REPAIR AND REHABILITATION OF CONCRETE STRUCTURES

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CAUSES OF DAMAGE

MAINTENANCE OF REPAIR

REHABILITATION

ASSESSMENTS O DAMAGE

REPAIRS OF DAMAGE

CAUSES OF DAMAGE

- PHYSICAL CAUSES
- CHEMICAL CAUSES
- CORROSION

ASSESSMENT OF DAMAGE

- Non-Destructive Testing Systems
- Partial Destructive Testing Systems
- Destructive Testing Systems

REPAIRS OF DAMAGE

- Selection of Repair Materials
- Repair of Cracks
- Rehabilitation Techniques
- Strengthening Techniques

MAINTENANCE OF REPAIR

- Classification & Necessity of Maintenance
- Maintenance Procedure
- Safety Maintenance

MECHANICAL PROPERTIES

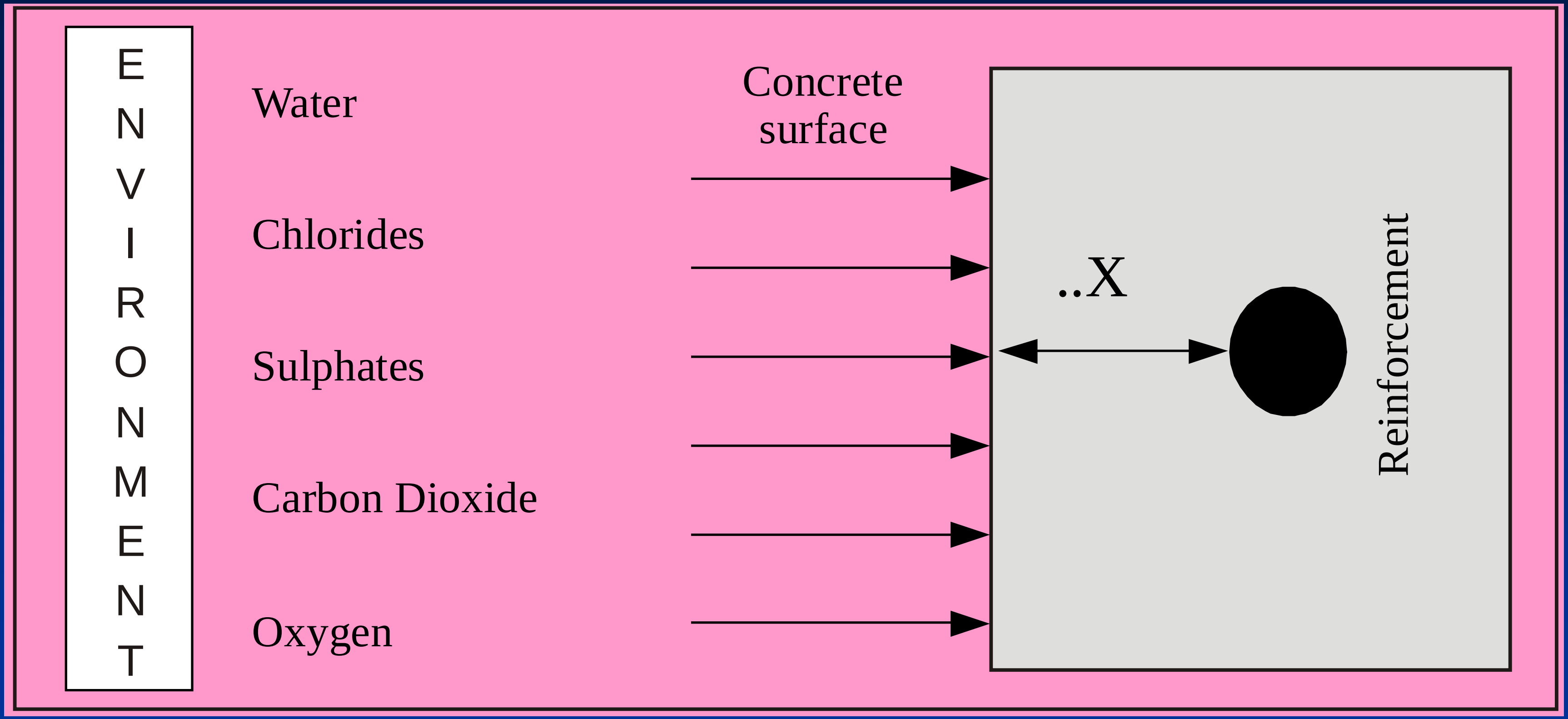
- Compressive strength
- Tensile strength
- Flexure strength
- Bond strength
- Shrinkage
- Elasticity
- Thermal expansion
- Creep

REHABILITATION

- Durability and Determination
- Damage Assessment
- Repair materials
- Rehabilitation and Strengthen Techniques
- Maintenance and Demolition Techniques

DURABILITY OF CONCRETE

- **A concrete is said to be durable if it withstand without deterioration, over a design period or design life of years.**
- **The influencing factors:**
- **(a) External factors**
- **(b) Internal factors**



Environmental Penetrations into Concrete

DAMAGES TO STRUCTURES

- Discoloration
- Cracking (includes pattern cracks)
- Spalling of materials
- Deformations / Deterioration
- A total or partial collapse

COMMON CAUSES

- Accidental Loadings
- Chemical Reactions
- Construction Errors
- Corrosion of Reinforcement
- Design Errors
- Freezing and Thawing
- Erosion, Abrasion, & Cavitations

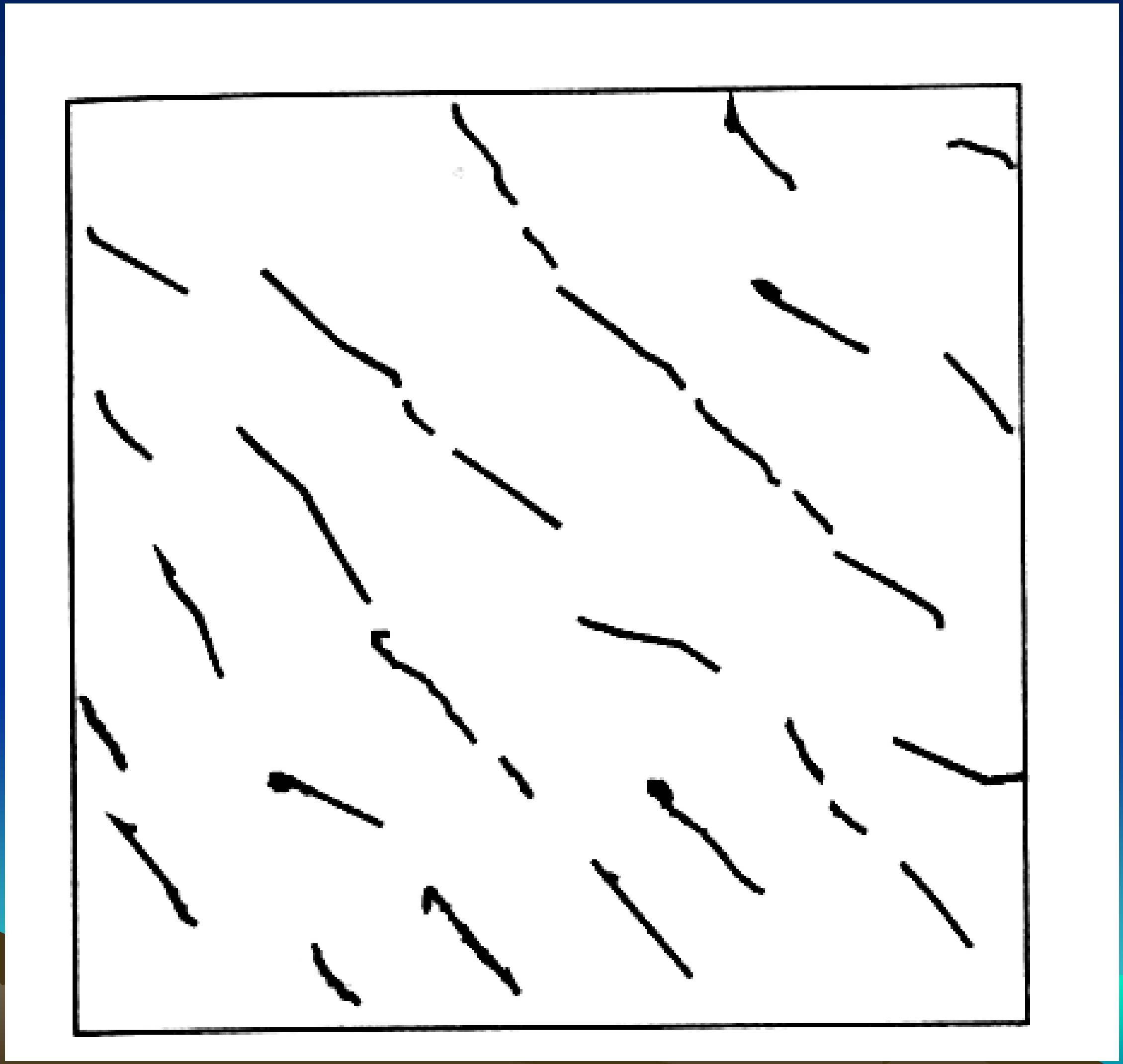
- Settlement and Movement
- Shrinkage
- Temperature Changes
- Weathering
- Effect of cover thickness
- Thermal properties
- Effect of cracking

SHRINKAGE

Shrinkage in concrete means moisture movement in concrete.

- **Plastic shrinkage**
- **Drying shrinkage**
- **Autogenous shrinkage**
- **Carbonation shrinkage**

PLASTIC SHRINKAGE CRACKS

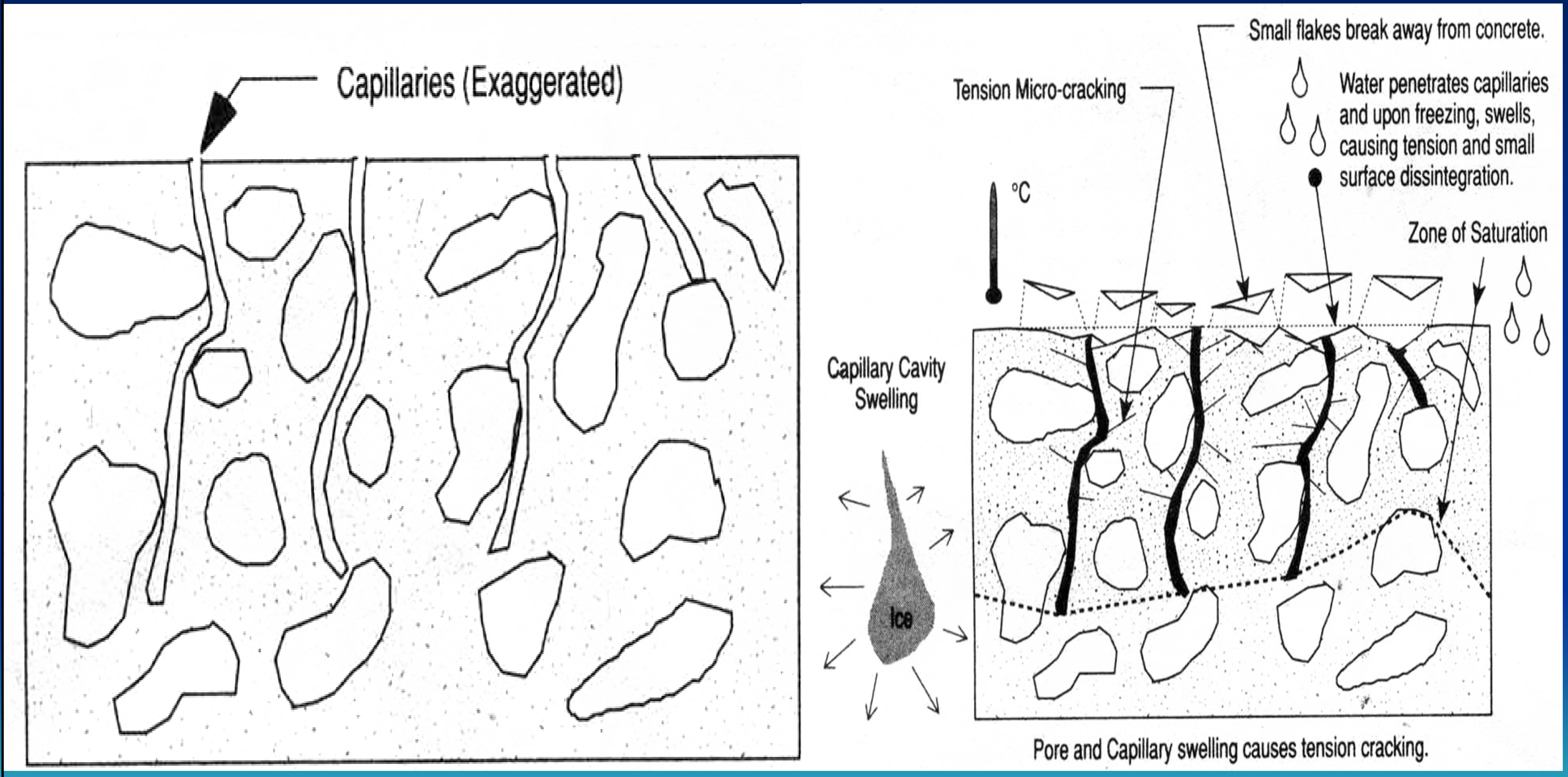


FREEZE AND THAW

Freeze-thaw disintegration or deterioration takes place when the following conditions are present:

- Temperature cycles within the concrete
- Porous concrete

Mechanism of Deterioration



CRAZING

- Development of a network of fine random cracks on the surface of concrete
- Excessive floating and traveling
- Spreading dry cement on a surface and sprinkling water on concrete

HONEY COMBING

- Honeycomb consists of exposed pockets of coarse aggregates not covered by a surface layer of mortar.
- It may be caused by inadequate consolidation, presence of excess water in concrete or by leaky forms, which allow the mortar to escape.

SWELLING

- Continuously in water from the time of casting exhibits a net increase in volume
- Due to continued hydration of cement is known as swelling.
- Due to the absorption of water by the cement gel.

POPOUTS

- A conical-shaped hole in the surface
- Occur outdoors on the hl & vl surfaces.
- Caused by freezing of water in aggregate
- Start to appear during the first winter following construction

- Do not harm the concrete but unsightly.
- Prevented only by avoiding aggregates which cause them

CREEP

- Concrete, brickwork and timber when subjected to sustained loads not only undergoes instaneous elastic deformation but also exhibit a time-dependent deformation known as creep.

ABRASION, EROSION AND CAVITATIONS

- Abrasion refers to wearing away of the surface by friction.
- Erosion refers to wearing away of the surface by fluids.
- The cavitations refer to the damage due to non-linear flow of water at velocities more than 12 m/sec.

TEMPERATURE CHANGES

Changes in temperature cause a corresponding change in the volume of concrete.

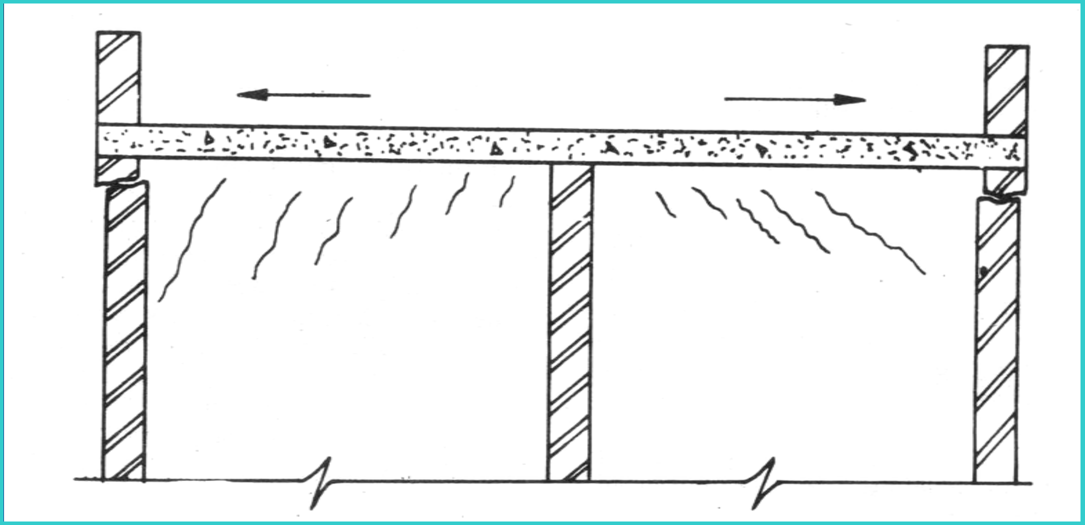
- Internally generated temperature differences
- Externally generated temperature differences

FIRE ON CONCRETE

A fire in a concrete structure causes damage.

