CONCRETE CRACKS: THEY AREN'T ALL THE SAME

- How to Identify Them
- What Caused Them
- How to Prevent Them
- How to Repair Them

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Dave Flax

- Civil Engineering Degree from RPI
- Over 45 years experience with concrete
- Years as a Field Engineer
- Years with contractors
- Years with the Corps of Engineers doing research
- Published dozens of articles
- Specialized in cement and concrete
- Patent for micro fibers in zero-shrinkage concrete
- Earned CDT and CCPR from CSI

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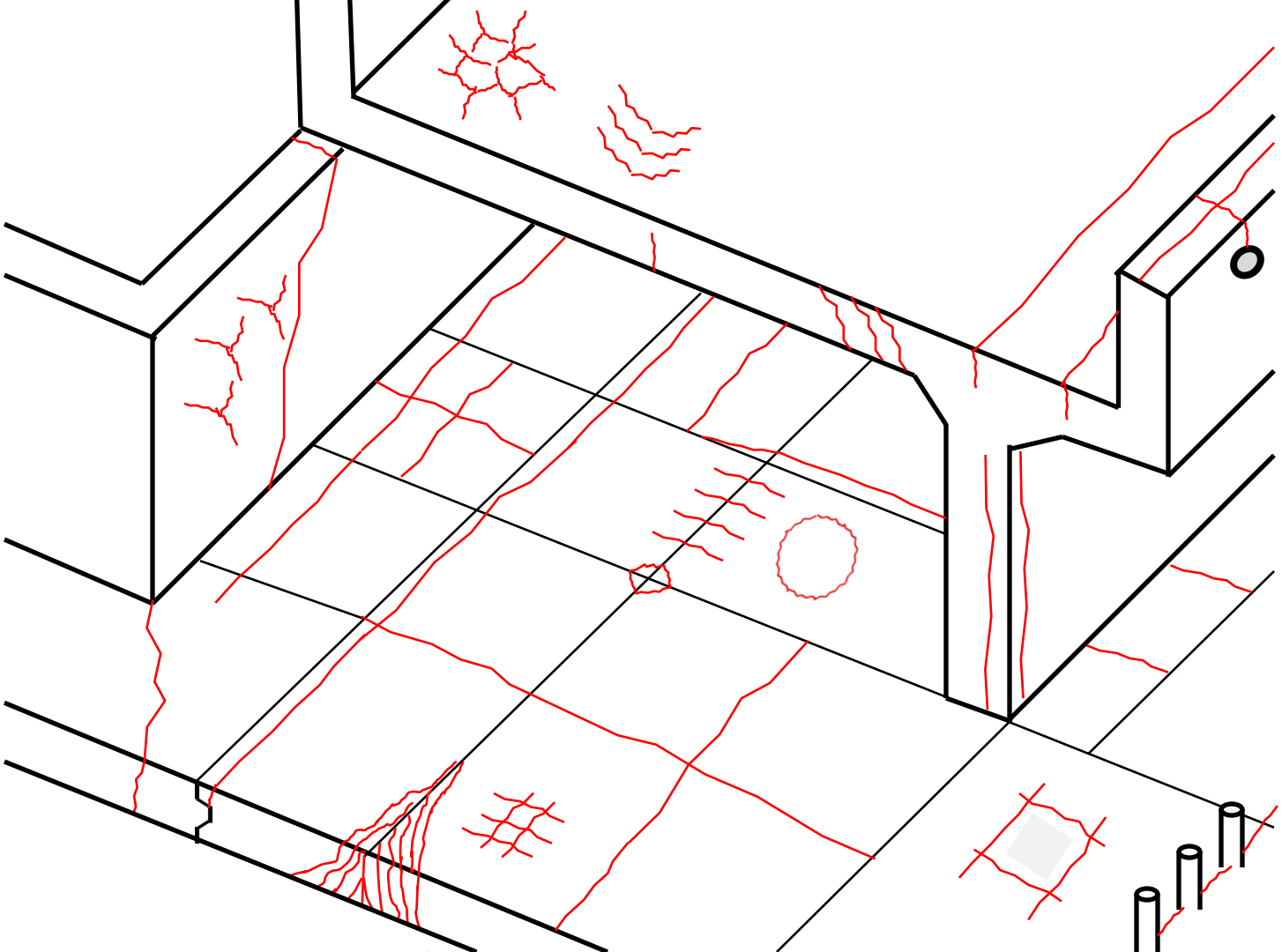
CRACKS

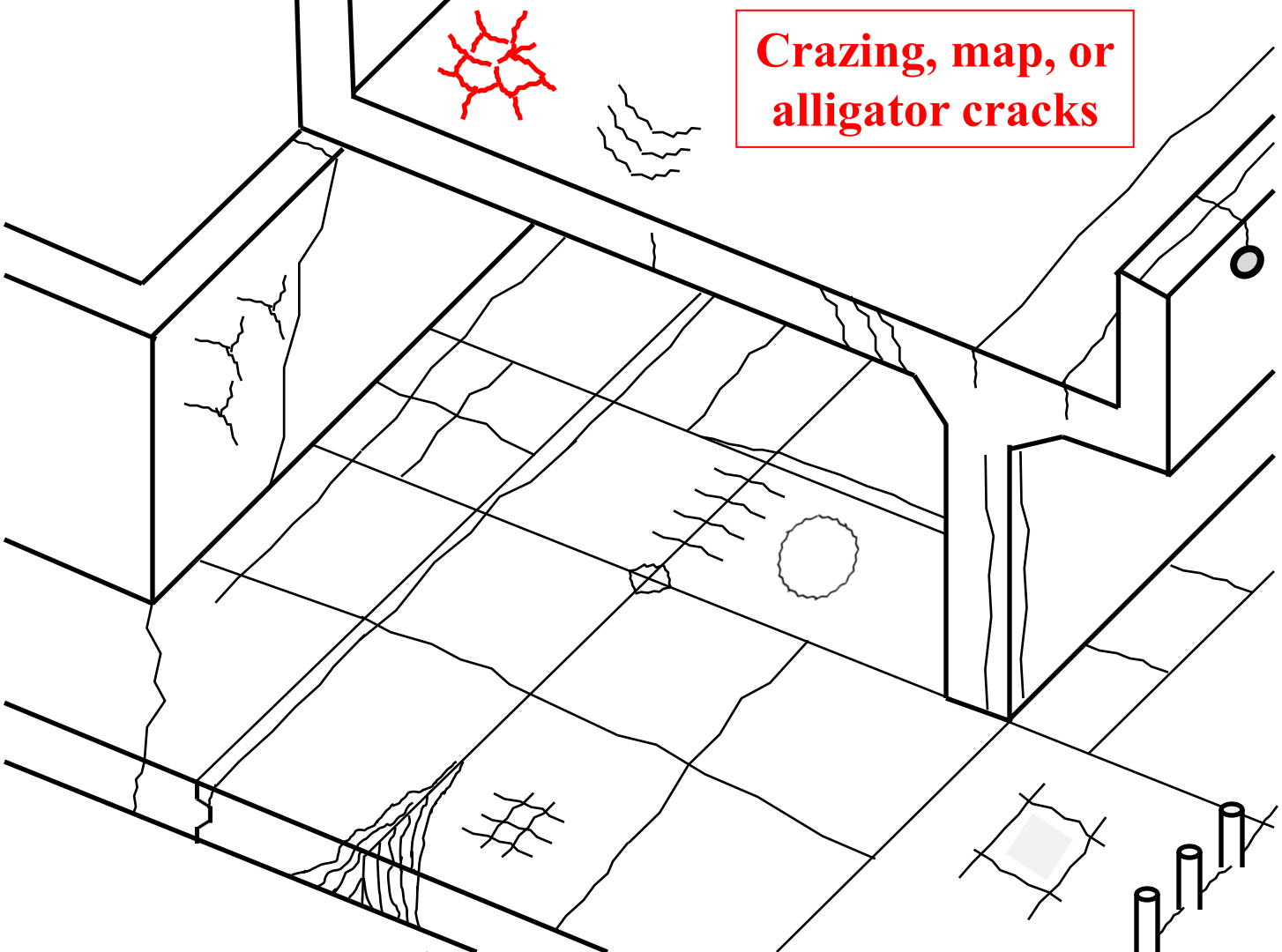
LET'S TALK ABOUT 23 KINDS

Live Content Slide

When playing as a slideshow, this slide will display live content

Poll: What causes the majority of the repairs you need to do?




Crazing, map, or
alligator cracks

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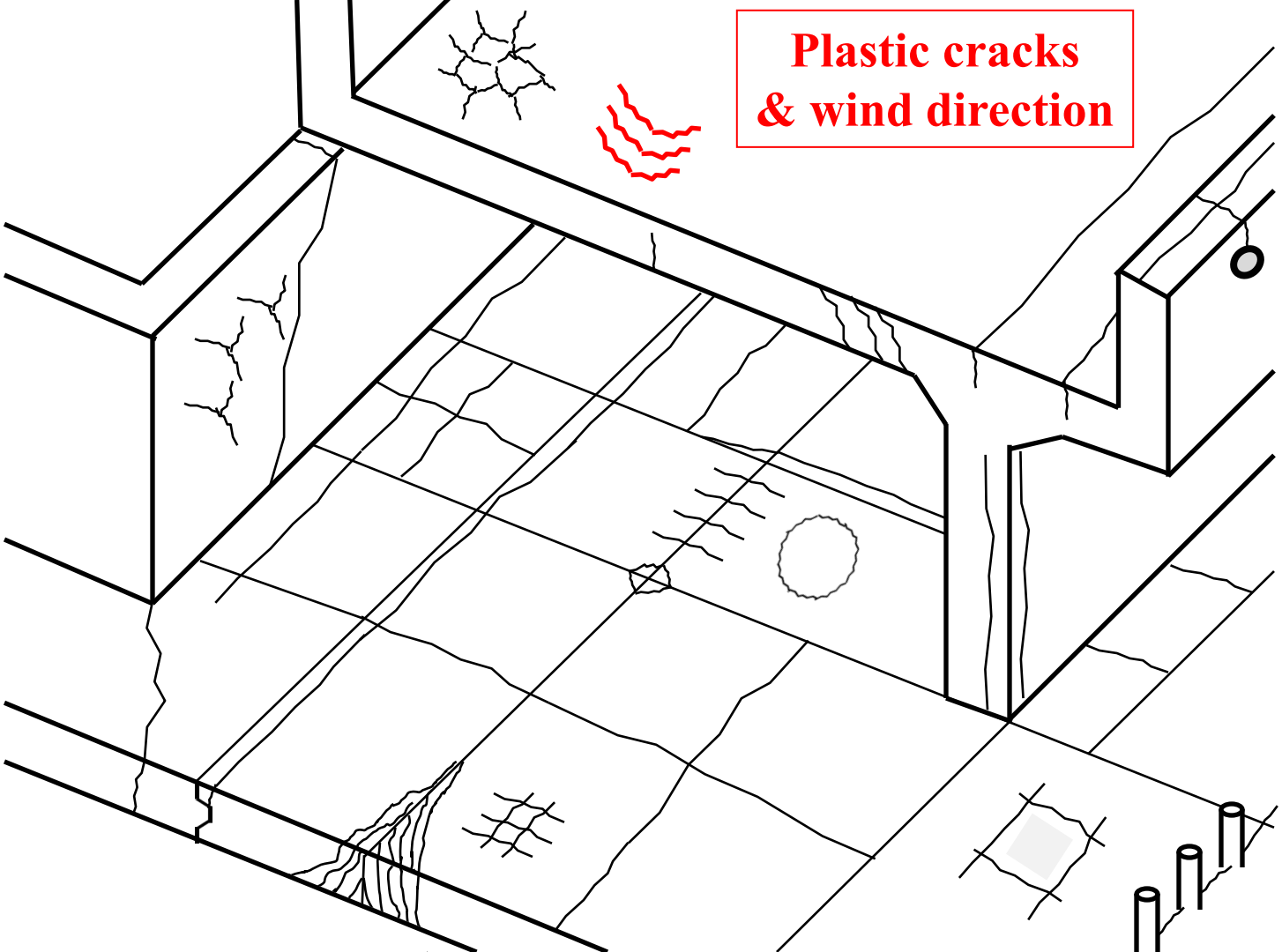
Plastic cracks
& wind direction

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WHEN WATER EVAPORATES OFF THE SURFACE TOO RAPIDLY, CRACKING USUALLY OCCURS

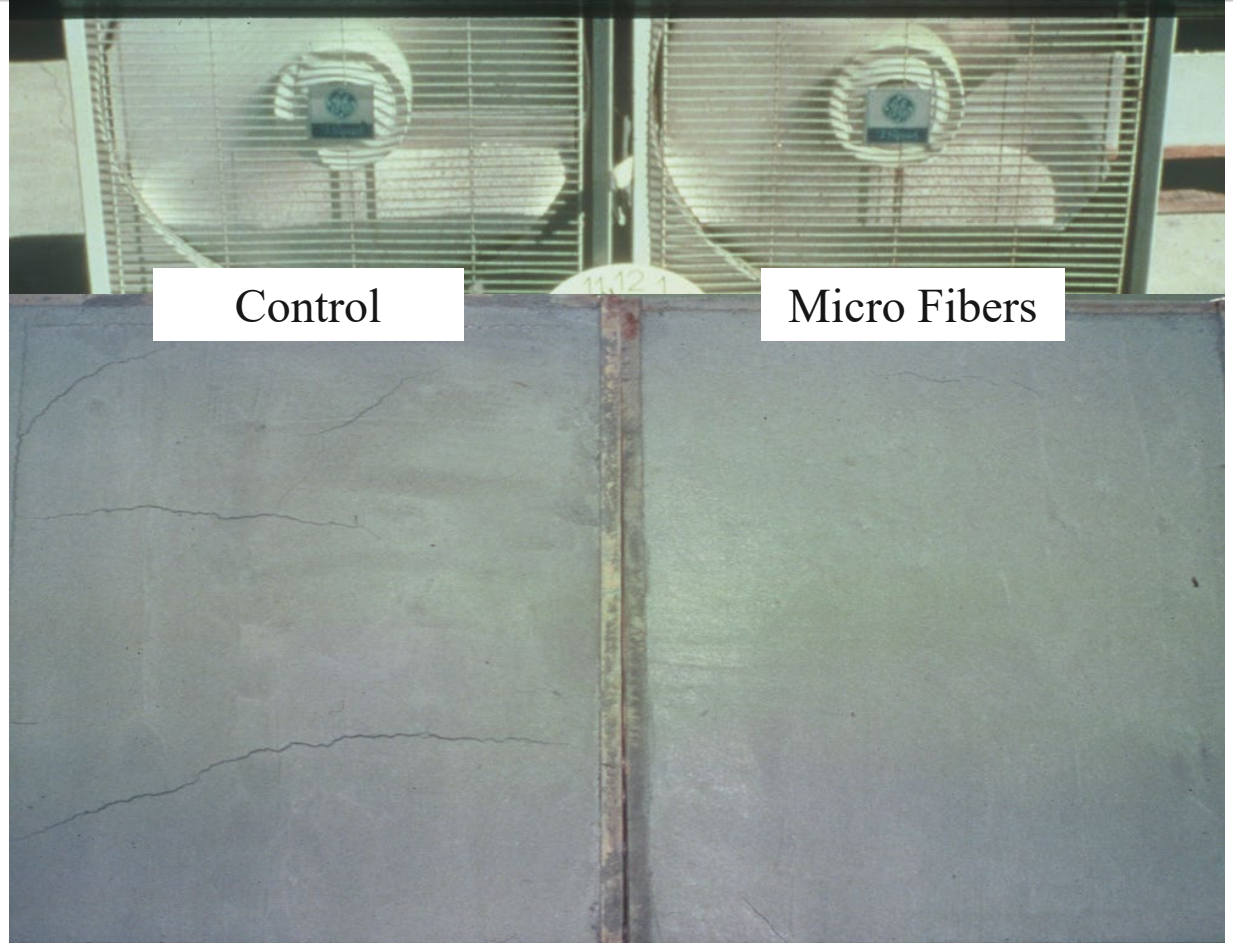
THERE ARE FOUR FACTORS THAT CONTRIBUTE TO THIS:

- **HIGH AMBIENT TEMPERATURES**
- **HIGH CONCRETE TEMPERATURES**
- **LOW HUMIDITY**
- **HIGH WINDS**

ACI Recommends

- Wind Screens
- Sun Screens
- Fogging

- Micro Fibers
- Evaporation Retarder



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Evaporation Retarder
Spray-On Monomolecular Film

