الأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري

Arab Academy for Science, Technology & Maritime Transport

Concrete Defects

CB 557

Inspection, Maintenance and Repair of Structures

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الأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري
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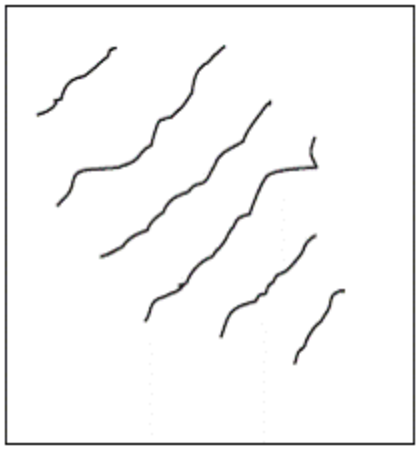
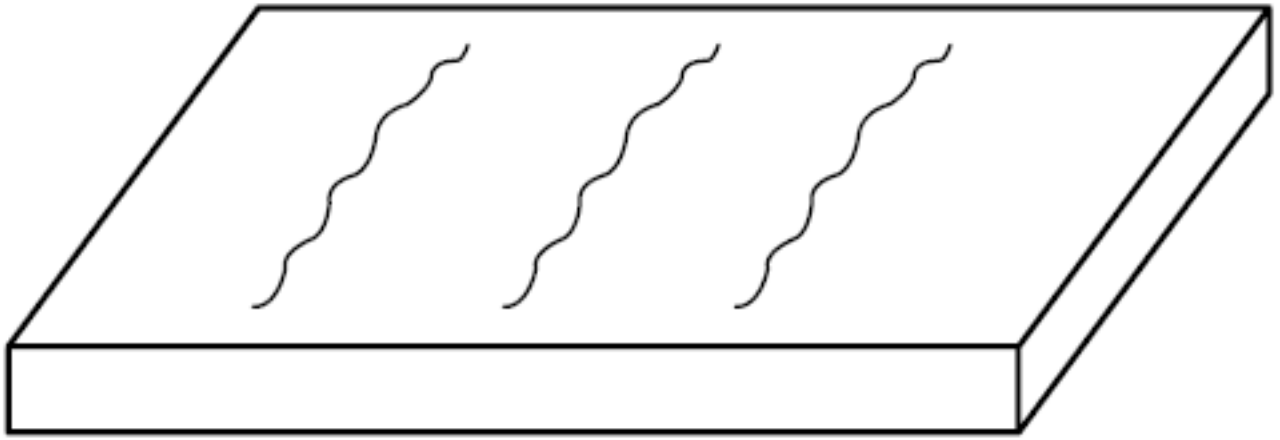
FRESH CONCRETE DEFECTS

Shrinkage Cracks

- Caused by evaporation of mix water in fresh concrete, the extent of which will depend on
  - The amount of water in concrete increasing water in the mix increases cracking
  - The weather conditions (heat, low humidity and wind increases evaporation and therefore cracks)
  - Curing (lack of curing increases shrinkage)

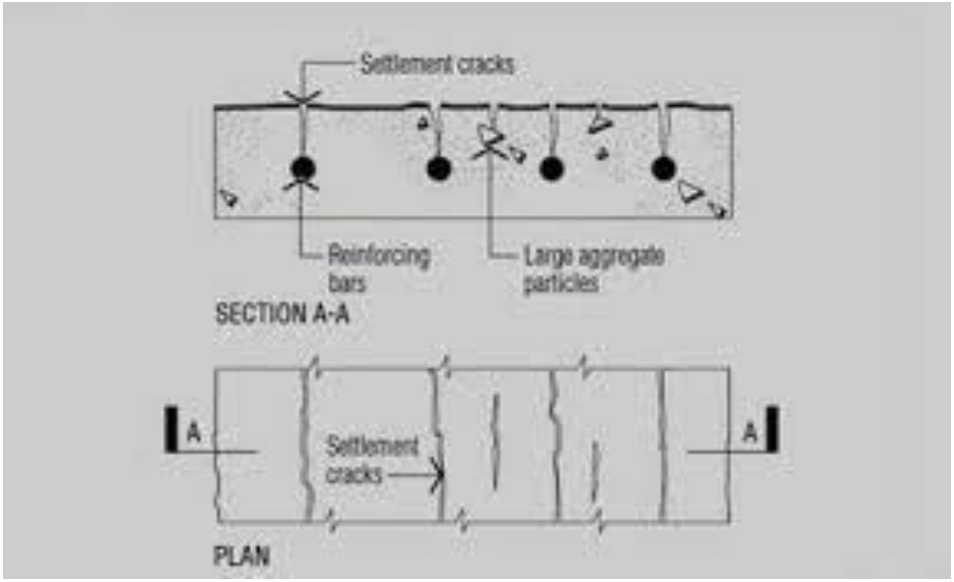
Shrinkage Cracks



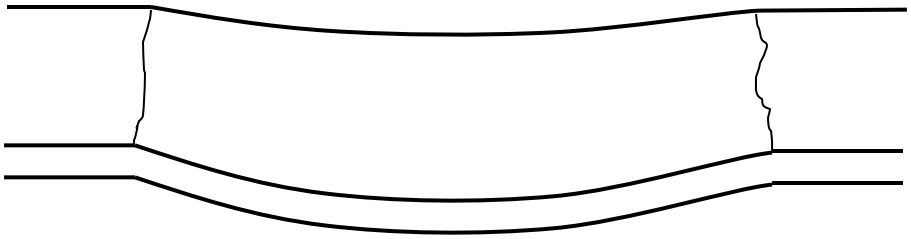


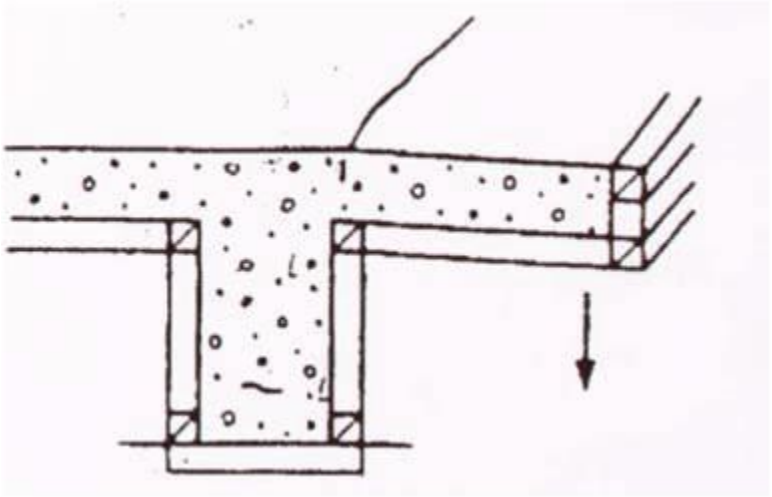
Settlement Cracks

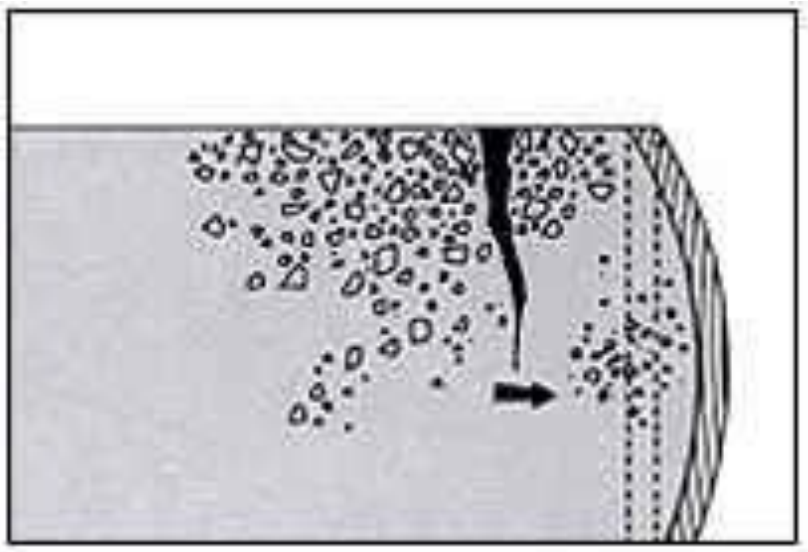
- Caused by settlement of concrete due to drying