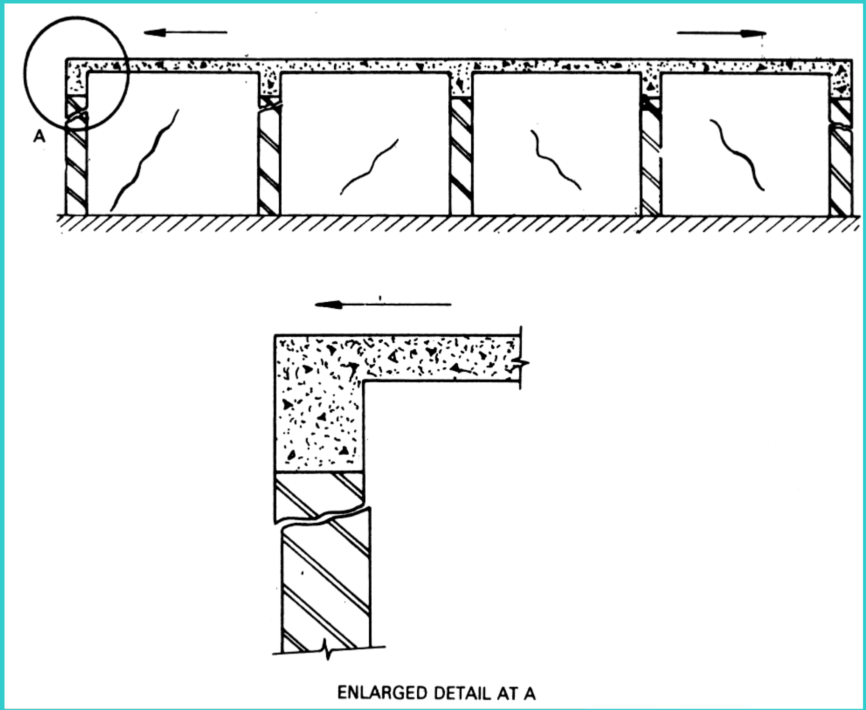
The extent of which depends upon the intensity and duration of the fire.

THERMAL MOVEMENT IN CONCRETE



Cracking in top most storey of a load bearing structure

Cracking in cladding and cross walls of a framed structure



CONSTRUCTION ERRORS

- Adding water to concrete
- Improper alignment of formwork
- Improper consolidation
- Improper curing
- Improper location of reinforcing steel
- Premature removal of shores / formwork
- Settling of the concrete

- **Settling of the sub-grade**
- **Vibration of freshly placed concrete**
- **Improper finishing of flat work**
- **Adding water to the surface**
- **Timing of finishing**
- **Adding cement to the surface**
- **Use of tamper**
- **Jointing**

LOADING ERRORS

- CRACKING DUE TO CONSTRUCTION OVERLOADS
- CRACKS DUE TO EXTERNALLY APPLIED LOADS
- ACCIDENTAL LOADINGS

DESIGN ERRORS

- Inadequate structural design
- Poor design details
- Abrupt changes in section
- Insufficient reinforcement
- Inadequate provision for deflection
- Inadequate provision for drainage

- Insufficient travel in expansion joints
- Incompatibility of materials
- Neglect of creep effect
- Rigid joints between precast units
- Unanticipated shear stresses in piers, columns, or abutments
- Inadequate joint spacing in slabs

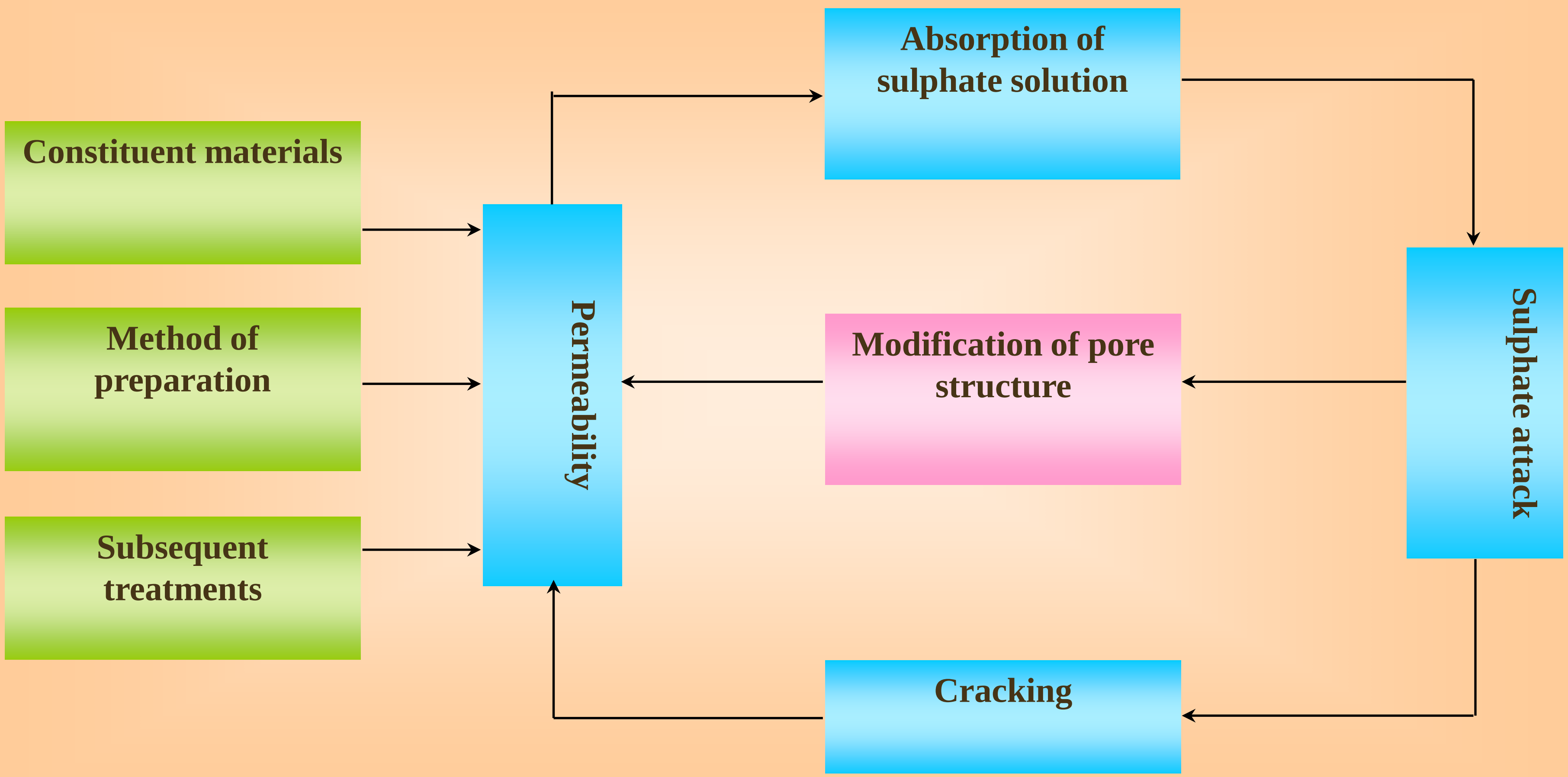
CHEMICAL ATTACK

- Acid attack
- Alkali attack
- Carbonation
- Chloride attack
- Leaching
- Salt attack
- Sulphate attack.

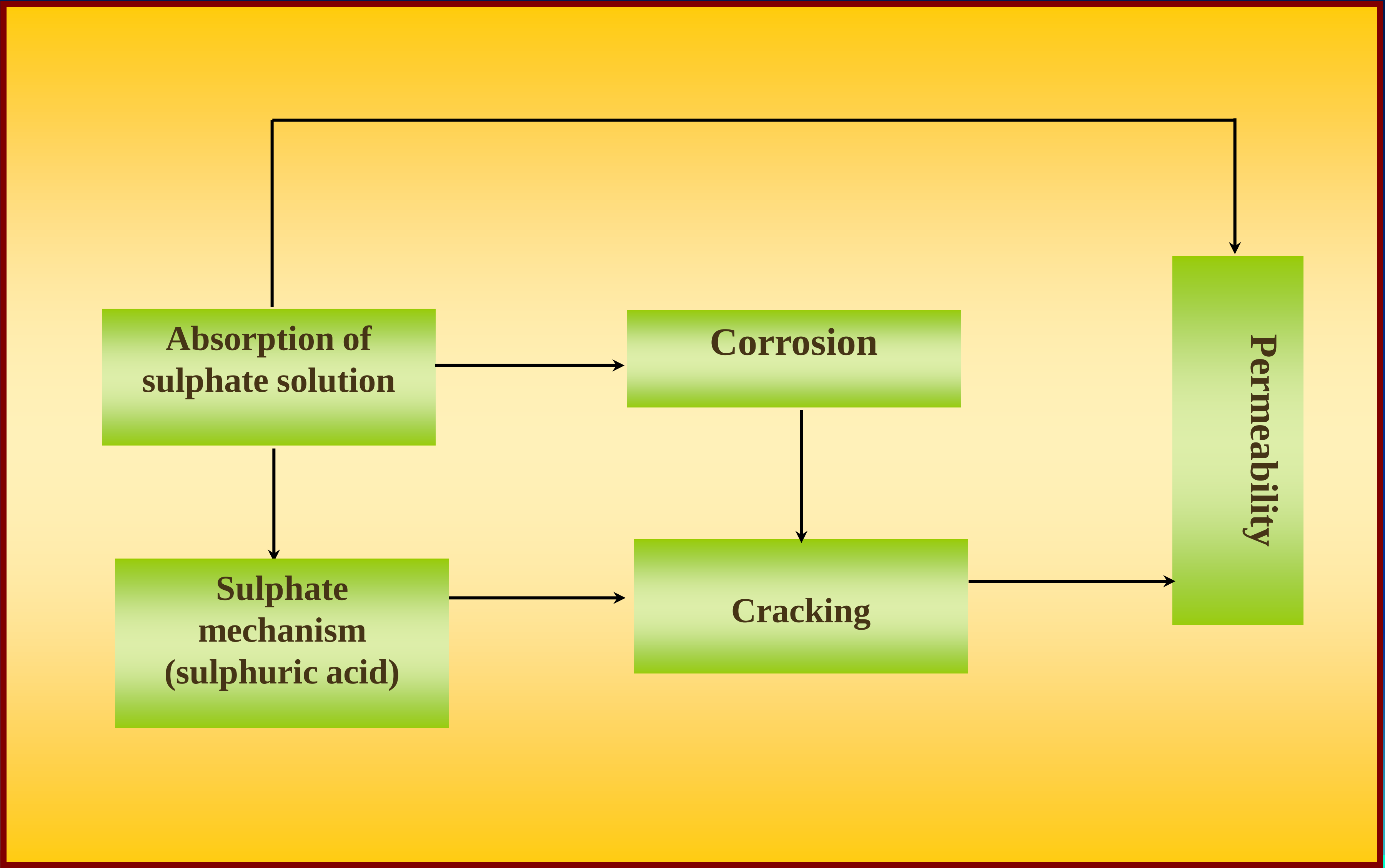
INFLUENCING FACTORS

- Time
- Cover to reinforcement
- Concentration of carbon-dioxide in the atmosphere
- Permeability of concrete
- Alkali content in the concrete
- Condition of concrete cover

SULPHATE ATTACK



ACID ATTACK


Absorption of sulphate solution
Corrosion
Permeability
Sulphate mechanism (sulphuric acid)
Cracking

CHLORIDE ATTACK

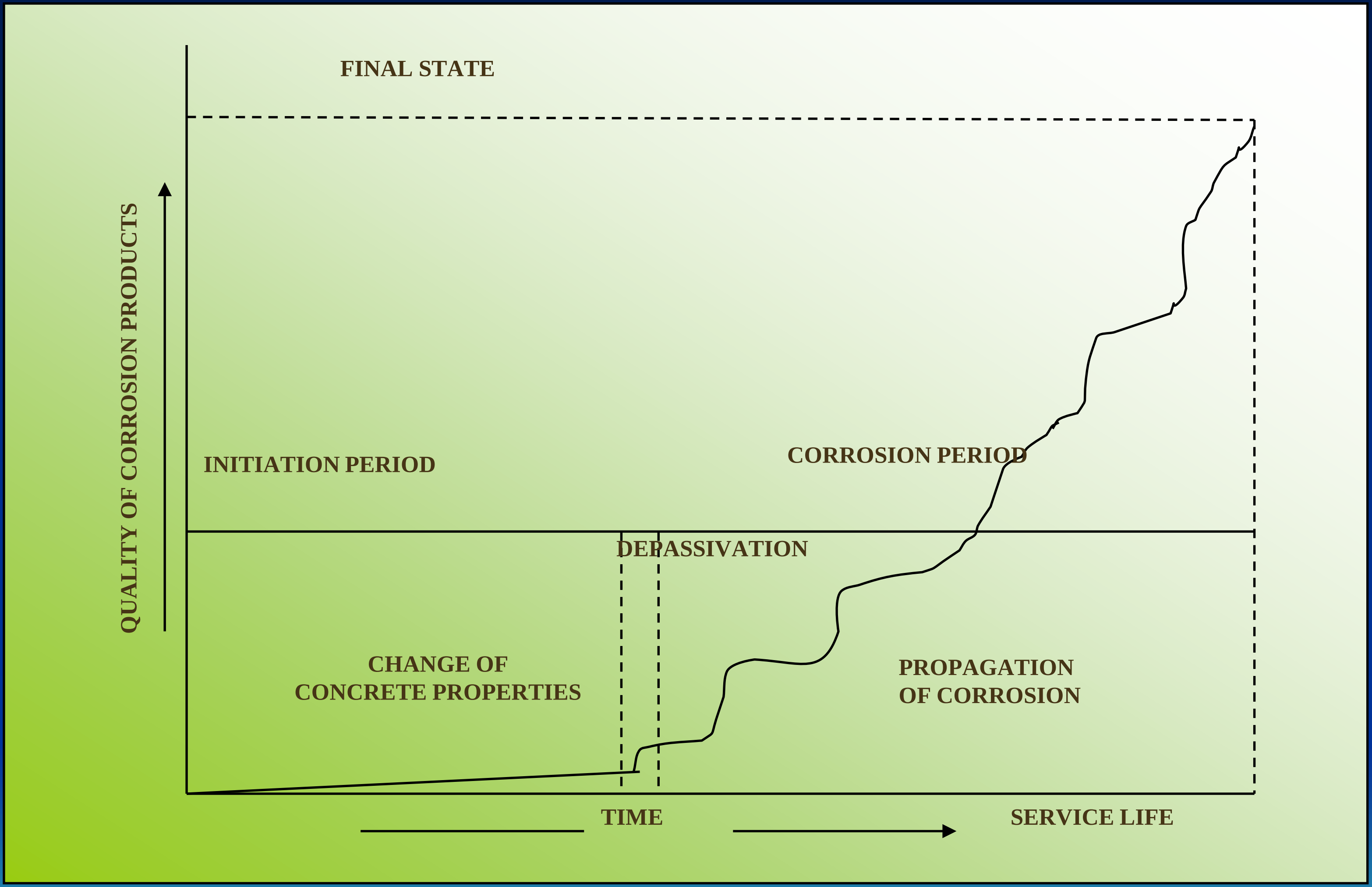
- **Chlorides can be introduced into concrete by coming into contact with environments containing chlorides, such as seawater or deicing salts.**

- Penetration takes time, depending upon:
  - The amount of chlorides coming into contact with the concrete
  - The permeability of the concrete
  - The amount of moisture present