Or Simply Have Ready Mix Add an Admixture to Reduce Excessive Bleeding

And both are Finishing Aids

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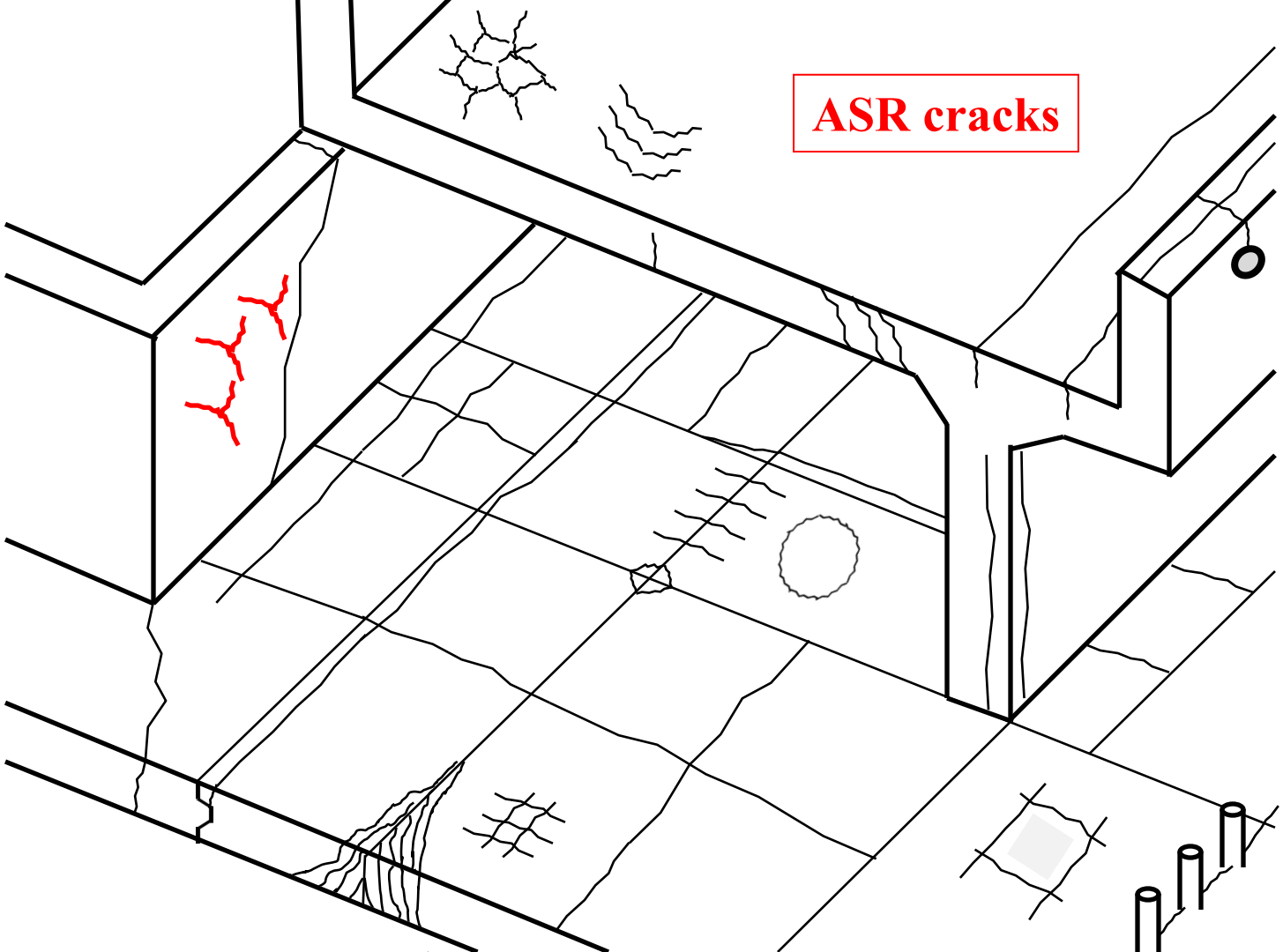
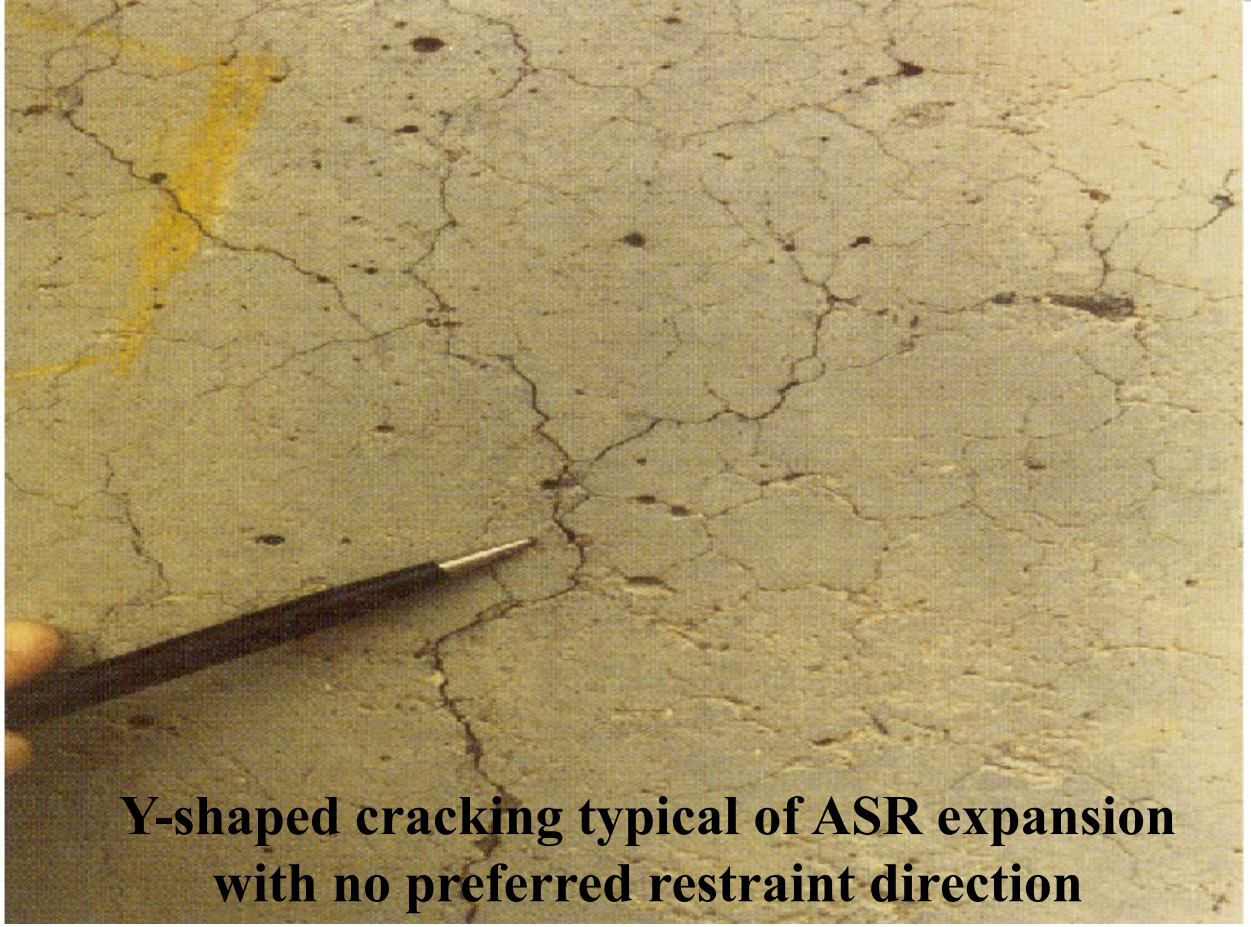

ASR cracks



Y-shaped cracking typical of ASR expansion with no preferred restraint direction

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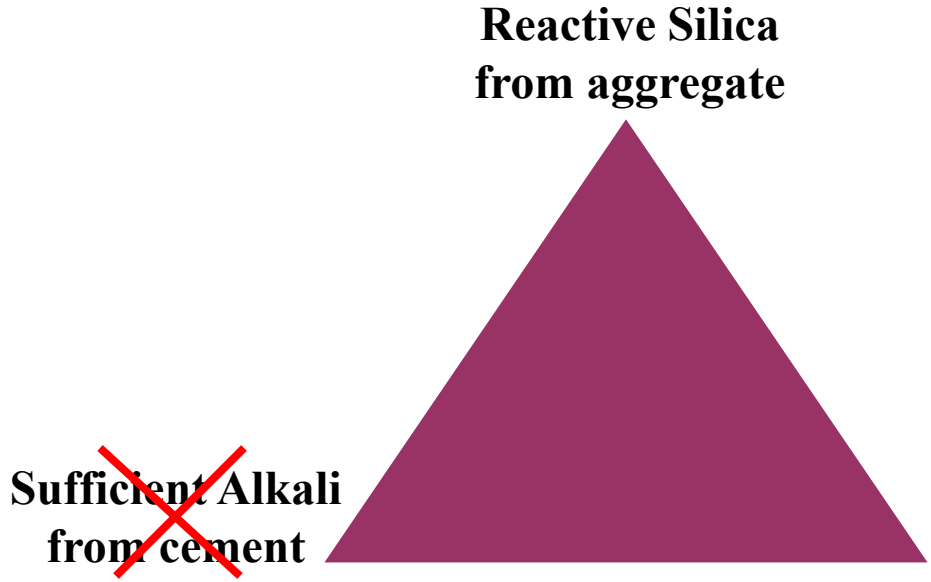
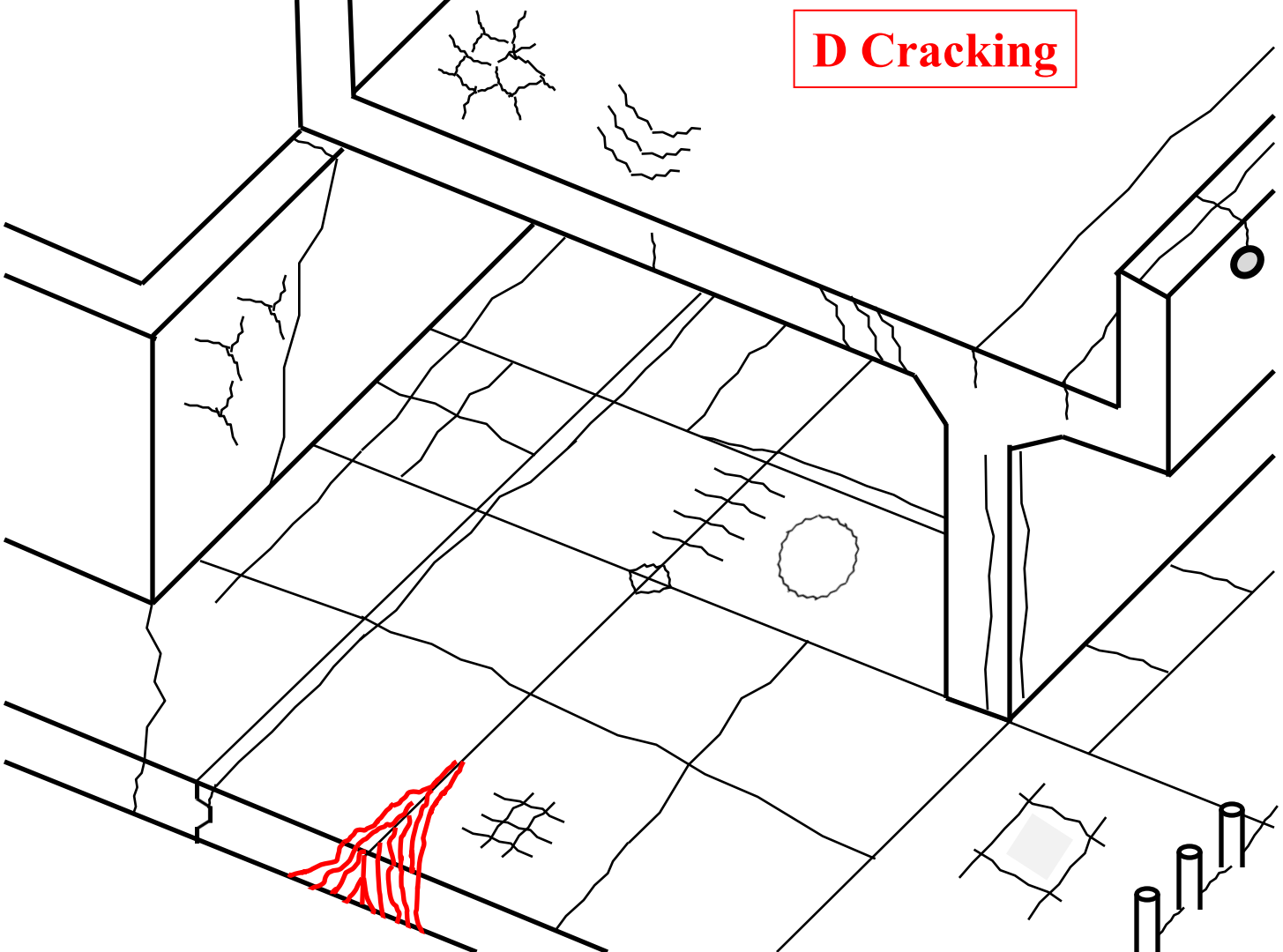
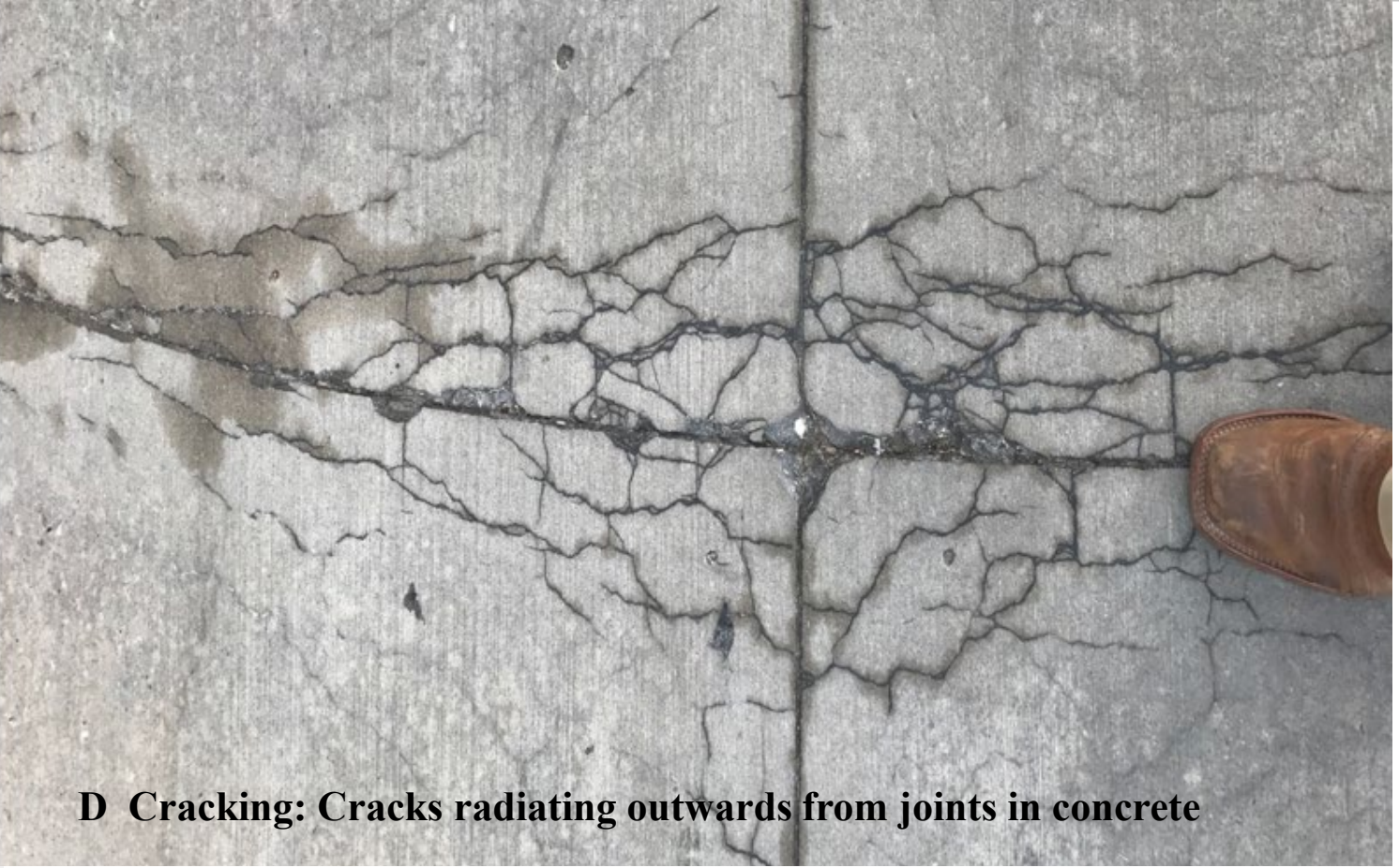
Three Necessities for Alkali Silica Reaction



Use SCMs

Lithium Nitrate based ASR Inhibiting Admixture combines with/neutralizes the alkalis


D Cracking



D Cracking: Cracks radiating outwards from joints in concrete

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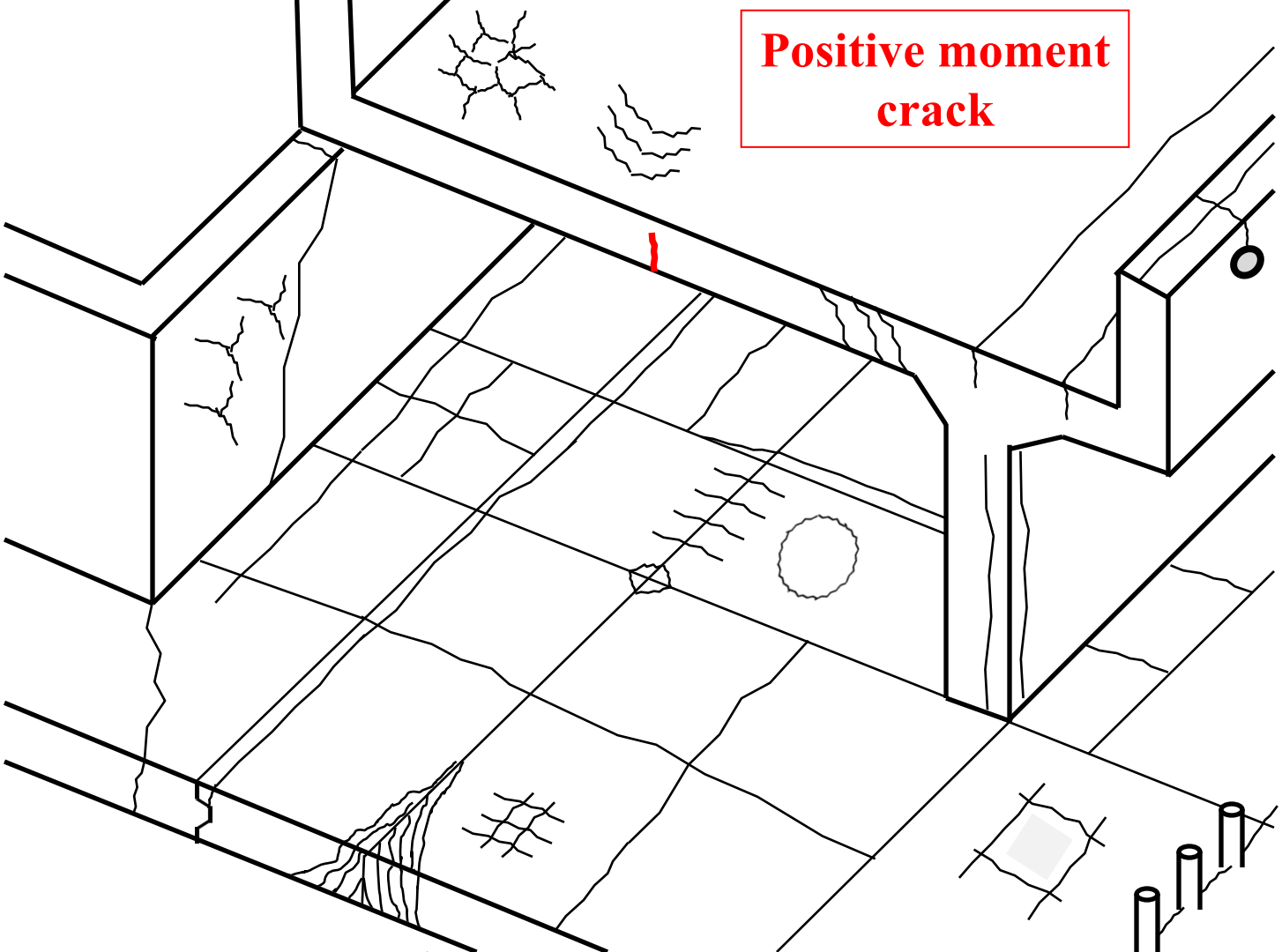
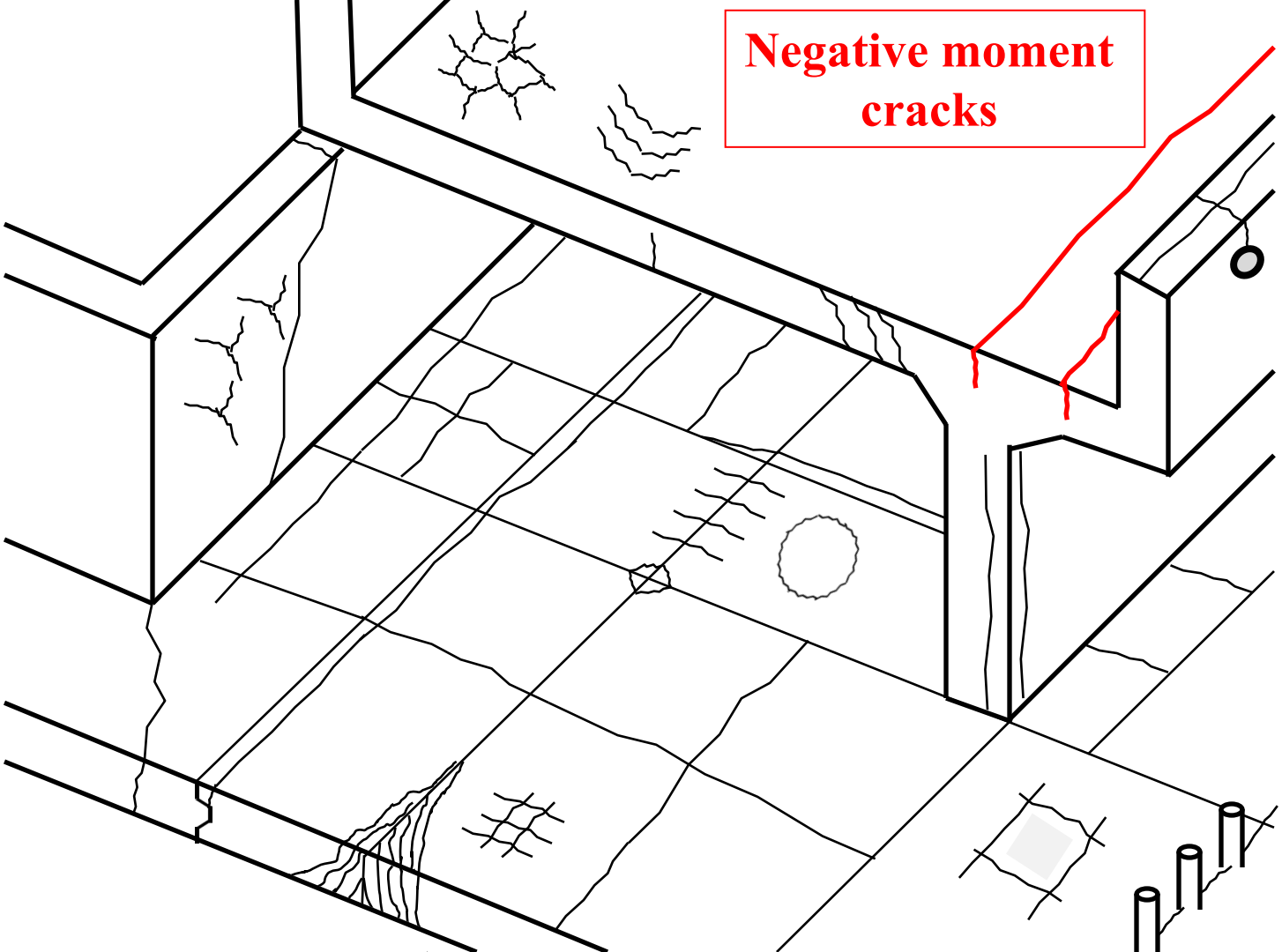
CAUSE:

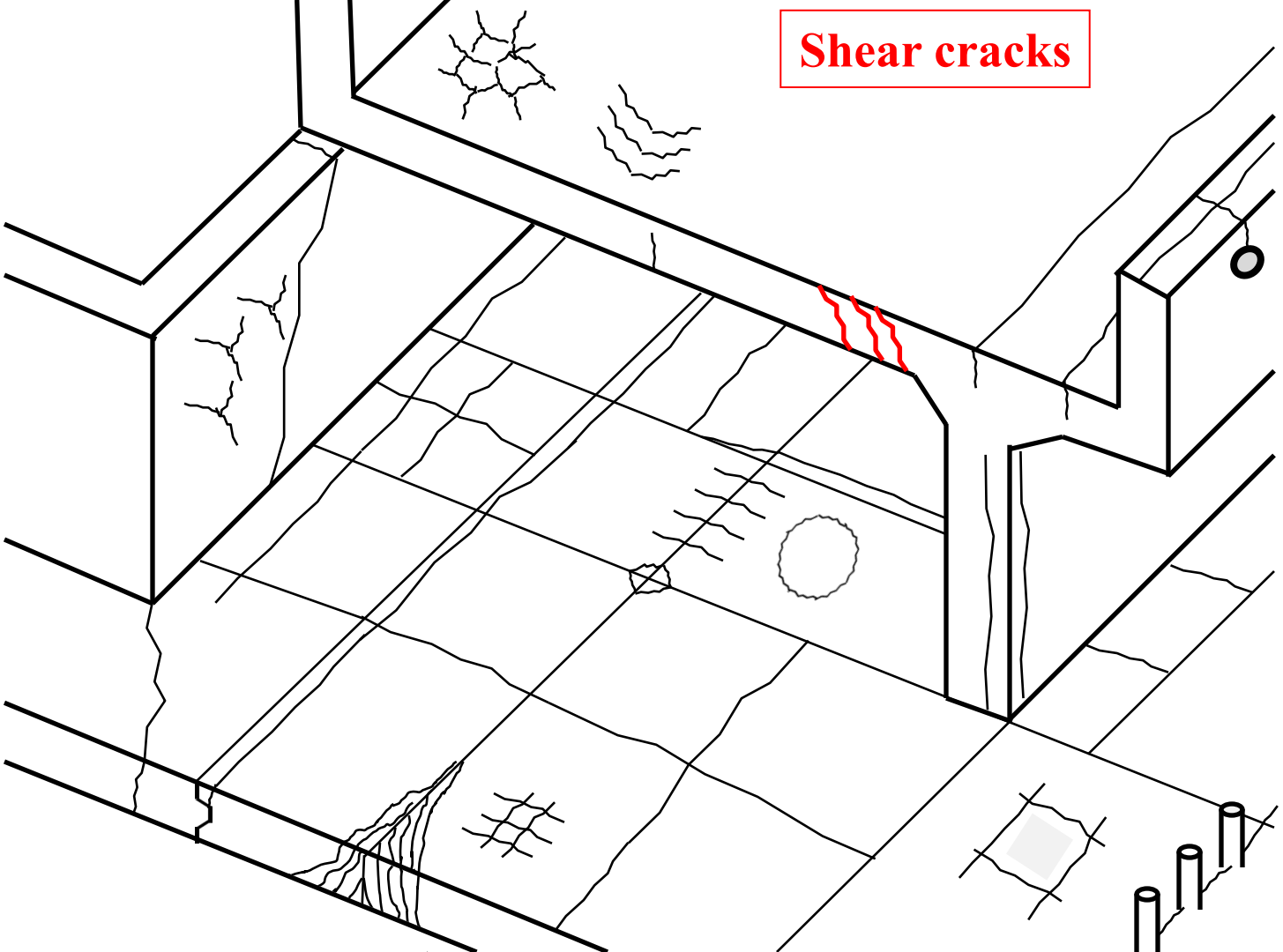
Coarse aggregate that is susceptible to absorption and cracking from freeze/thaw

PREVENTION:

- Quality aggregates
- Seal the joints and slab


Positive moment
crack


Negative moment cracks


Shear cracks

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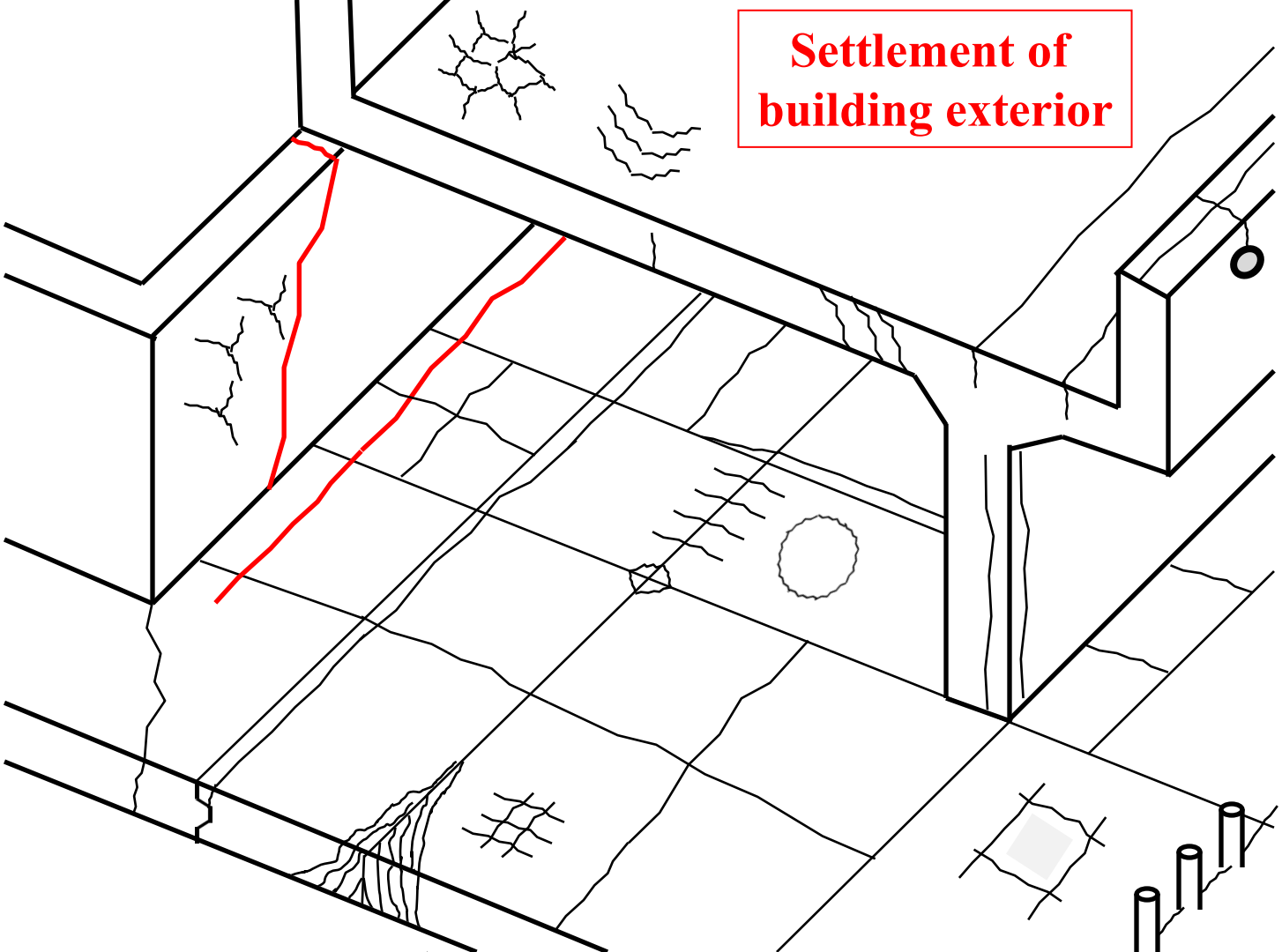
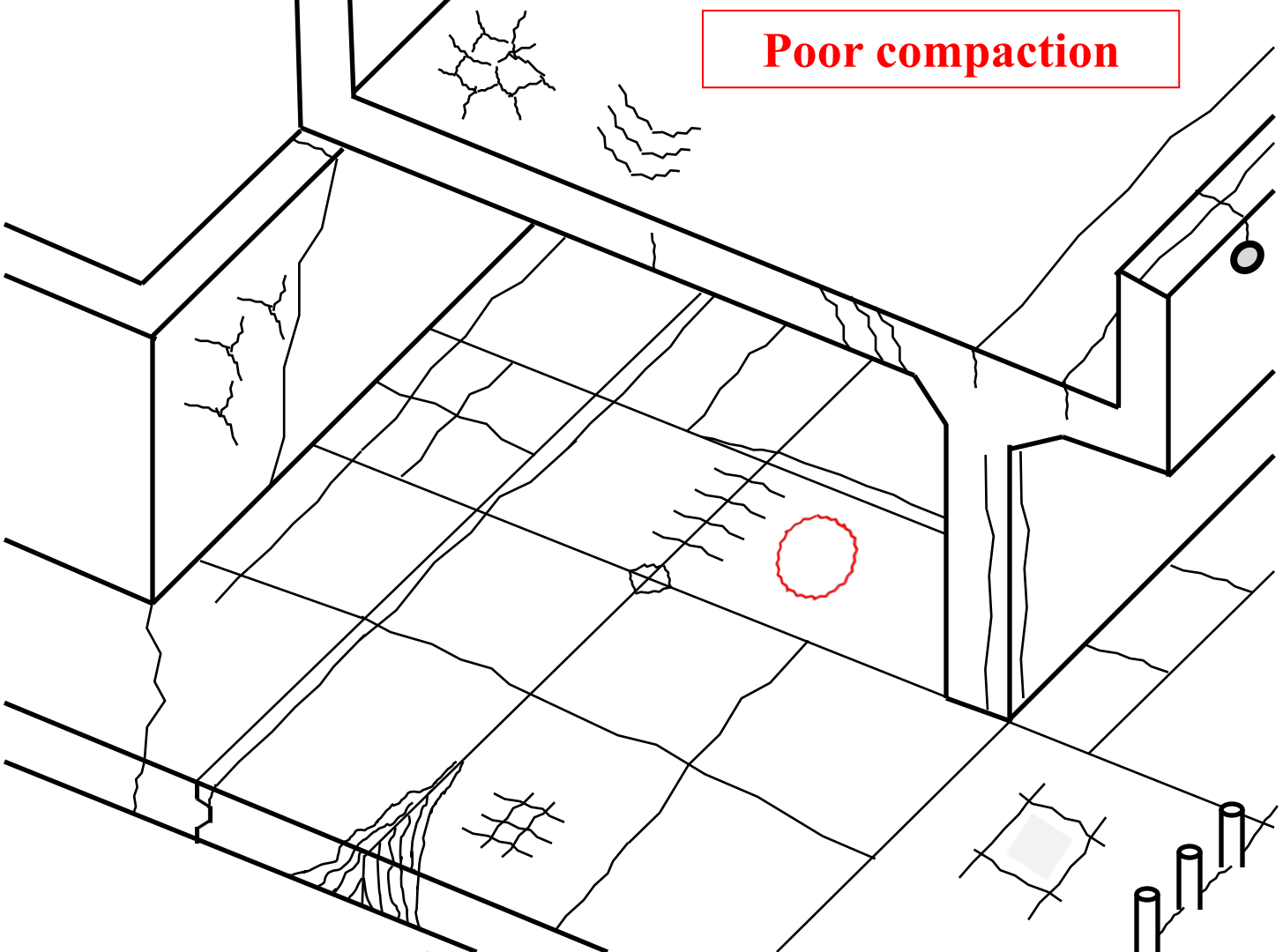
These three are all structural and could have been caused by:

- **Incorrect reinforcement placement**
- **Under design**
- **Change of use**
- **Excessive loading**
- **Poor compaction**
- **Earthquake**
- **Etc**


Settlement of
building exterior


Poor compaction

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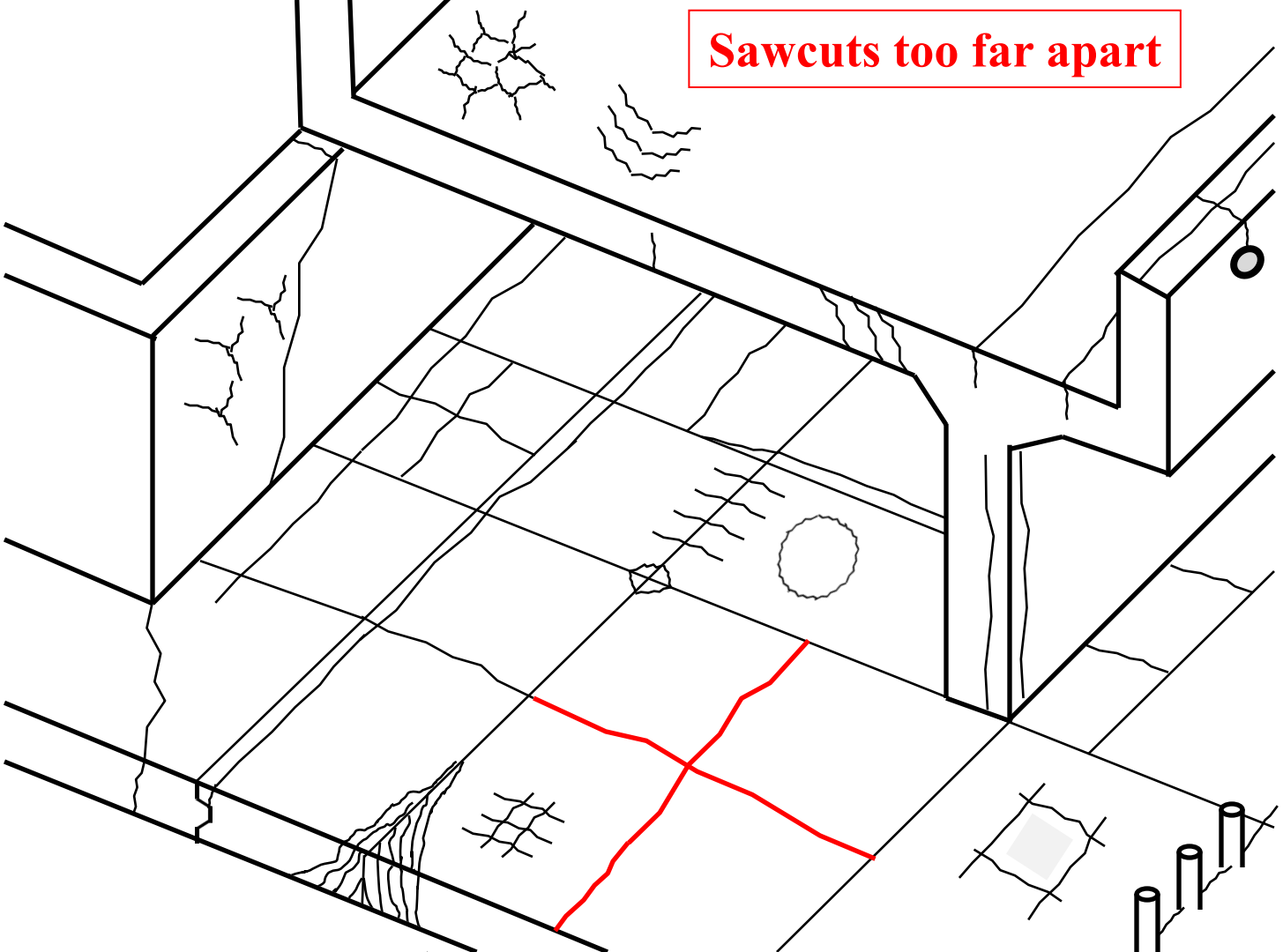
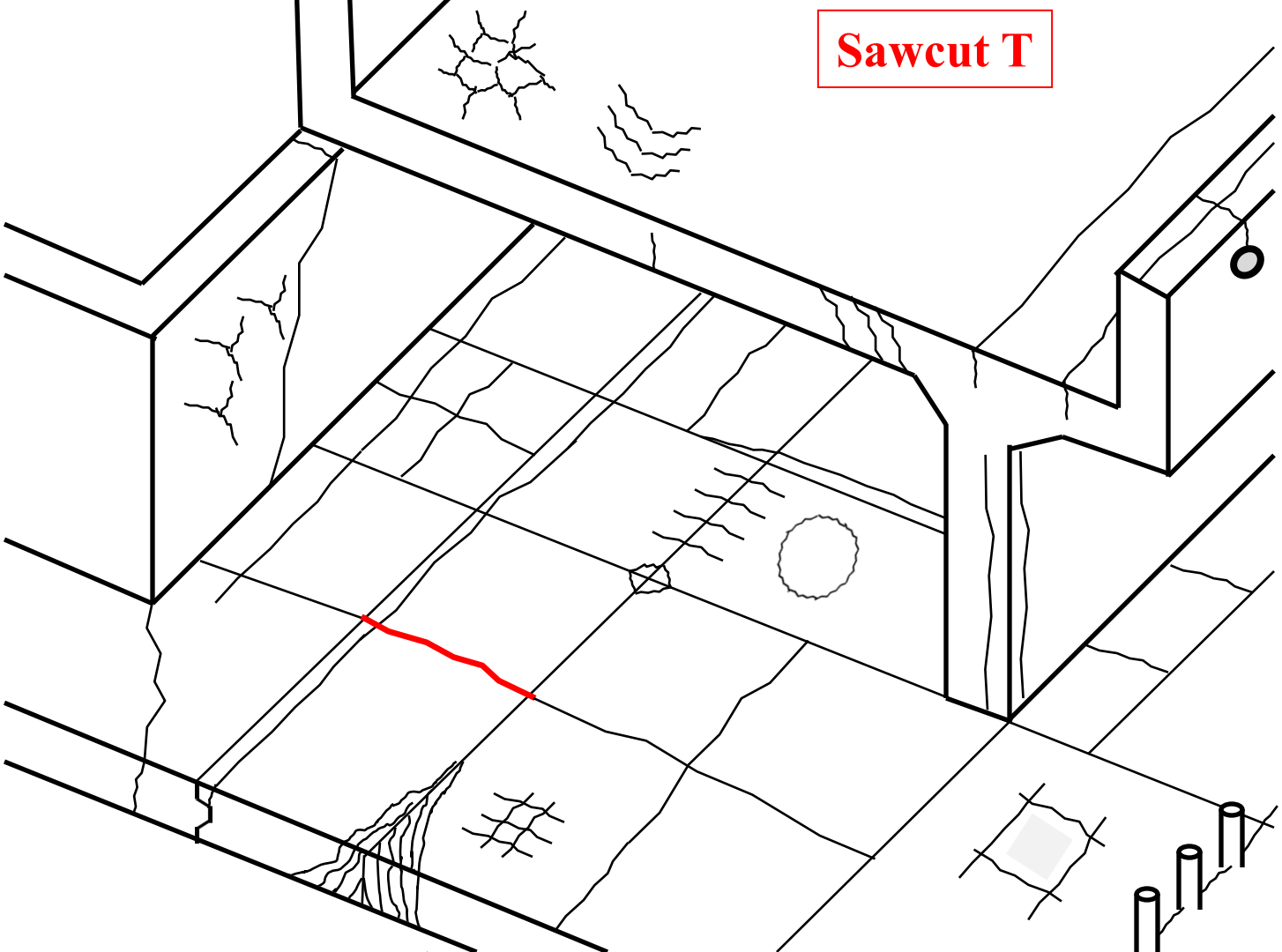
Primary cause of settlement cracking is poor compaction


