Eurocode 2 – Design of Concrete Structures – Part 3 : Liquid retaining and containment structures

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Introduction

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Summary

Introduction

Project Team

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Task to Convert part 4 of the ENV to part 3 of EN1992.

Why do we have part 3?

- **Very few specific items**
- **Some manipulation of part 1 equations**
- **Some other rules that more correctly belong in part 1.**
- **Aim for next version to be included in part 1**

Scope of EN1992-3

- Additional rules for …… the containment of liquids or granular solids
- Only for those parts that directly support the stored materials
- Stored materials at -40°C to +200°C
- “clauses covering liquid tightness may also be relevant to other types of structure”

Excludes

- Storage of materials at very high or low temperatures.
- Storage of materials leakage of which would constitute a major health risk.
- Pressurised vessels
- Floating structures
- Large dams
- Gas tightness

Changes to Part 1

- Background to why changes to part 1 are required
- Some background to their basis.

Basic Design Variables

Special design situations

- Operating conditions
- Explosions
- Temperature of Stored materials
- Testing

- Reference to EN1991-4 for Actions

Materials

Concrete

- **Effect of temperature on Material Properties (including creep) – Annex K**
- **Thermal Coefficient of Expansion – warning on variability.**

Reinforcement

- **Reference to EN1992-1-2 for temperatures >100°C**

Durability

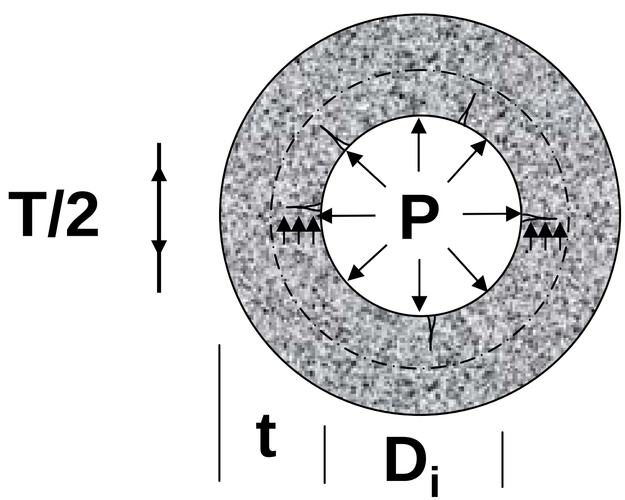
Abrasion due to:

- Mechanical Attack
- Physical Attack
- Chemical Attack

Analysis

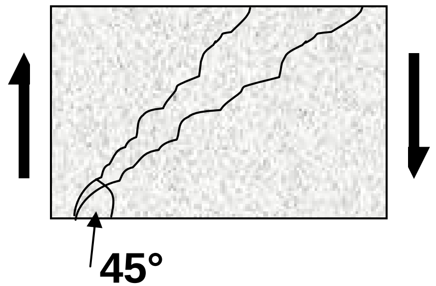
- **Consideration of temperature effects (gradients)**
- **Consideration of internal pressures**
  - Solids at the surface
  - Liquids at the centre line

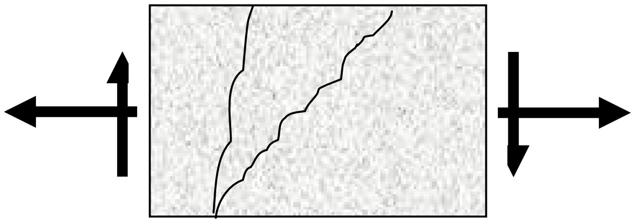
$$T=P(D_i+t)$$



Ultimate Limit State

Shear under tension – Cot θ conservatively limited to 1.0





Note EN1992-1 limit of Cot θ for tension flanges = 1.25 – could have been a general rule

Design for dust explosion

Basic guidance given in EN 1991-4 and EN 1991-1-7

But TG thought that more helpful information should be provided:

- Venting and protection of surroundings
- Actions considered acidental
- Combination with other actions (part filled bins)
- Need for specialist assistance