BIOLOGICAL ATTACK

- **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.**

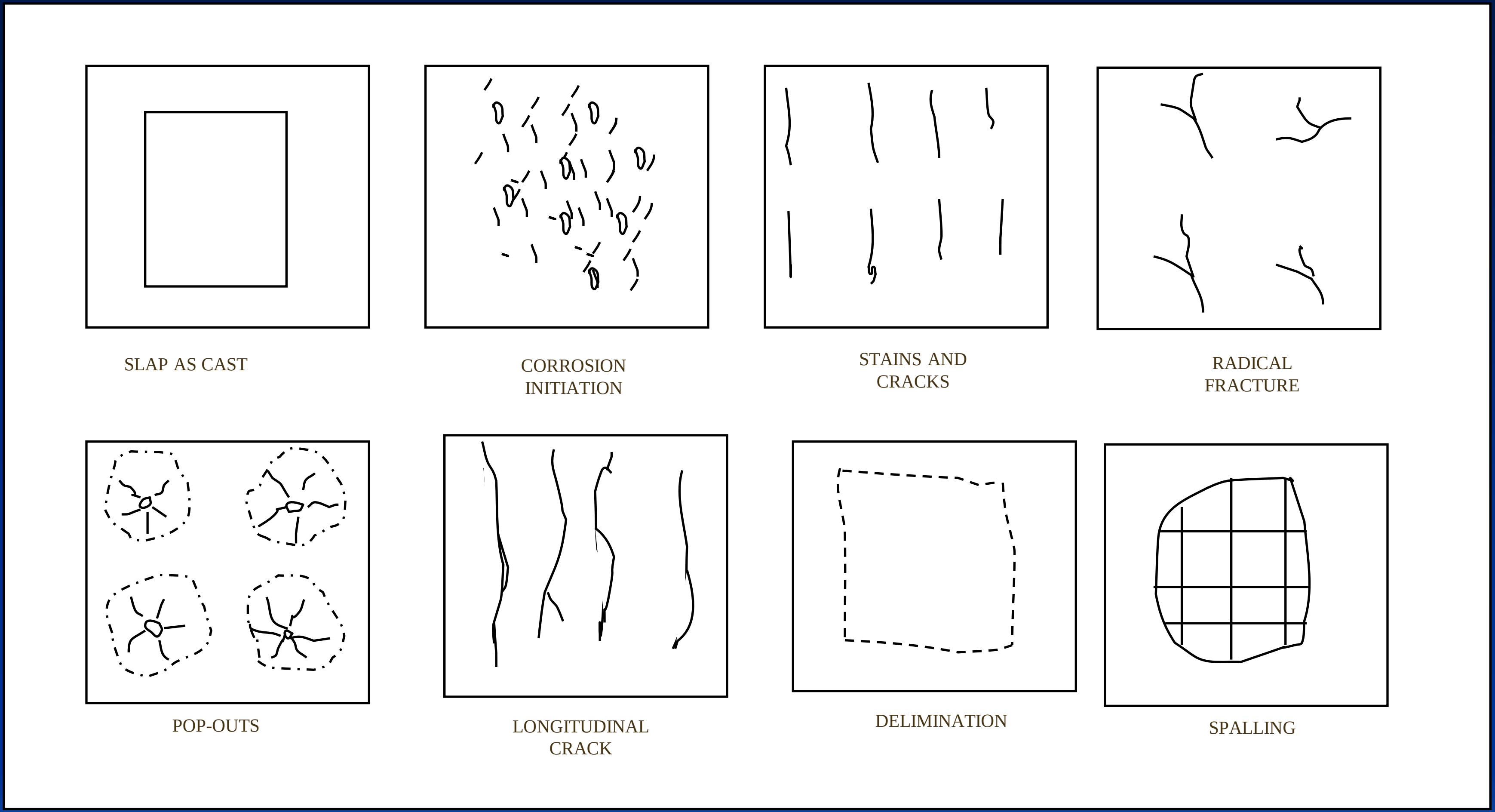
CORROSION PROCESS



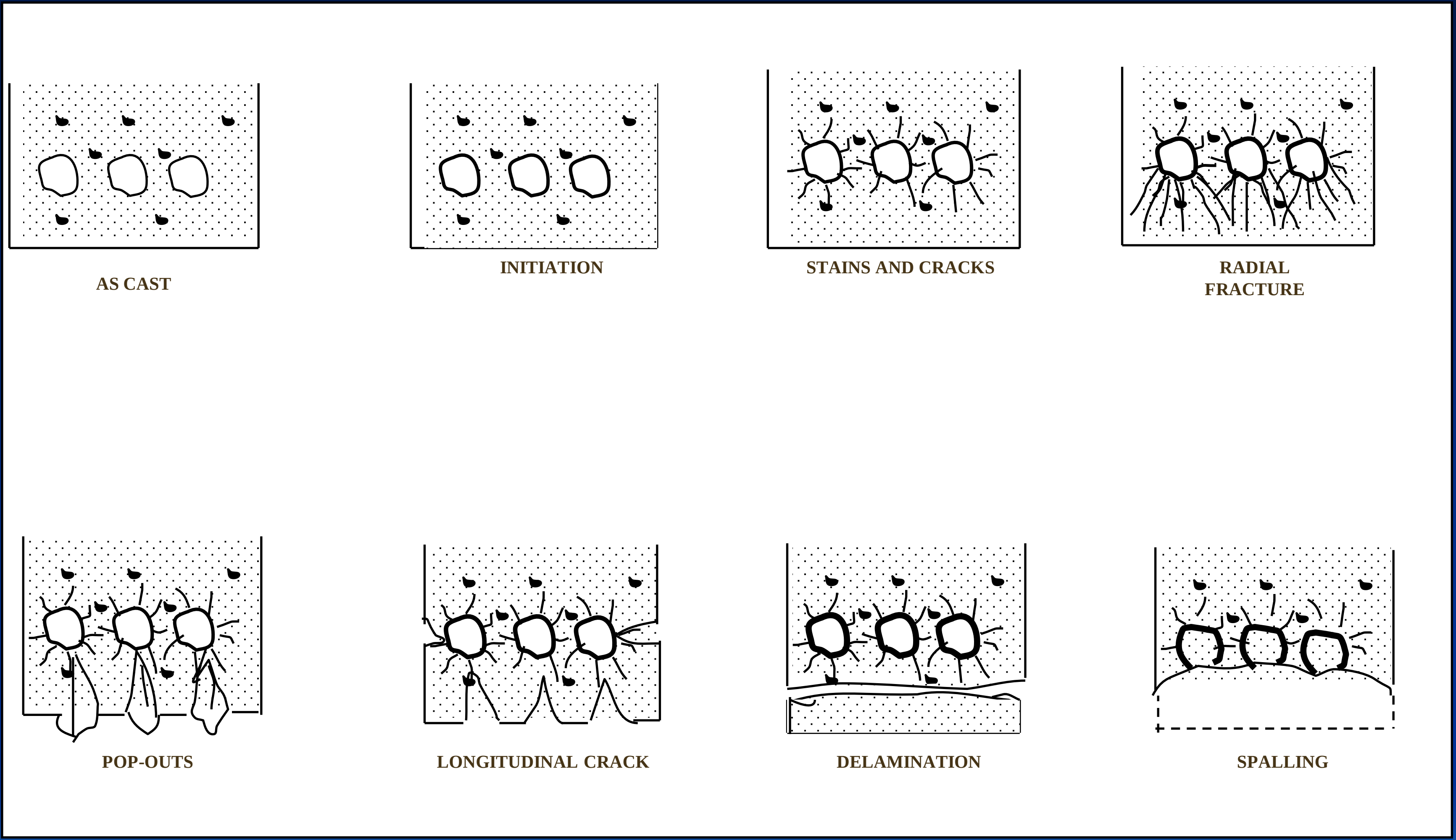
Service life model for corrosion affected structures

INFLUENCING FACTORS

- The environment to which the structure is exposed
- The cover thickness
- Quality of cover concrete
- The type of steel
- Critical chloride in concrete and
- Presence of cracks



Typical symptoms of corrosion in RC slab



Typical symptoms of corrosion in RC beam

CORROSION PROTECTION TECHNIQUES

- Coating to reinforcement
- Galvanized reinforcement
- Improving metallurgically
- Using stainless steel
- Using non-ferrous reinforcement
- Using corrosion inhibitors
- Coating to concrete
- Cathodic protection
- Electrochemical chloride removal
- Improving the cover concrete.

INVESTIGATION OF DAMAGE

- Documentation of damage
- Visual observation
- Measurements on geometrical parameters
- Experiments for evaluating material properties
- Interpretation and analysis of test results
- Analysis of the building its damaged state

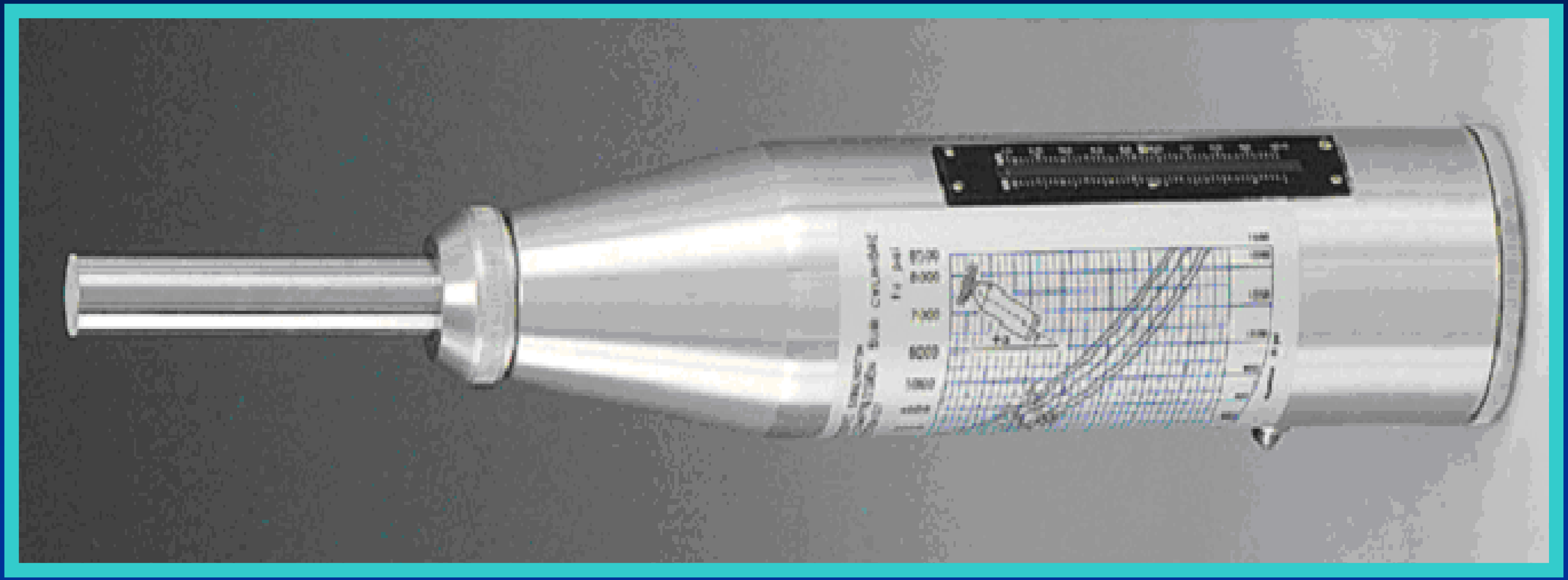
TESTING SYSTEM OF HARDENED CONCRETE

- (a) Non – Destructive Testing System (NDTS)
- (b) Partially Destructive Testing System (PDTS)
- (c) Destructive Testing System (DTS)

Non–destructive Testing Methods

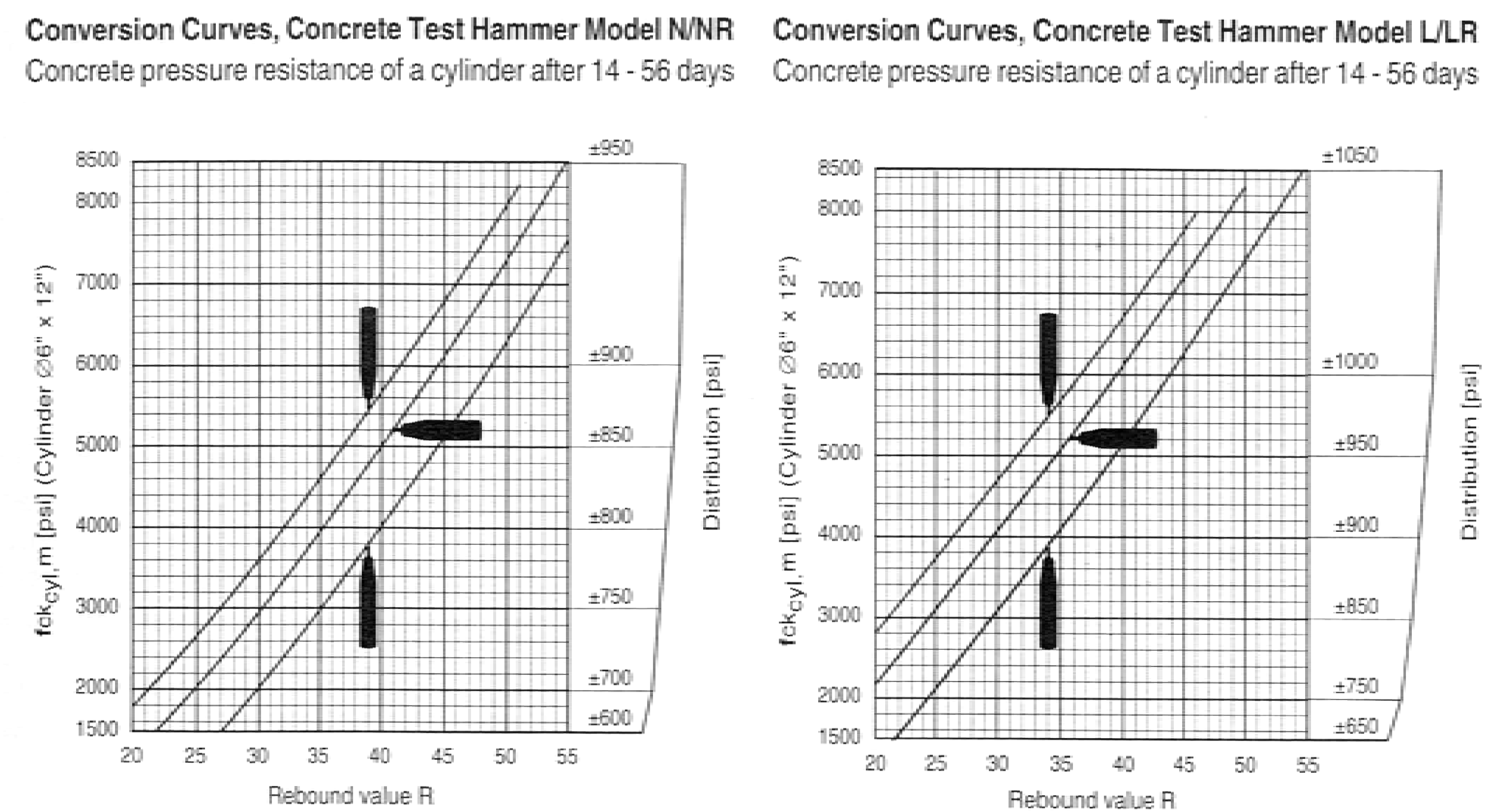
- Surface Hardness Method
- Ultrasonic Pulse Velocity Method
- Resonant Frequency Method
- Dynamic or vibration method
- Pulse Attenuation Method
- Pulse Echo Method
- Radioactive Method
- Nuclear Methods
- Magnetic Methods
- Electro magnetic methods
- Electrical Methods
- Acoustic Emission Technique
- Radar Technique
- Radiography Methods

Surface Hardness Test



A Typical Rebound Hammer

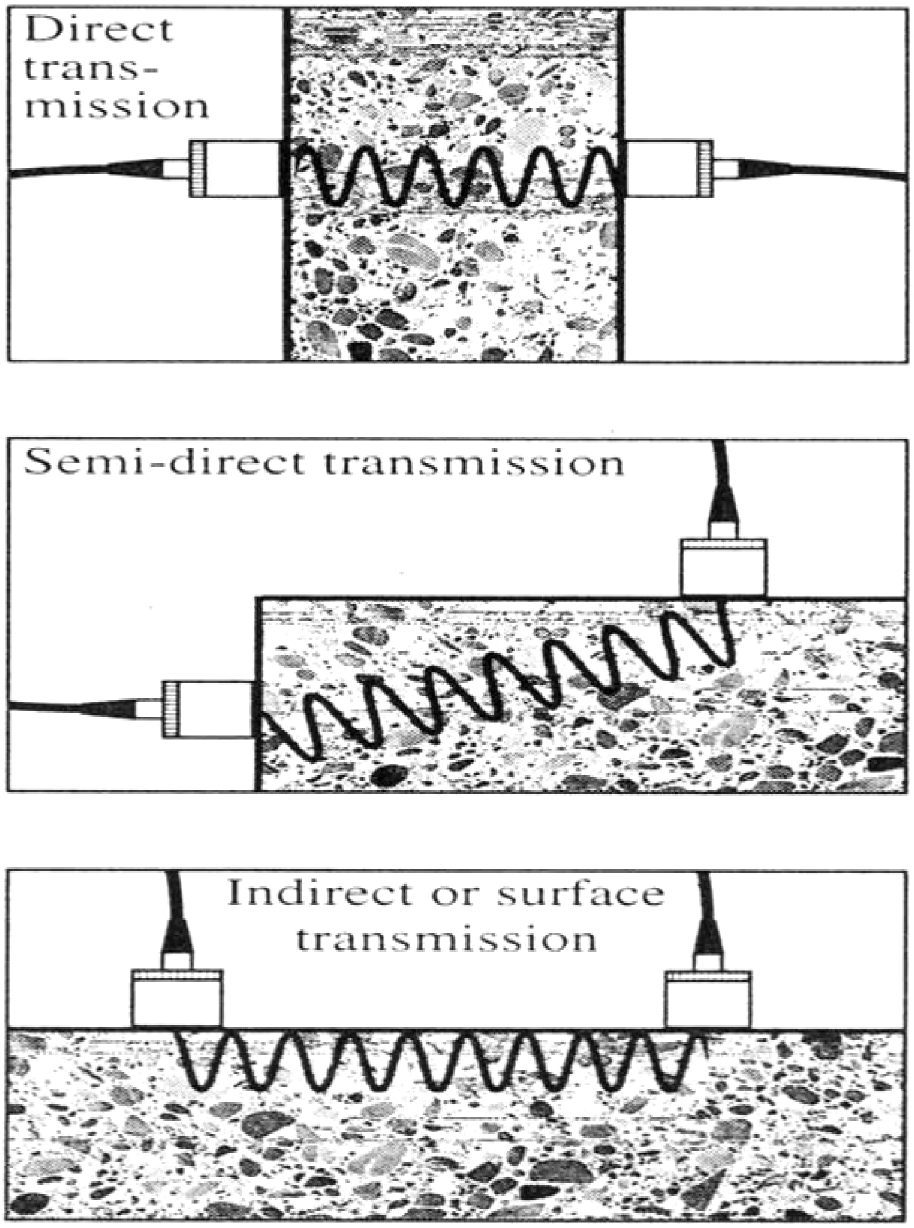
Typical Calibration Curves



Quality of Cover Concrete from Rebound Number

Average rebound number	*Quality of concrete*
Greater than 40	very good hard layer
30 to 40	good layer
20 to 30	fair
less than 20	poor concrete
0	delaminated