Sawcuts too far apart


Usually Mid-Panel


Sawcut T

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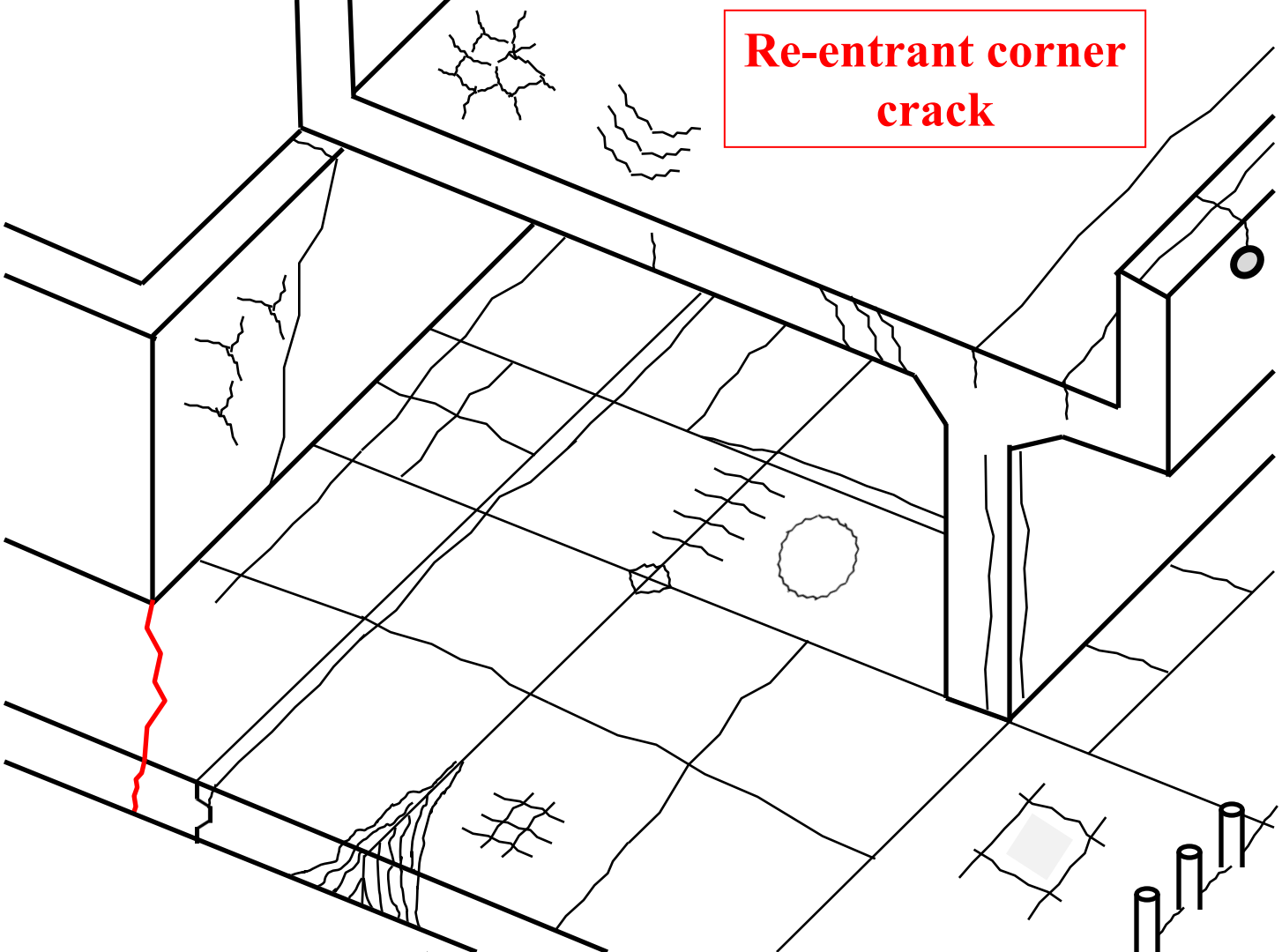
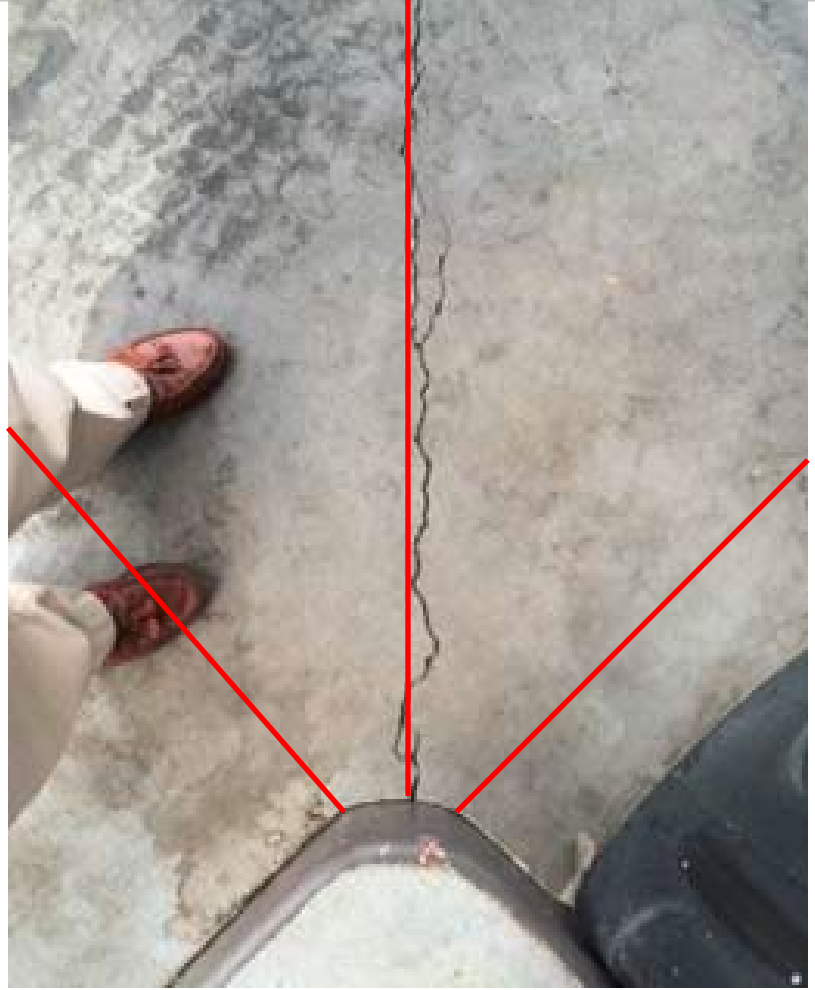

Re-entrant corner crack



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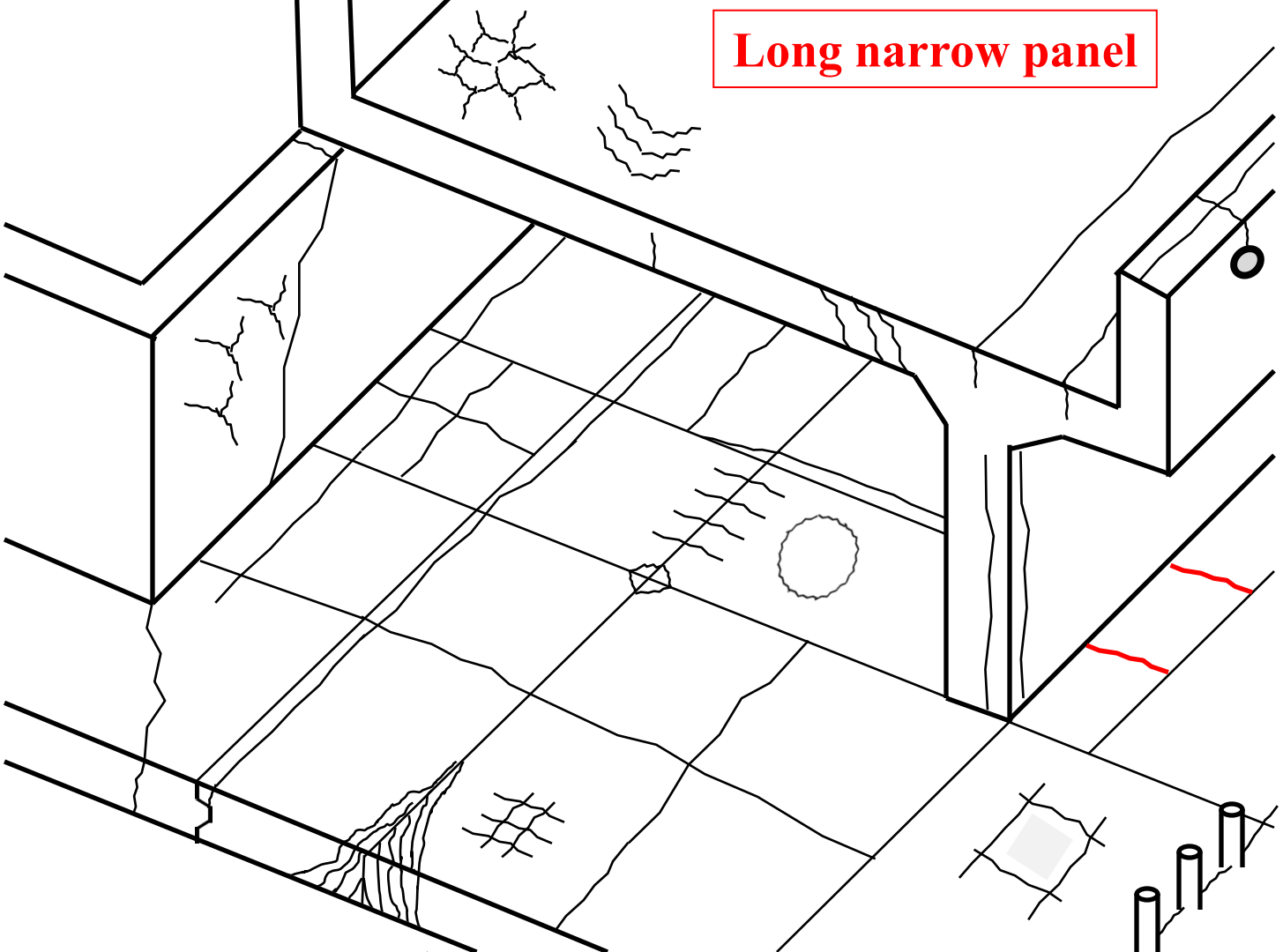
Long narrow panel

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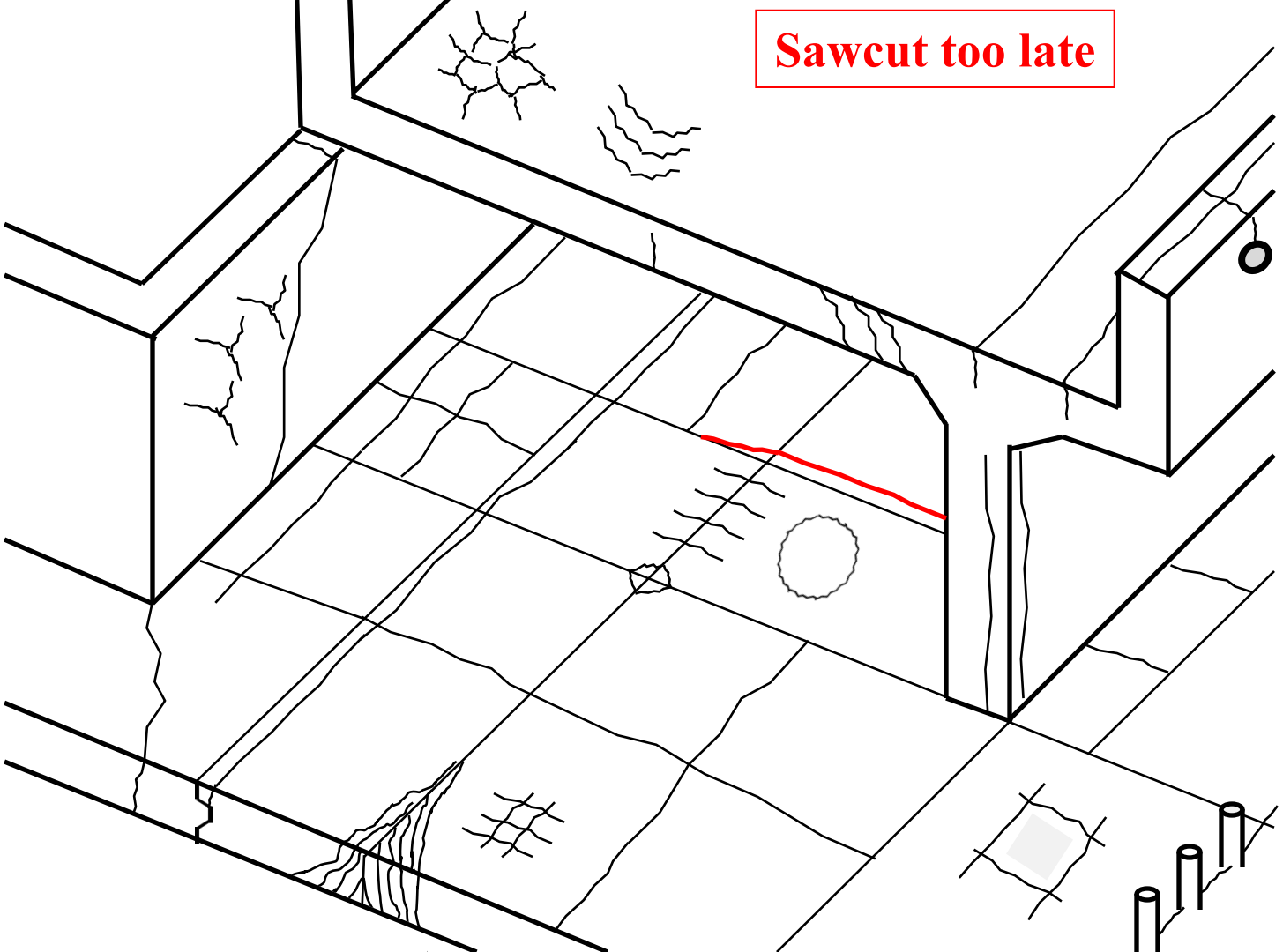
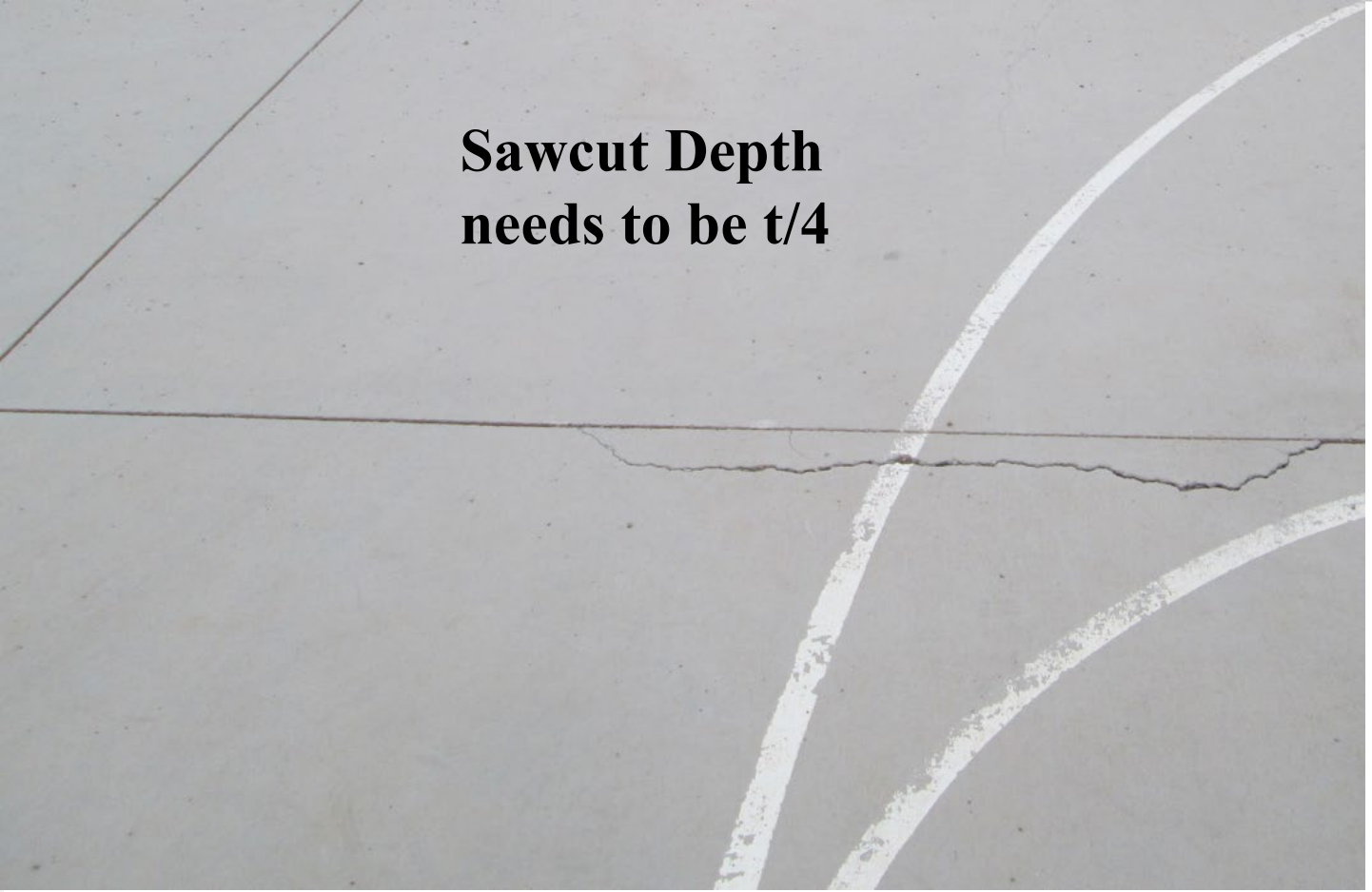
A few simple rules for Joint Layout from ACI 318:

1. **Maximum joint spacing 24 to 36 times thickness**
   For instance: 5” thick x 24 = 120” which is 10’
   5” thick x 36 = 180” which is 15’
   (stated differently: 2 to 3 times the thickness in feet)
   Good rule of thumb is the middle: 2.5 times thickness
2. **Maximum length to width ratio 1.5 to 1**
   (1:1 Square is even better)
3. **Joints at every re-entrant corner**
4. **No T’s**

Note that 1, 2, and 3 can vary if shrinkage compensating cement is used.