Serviceability

Table 7.105 — Classification of tightness

Tightness Class	Requirements for leakage
0	Some degree of leakage acceptable, or leakage of liquids irrelevant.
1	Leakage to be limited to a small amount. Some surface staining or damp patches acceptable.
2	Leakage to be minimal. Appearance not to be impaired by staining.
3	No leakage permitted

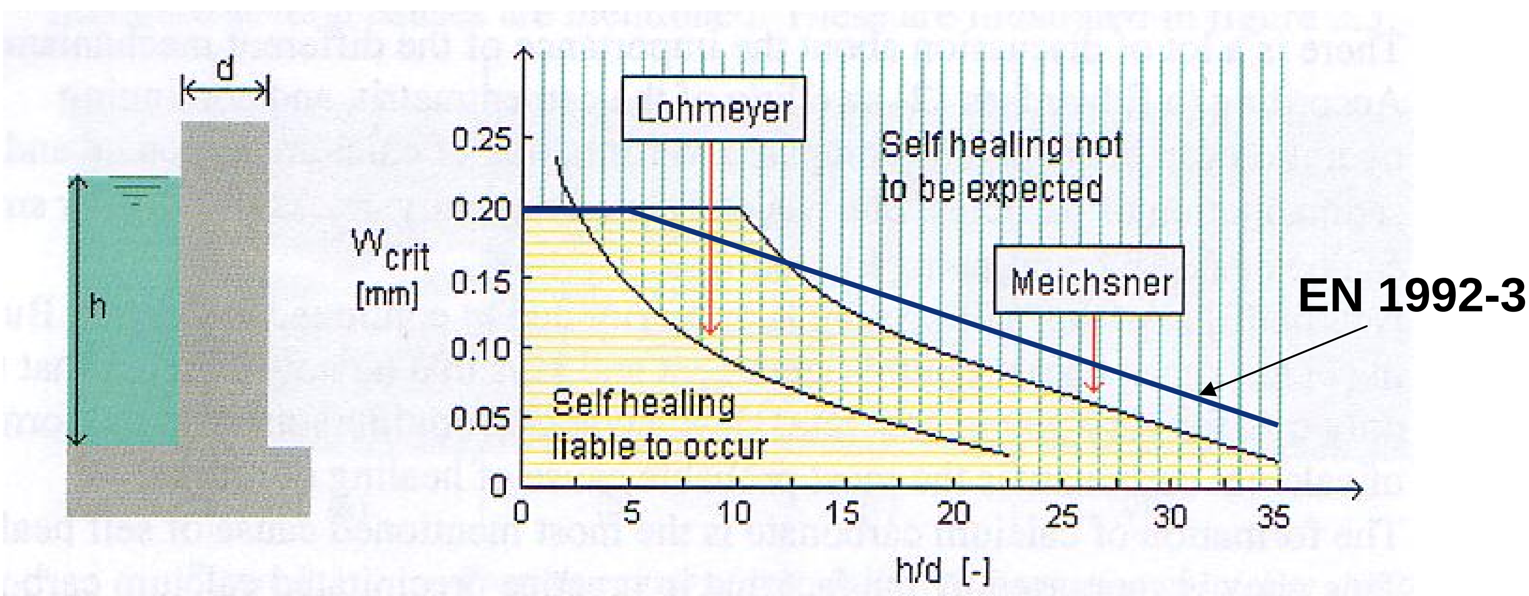
Tightness Class 0. — the provisions in 7.3.1 of EN 1992-1-1 may be adopted.

Tightness Class 1. — any cracks which can be expected to pass through the full thickness of the section should be limited to w_{k1}. The provisions in 7.3.1 of EN 1992-1-1 apply where the full thickness of the section is not cracked and where the conditions in (112) and (113) below are fulfilled.

Tightness Class 2. — cracks which may be expected to pass through the full thickness of the section should generally be avoided unless appropriate measures (e.g. liners or water bars) have been incorporated.

Tightness Class 3. — generally, special measures (e.g. liners or prestress) will be required to ensure watertightness.

