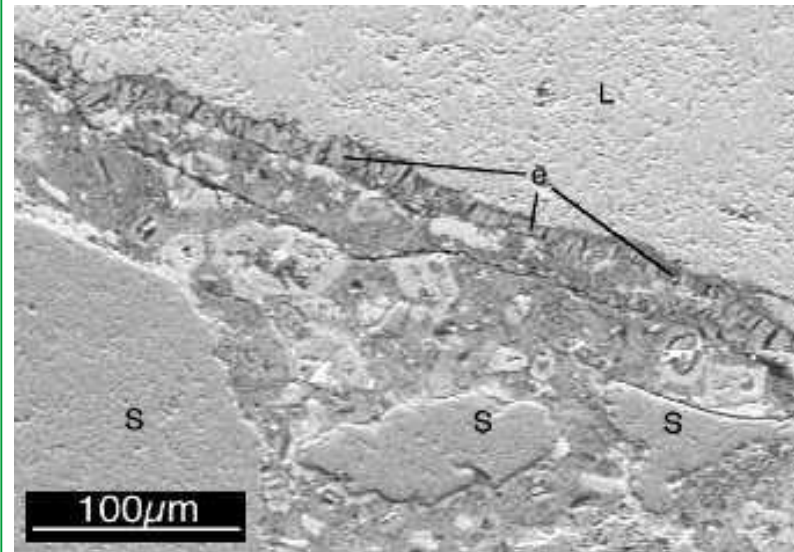
- Major infrastructure projects such as dams, roadways or airport runways require enormous quantities of aggregates.
- Some aggregates can exhibit an increased or high risk of ASR.
- Alkali-Silica Reaction is a chemical reaction which occurs between the amorphous silica in the aggregate and the pore solution (alkalis) of the cement matrix.
- The reaction results in an increase of concrete volume, causing cracking and spalling when the generated forces exceed the tensile strength of the concrete.



The appearance of ASR damage can be assessed very well on the drying concrete surface of this bridge pylon. Damage can appear within years or only after decades.

Delayed ettringite formation (DEF)

- Delayed ettringite formation (DEF) is expansion and cracking of concrete associated with the delayed formation of the mineral ettringite which is a normal product of early cement hydration.
- DEF is a result of high early temperatures (above 70°C – 80°C) in the concrete which prevents the normal formation of ettringite.
- DEF-induced damage is not a common phenomenon in concrete.
- Water or moisture from an external source is required for the reaction to occur, the availability of which will affect both the rate and the extent of expansion.



Delayed ettringite formation:

(e) ettringite

(L) surrounds the coarse limestone aggregate

(s) Fine aggregate is silica sand

<http://www.whd.co.uk/Concrete/concretebysem.html>

Other damage: Fire damage

Concrete Color	Temperature	Other Possible Physical Effects
Buff	950 C	900 C Powdered, light colored, dehydrated paste
Black		800 C Spalling, exposing not more than 25 percent of reinforcing bar surface
Through Gray to Buff	600 C	575 C 550 C Popouts over chert or quartz aggregate particles Deep cracking
Pink to Red	300 C	300 C Surface crazing
Normal	40 C	None



Fig 1 - Scarred and spalled underside of flat slab concrete beam (temperature about 150°C - 200°C)



Fig 2 - Explosive spalling, pink tint, exposure of steel ligatures, main corner bars and pre-stressing tendons. Temperature above 300°C

Other damage: **Fire damage**

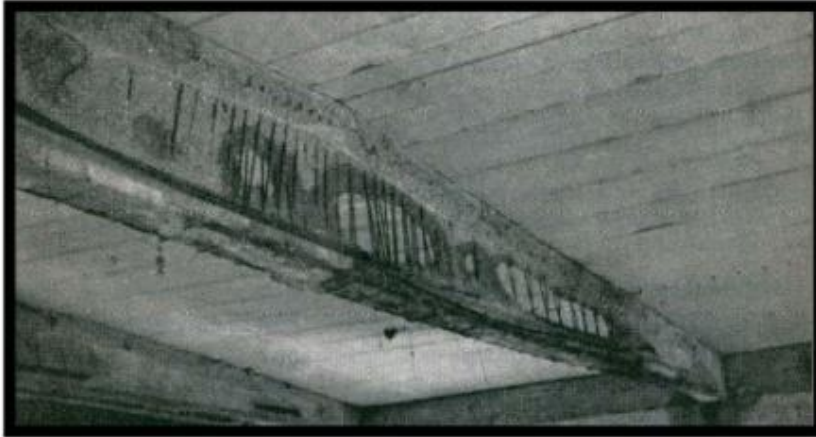


Figure 2.4 Spalling of pre-stressed beams due to fast cooling by adding water described by the Swedish Tariff Association (1959).

http://www.brandforsk.se/MediaBinaryLoader.axd?MediaArchive_FileID=43f89b58-b5fa-45ae-a60f-56ba9b14d57b&FileName=BF_306_071_Rapport.pdf&MediaArchive_ForceDownload=true



Figure 2.8 Spalling of the concrete cover during a moderate fire after the San Francisco earthquake.