Movement of formwork







How to minimize fresh concrete cracks

- Do not use excessive water in the mix
- Proper compaction
- Do not cast in hot weather
  - If you have to cast in hot weather use chilled water or crushed ice
- Proper curing
- Proper construction and monitoring of formwork during pouring of concrete

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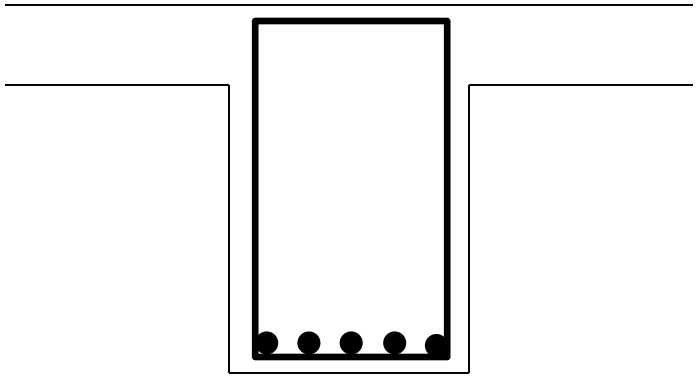
DESIGN AND DETAILING ERRORS

Design Errors

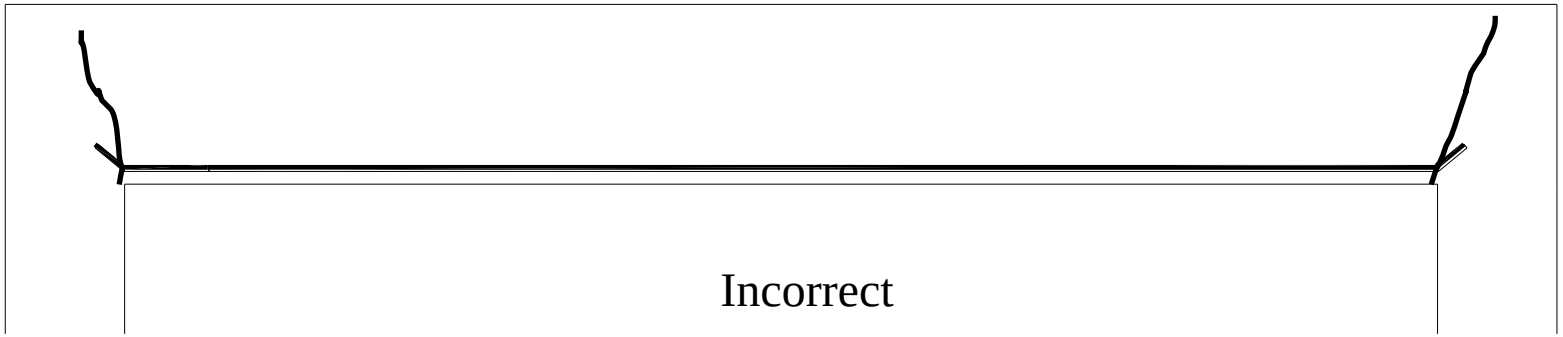
- Not taking into consideration all load cases e.g. temperature, wind, construction loads etc.
- Not taking into consideration order of construction
- Complex details
- Not complying with minimum design requirements like minimum spacing and reinforcement ratios
- Not providing sufficient details specially in cases of irregular geometry or cases where suggested code detail do not apply

Detailing Errors



Insufficient Spacing between bars
Causes honey combs and voids
Distance between bars 1.5 max aggregate size or ϕmax

Detailing Errors



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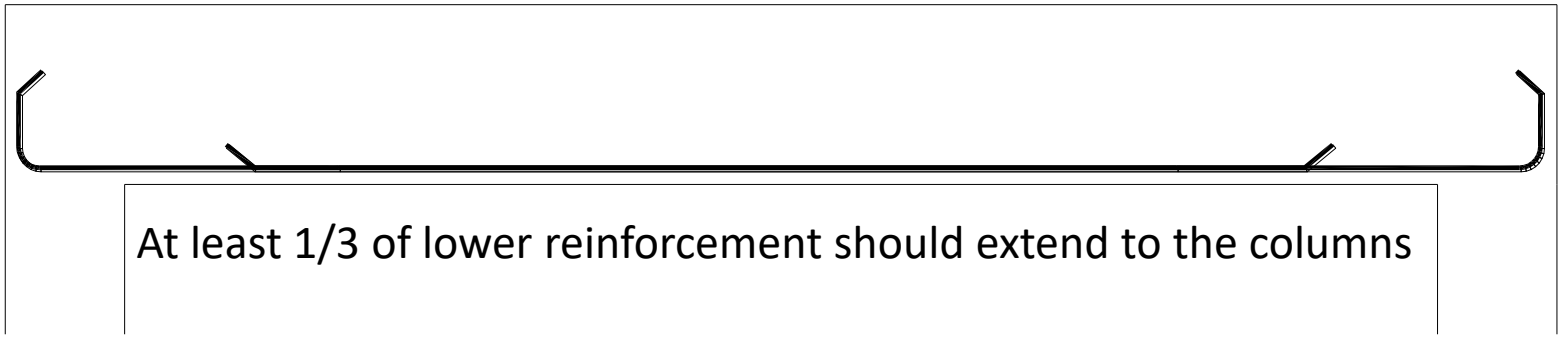
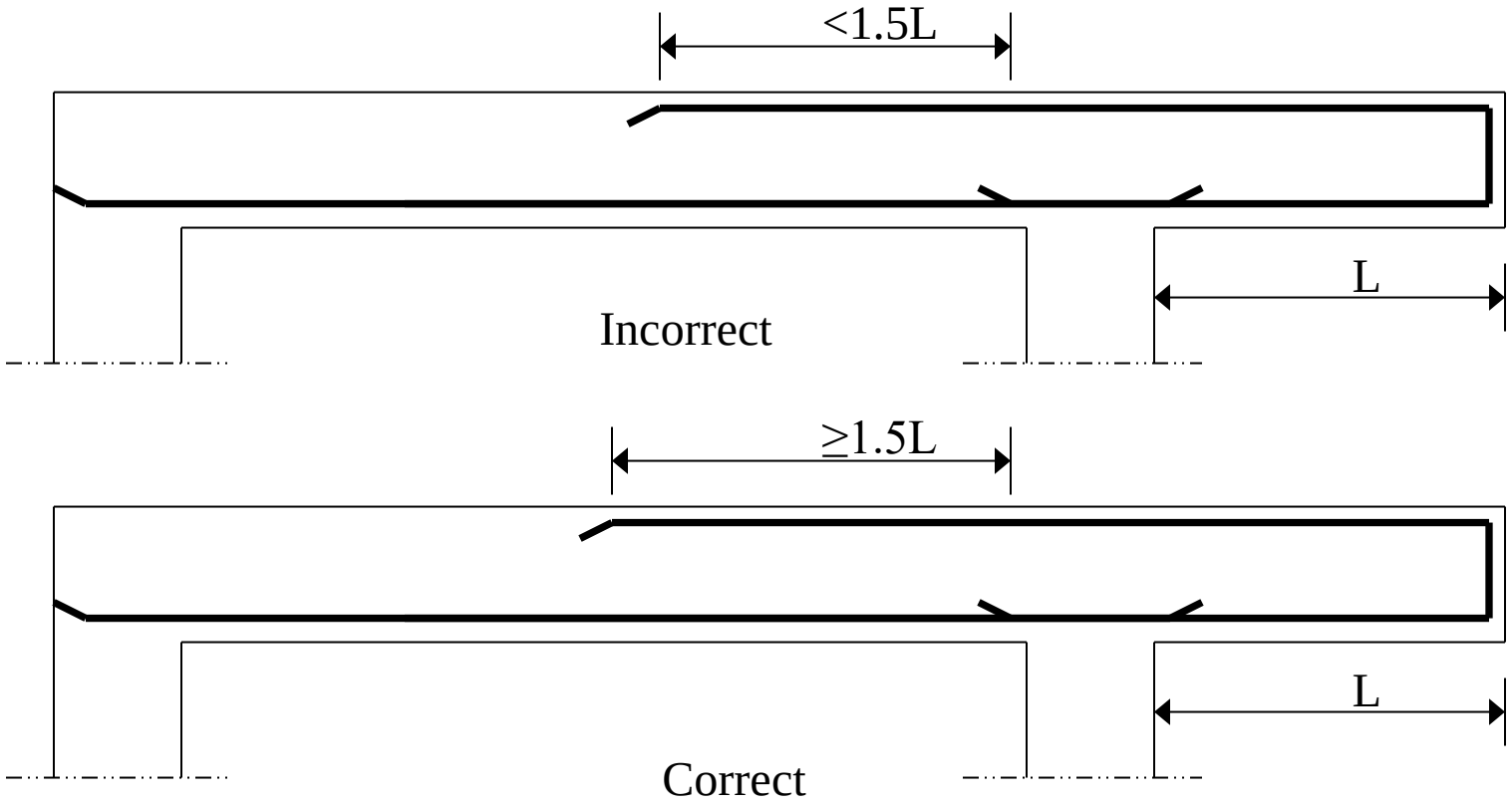