Tightness Class 1 – Through Cracking



Original Diagram from Walraven

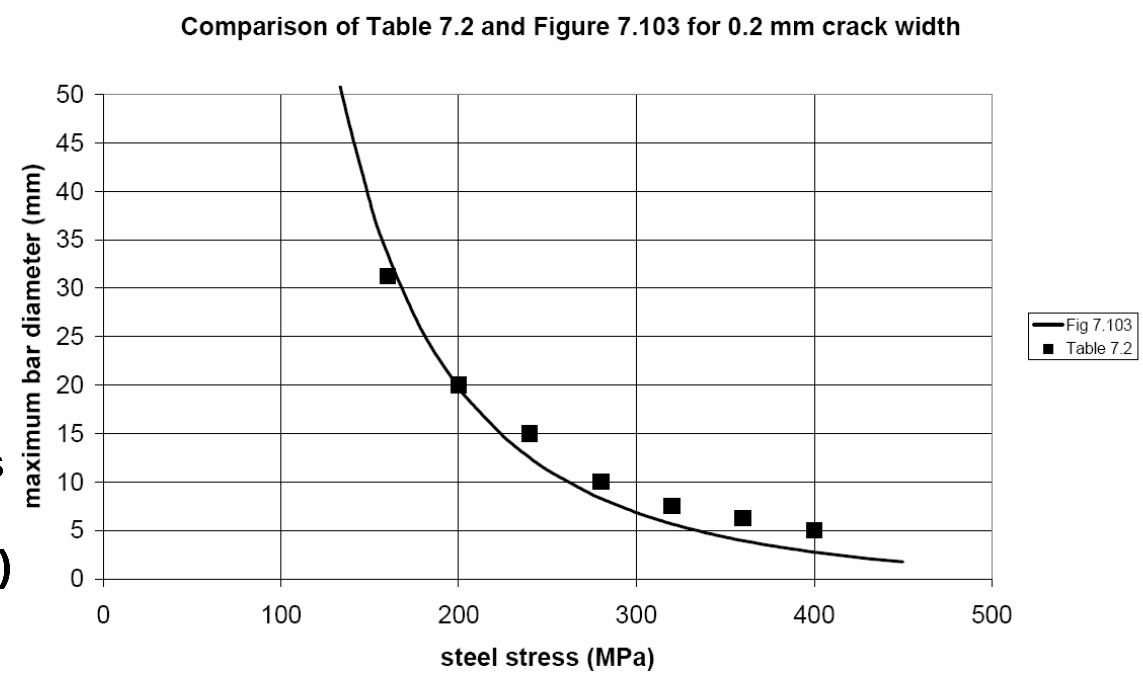
– Cracks may be expected to heal when range of strain under service conditions is less than 150×10^{-6}

Tightness Class 2

Minimum depth of compression zone (or section that remains in compression lesser of 50mm or 0.2h under quasi permanent loads

Control of cracking without direct calculation

Revised figures for maximum bar spacing/bar stress given – These are as Part 1 except for Tension rather than Flexure



[Note: This also means the bar diameter modification (exp 7.7N) is modified slightly]

Calculation of crack width – refer to Annexes L and M

Minimising cracking due to restraint

- Limit temperature rise
- Reduce restraints
- Use concrete with low thermal expansion
- Use concrete with high tensile strain capacity
- Apply prestress.

Detailing

Guidance on:

- Postensioning of circular tanks
- Minimum wall thicknesses in prestressed tanks
- Temperature effects on unbonded tendons
- Opening moments in the corners of tanks
- Provision of movement joints.

Annexes (all informative)

Annex K – Effect of temperature on the properties of concrete

Annex L – Calculation of strians and stresses in concrete sections subjected to restrained imposed deformations

Annex M – Calculation of crack widths due to restraint of imposed deformations

Annex N – Provision of movement joints

Annex K – Effect of temperature in the properties of concrete.