Sawcut too late



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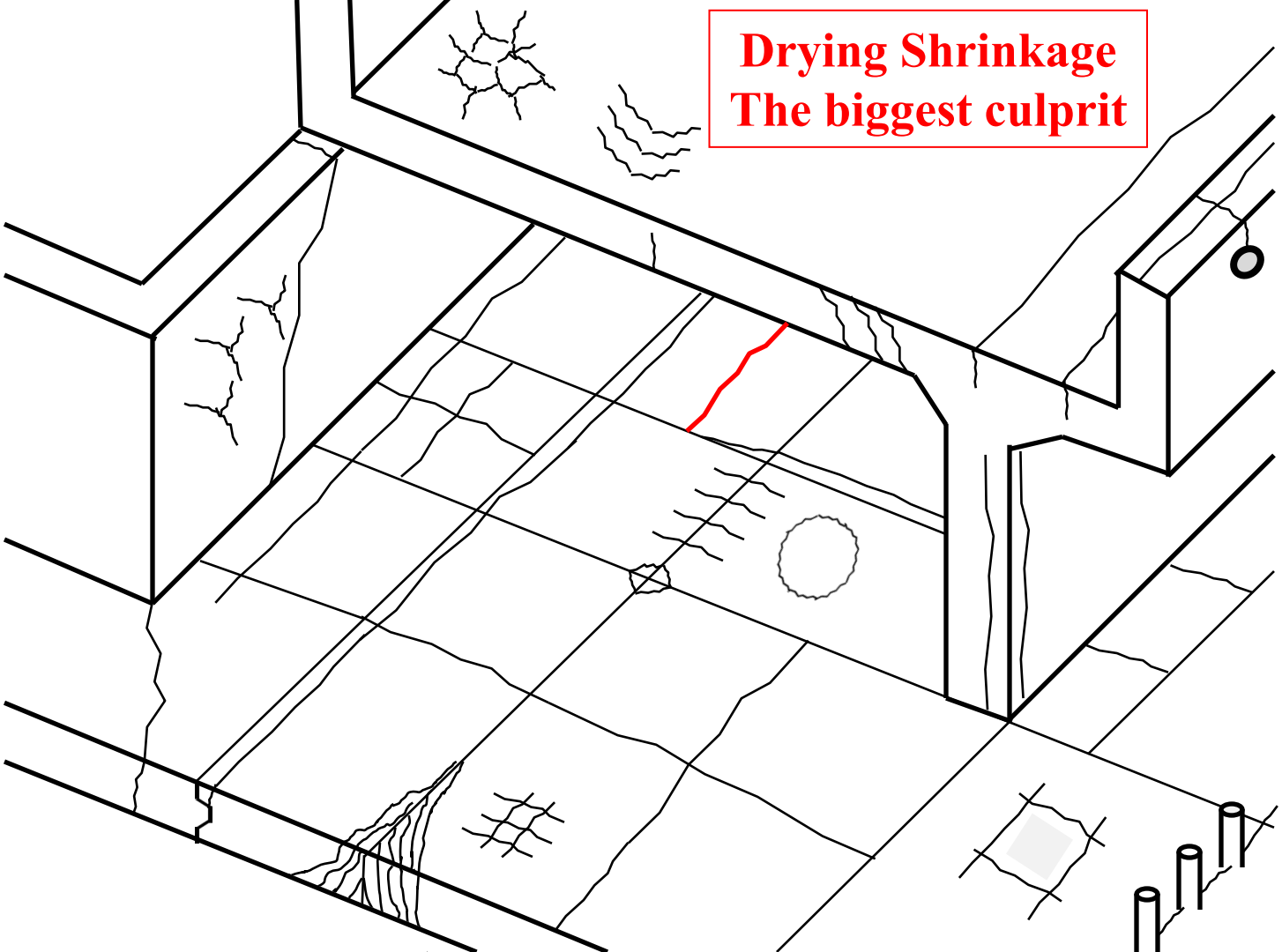
This one looks similar, but the cause is different

It was tooled, but not deep enough


Drying Shrinkage
The biggest culprit

The Good News: There are lots of ways to Reduce or Eliminate Drying Shrinkage

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CURING

ACI 302.1R
Purpose of Curing:

"After concrete placement and finishing of suitable concrete, curing is the single most important factor in achieving a high-quality slab.

The primary purpose of curing is to slow the loss of moisture from the slab. A longer period of moisture retention permits more complete hydration of the cement, resulting in greater strengths."

SPEC NEEDS TO SAY:
“Backroll with short nap roller.”

This will make the coverage uniform.

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WATER

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Effect of High Range Water Reducer

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COARSE AGGREGATES

MORE AND LARGER COARSE AGGREGATE

MEANS	**LESS SURFACE AREA AND LESS SPACE TO FILL**
WHICH MEANS	**LESS PASTE**
WHICH MEANS	**LESS CEMENT**
WHICH MEANS	**LESS WATER**
WHICH MEANS	**LESS EXCESS WATER**
WHICH MEANS	**LESS SHRINKAGE**
WHICH MEANS	**LESS CRACKING & CURLING**

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And the reason that all this is so important is…

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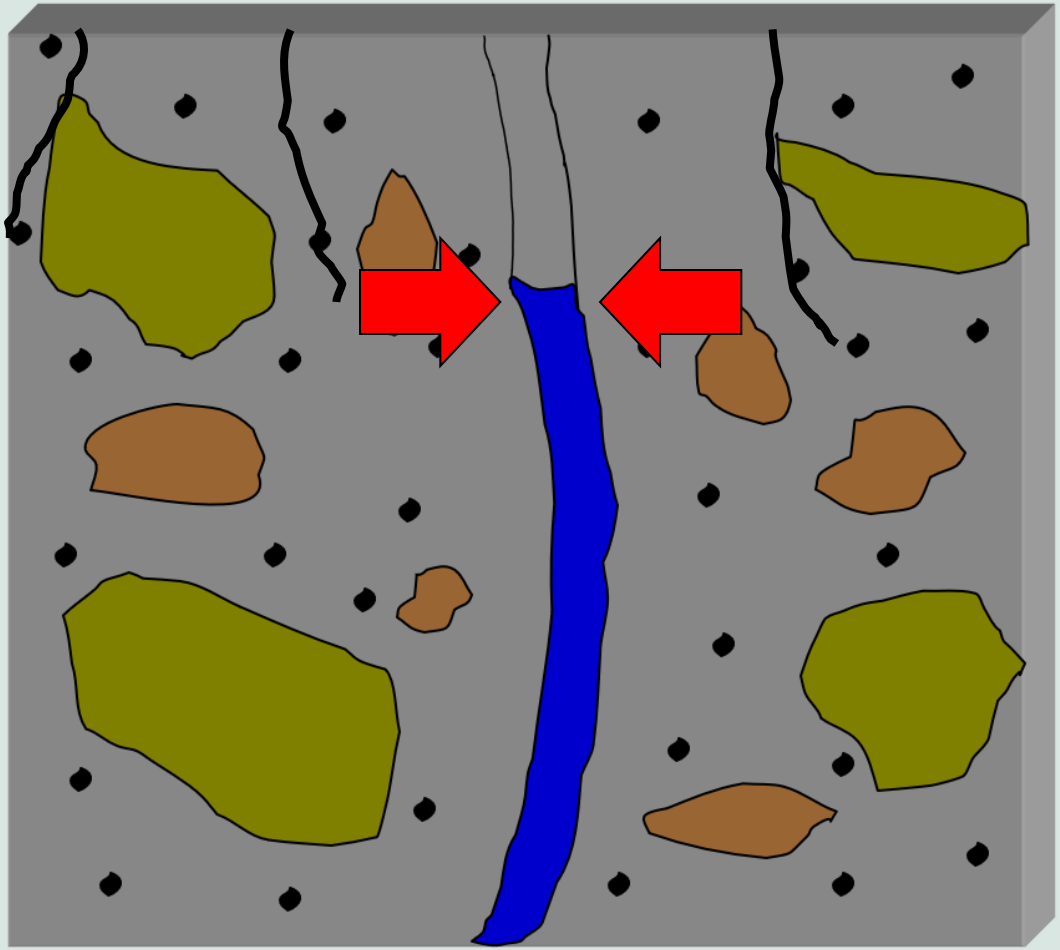
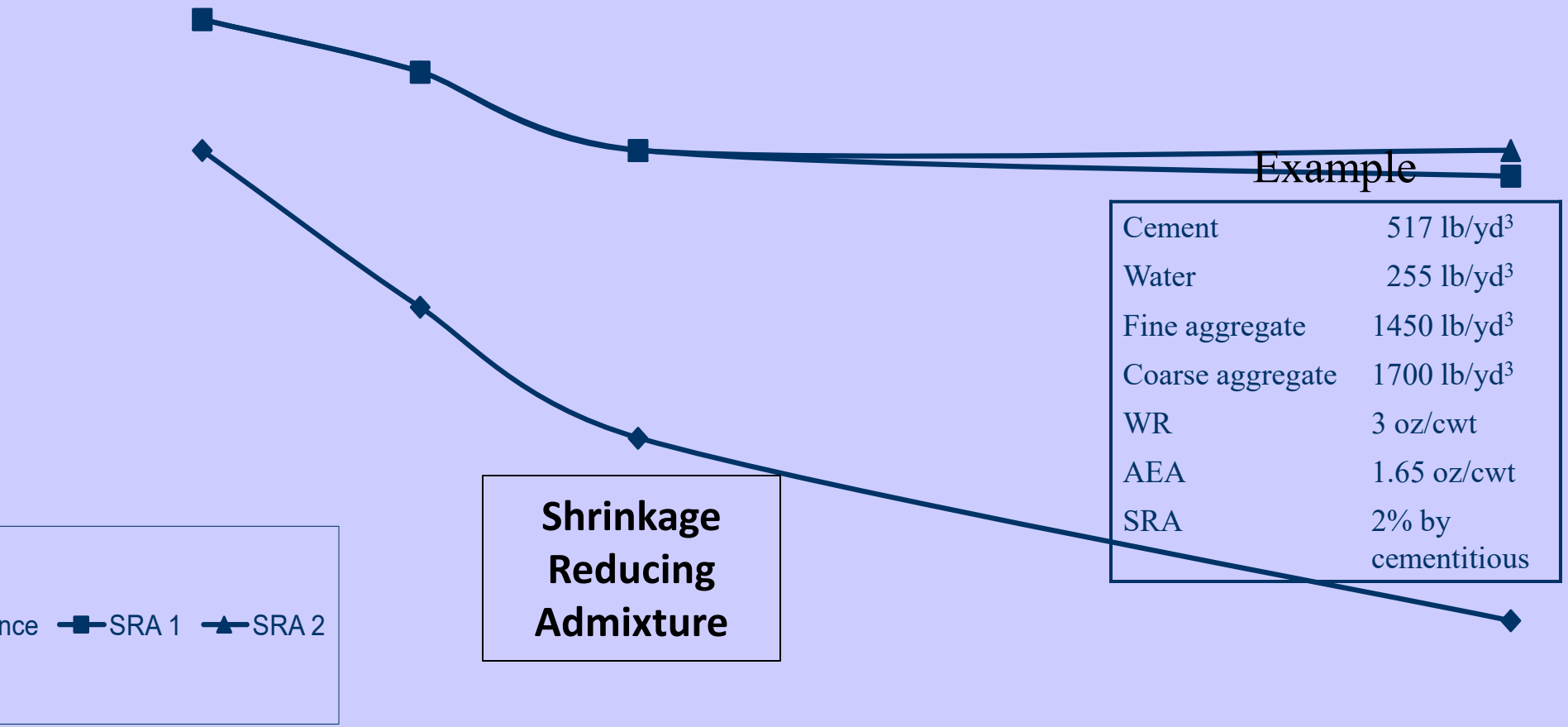
SHRINKAGE REDUCING ADMIXTURE

Capillary Pore Stress





Example

Cement	517 lb/yd^3
Water	255 lb/yd^3
Fine aggregate	1450 lb/yd^3
Coarse aggregate	1700 lb/yd^3
WR	3 oz/cwt
AEA	1.65 oz/cwt
SRA	2% by cementitious

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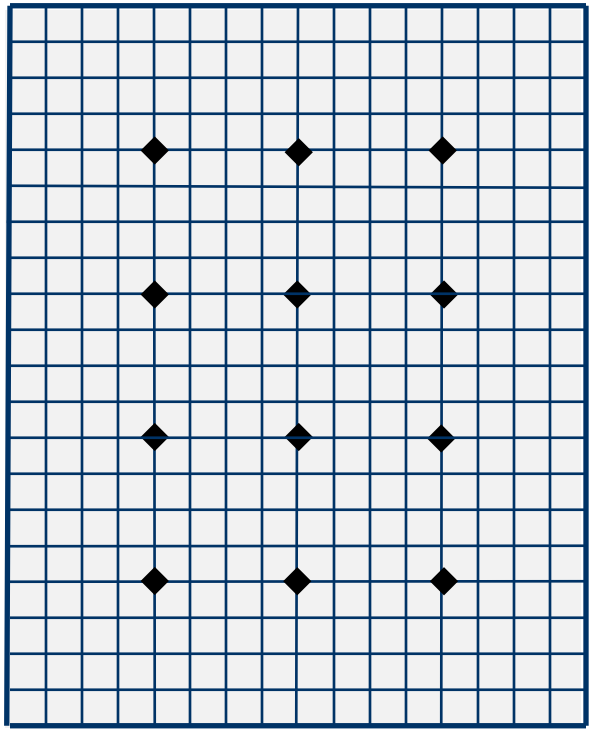
SHRINKAGE COMPENSATION

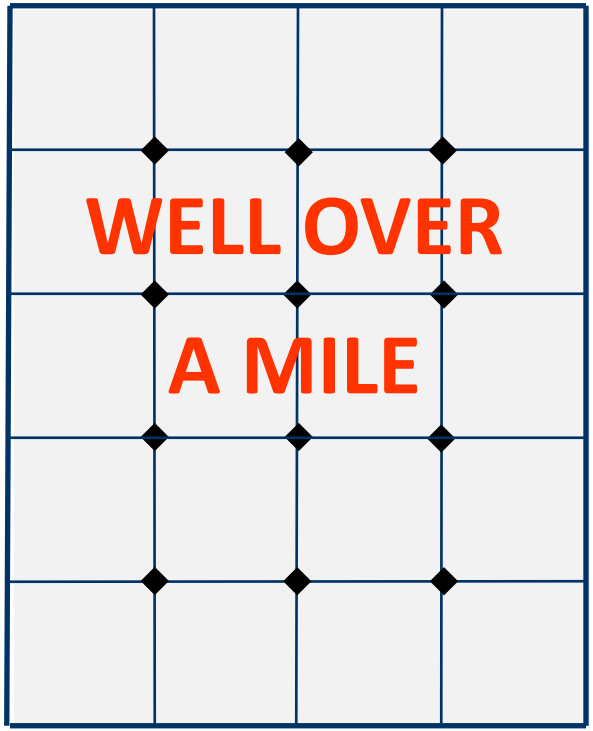
TYPICAL 5” SLABS **200’ by 250’** **50,000 ft²**

Joints 12.5’ x 12.5’