Correct

Detailing Errors



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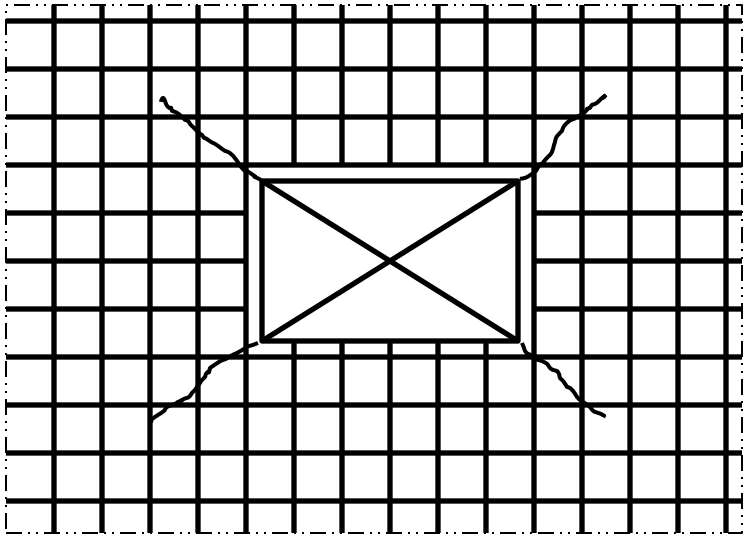
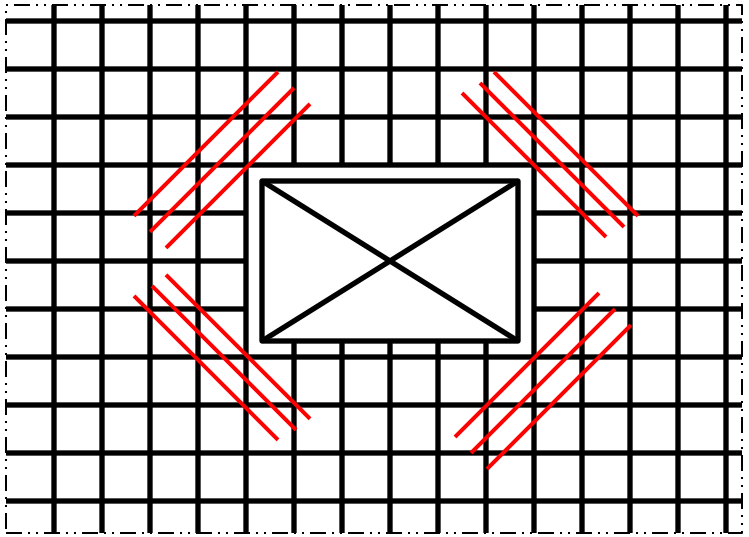
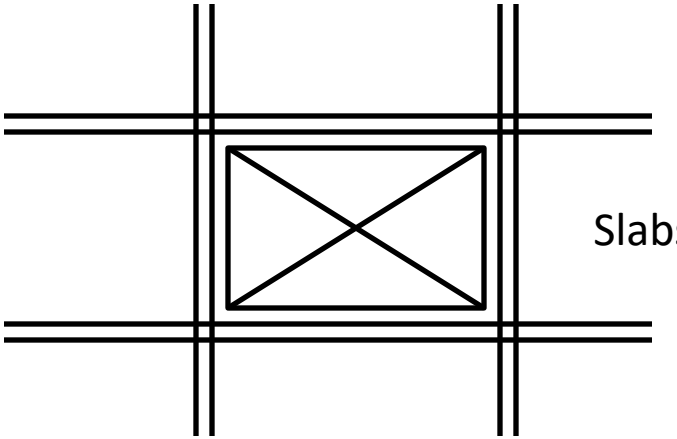


Incorrect (Walls)



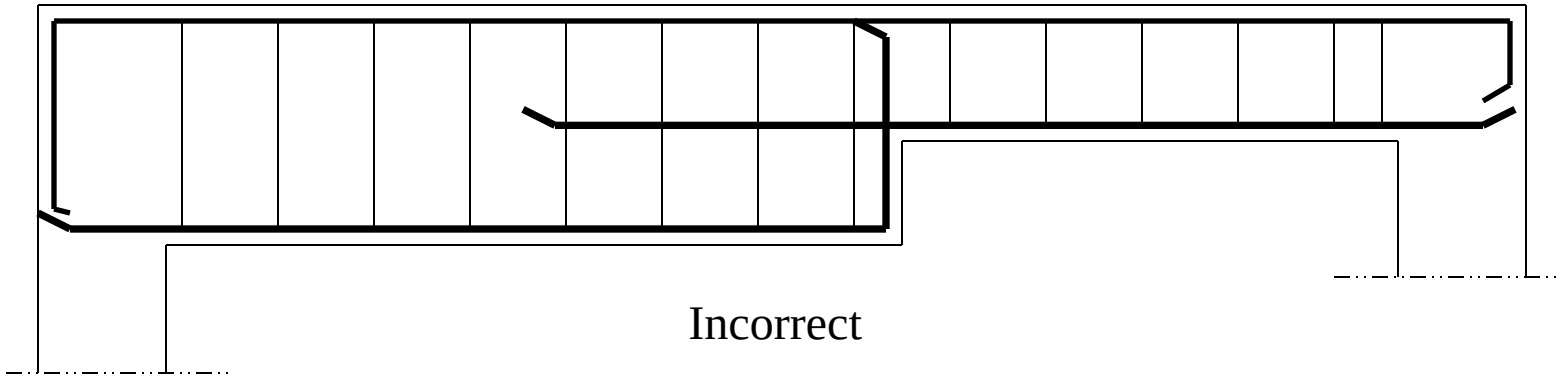
Correct (Walls)