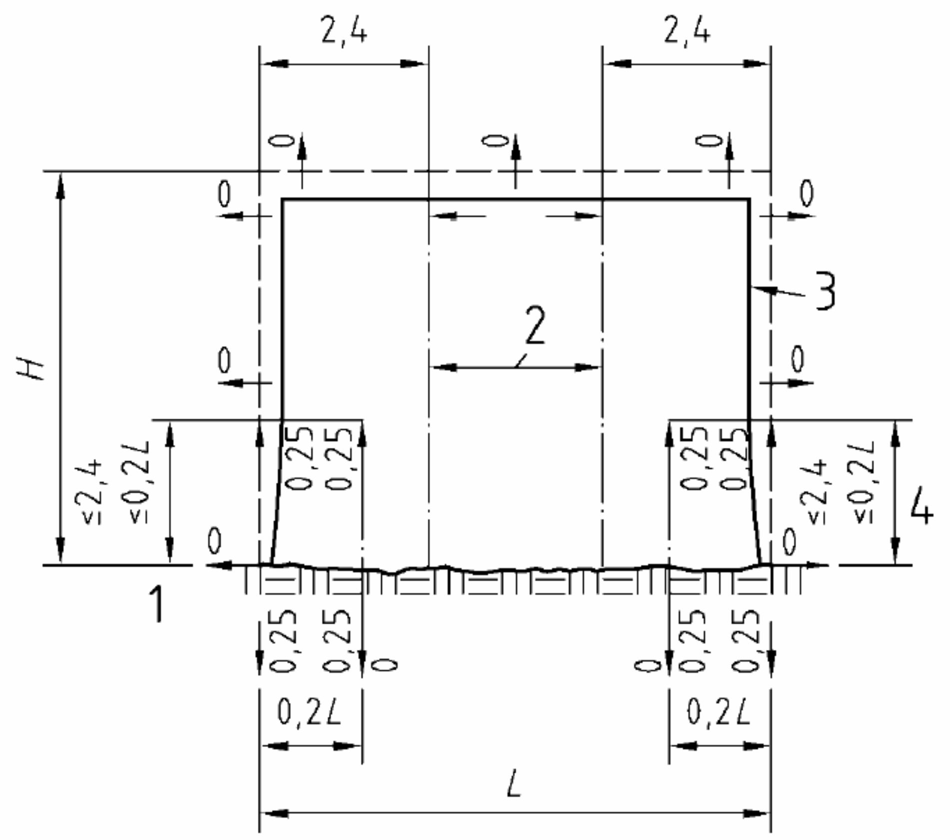
- Material enhancements given for sub zero temperatures – not always conservative to ignore.
- For elevated temperatures reference to fire part, to avoid duplication.
- Methods presented to calculate increased creep (and transitional thermal strain) and reduced elastic modulus.

Annex L – Calculation of the strains and stresses in concrete sections subjected to restrained imposed deformations

Actual strain $\varepsilon_{az} = (1-R_{ax})\varepsilon_{i_{av}}$

Stress in concrete $\sigma_z = E_{c,eff}\,(\varepsilon_{i_{av}} - \varepsilon_{az})$

Restraint Factor

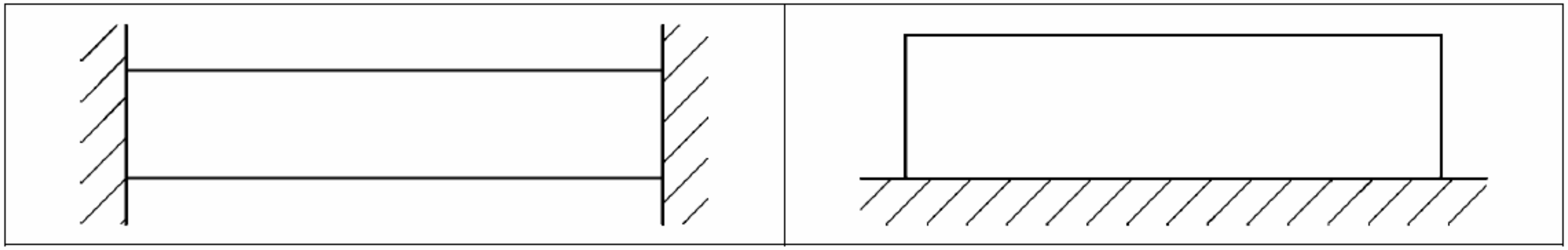


(a) Wall on base

Restraint Factor

Annex M – Calculation of crack widths due to restraint of imposed deformations

Two case considered:

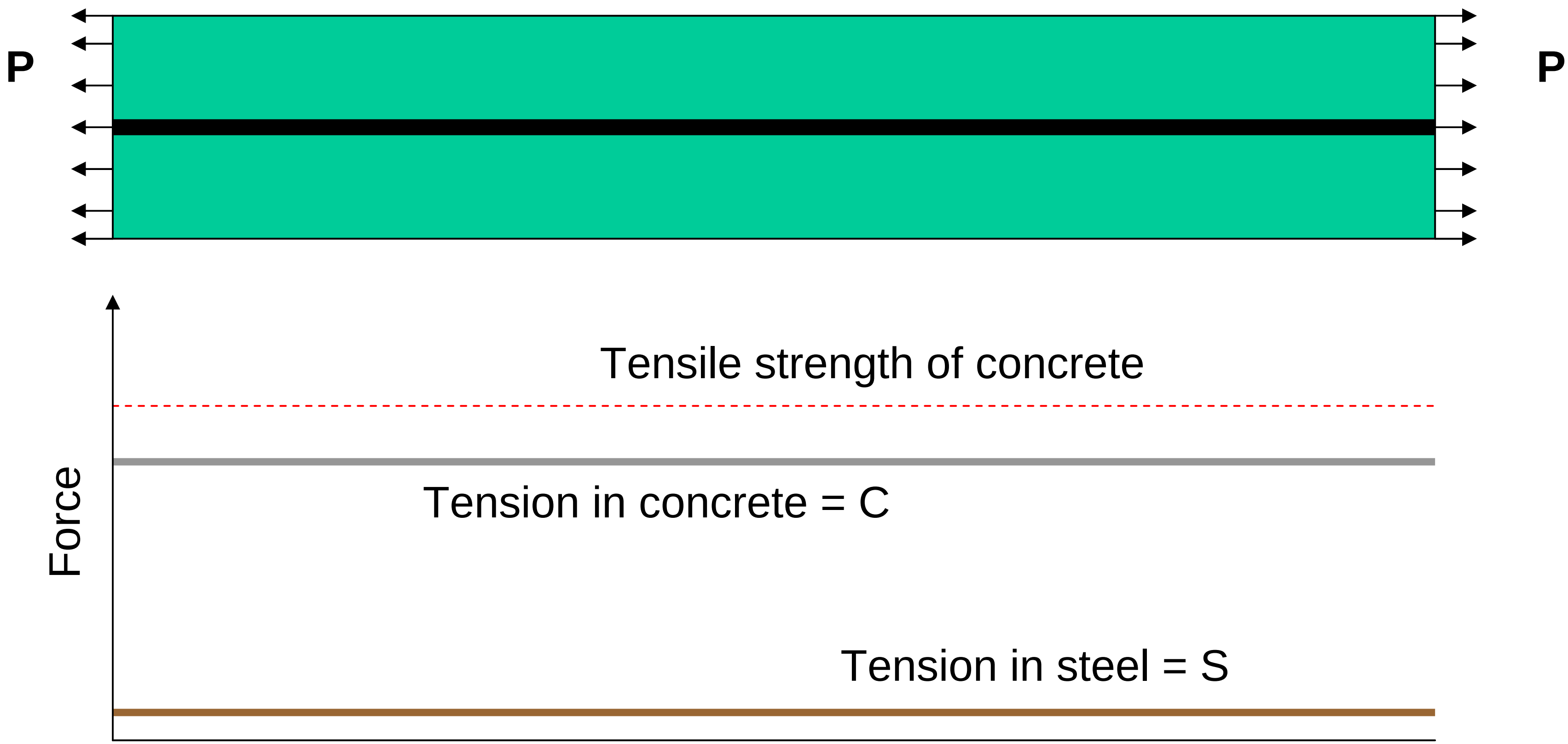


(a) restraint of a member at its ends

(b) restraint along one edge