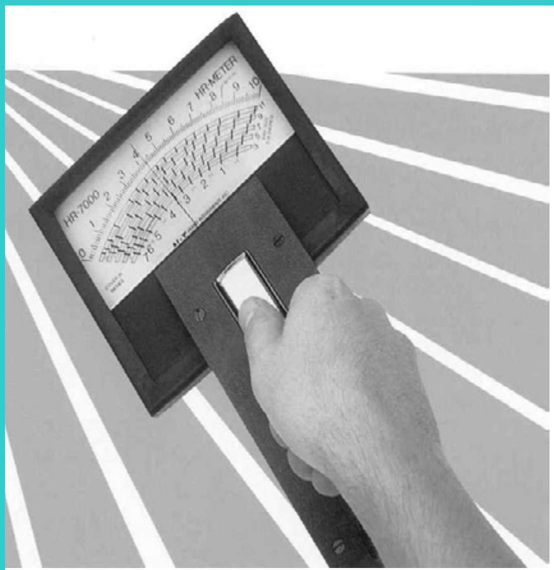
Ultrasonic Pulse Velocity (UPV) Test


Direct trans- mission
Semi-direct transmission
Indirect or surface transmission

Quality of Concrete from UPV

UPV value km/sec (V)	*Concrete quality*
V greater than 4	Very good
V between 3.5 & 4	Good
V between 3 & 3.5	Poor
V between 2.5 & 3	Very poor
V between 2 & 2.5	Very poor & low integrity
V less than 2	Large voids suspected

Electro Magnetic Method



HR Rebar Locator

Datascan

Datascan MK II

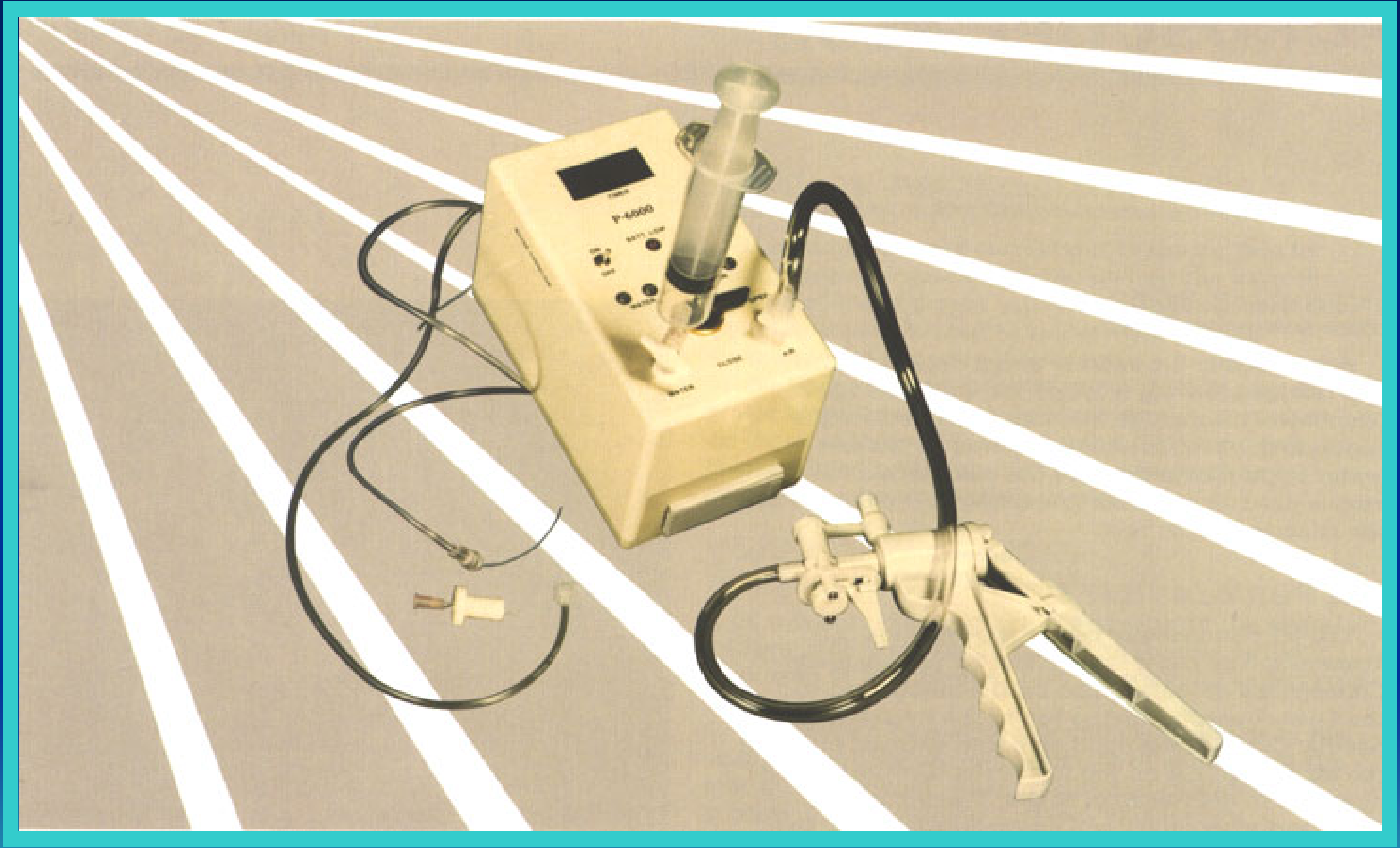
Semi-Destructive Testing Systems

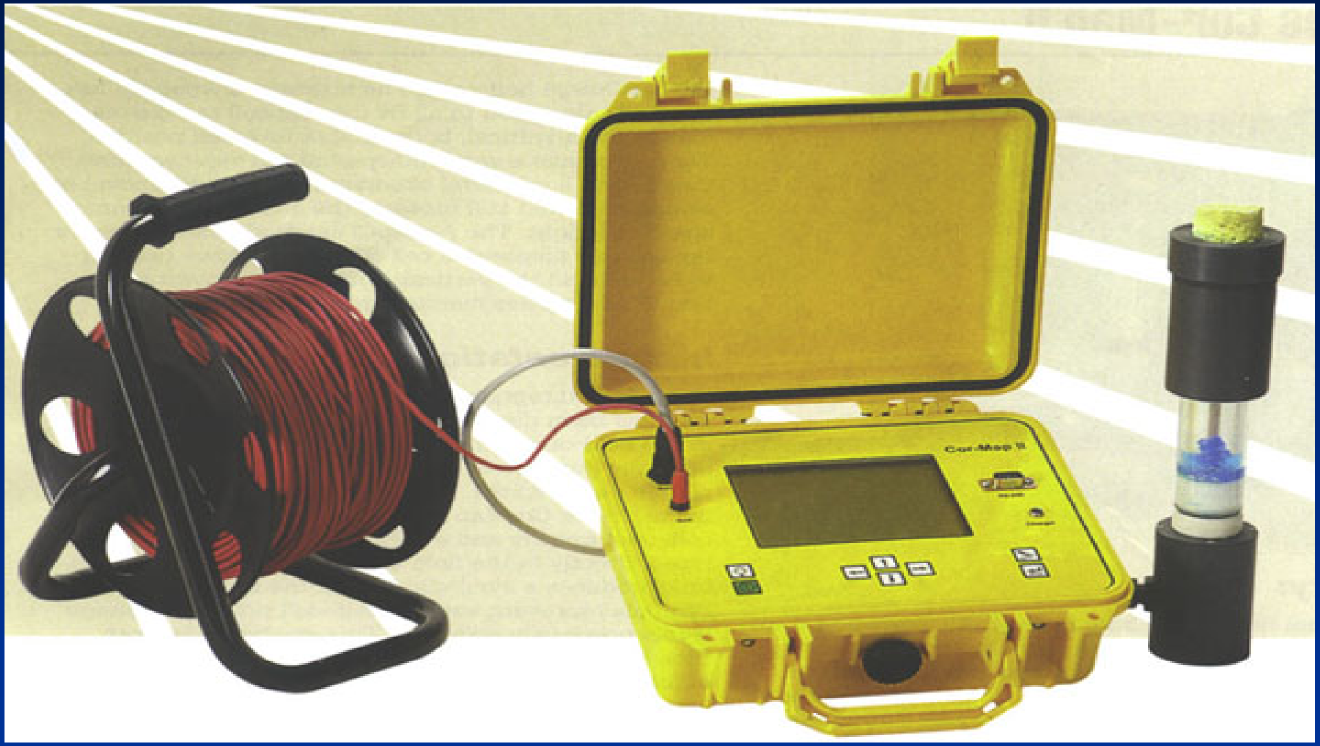
- Penetration Techniques
- Pull-out and Pull-off Tests
- Core sampling and testing
- Break off test
- Permeability Test
- Half–cell potential survey
- Resistivity survey
- Carbonation and pH value test
- Chloride content test
- Abrasion resistance test.

Core Sampling and Testing

- Core location and size
- Testing
- Trimming
- Capping
- Density determination

Advanced Permeability Tester





Corrosion analyzer equipment – Cor map II

Corrosion Risk based on Resistivity Values

Resistivity ohm cm	*Corrosion probability*
Greater than 20,000	**Negligible**
10,000 to 20,000	**Low**
5,000 to 10,000	**High**
less than 5,000	**Very high**

Classification of Repair Material

- Patch Repair Materials
- Injection Grouts
- Bonding Aids
- Resurfacing Materials
- Other Repair Materials

ADMIXTURES FOR REHABILITATION

- Polymer dispersions or lattices
- Latex modified system
- Epoxy resins
- Polymeric materials
- Organic polymers

The repair of cracks can be achieved with the following techniques:

- Resin injection
- Routing and Sealing
- Stitching
- External stressing
- Bonding
- Blanketing
- Overlays
- Dry pack
- Vacuum impregnation
- Polymer impregnation

- Autogenous healing
- Flexible sealing
- Drilling and Plugging
- Bandaging
- Coating
- Grinding
- Sand blasting
- Resurfacing
- Acid etching
- Caulking

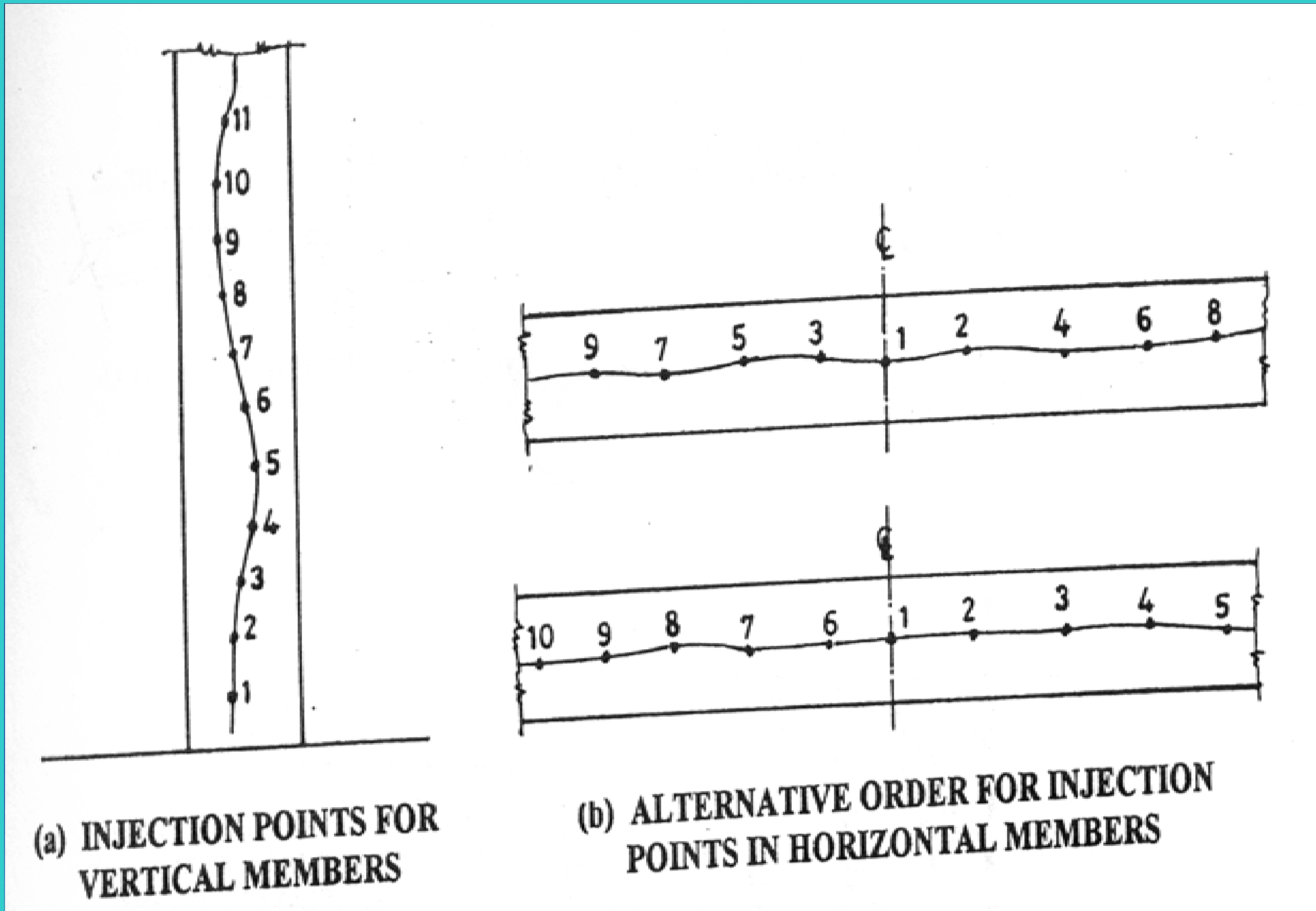
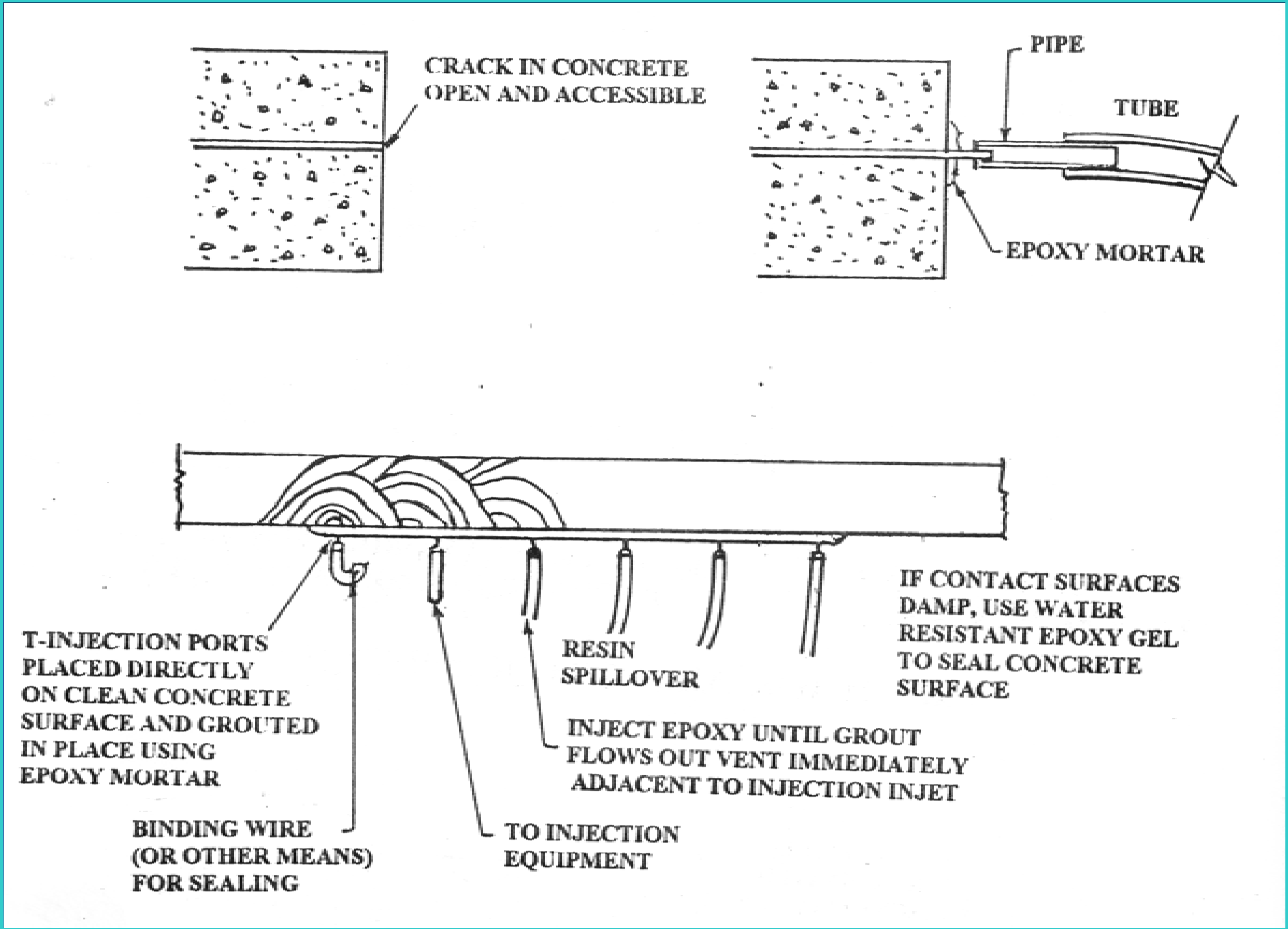
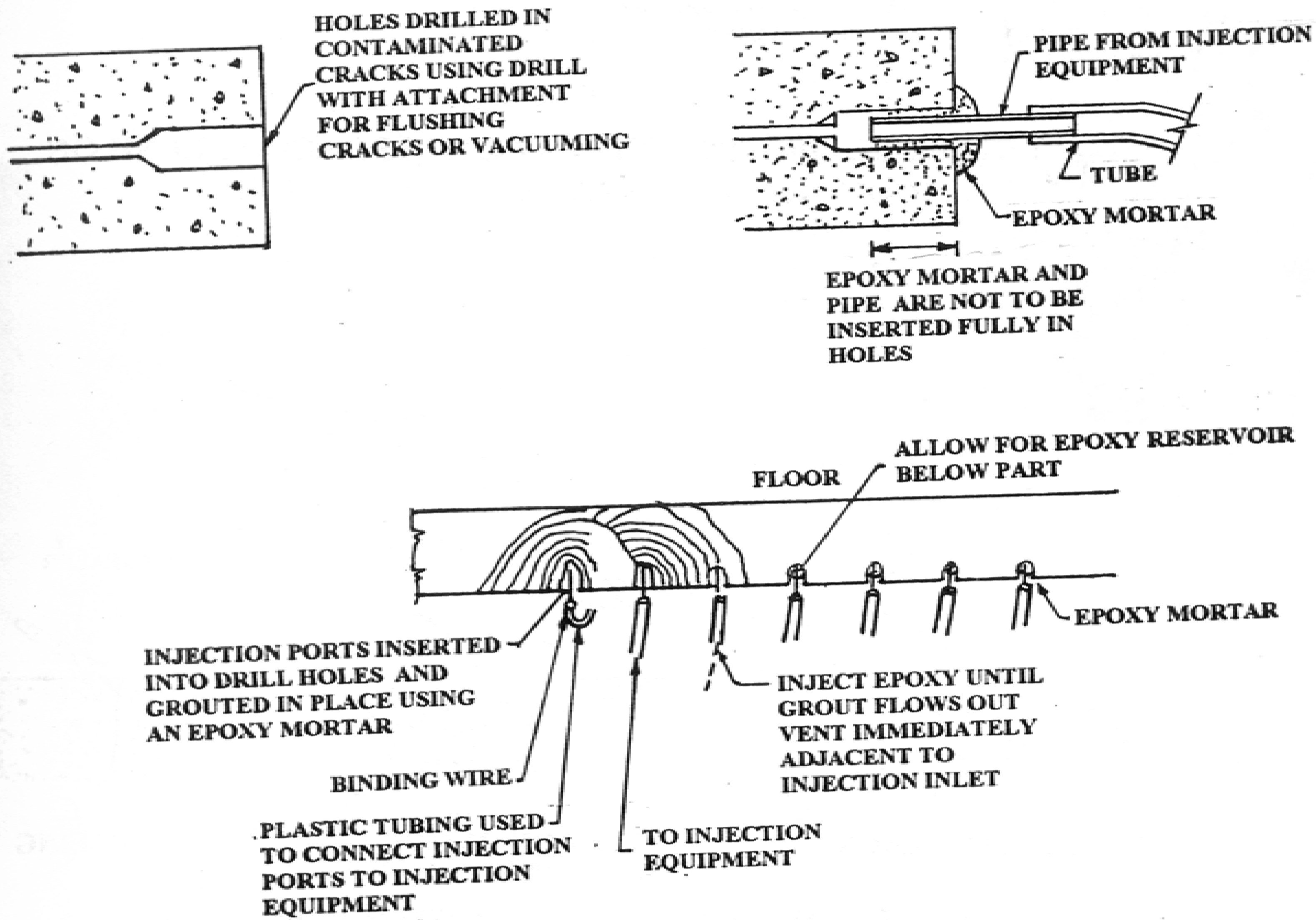