Slabs

Detailing Errors

- Sudden change in depth



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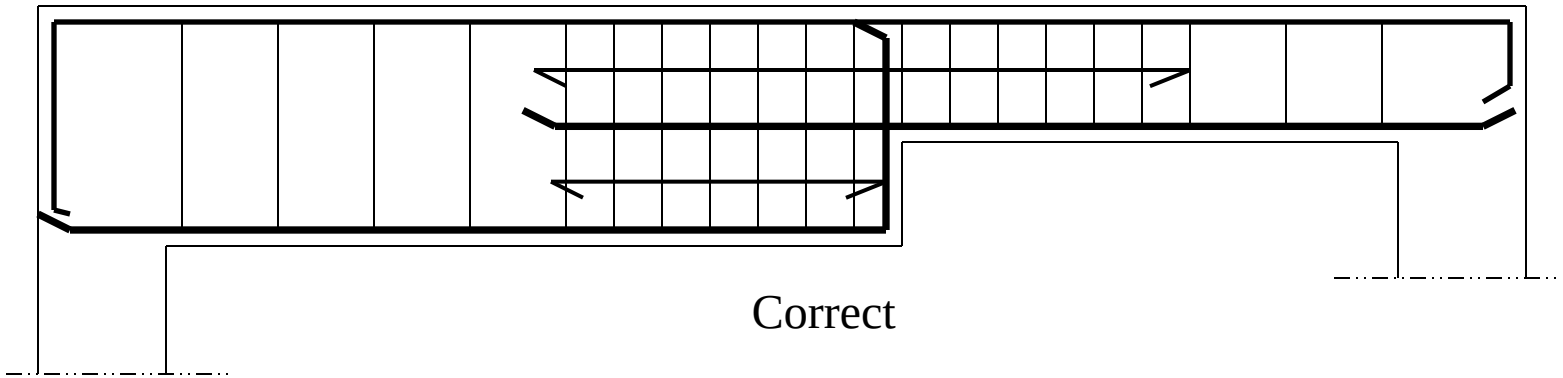
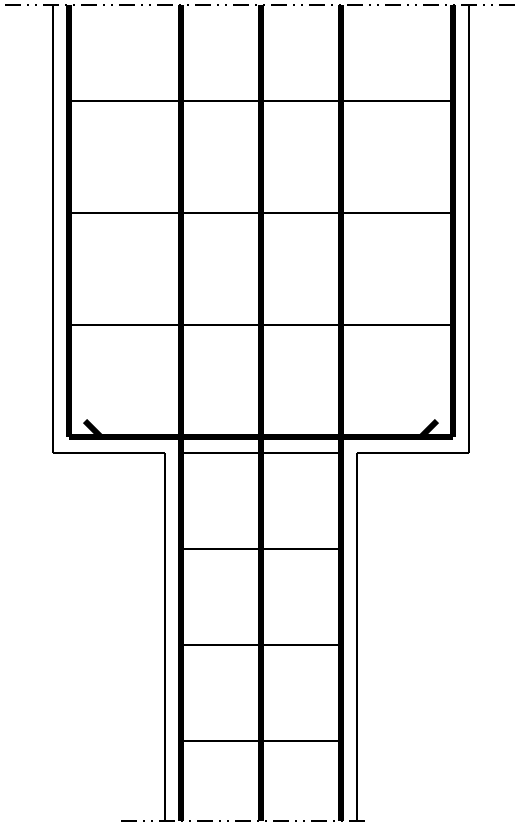
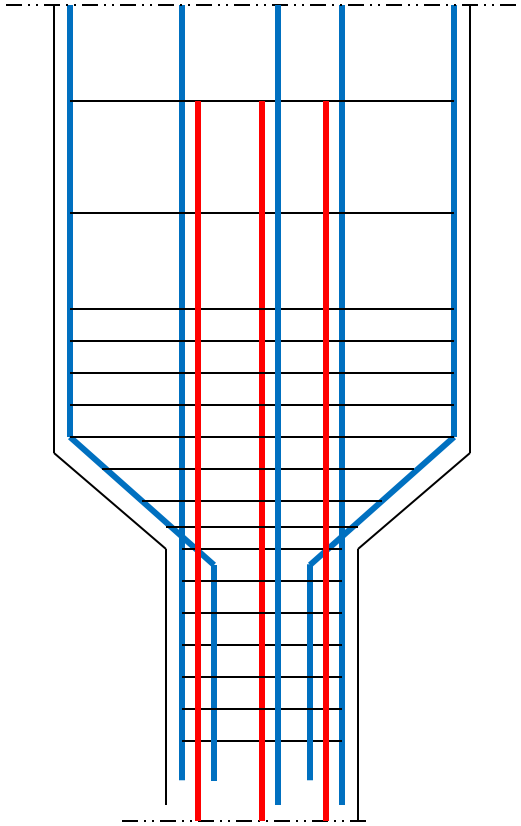


Correct

Detailing Errors





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CONSTRUCTION ERRORS

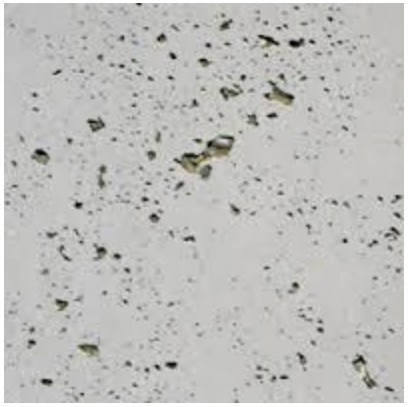
Construction Errors

- Increasing water in the mix
  - Increased shrinkage
  - Decreased strength
  - Increase void sizes which decrease durability

Insufficient Compaction

- Causes Voids and honeycombs which reduces durability as it exposes the reinforcement to the environment and may reduce the strength of the concrete sections

Honey Combs and Voids

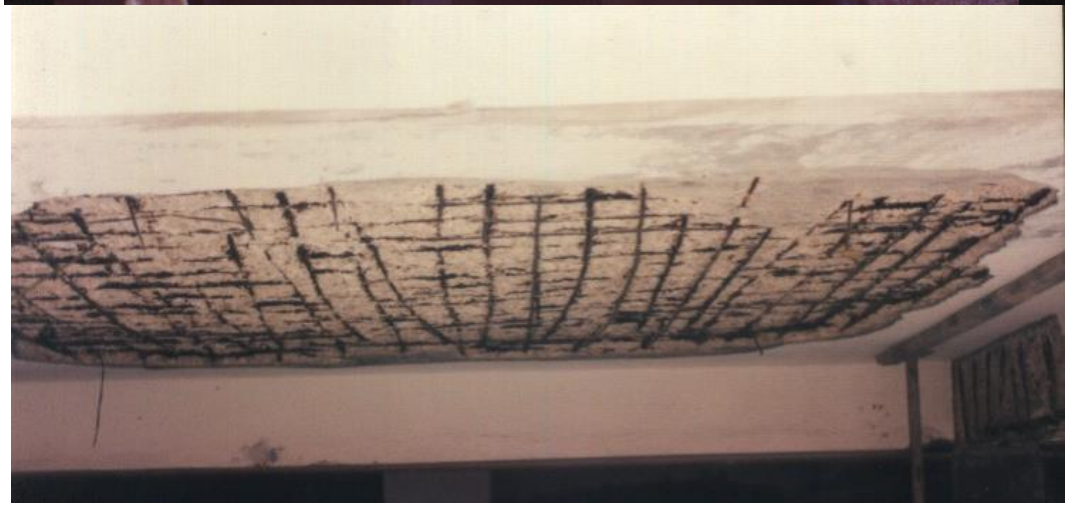


Construction Errors

- Excessive vibration of concrete
  - Causes bleeding and segregation of concrete