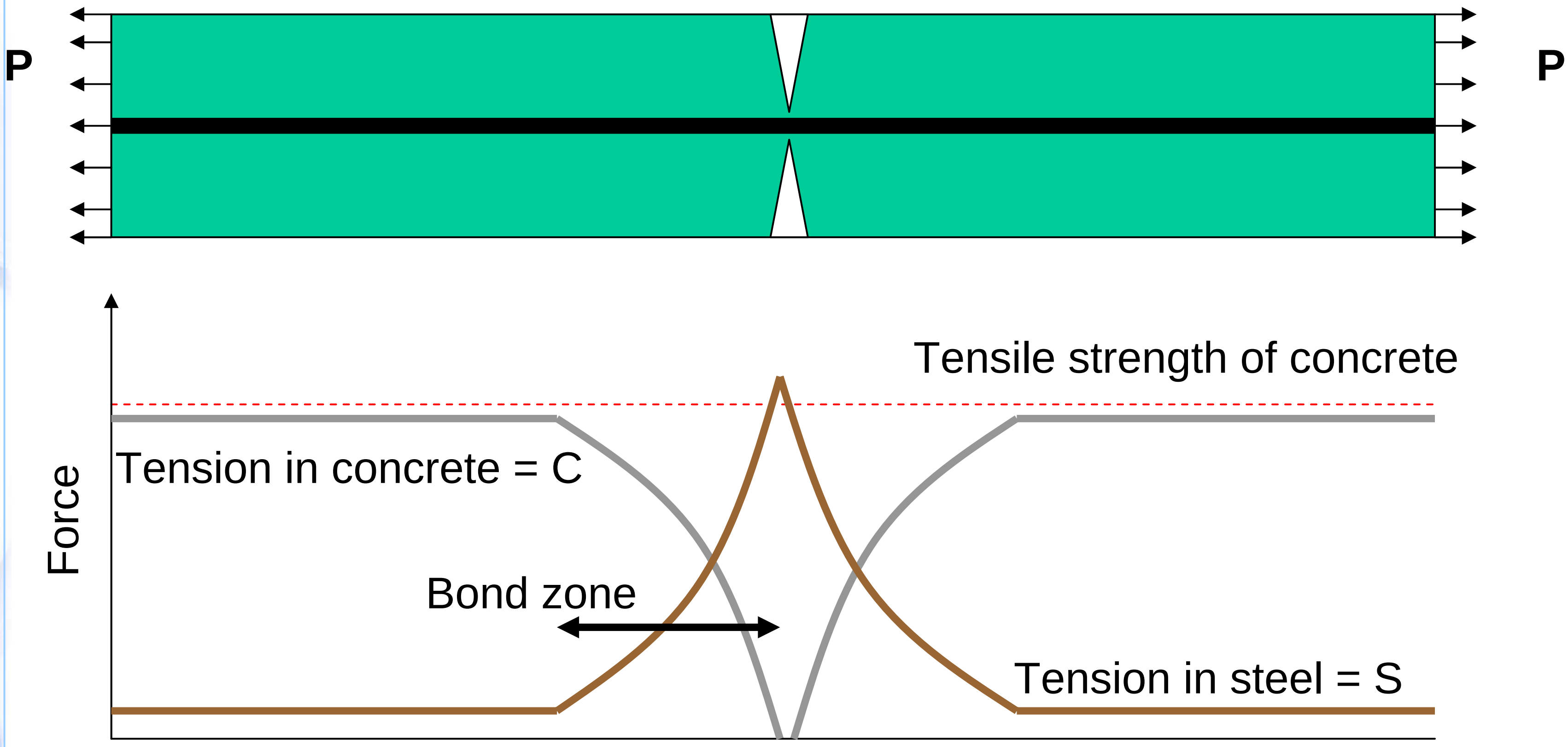
Figure M.1 — Types of restraint to walls