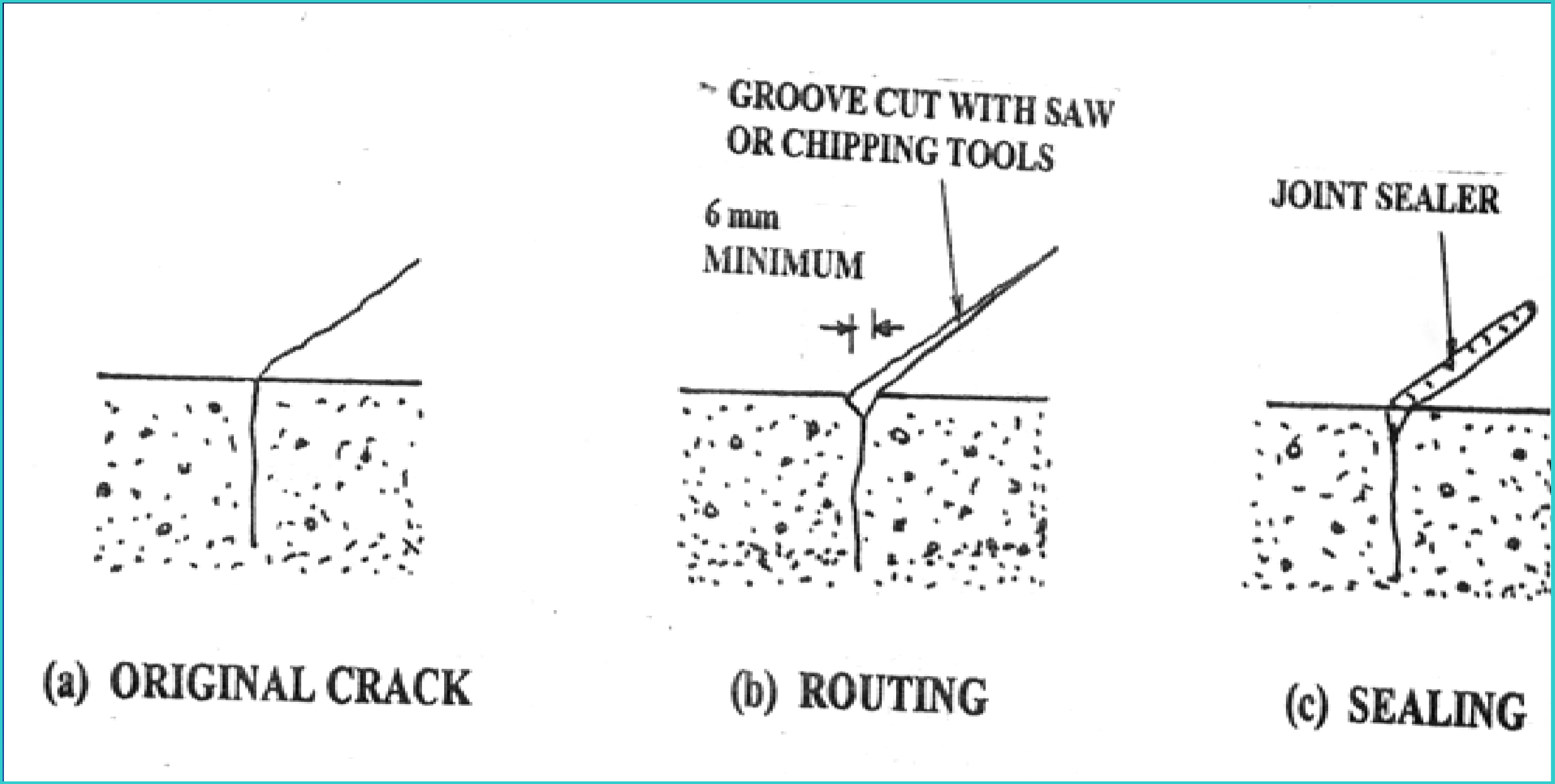
Diagram of Crack Injection



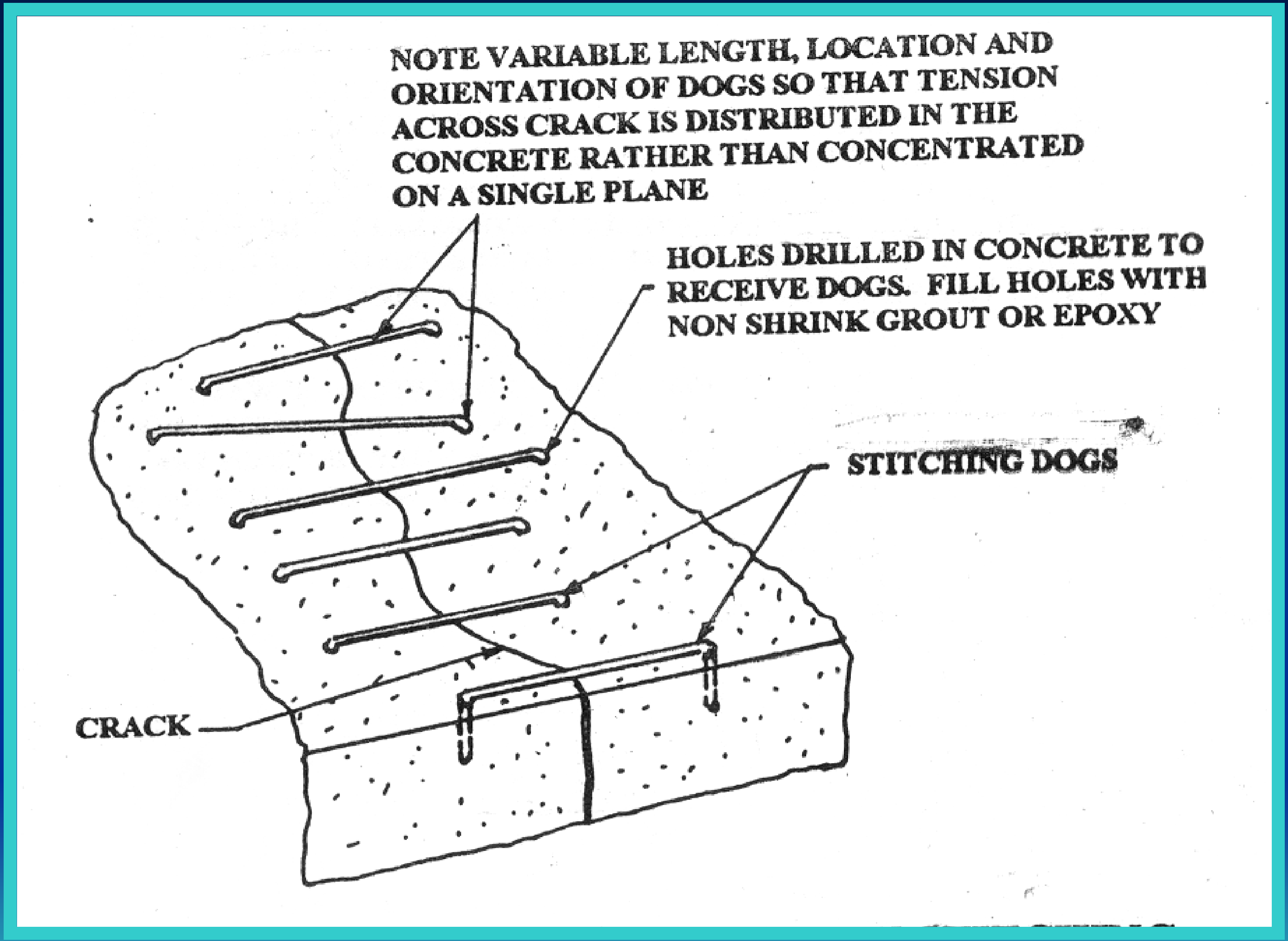
Use of injection ports in drilled holes



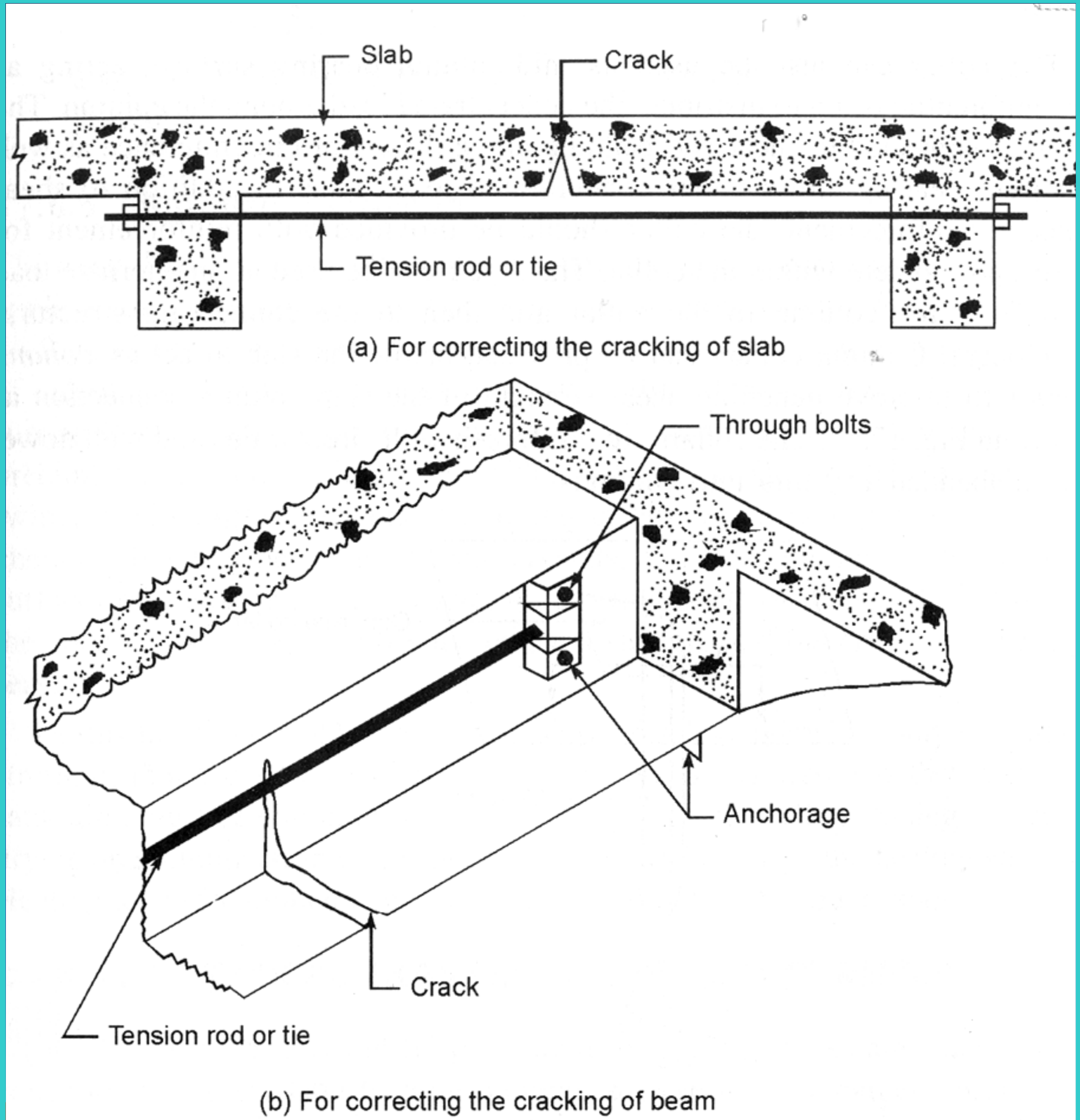
Use of T-injection ports placed flush on concrete surface