Possible Sources and Effects of Masonry Distress

Estimated Time to Repair of Materials

Material	Use	Estimated Time to Repair (Years)
Brick	Walls	100+
Sealant	Joints	5-20
Metal	Coping/Flashing	20-75
Metal	Anchors & Ties	15+
Mortar	Walls	25+
Plastic	Flashing	5-25
Finishes		
Paint	Appearance	3-5
Water Repellents	Dampproofing	5-10
Stucco	Appearance	5-10

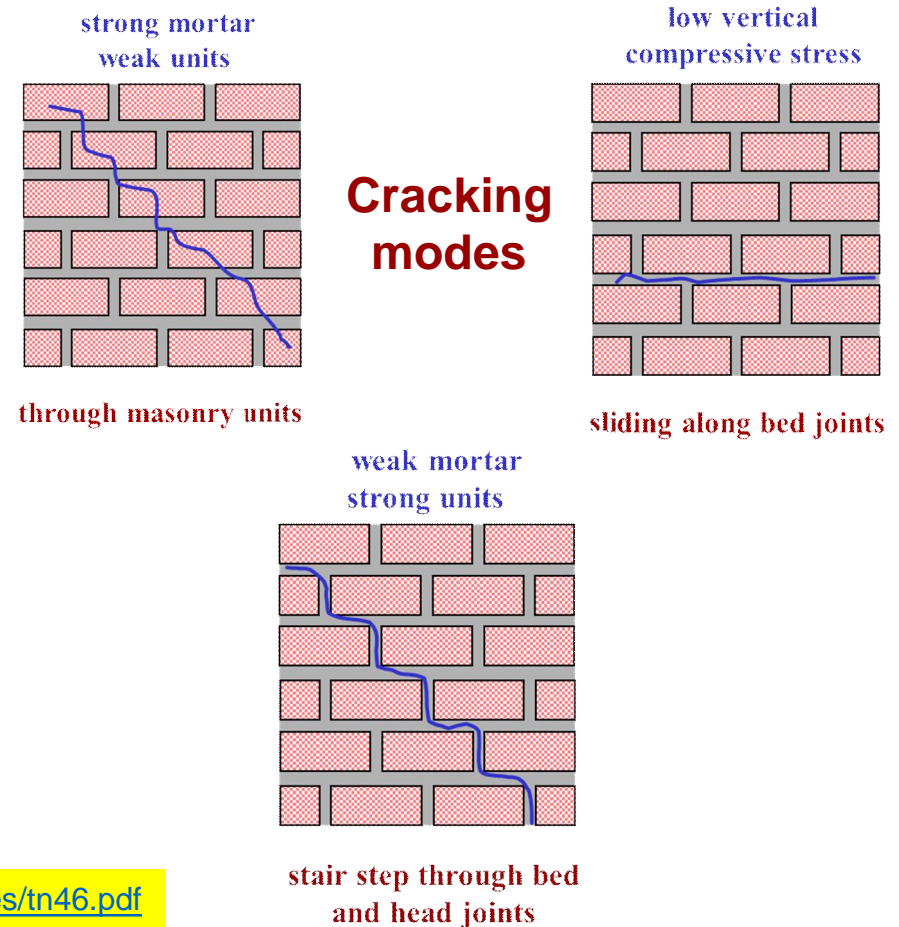
<http://www.gobrick.com/portals/25/docs/technical%20notes/tn46.pdf>

Possible Sources and Effects of Masonry Distress

Masonry

- Cracked Units
- Loose Units
- Spalled Units
- Hairline Cracks in Mortar
- Deteriorated Mortar Joints
- Missing or Clogged Weeps
- Plant Growth
- Deteriorated/Torn Sealants
- Out-of-Plumb
- Efflorescence
- Stains
- Water Penetration

<http://www.gobrick.com/portals/25/docs/technical%20notes/tn46.pdf>



Brick Efflorescence

Brick Efflorescence Analysis

- **Firstly:** There must be water-soluble salts present somewhere in the wall.
- **Secondly:** There must be sufficient moisture in the wall to render the salts into a soluble solution.
- **Thirdly:** There must be a path for the soluble salts to migrate through to the surface where the moisture can evaporate, thus depositing the salts which then crystallize and cause efflorescence.
- All three conditions must exist.
 - If any one of these conditions is not present, then efflorescence cannot occur.



<http://www.masonryworktools.com/brickefflorescence.html>

Eroded Mortar Joint

What To Look For:

- Slight or local erosion of mortar in joint.
- Small erosion depth relative to exterior face of brick.
- Aggregate (fine sand) exposed.

Probable Causes:

- Erosion due to wind or frost cycles.
- Disaggregating of lime component of the binder.

FAÇADE CONDITIONS: An Illustrated Glossary of Visual Symptoms, Edited by Dan Eschenasy



Classification of the defects in wall renderings

Aesthetic defects	Defects associated with humidity	Mechanically-related defects
Graffiti	Infiltrations / dampness stains	Adherence loss/detachment
Corrosion stains	Efflorescence / cryptoflorescence	Map cracking
Dirt / deposits of particles	Biological colonization	Cohesion loss/crumbling
Colour change/discolouration	Carbonation	Scratches / grooves
	Vegetation growth	Linear cracking

http://ijce.iust.ac.ir/files/site1/user_files_6k93w6/eng/jorgedebrito-A-10-1399-1-8b1ef1b.pdf

Examples of rendering defects



Examples of rendering defects



Map cracking



Summary

Lecture summary

- Concrete Defects and Damage
- Concrete Damage due to Reinforcement Corrosion
- Typical times of appearance of defects
- Recognizing defects and probable causes
 - Defects due to construction
 - Load-induced Defects
 - Defects related environmental factors and material properties
 - Other defects (ASR – DEF – Fire – Masonry and rendering defects)

Next lecture

- Condition survey overview
- Condition survey parts:
 - Review of plans and relevant documents
 - Visual inspection
 - Non-destructive testing
 - *Laboratory and destructive testing (the following lecture)*