End Restraint



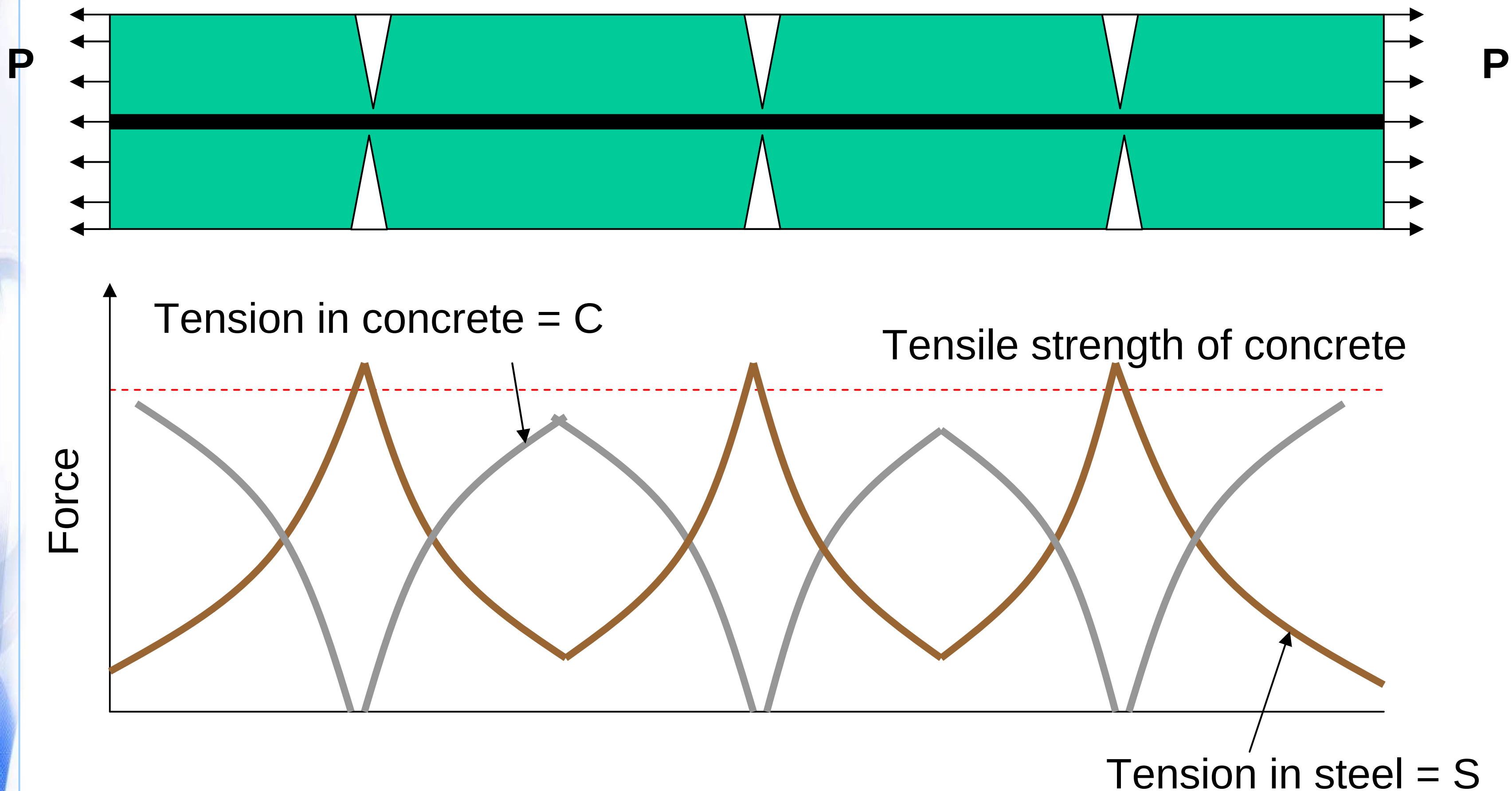
At any point along the element force = P = C+S