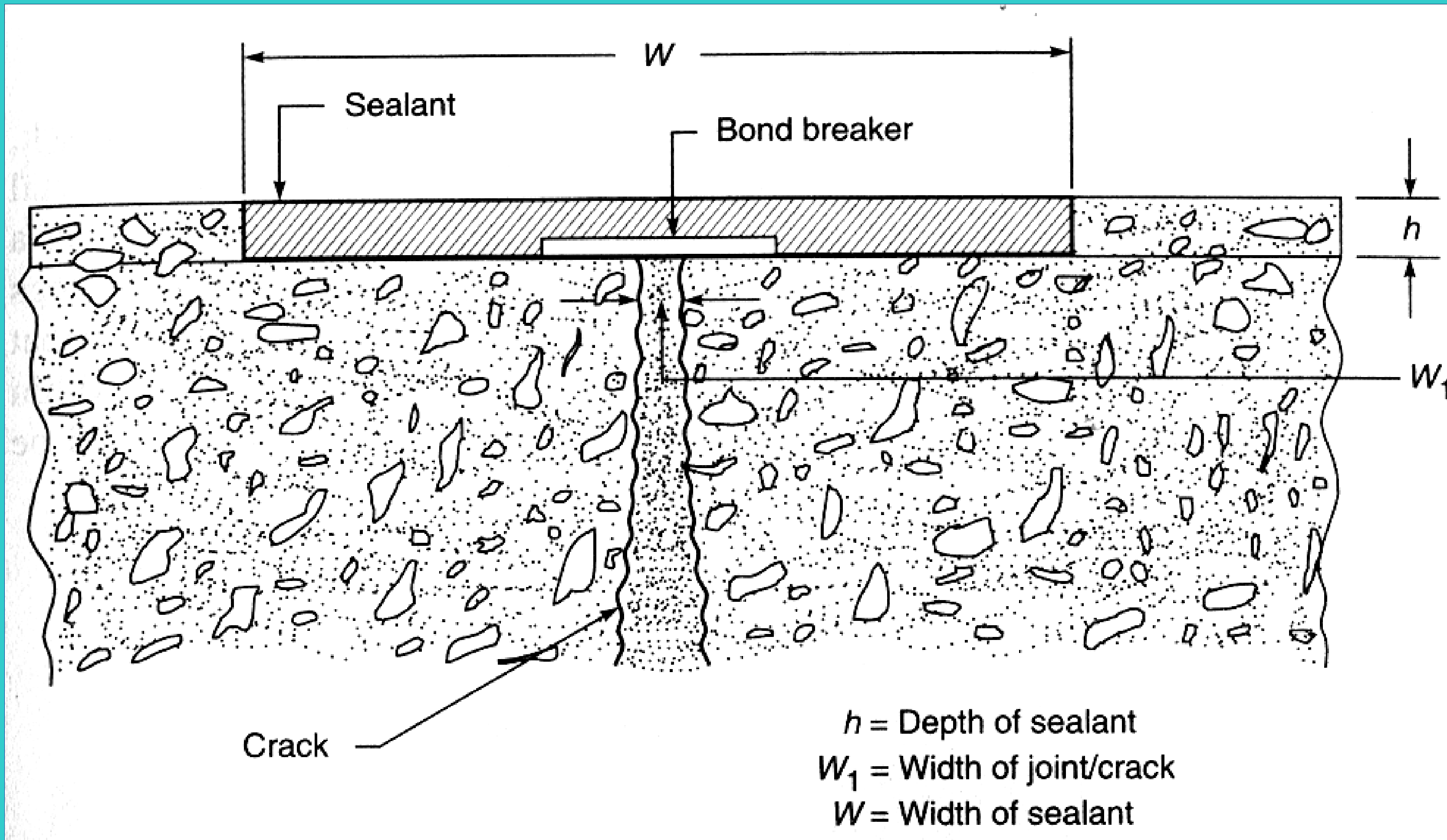
Repair of crack by routing and sealing



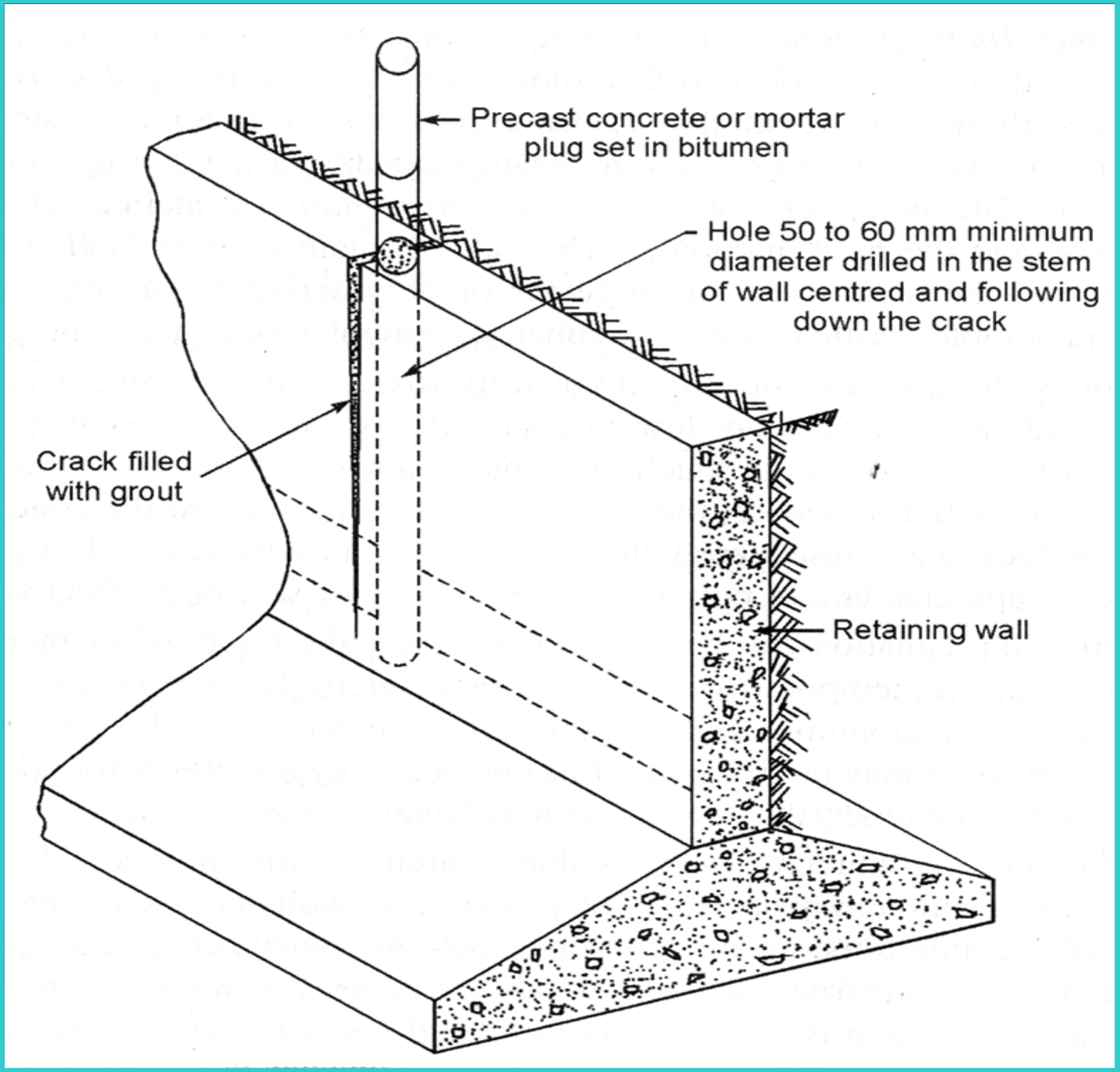
Repair of crack by stitching



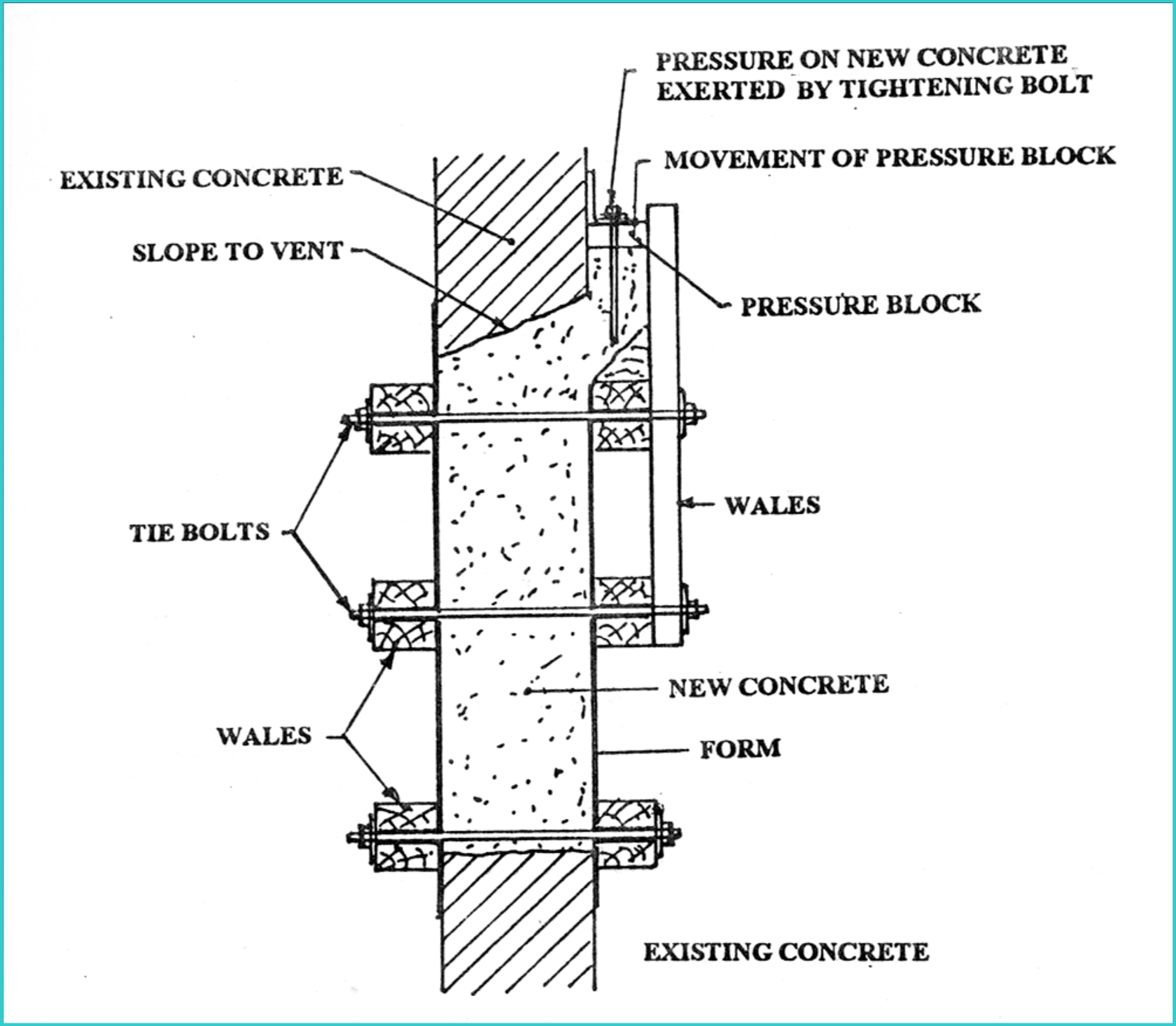
Repair of cracks by external stressing



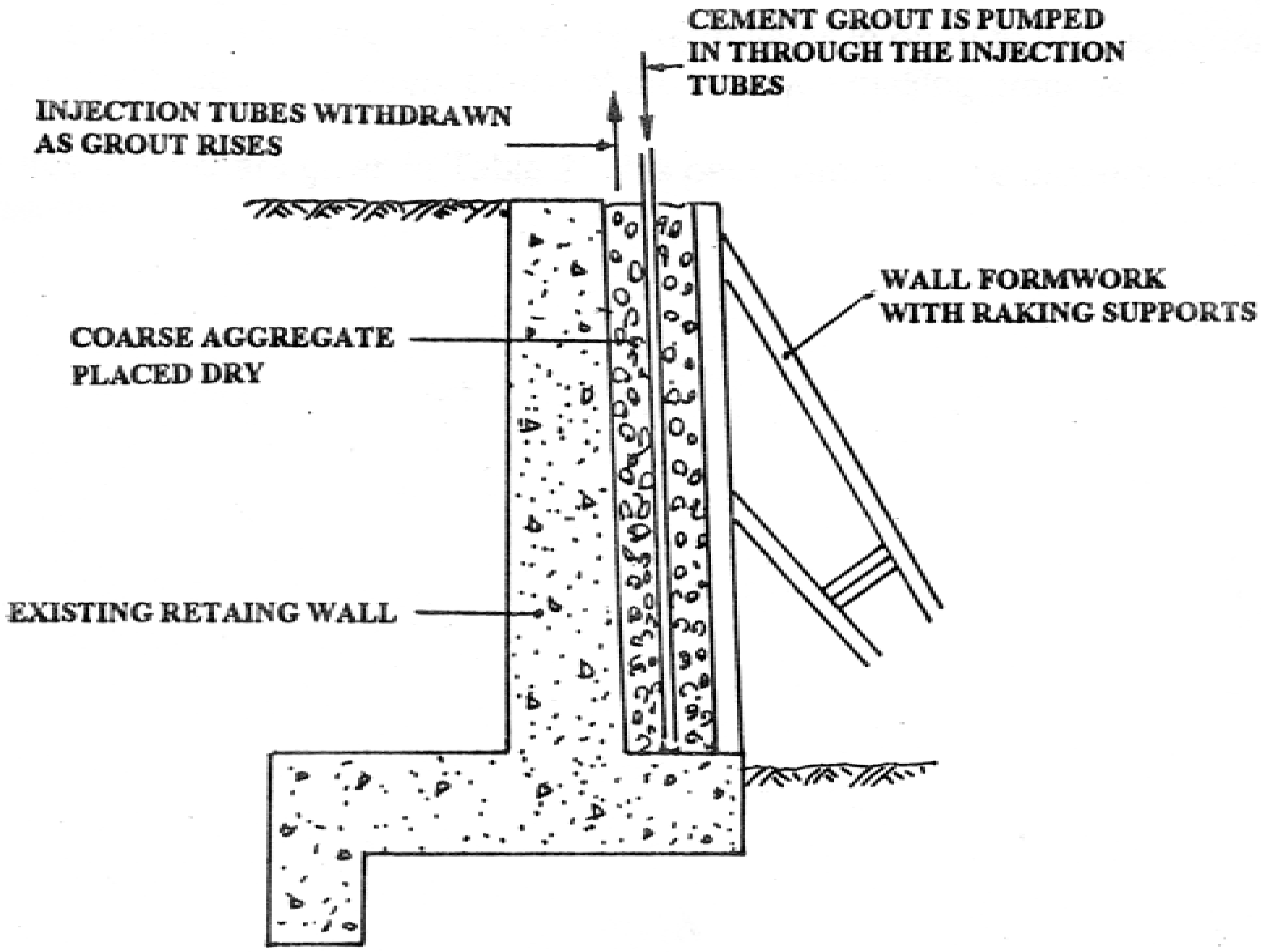
Repair of an active crack by flexible sealing



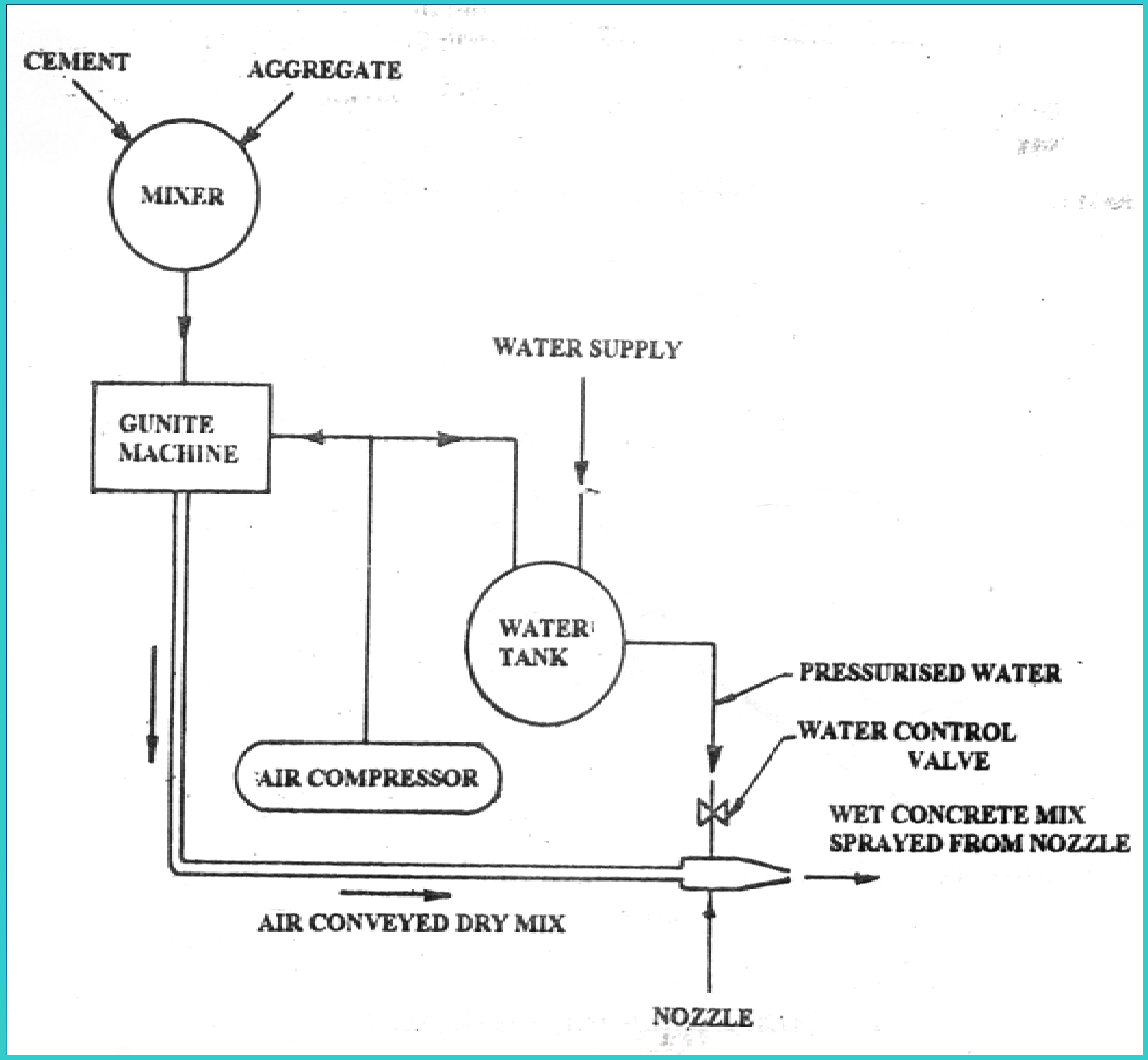
Repair of crack by drilling and plugging