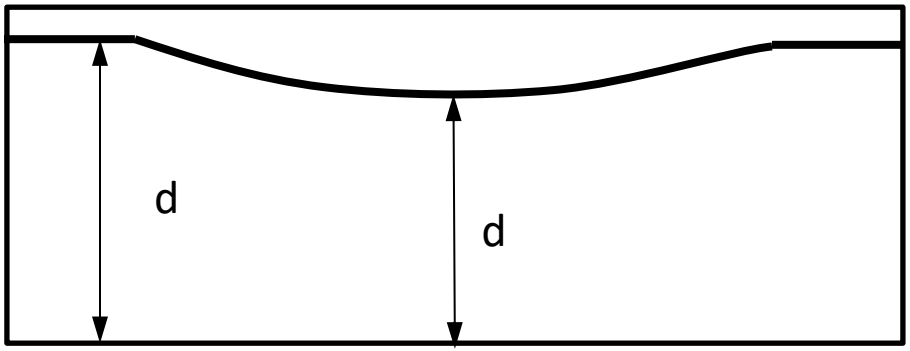
Insufficient tying of reinforcement

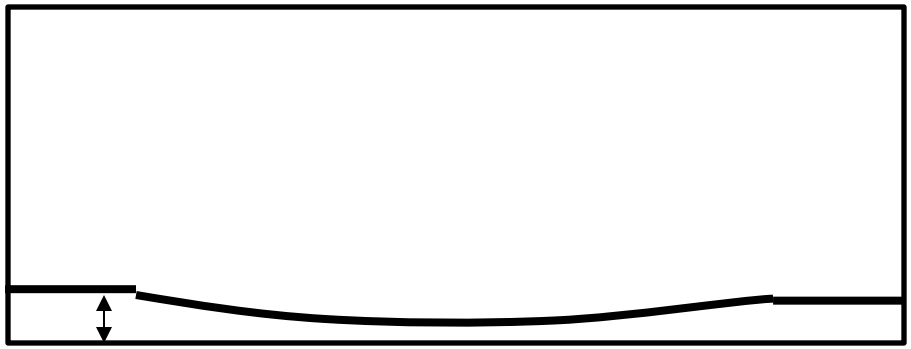
- Causes movement of reinforcement



Insufficient chairs and spacers

- Causes sagging of reinforcement which leads to
  - Reduction in concrete cover
  - Reduction in effective depth of sections





Concrete cover

Improper Casting of long Columns

- Causes segregation of concrete

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TEMPERATURE EFFECTS

Drying Shrinkage and Dimensional Changes Caused by Temperature

- Changes in dimensions either due to drying shrinkage or thermal expansion or contraction will cause stresses in restrained structures
- Cracking will occur due if the stresses exceed the capacity of the concrete this will occur in the following cases
  - Construction errors leading to excessive shrinkage
  - Poorly designed or constructed expansion joints
  - Design errors

Freezing and Thawing

- Water present in the voids of concrete will expand on freezing causing some internal pressure.
- The repeated cycles of freezing and thawing will weaken the concrete causing crakes and spalling
- This could be prevented by using air entrained concrete

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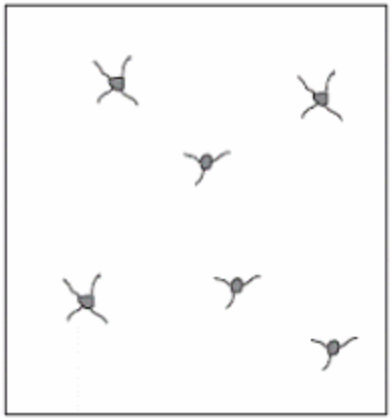
CHEMICAL EFFECTS

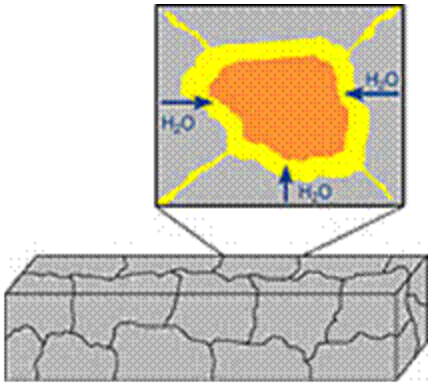
Alkali Aggregate Reaction

- Alkali aggregate reaction results in deleterious expansive cracking of concrete occurring at later ages after construction. While mostly inert, some concrete aggregates, can react in the highly alkaline environment in concrete resulting in internal expansion that causes deleterious cracking

Alkali Aggregate Reaction



Slabs



Walls and Abutments

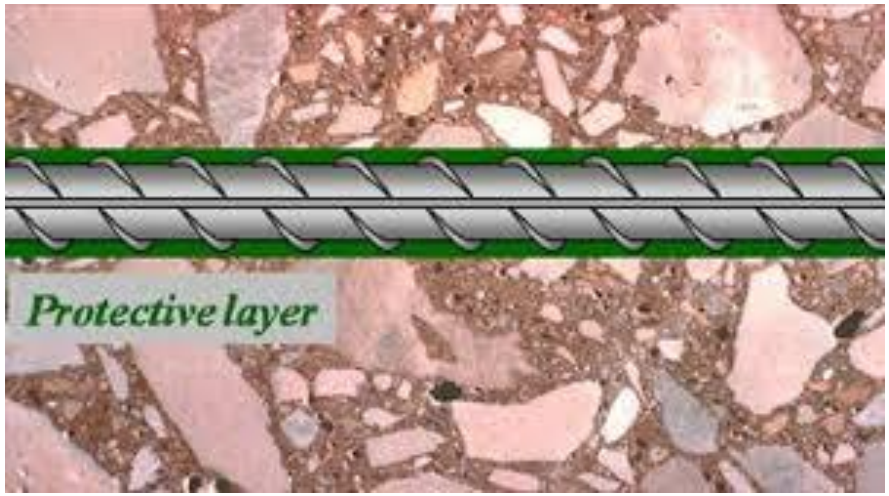
Sulphate Attack

- Solution of the sulfates of various bases including sodium, potassium, magnesium and calcium react with hydrated cement paste forming gypsum or a compound called ettringite (sulphoaluminate) which leads to the expansion and disruption of the concrete and mortar this process is referred as sulphate attack.