End Restraint



At any point along the element force = P = C+S

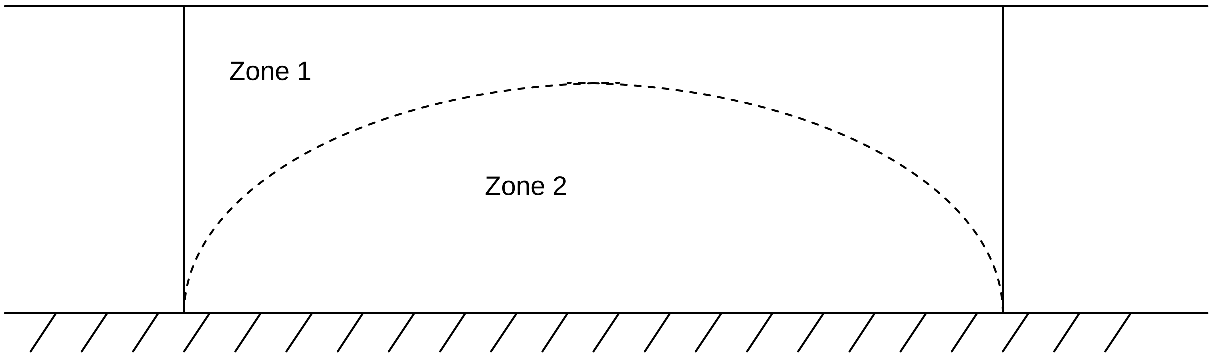
End Restraint



At any point along the element force = P = C+S

$$\varepsilon_{sm}-\varepsilon_{cm}=0{,}5\alpha_e k_c k f_{ct,eff}(1+1/(\alpha_e\rho))/E_s$$

Edge Restraint



Zone 1 end restraint
Zone 2 edge restraint

Edge Restraint

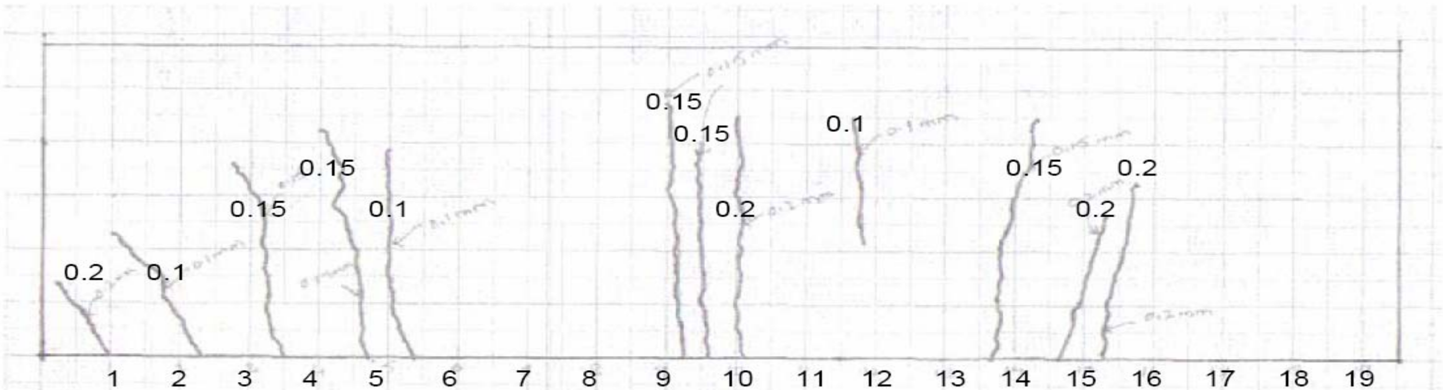


Figure 2 *Crack pattern observed in a 19.5m long wall*

From Bamforth

$$\varepsilon_{sm} - \varepsilon_{cm} = R_{ax}\,\varepsilon_{free}$$

Annex N – Provision of Movement Joints

Table N.1 — Design of joints for the control of cracking

Option	Method of control	Movement joint spacing	Reinforcement
(a)	continuous – full restraint	Generally no joints, though some widely spaced joints may be desirable where a substantial imposed deformation (temperature or shrinkage) is expected.	Reinforcement in accordance with Chapters 6 and 7.3
(b)	Close movement joints – minimum restraint	Complete joints at greater of 5 m or 1.5 times wall height	Reinforcement in accordance with Chapter 6 but not less than minimum given in 9.6.2 to 9.6.4.

National Choices

- Definition of w_{k1} (crack width limit for tightness class 1 structures)
- X_{min} depth of section to remain in compression for tightness class 2 structures
- κ maximum duct size related to wall thikness
- t_1 and t_2 minimum wall thicknesses for class 0 and class 1 or 2 structures respectively.

Summary

- Relatively short document
- Most of what is in the main code could be handled in Part 1
- There is useful information in the Annexes which are all informative to allow local interpretation as appropriate.