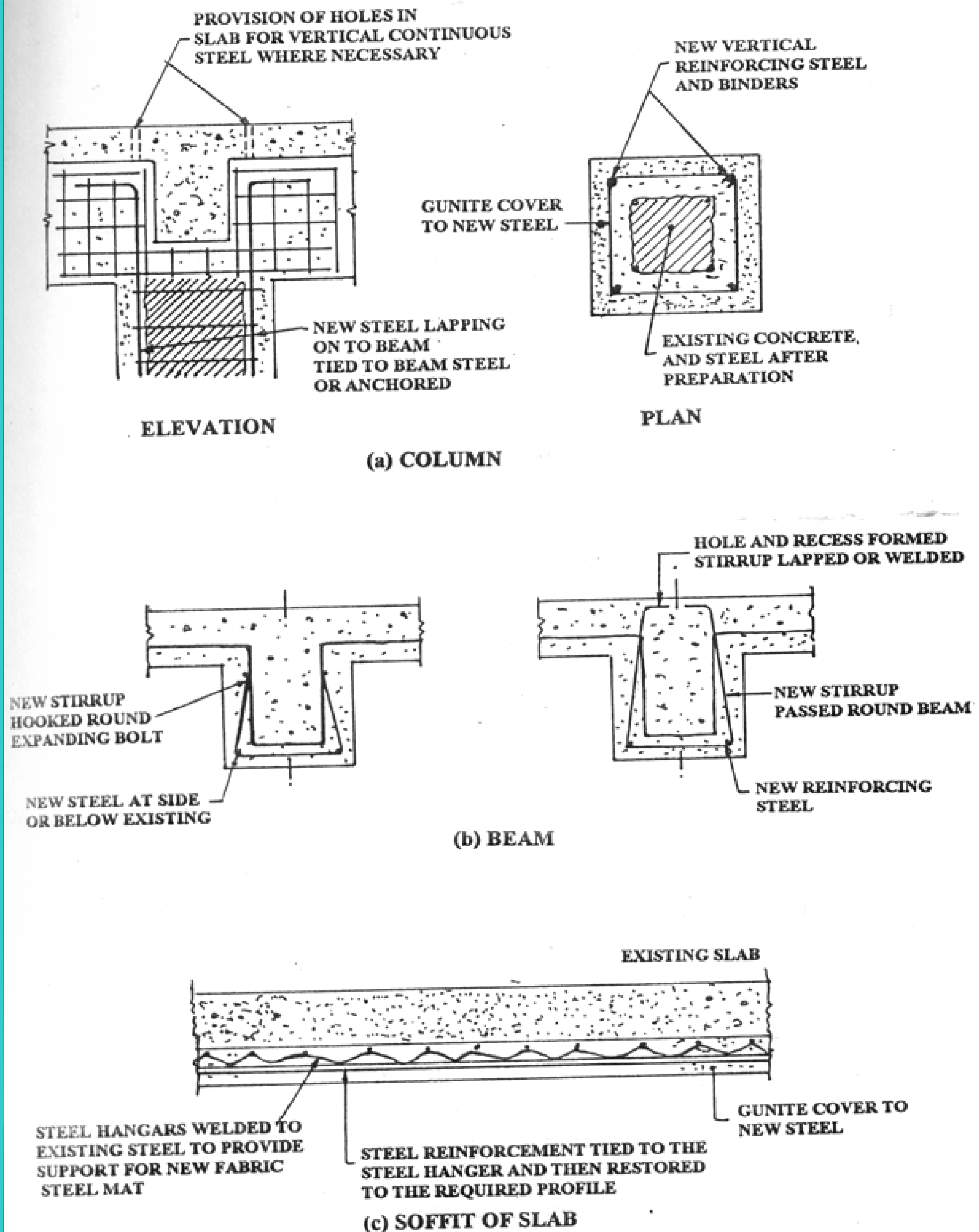
Replacing of concrete using pressurized form



Preplaced Aggregate concrete



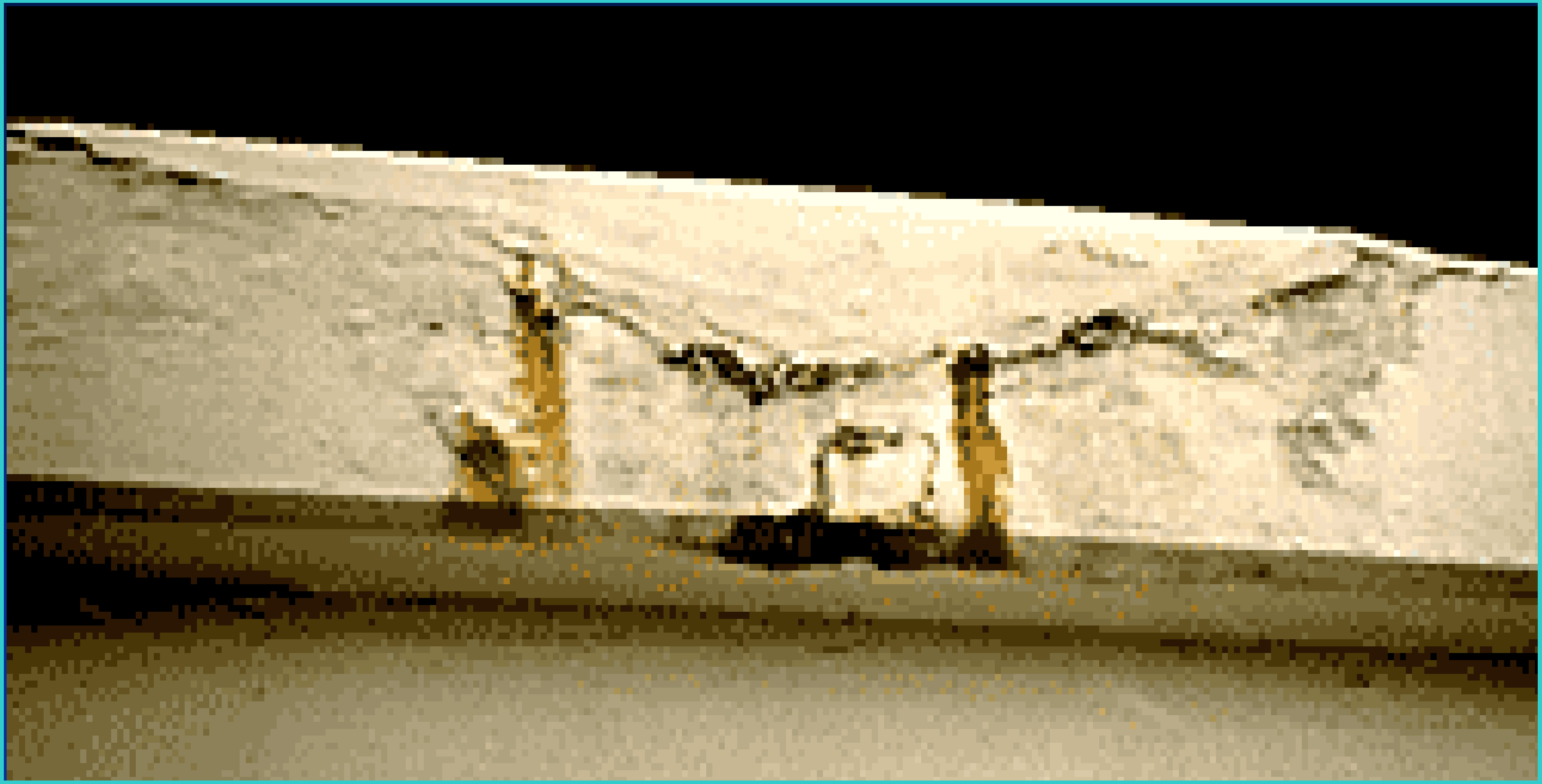
Diagrammatic representation of gunite process



Examples of grouting process

Need for Strengthening

- Load increases due to higher live loads
- Damage to structural parts
- Improvements in suitability for use
- Modification of structural system
- Errors in planning or construction

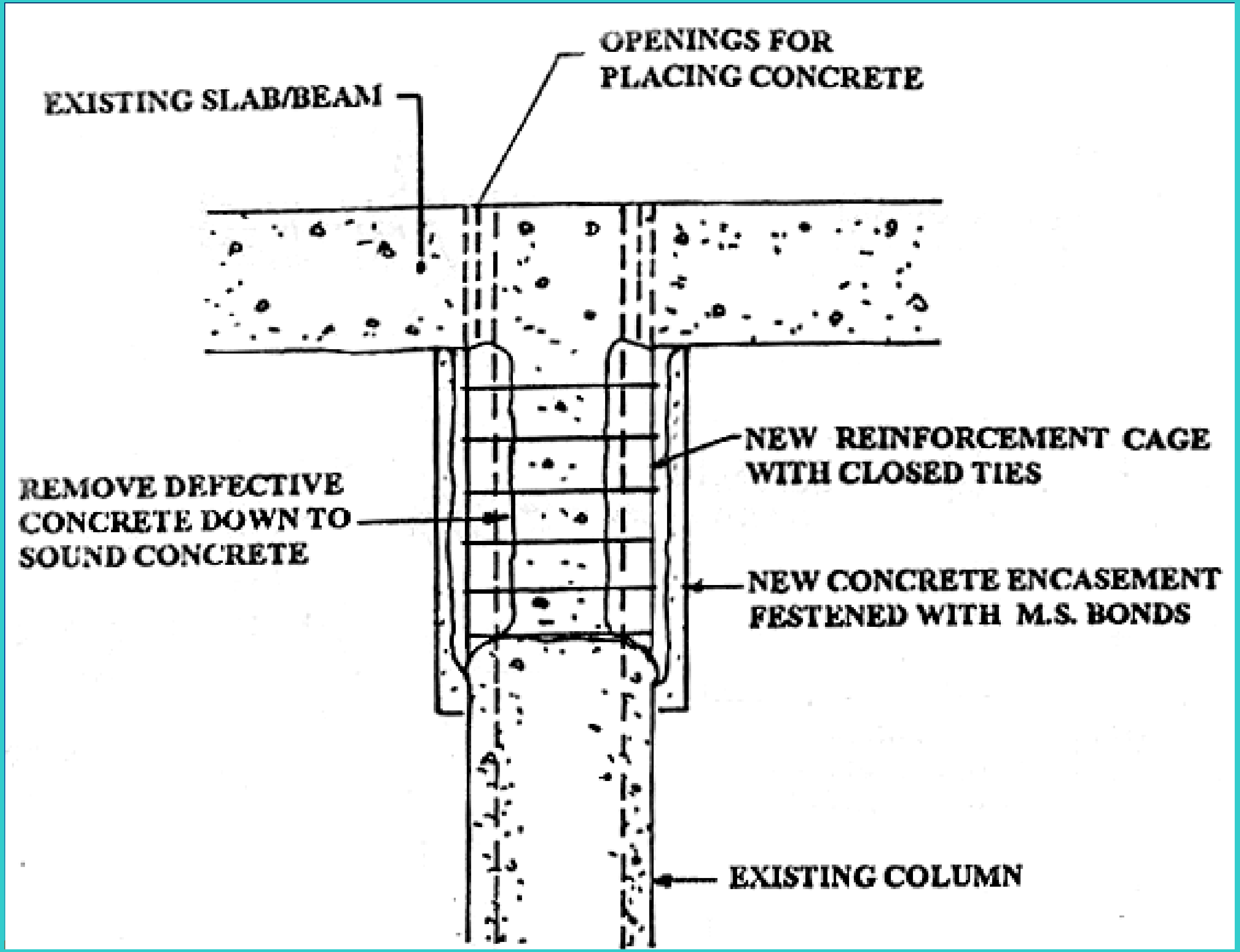


Unsuccessful Concrete Repair

STRUCTURAL CONCRETE STRENGTHENING

- Column strengthening
- Strengthening and stiffening of beams and girders
- Strengthening and stiffening of slabs

Jacketing Technique



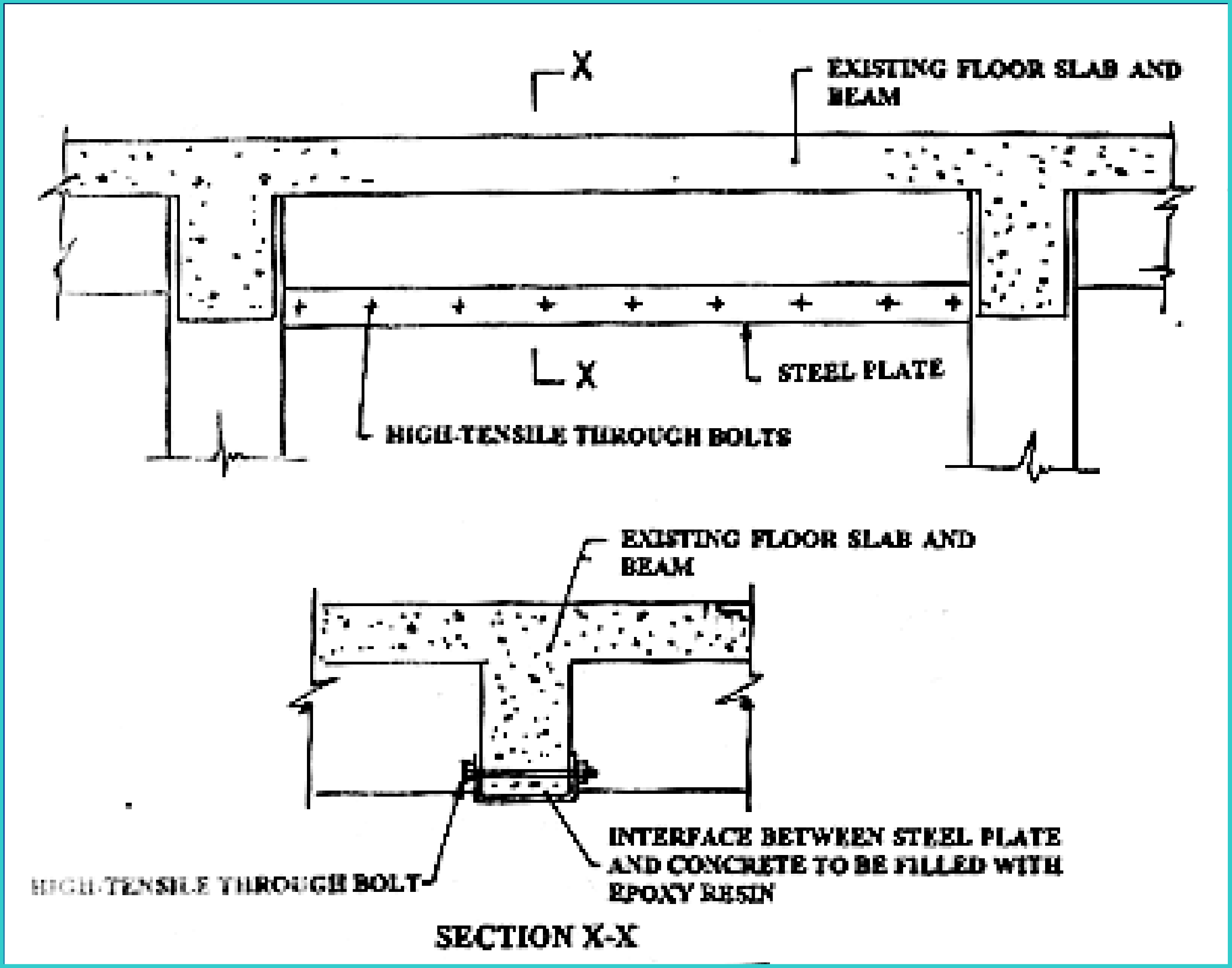
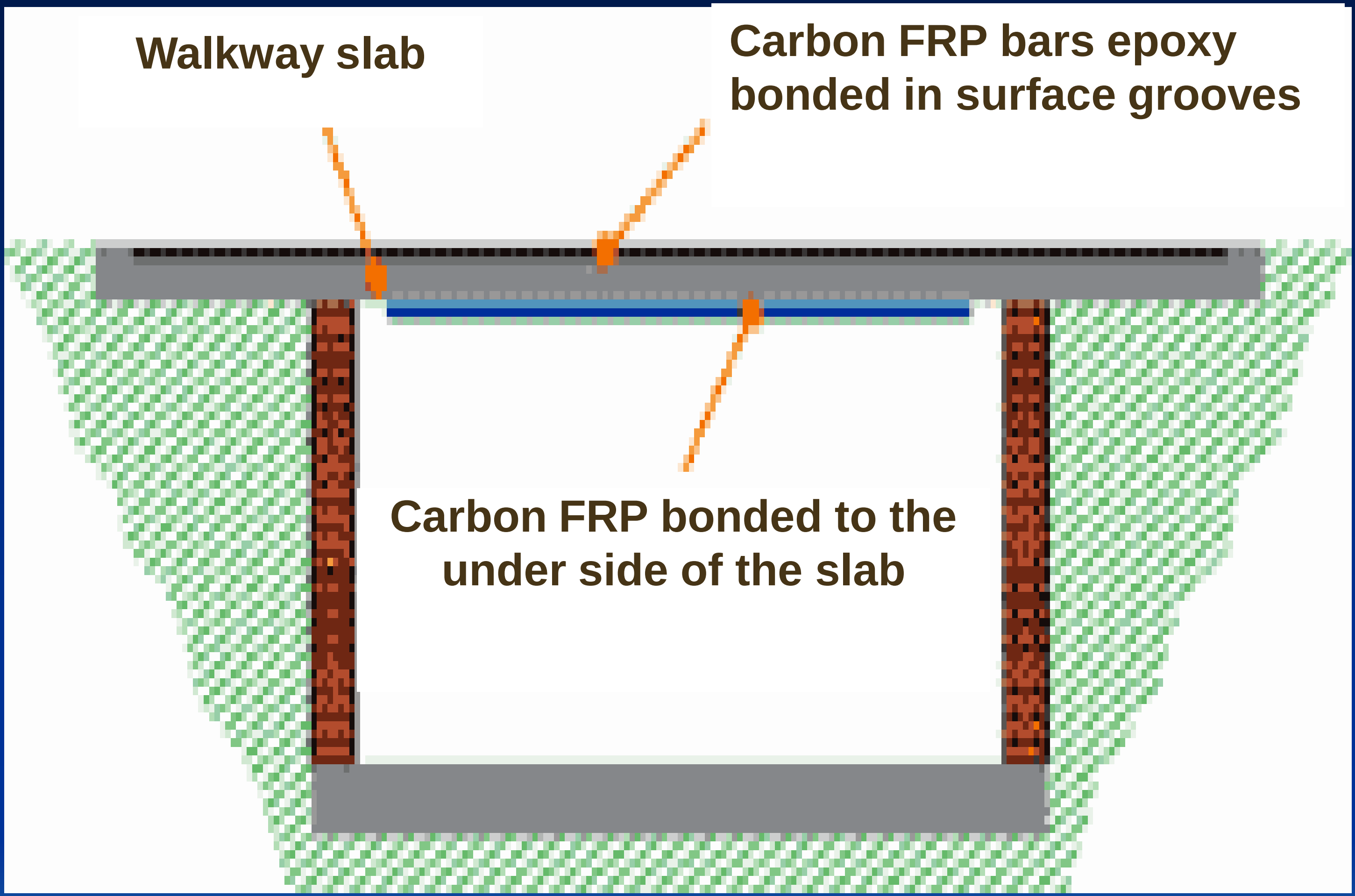