Sulphate Attack

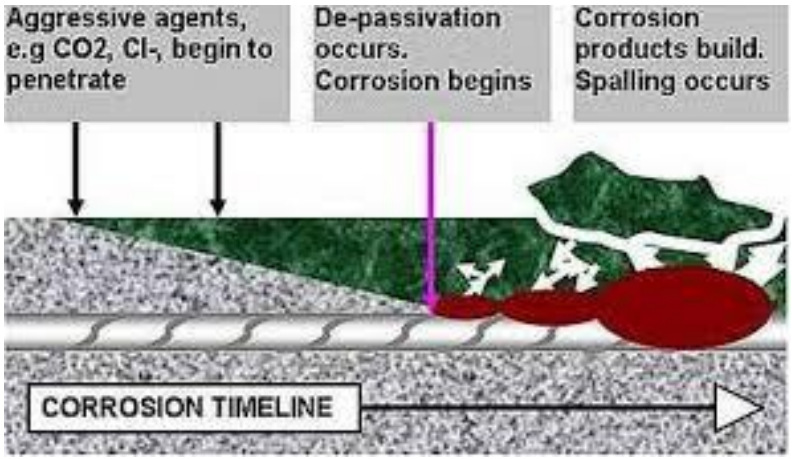
Corrosion of Reinforcement Steel

- The alkalinity of concrete provides a protective layer that protects the reinforcement from corrosion



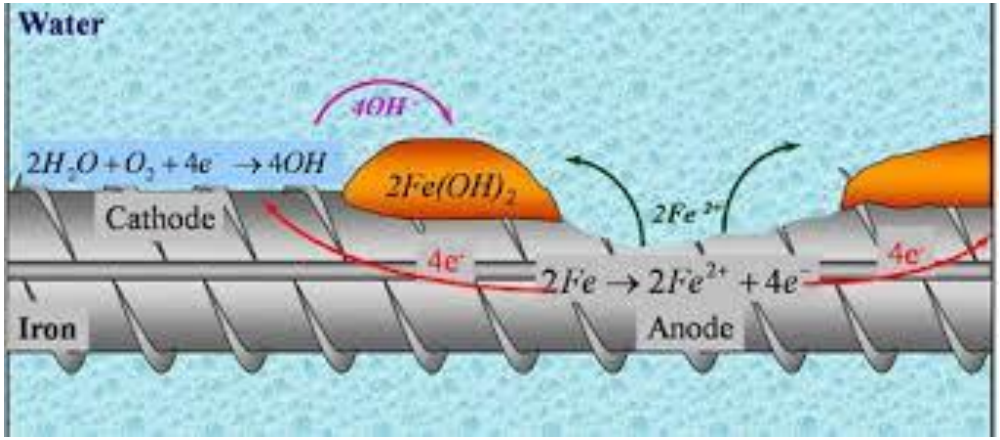
Corrosion of Reinforcement Steel

- If the PH of the concrete is reduced below 9 by carbonation for example or if the protective layer is eroded by the presence of chemicals like chlorides or sulphates either from the environment or from within the concrete corrosion will occur



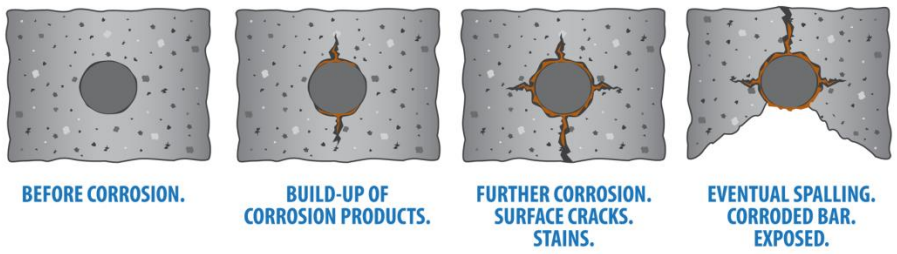
Corrosion of Reinforcement Steel

- Corrosion is an electro-chemical reaction that requires the presence of
  - Oxygen
  - Water
  - Conductive medium



Corrosion of Reinforcement Steel

- Corroded steel is pours, weak and expansive which allow the progress of the corrosion process also causes cracking of the concrete



The corrosion cycle of steel begins with the rust expanding on the surface of the bar and causing cracking near the steel/concrete interface. As time marches on, the corrosion products build up and cause more extensive cracking until the concrete breaks away from the bar, eventually causing spalling.

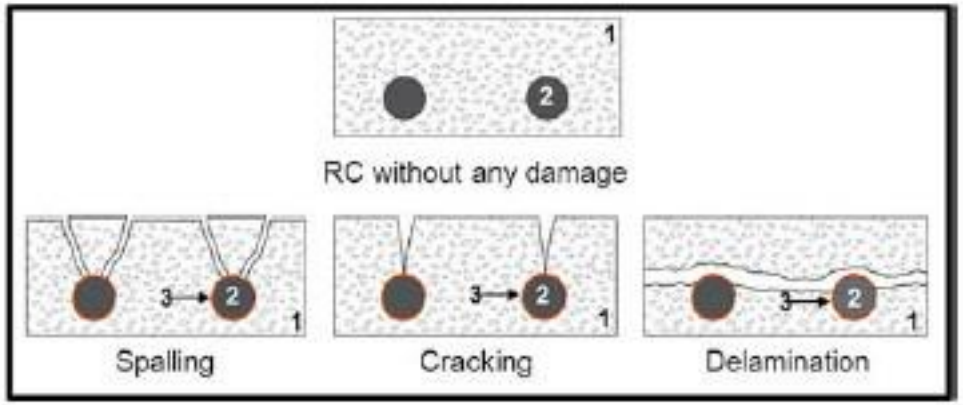
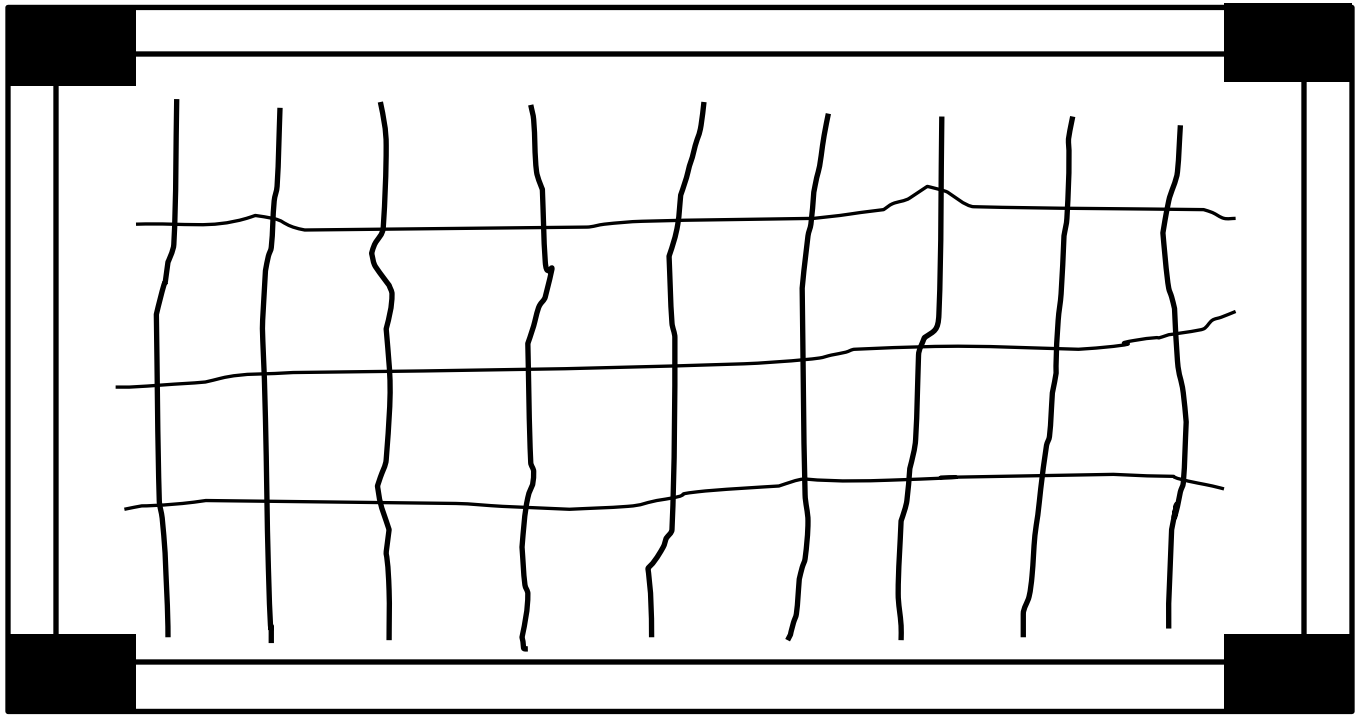


Fig. 1 - Spalling, cracking and delamination of RC structures (adapted from [2]). (1 – concrete; 2 – steel rebar; 3 – corrosion oxides).