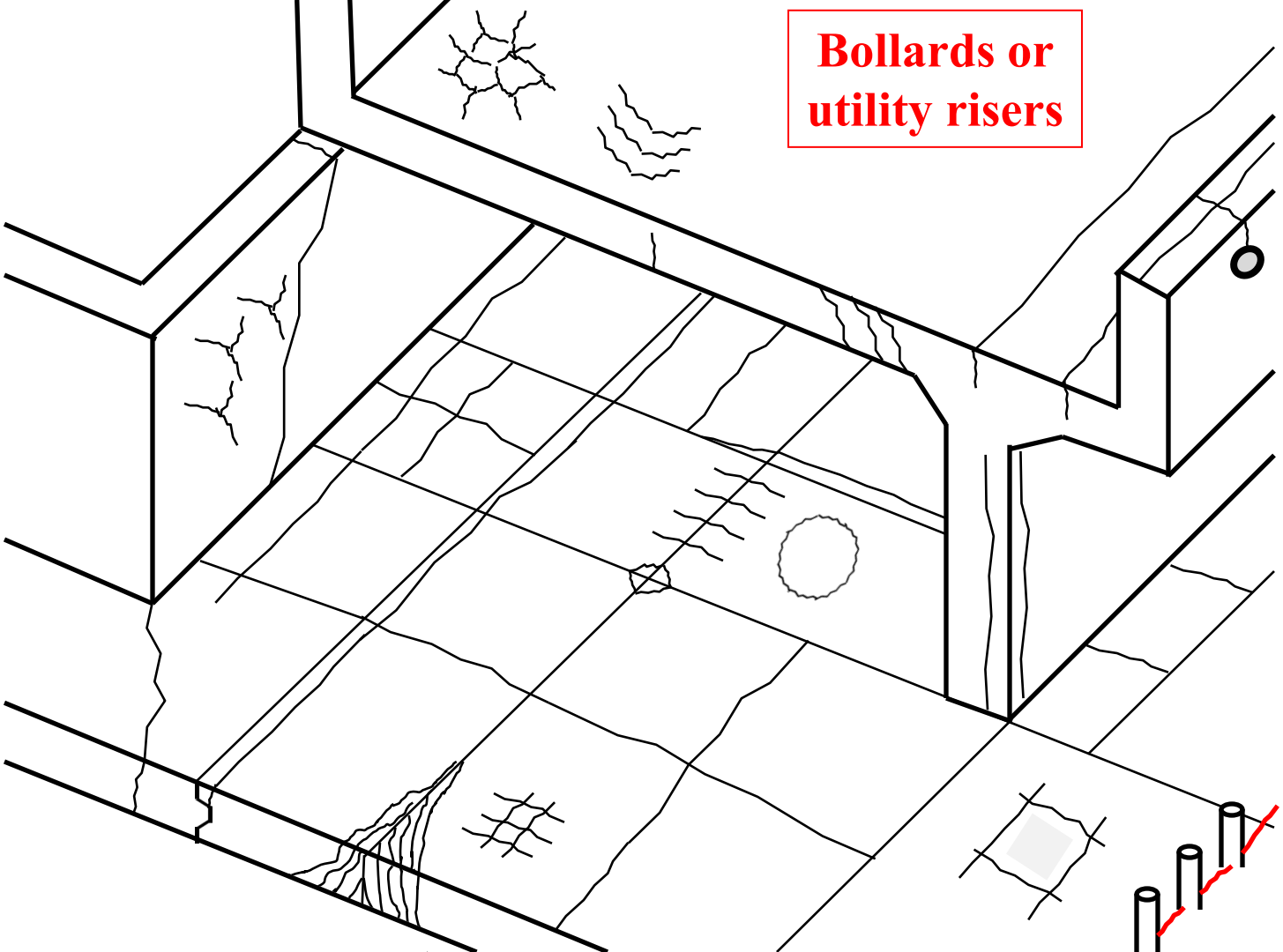
Portland Concrete
7,550 lf of joints

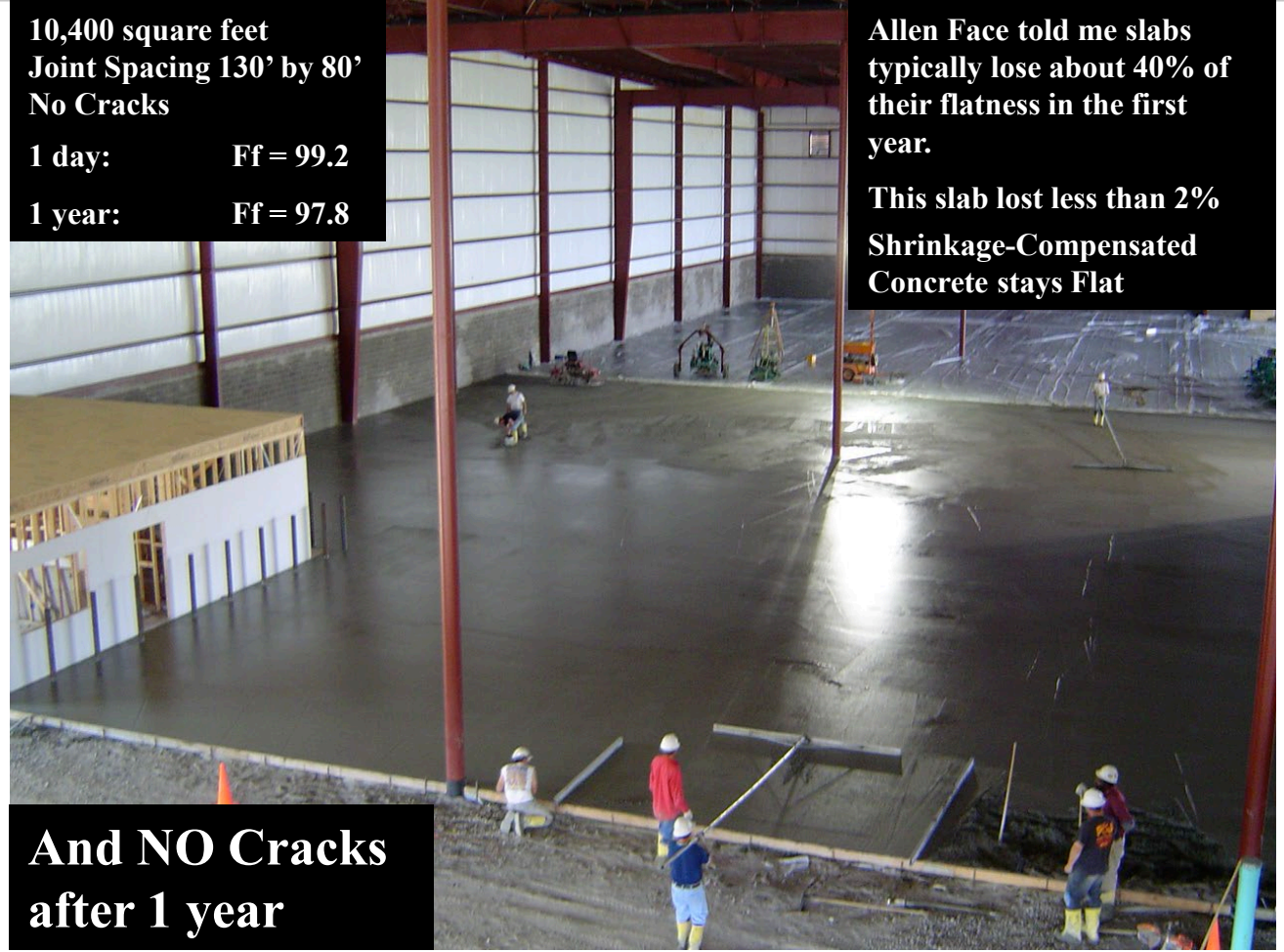
Joints 50’ x 50’



Shrinkage-Compensating
1,550 lf of joints

SAVED 6,000 LF OF JOINTS


Bollards or
utility risers



10,400 square feet
Joint Spacing 130' by 80'
No Cracks

1 day: Ff = 99.2

1 year: Ff = 97.8

Allen Face told me slabs typically lose about 40% of their flatness in the first year.

This slab lost less than 2%

Shrinkage-Compensated Concrete stays Flat

And NO Cracks after 1 year

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- *Extended joint spacing*
- *Few if any cracks*
- *Flat slabs*
- *That stay flat*

- *High bay racking*
- *Etc*

Shrinkage-Compensated Concrete is the perfect choice.

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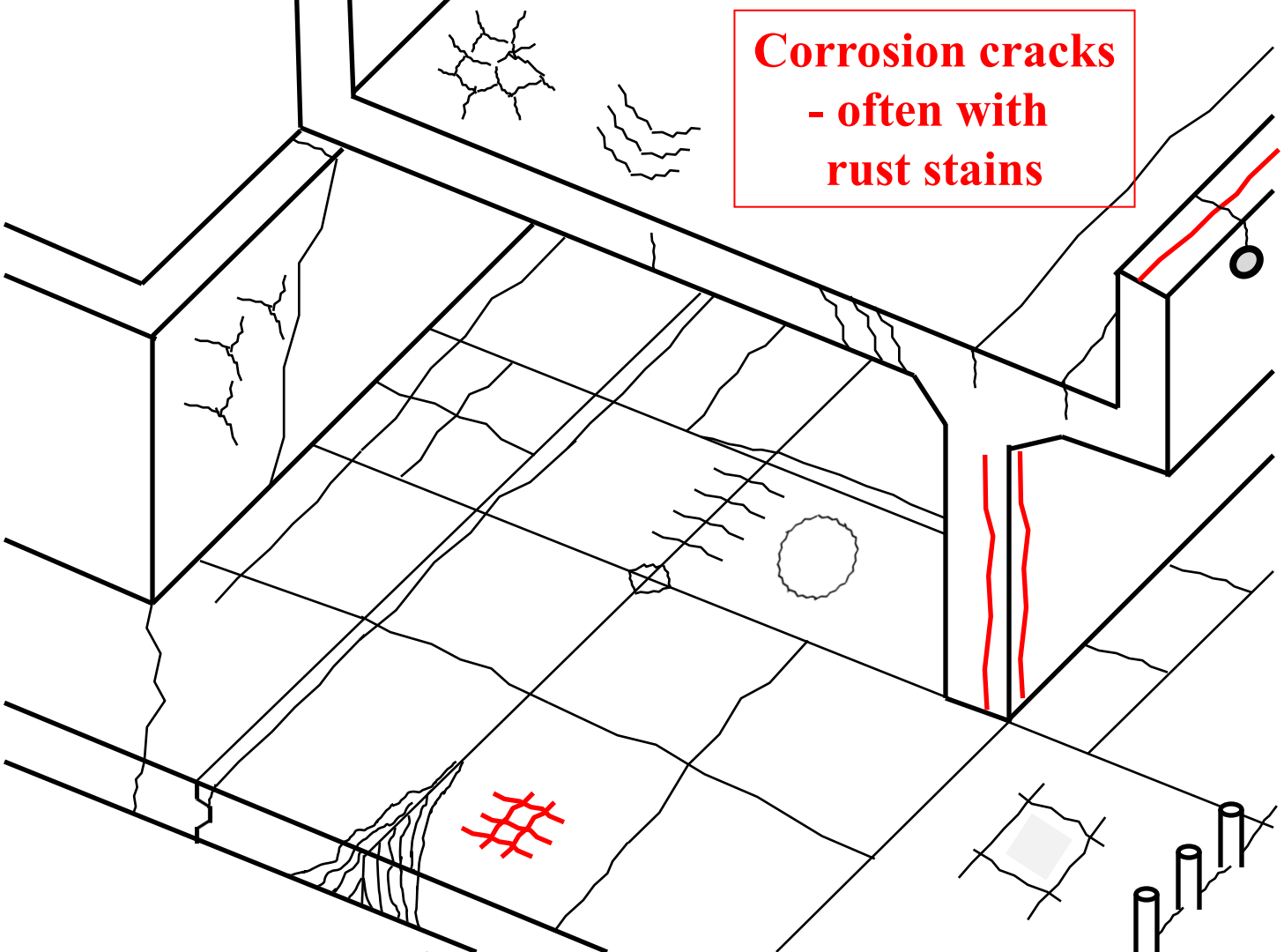
Corrosion cracks
- often with
rust stains

Rebar + Water

=

Corrosion, Expansion, Breaking

Highway Barrier

Copper Mine

We should have used corrosion inhibiting admixture

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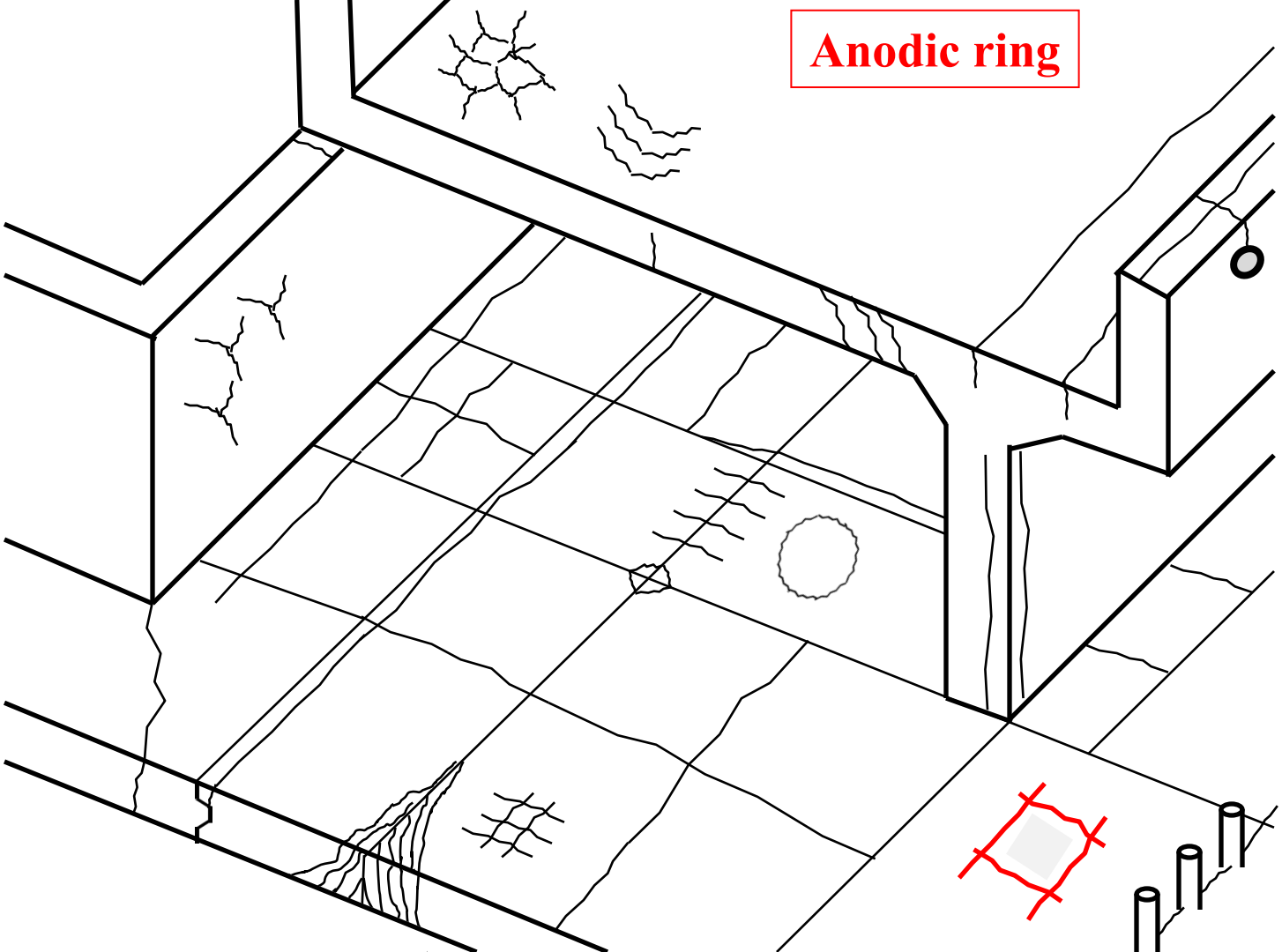
Corrosion Inhibiting Admixture:

- Calcium Nitrite
- Reacts to creates a passivity layer

- **Delays the onset of corrosion**
- **Decreases the rate of corrosion**
- **Increases the service life of the structure**


Anodic ring

The repair material contained a Corrosion Inhibitor.

So there is accelerated corrosion around the repair.

Galvanic Anode

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STRUCTURAL SYNTHETIC MACRO FIBERS

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We should have used Structural Synthetic Macro Fibers

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Finished Surface

Welded Wire Fabric

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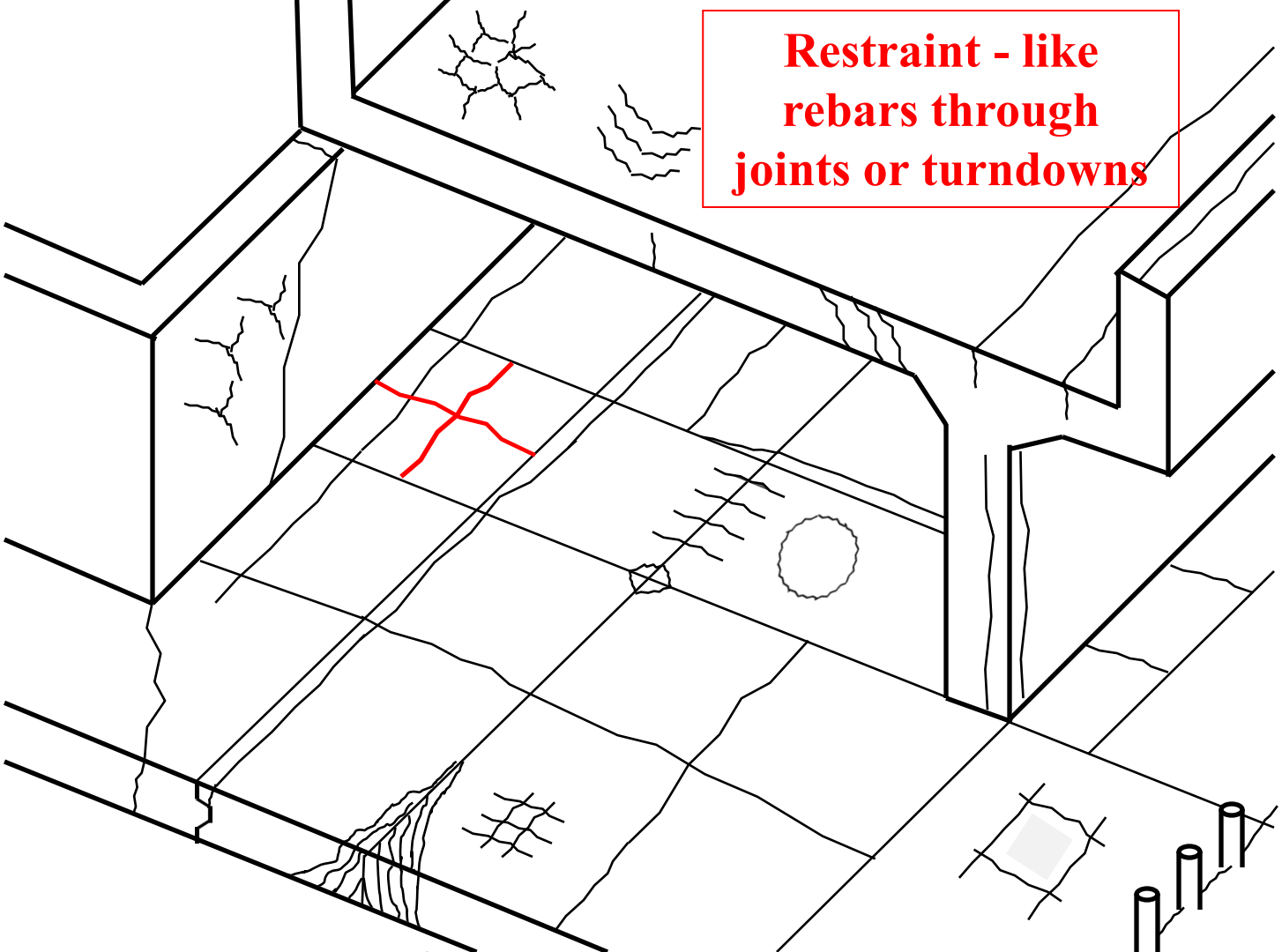
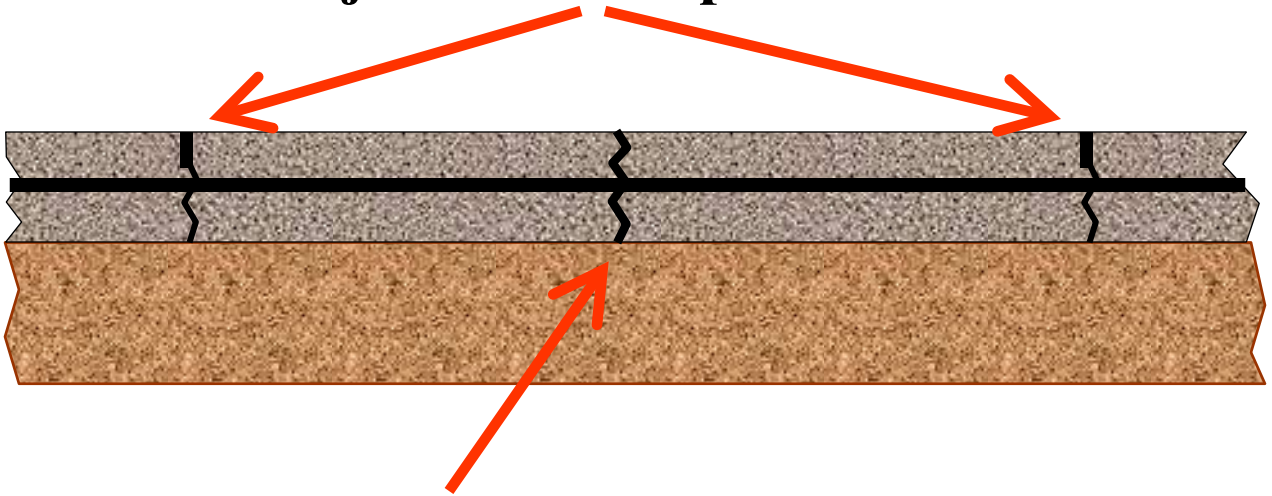
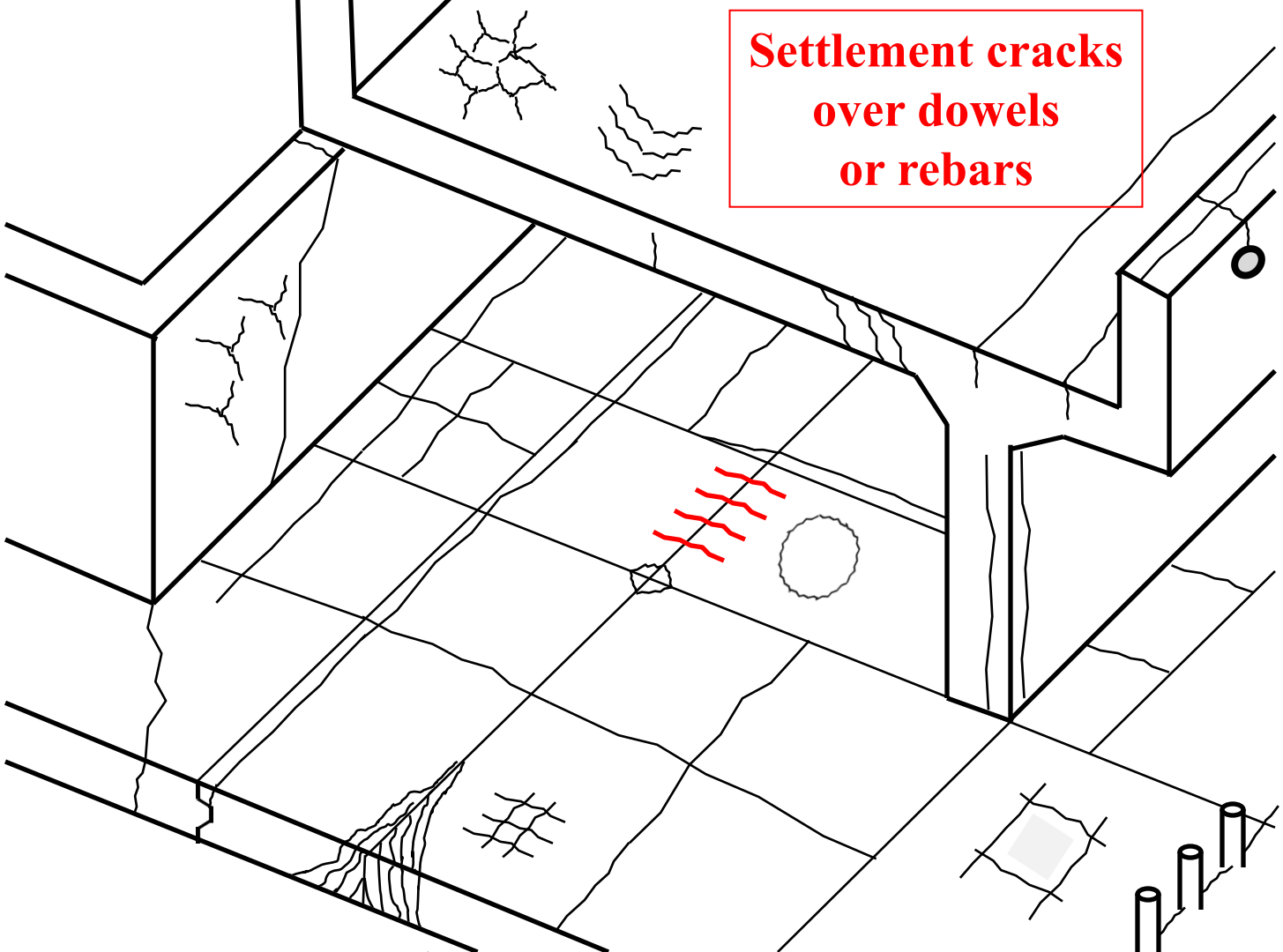

Restraint - like
rebars through
joints or turndowns

If the rebars run through the sawcut joints, the joints can't open as much



and mid-panel cracks are likely to occur.