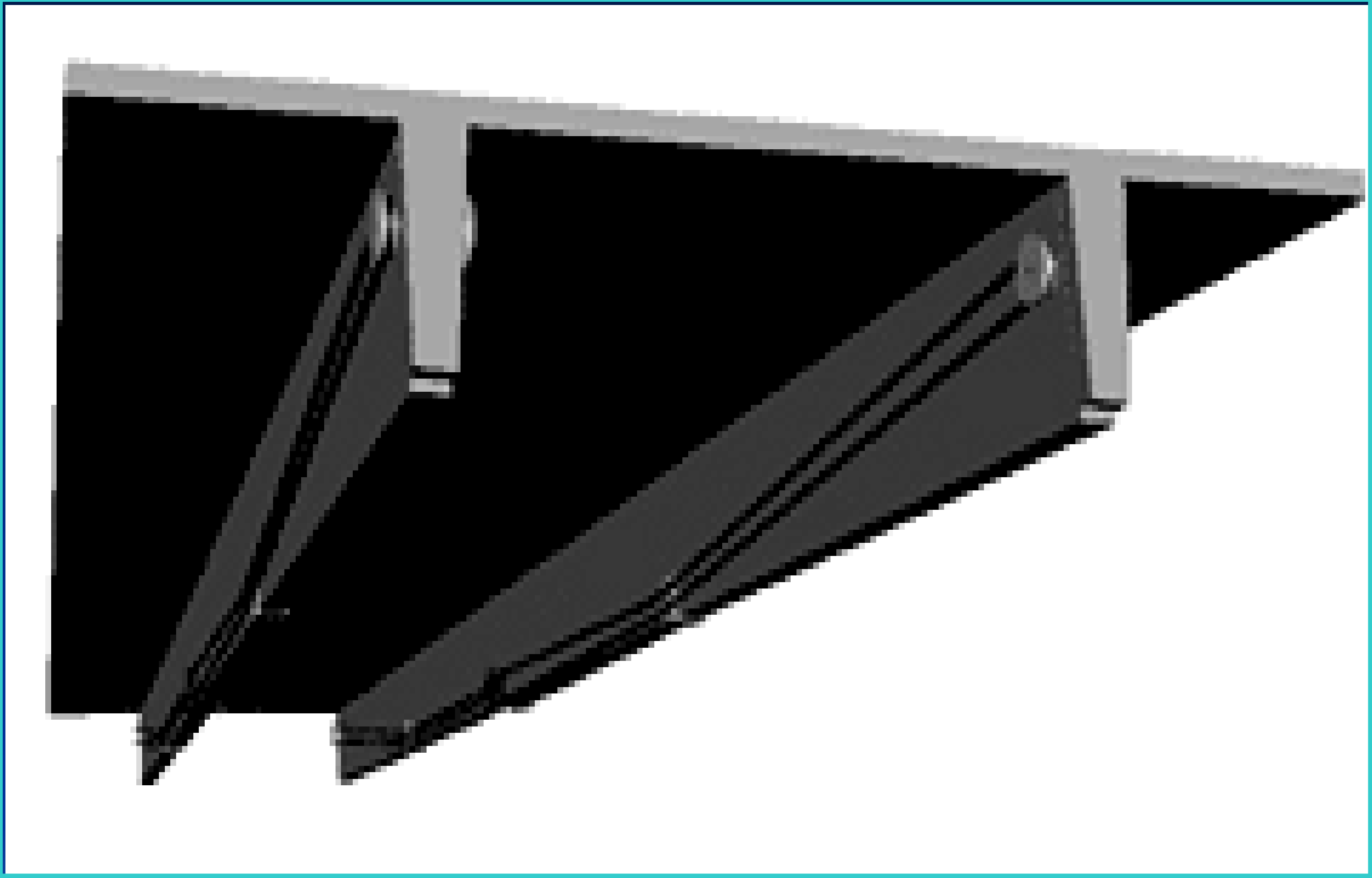
Plate Bonding Technique

Externally bonded steel plates with FRP

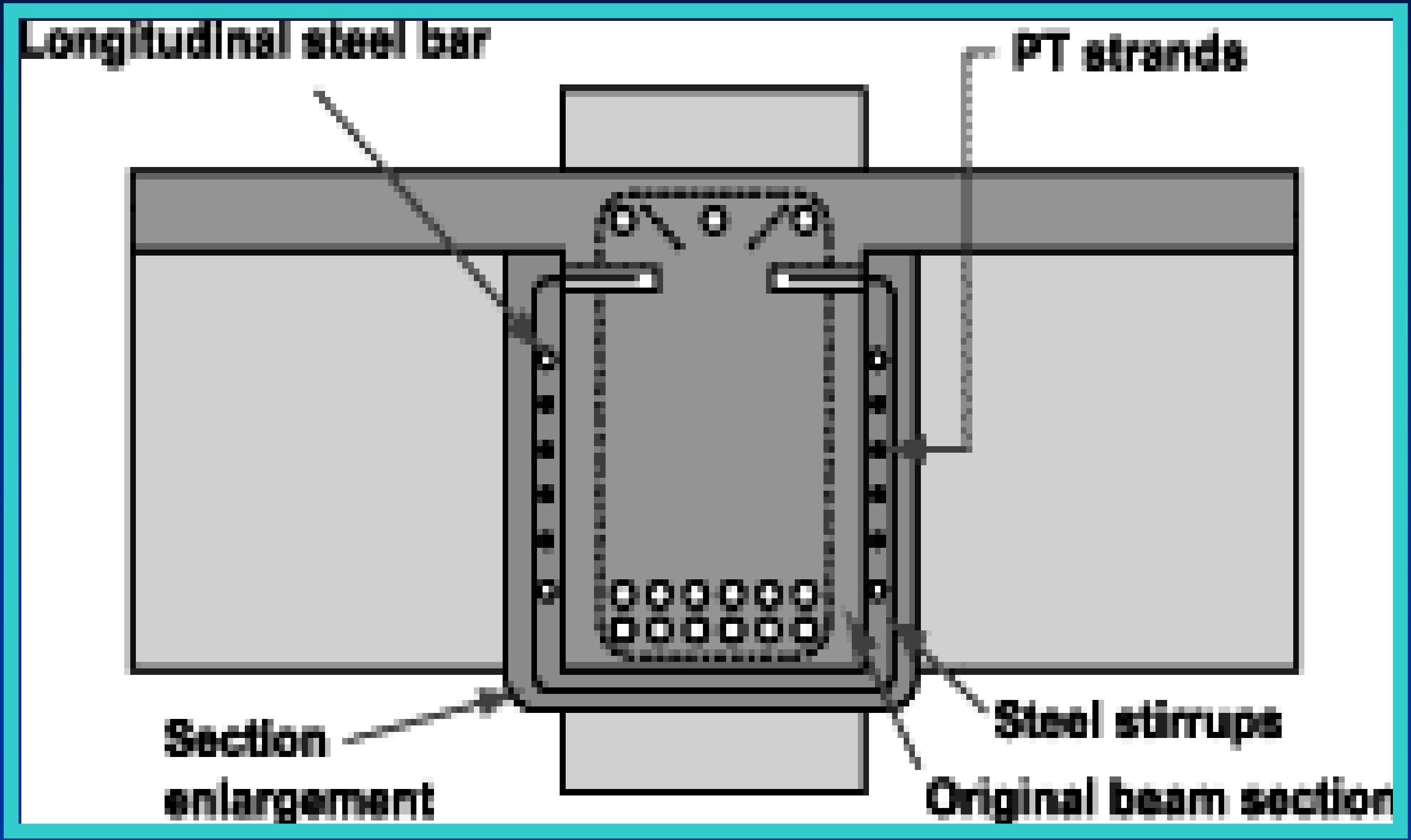


Strengthening with carbon FRP sheets

Short Spanning Technique



External Post-Tensioning Technique



Section Enlargement Technique

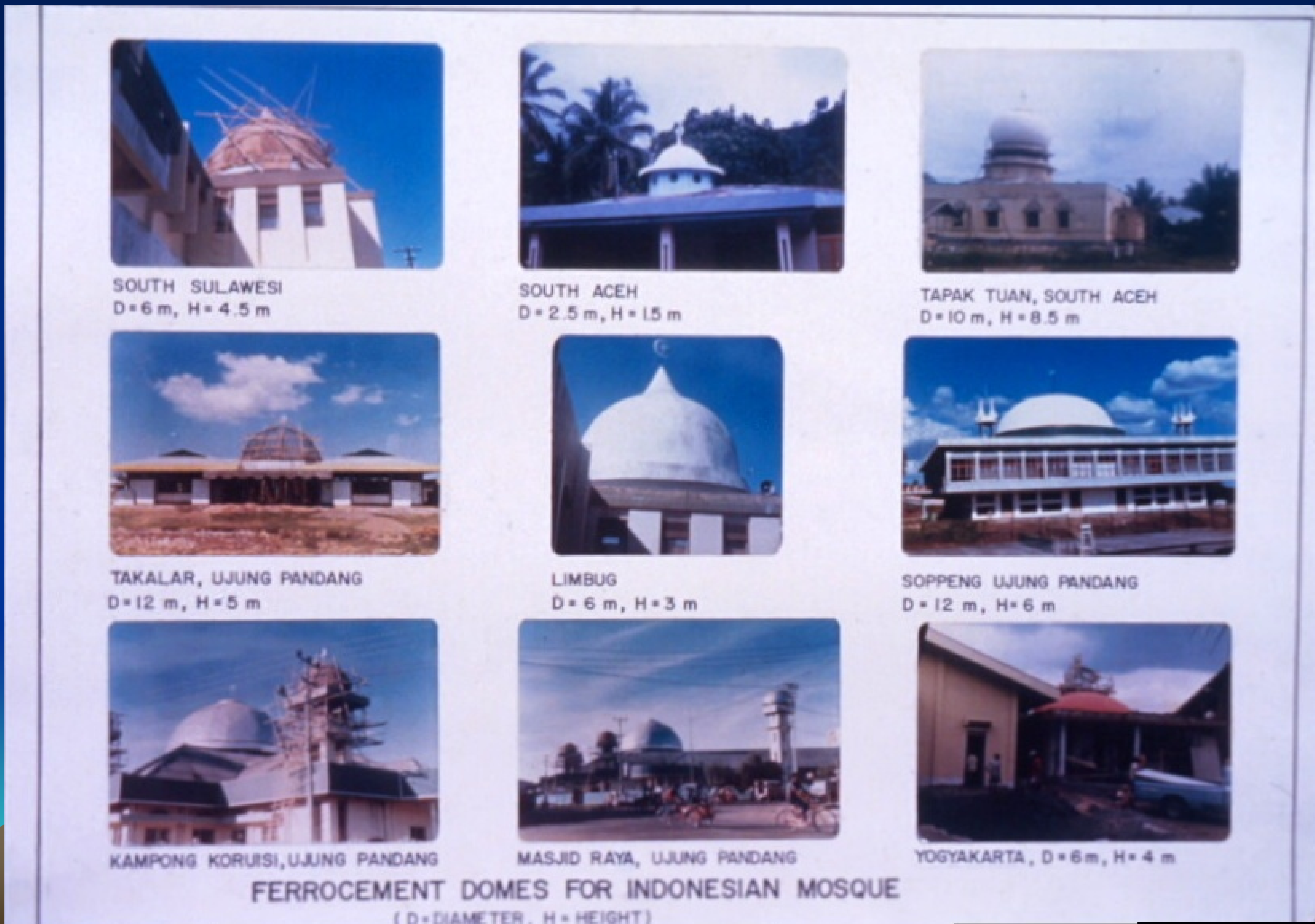
Routine Building Maintenance

- Whitewashing or color washing
- Distempering
- Plaster and roof repairs
- Roof repair for leakages
- Replacement of fittings and fixtures

TYPES OF DEMOLITION

- Selective Demolition
- Hydro Demolition
- Marine Demolition
- Underwater Demolition
- Bridge Demolition
- Building Demolition
- Nuclear Demolition
- Runway Demolition

FERROCEMENT DOMES



FERROCEMENT ROOFING PANELS & DOORS

FERROCEMENT IN BUILDING INDUSTRY

Crashed Balcony

Closed view of new ferrocement Balcony

FIBERS IN CONCRETE

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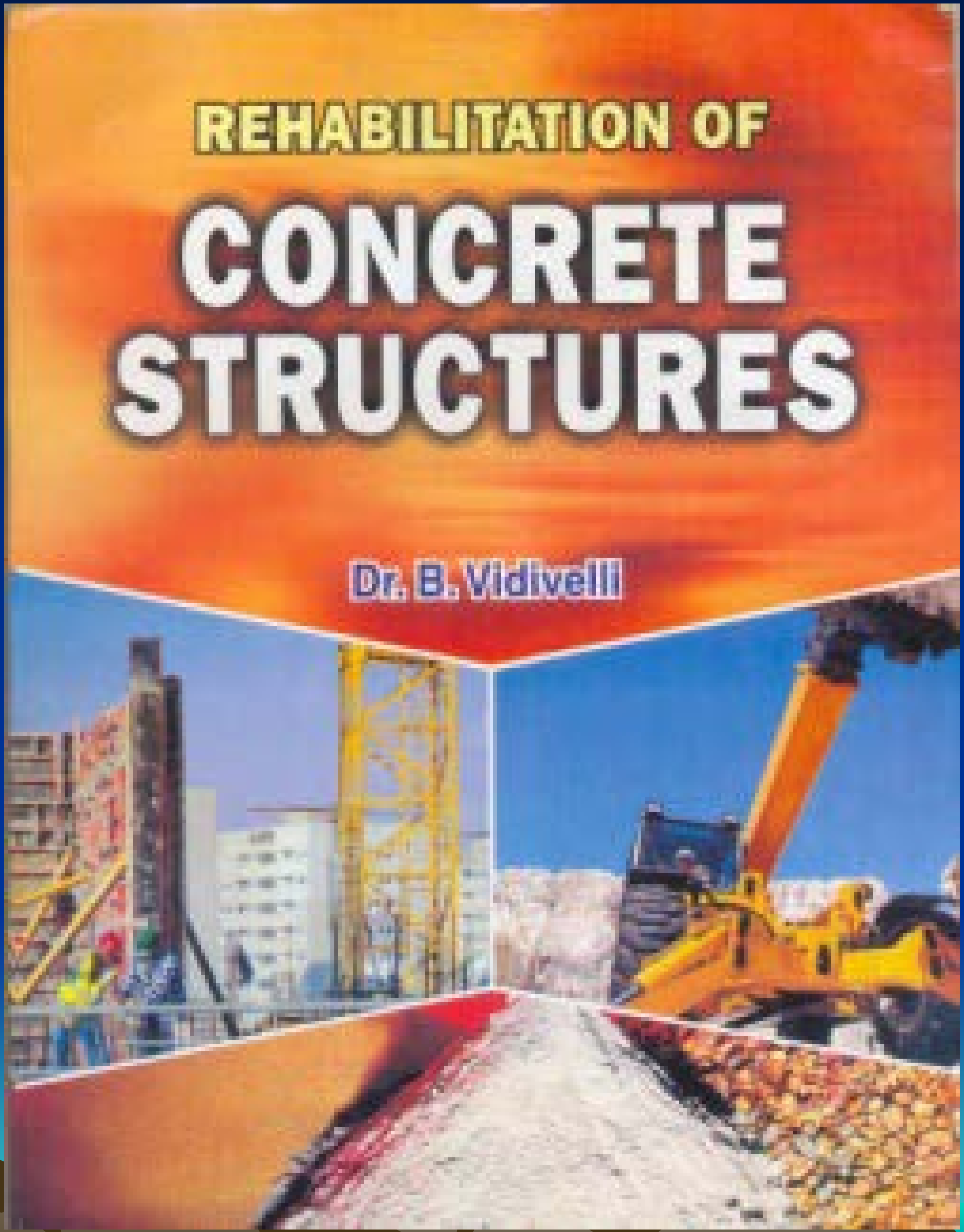
THANK YOU


REHABILITATION OF
CONCRETE STRUCTURES
Dr. B. Vidivelli