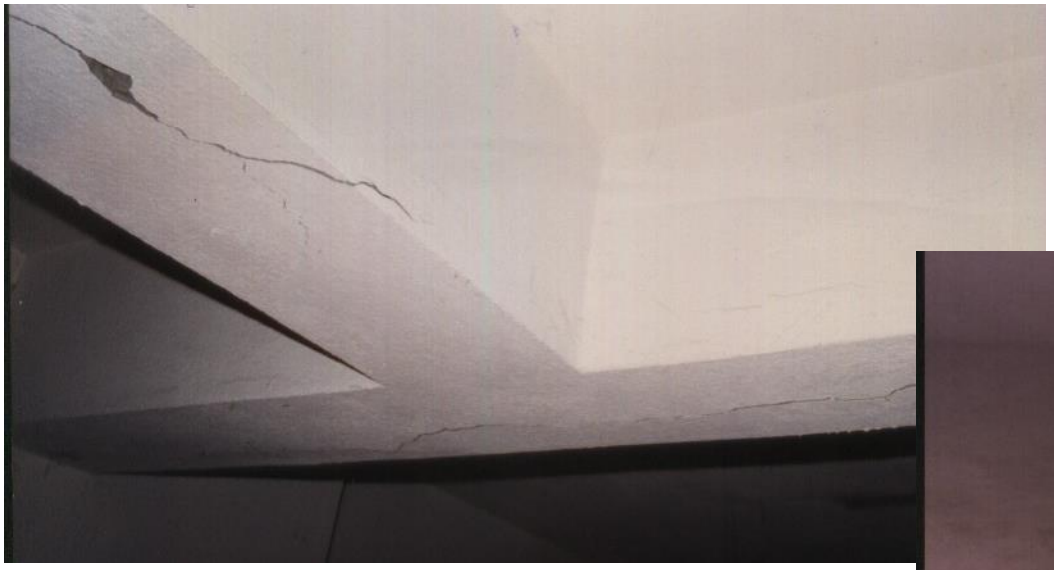
Corrosion of Reinforcement Steel

- Crack patterns slabs



Corrosion of Reinforcement Steel

- Crack patterns beams



Corrosion of Reinforcement Steel

- Crack patterns columns

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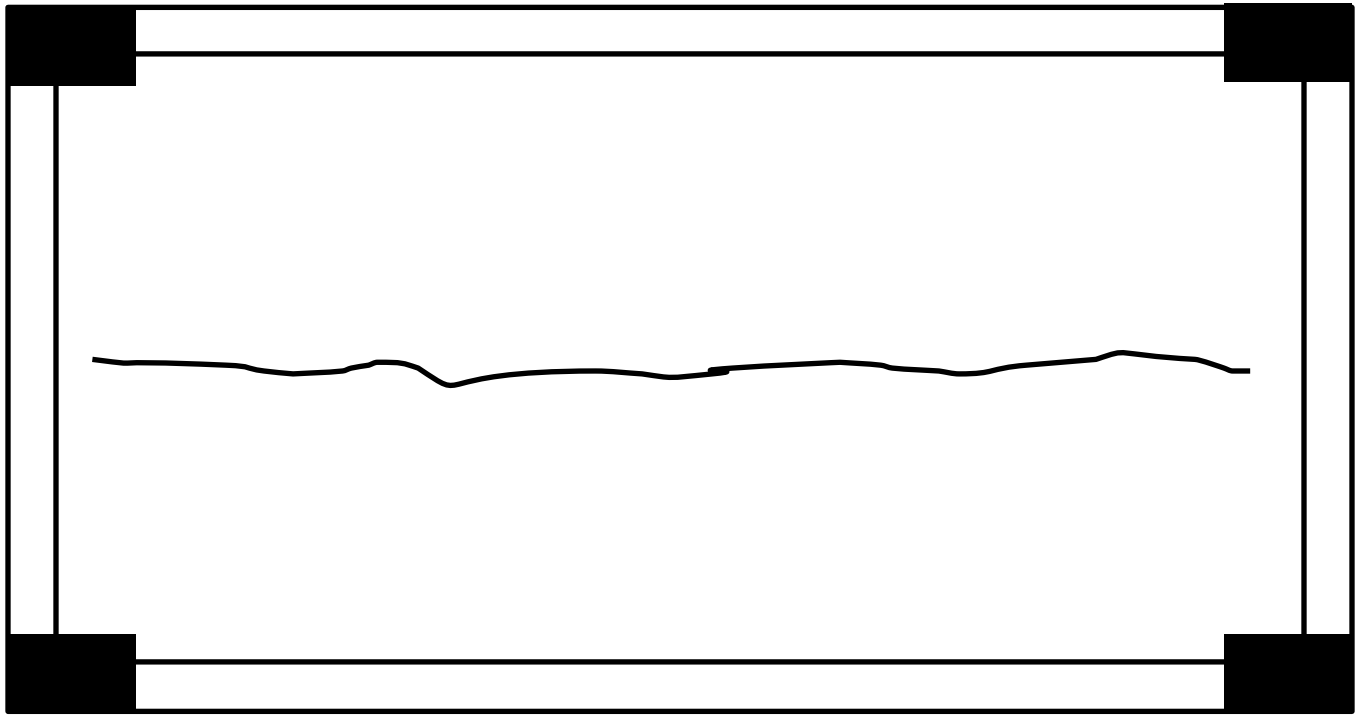
OVERLOADING