Settlement cracks
over dowels
or rebars

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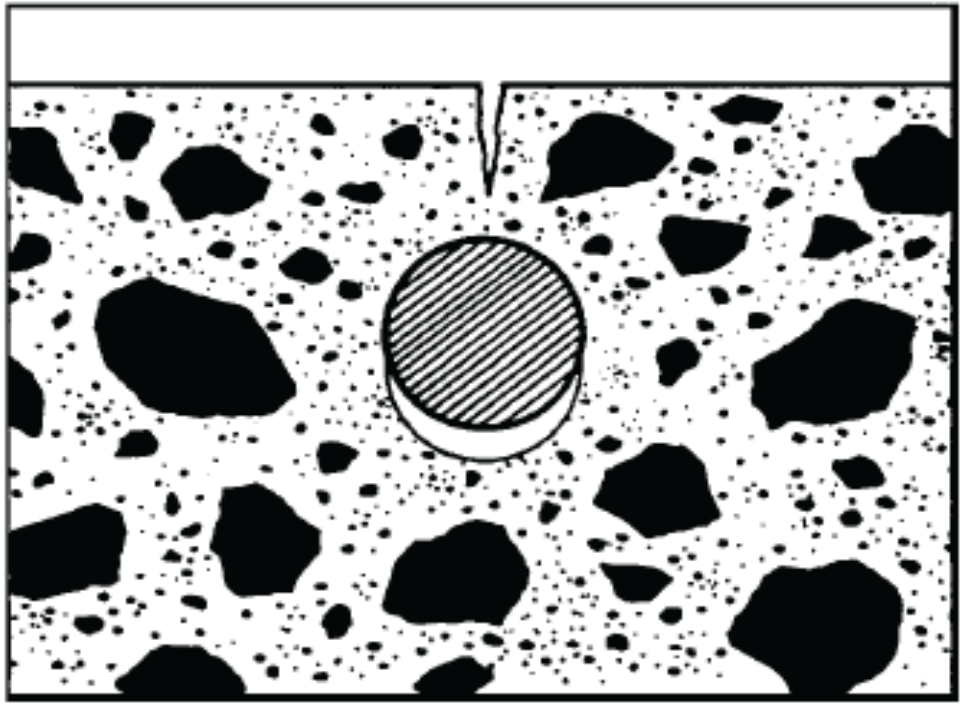


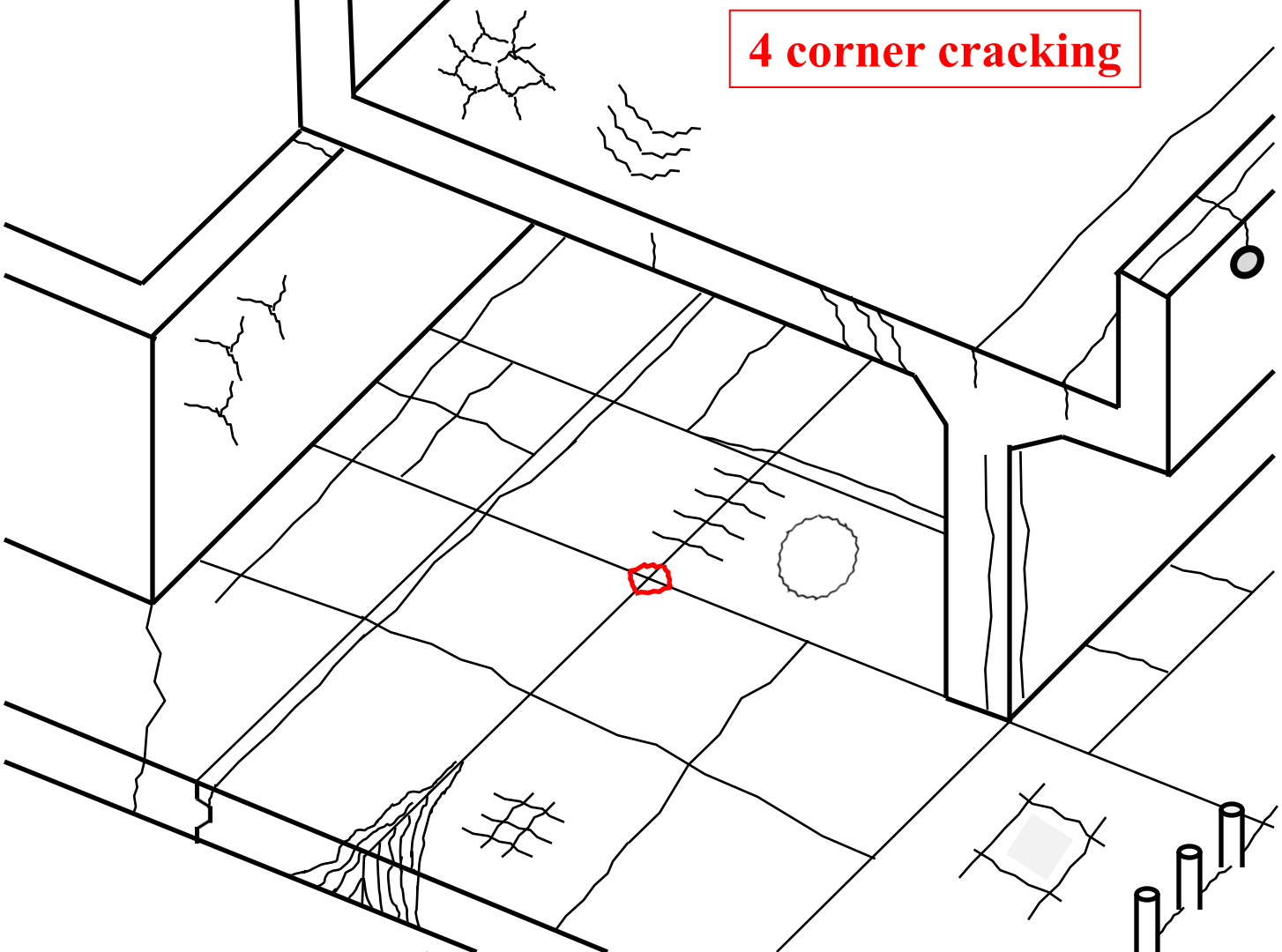
Fig. 1.2—Crack formed due to obstructed settlement (Price 1982).

CAUSES:

- **Bigger Bars**
- **Less Cover**
- **Insufficient Vibration**
- **Leaking or Highly Flexible Forms**

PREVENTION:

- **Address those Causes**
- **Use Macro Fibers not Rebars**


4 corner cracking

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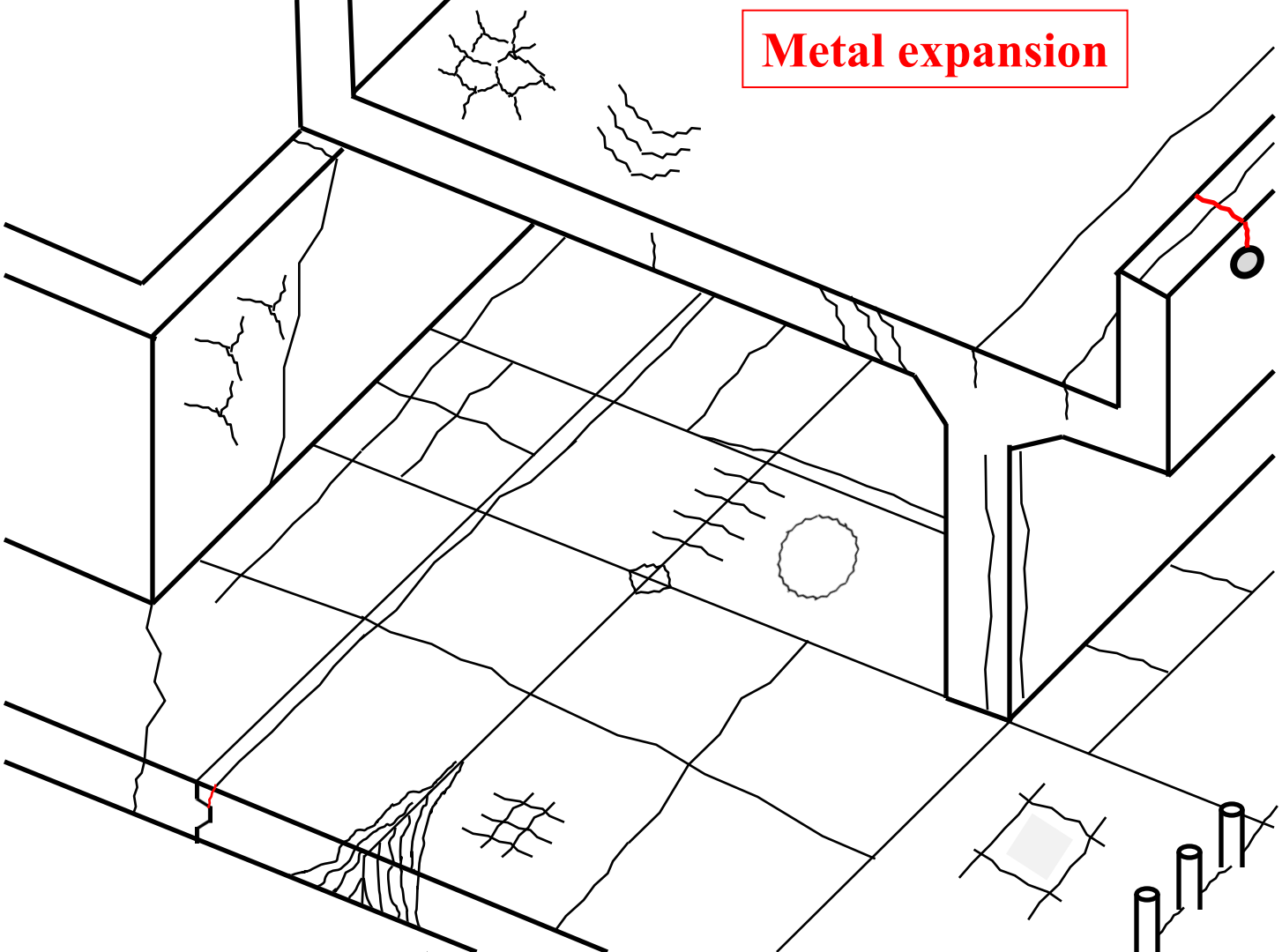
Prevention includes specifying concrete with reduced shrinkage, cracking, and curling.

Better curing.


Metal expansion

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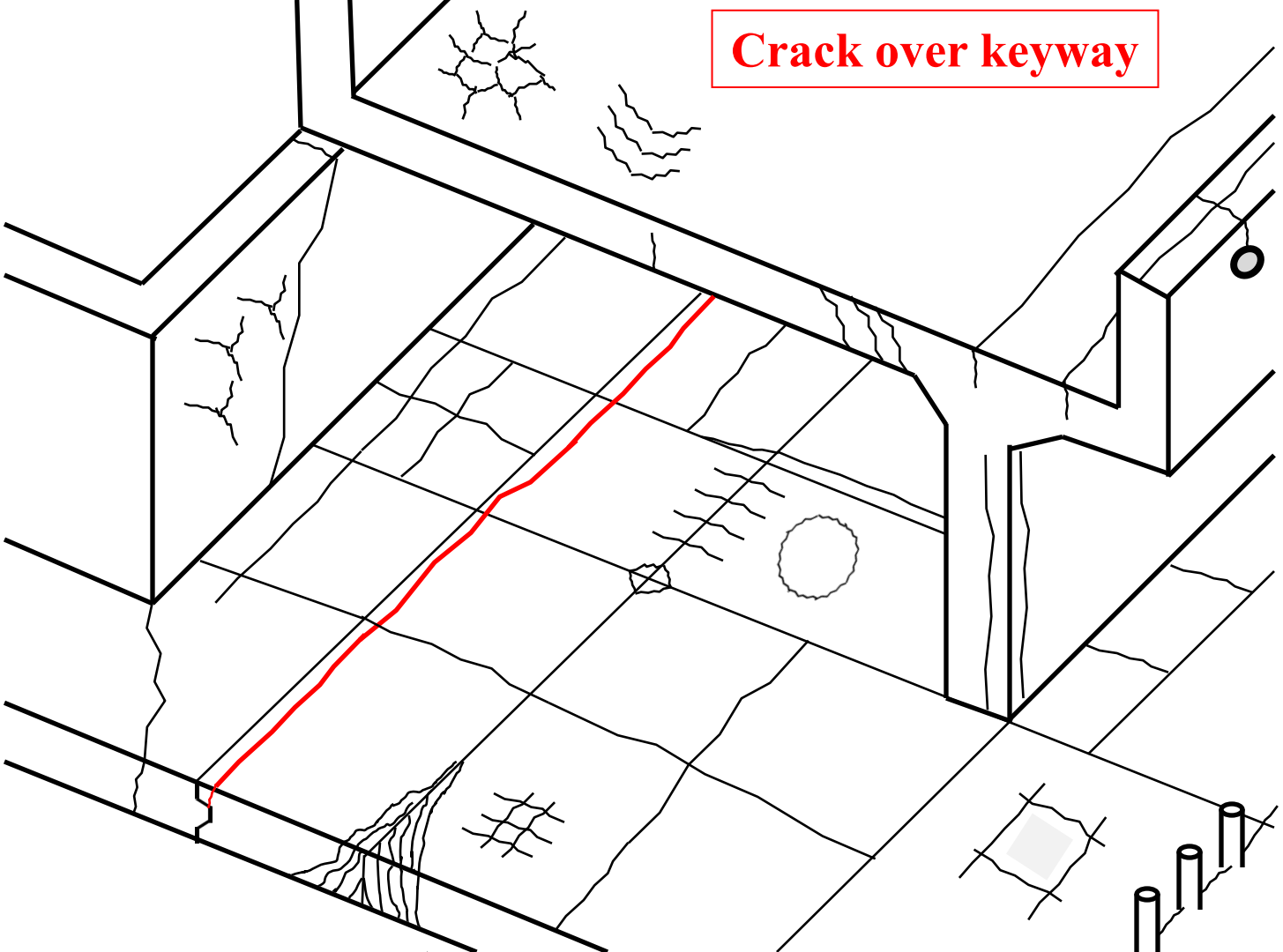
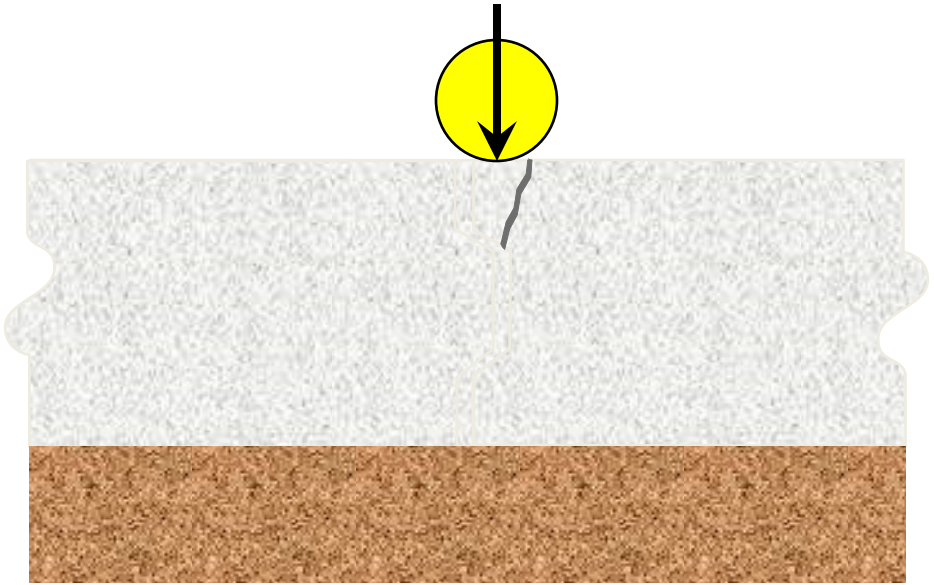
Repair the concrete leaving space for the steel tube to expand.


Crack over keyway

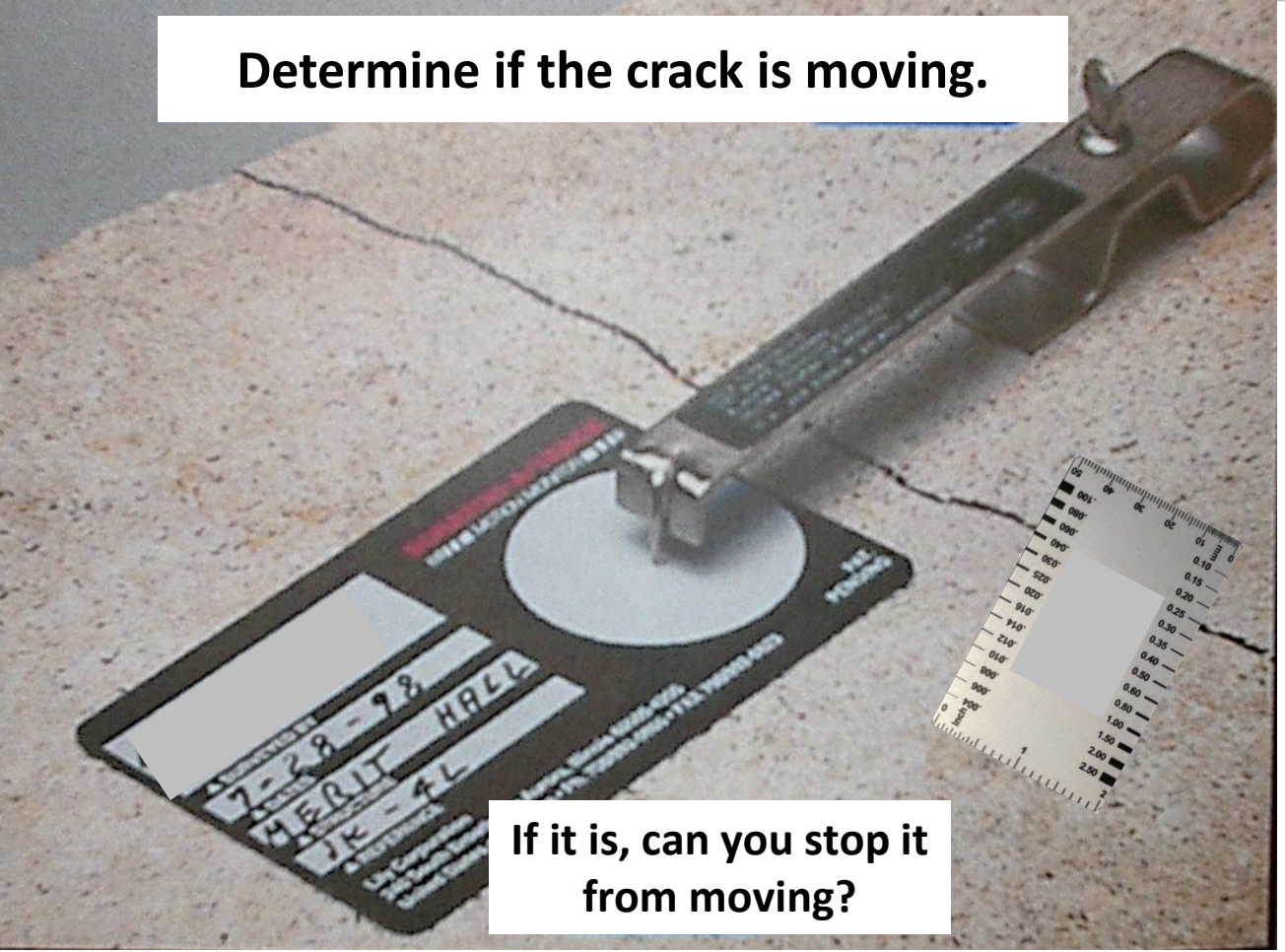
Broken Key Joint



Not for exposed wheel traffic

HOW TO REPAIR CRACKS

Determine if the crack is moving.



If it is, can you stop it from moving?

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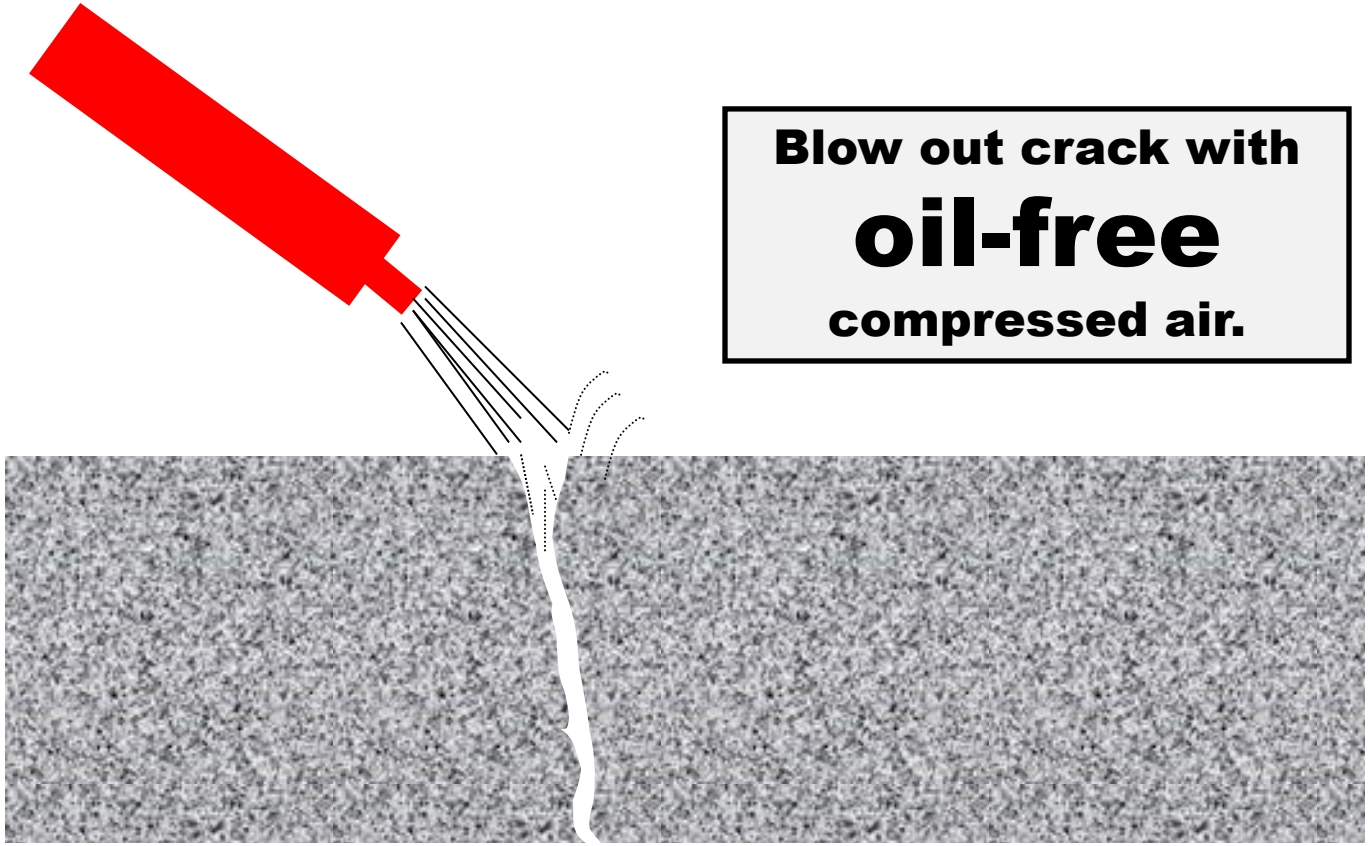

Blow out crack with

oil-free

compressed air.

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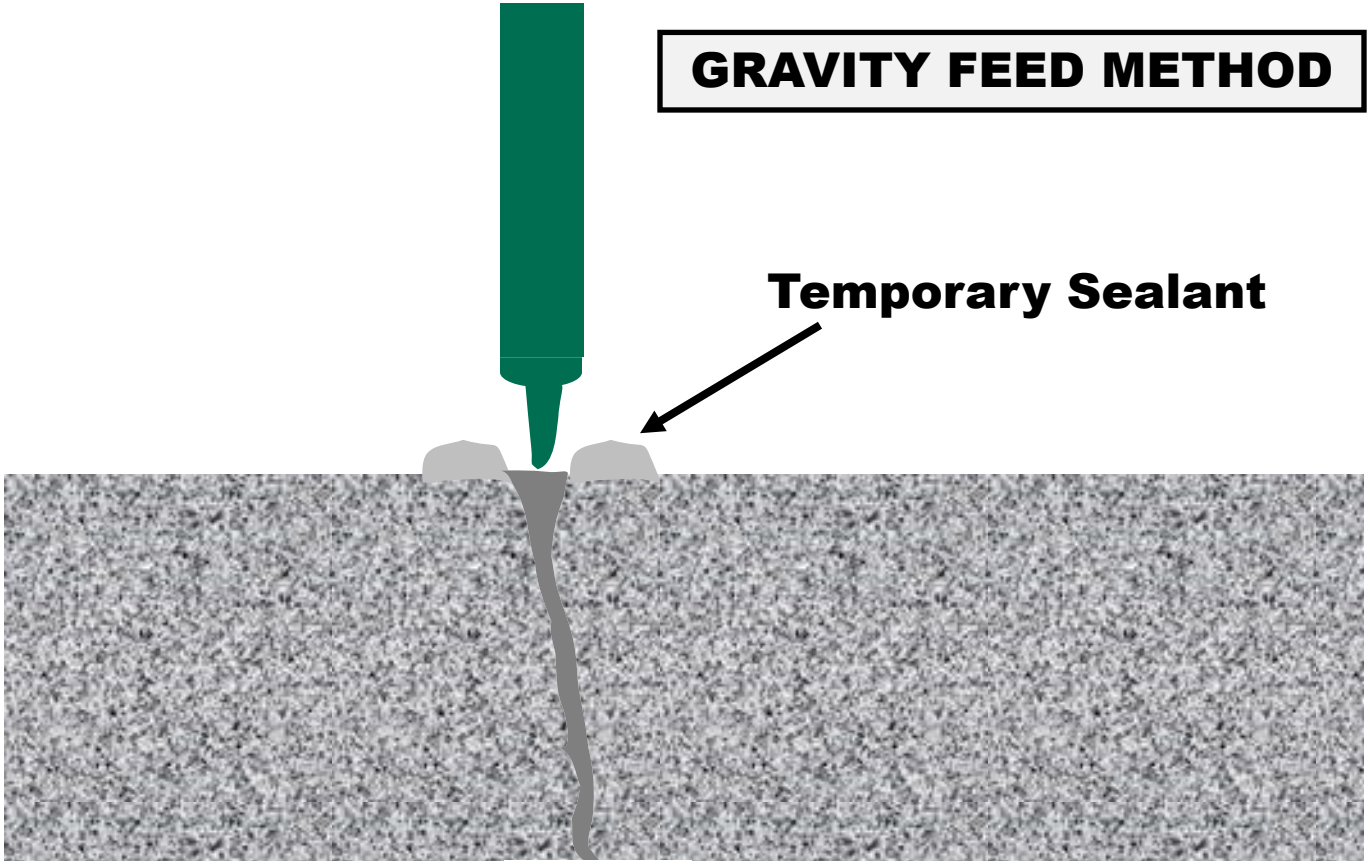
GRAVITY FEED METHOD



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STRUCTURAL

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Epoxy Crack Injection

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HEALER SEALER

The Grand Ronde River Bridge, Oregon

HEALER Increases:
- Abrasion Resistance

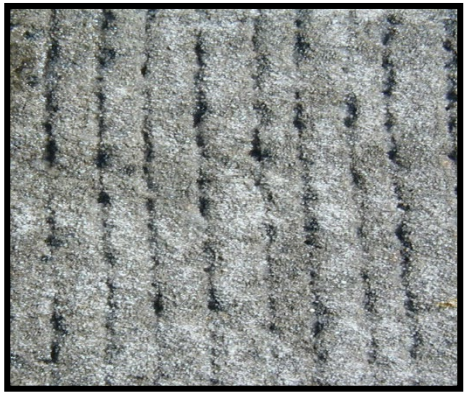
SEALER Decreases:
- Penetration of Liquids
- Carbonation

Pre-treat larger cracks if necessary

Flood surface with properly mixed epoxy

Use rollers or squeegees to distribute

Remove excess epoxy and immediately apply fine sand into the wet epoxy



When cured, remove excess sand and open to traffic

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Aesthetic crack, gouge and small spall repairs

CRACKS WITH FLOWING WATER

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Two More Crack Repair Techniques

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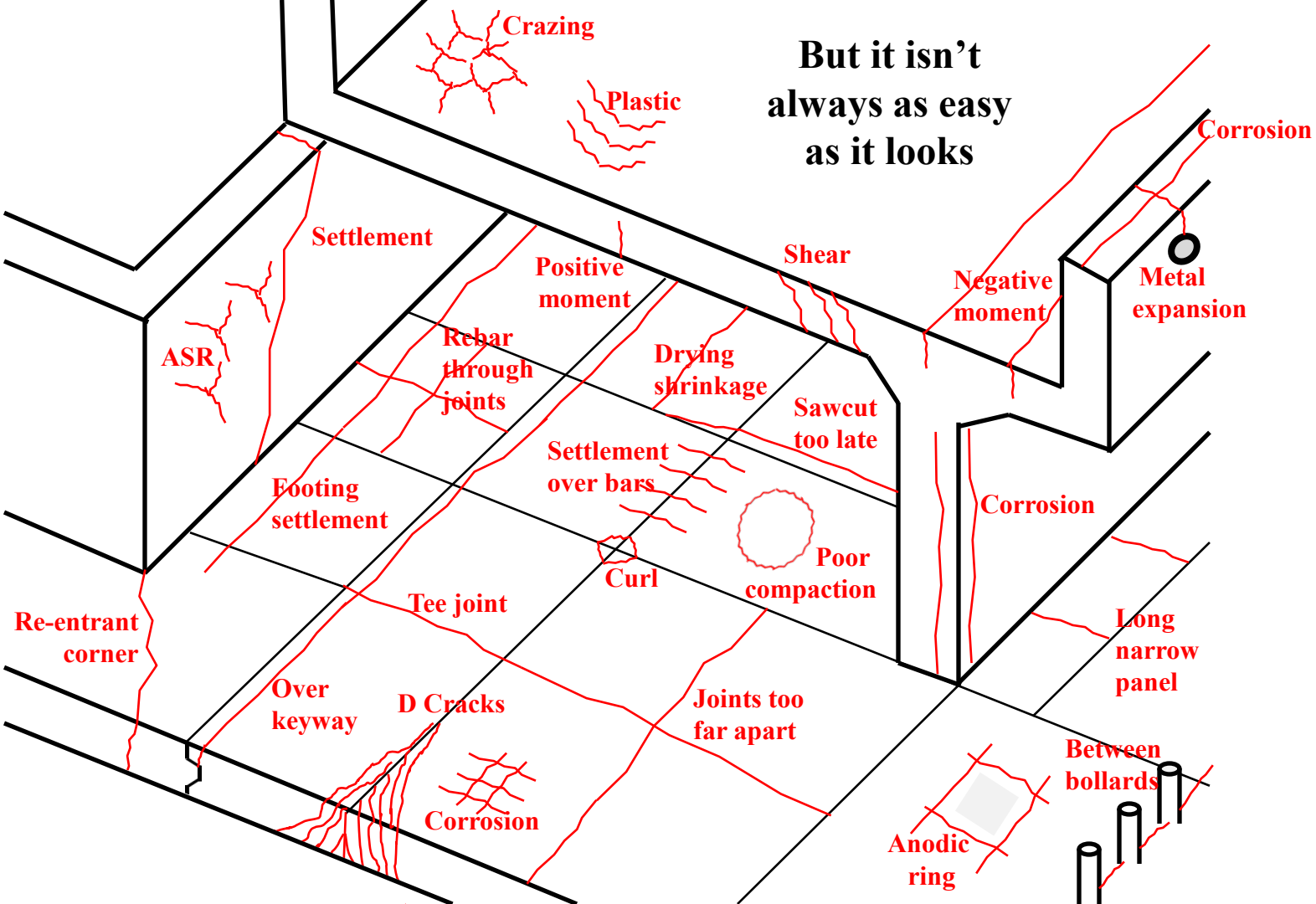
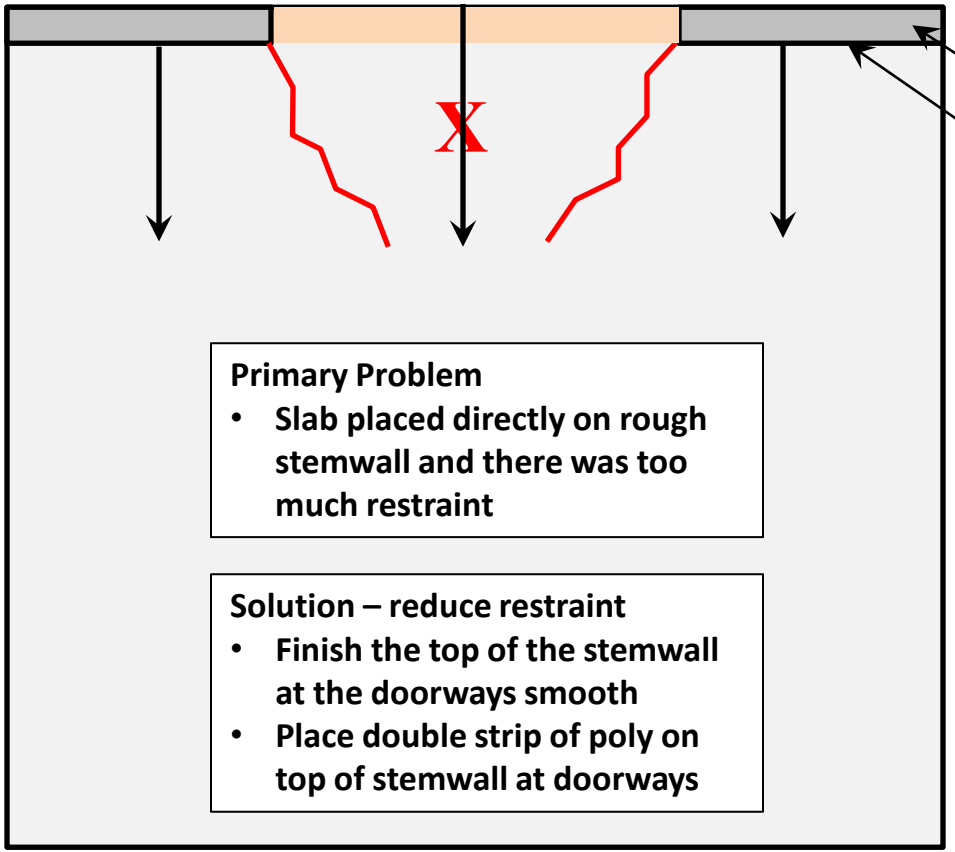

But it isn't always as easy as it looks
Crazing
Plastic
Corrosion
Settlement
Positive moment
Shear
Negative moment
Metal expansion
ASR
Rebar through joints
Drying shrinkage
Sawcut too late
Settlement over bars
Footing settlement
Corrosion
Poor compaction
Curl
Tee joint
Re-entrant corner
Long narrow panel
Over keyway
D Cracks
Joints too far apart
Between bollards
Corrosion
Anodic ring

Warehouses with many overhead doors



CMU wall

Foam expansion joint

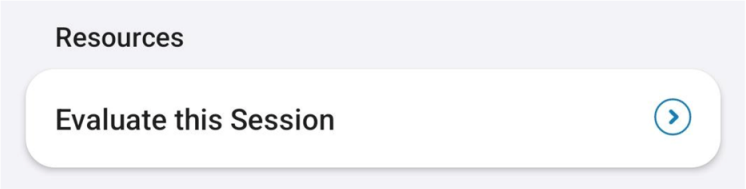
Primary Problem

- Slab placed directly on rough stemwall and there was too much restraint

Solution – reduce restraint

- Finish the top of the stemwall at the doorways smooth
- Place double strip of poly on top of stemwall at doorways

SESSION EVALUATION



To complete the session evaluation, open the ICRI Convention App.

Under **Plan Your Event,** select Schedule, and then the Technical Session you are attending. Select the sub-session you are attending, scroll down to Resources, and select Evaluate this Session.

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EUCLID CHEMICAL

THANK YOU

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CONCRETE CRACKS: THEY AREN'T ALL THE SAME

- How to Identify Them
- What Caused Them
- How to Prevent Them
- How to Repair Them

ICRI Committee 320
Today at 10

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QUESTIONS?

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