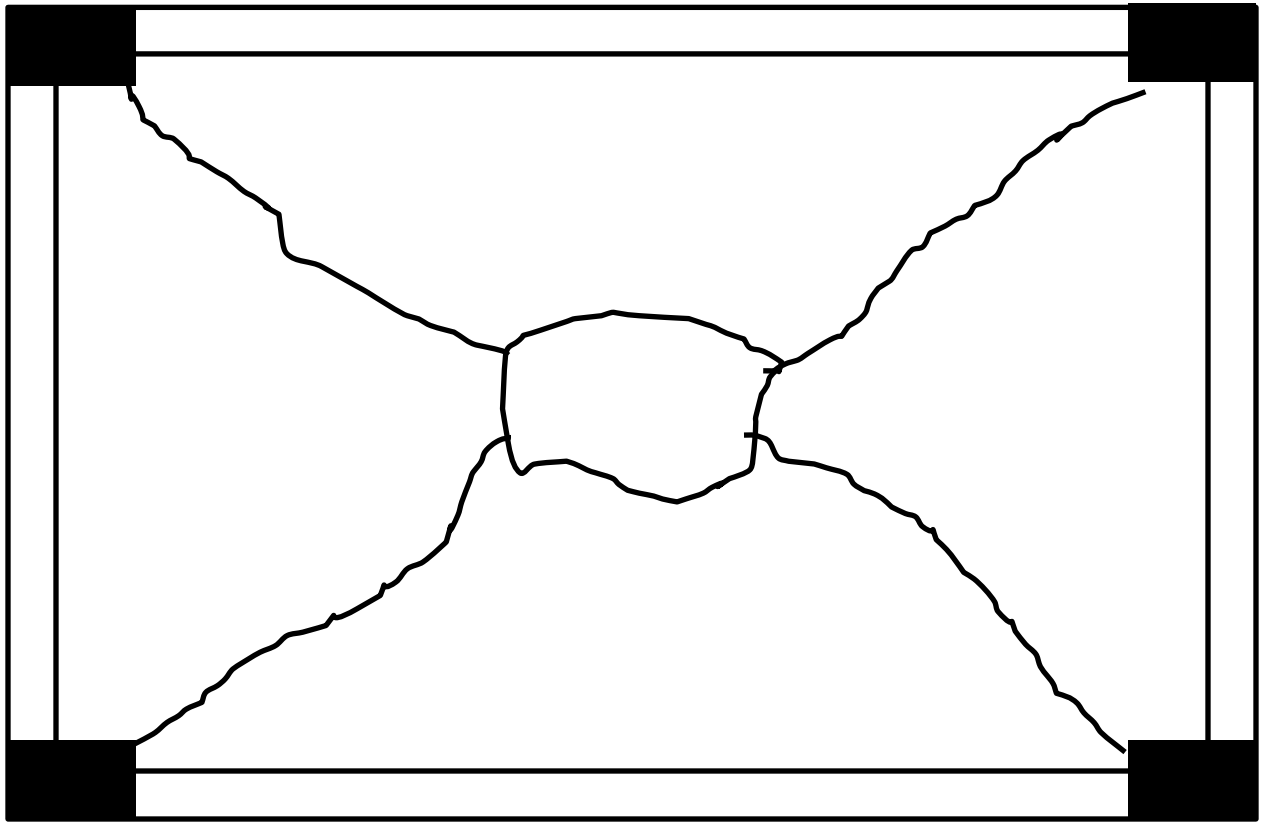
Overloading

- Accidental
- Intentional
  - Change of use
  - Violation of load limits
- Design or construction errors
- During construction
  - Excessive Storage
  - Insufficient shoring
  - Early removal of formwork

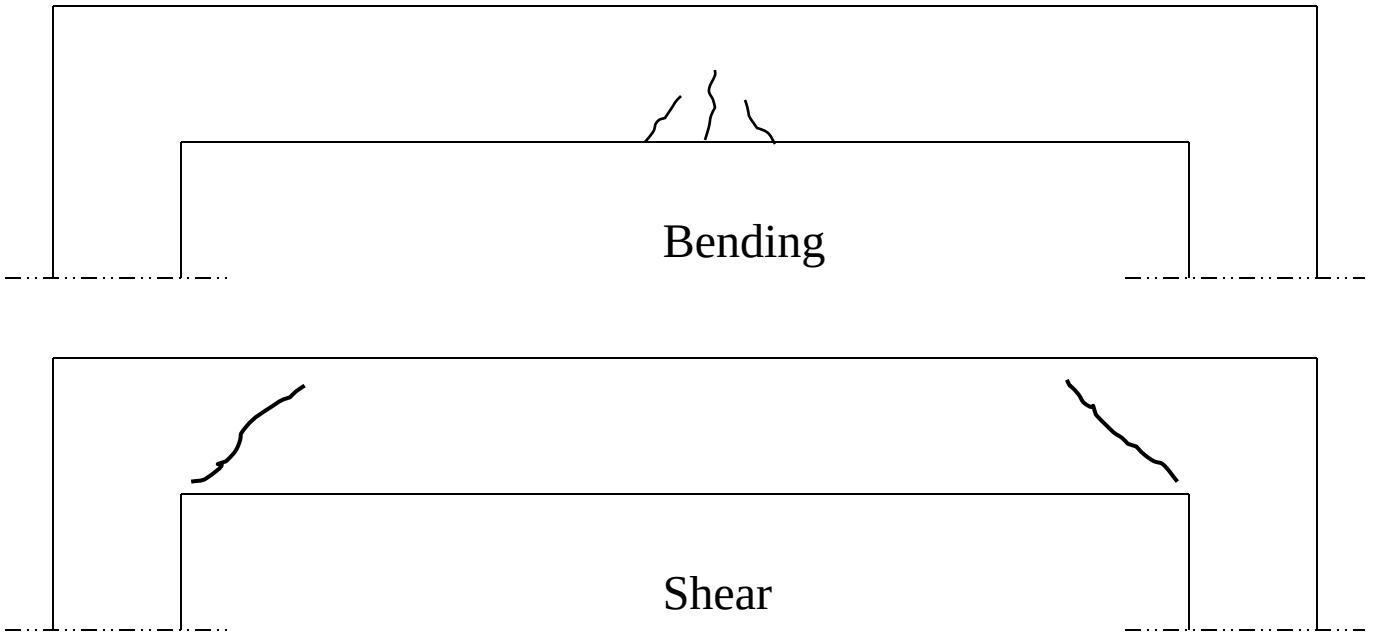
Overloading One Way Slabs



Overloading Two Way Slabs



Overloading Beams



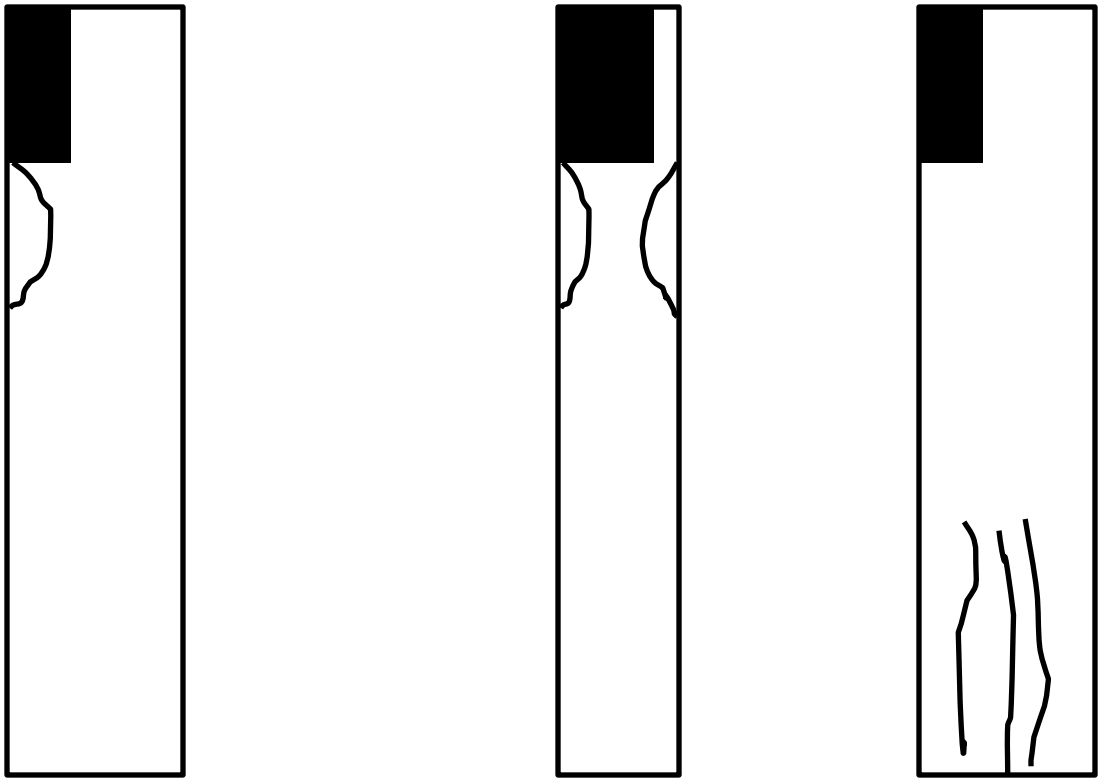
Overloading Columns

Shear

Compression

Buckling

Overloading Columns



Compression