Restrained Shrinkage Ring Beam Testing for Concrete

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Shrinkage testing

Conventional AS1012 unrestrained shrinkage:

- A poor representation of restrained structures
- Tensile creep plays no role in early-age shrinkage in the concrete
- No restraint means no cracking
- There is no indication of strength of concrete at cracking or strain capacity before cracking
Engineers have known for a long time that behaviour of unrestrained beamlets has little relationship to behaviour of real structures.

Dog-bone shaped tension members have been tried as restrained representations of concrete structures, but are too complex in terms of restraint requirements.

Plates with crack-inducing risers (eg. ASTM C1579) have been used for shotcrete and repair mortars, but are impractical for larger applications involving 20 mm aggregate.

Ring beam was developed in 1980s at North Western University in USA and immediately offered researchers multiple advantages.
A concrete ring encases a steel annulus that is instrumented to record strains which can be used to calculate both the strain at cracking and the strength of the concrete upon cracking (when elastic modulus is known).
Principal of Restrained Ring

- Initial ring beams were small (Ø300mm) and sealed on the flat faces so that evaporation occurred from the curved side (ASTM C1581).

- Prof. J. Weiss developed an alternative version in which the curved side was sealed and evaporation occurred from the flat faces.

- This version is a much better representation of evaporation and shrinkage in slabs.

- The thickness, diameter, and composition of the metal annulus determines the Degree of Restraint (DOR) to the concrete.
TSE Ring Beam Test

The apparatus at TSE is the largest in the world

- Size matters, because size effects are important when concrete with 20 mm aggregate and fibres are used.

- 200×200 mm ring cross-section and 1600 mm diameter provides a good representation of shrinkage behaviour in real pavements and ground slabs (linear length = 4400 mm).

- ‘Real’ concrete can be used without modification.
Rings with ASTM C-1581 dimensions have been extensively analysed, and most conclusions are equally relevant to larger rings.
A steel annulus is a good representation of the centre of a square slab since both act to restrain the concrete surrounding the centre. Changing the thickness of the annulus permits control of the Degree of Restraint.
Rings experience shrinkage relatively uniformly, but there is always a weaker region of the ring that cracks first. The large size of the rings at TSE means that apparent strength of the concrete is realistic.
Control of Cracking in Ring

\[ \Phi(t) = \frac{E_C(t)}{E_s} \left( \frac{(1 + \nu_S)R_{IS}^2 + (1 - \nu_S)R_{OS}^2}{(R_{OS}^2 - R_{IS}^2)} \right) + \left( \frac{(1 - \nu_C)R_{OS}^2 + (1 + \nu_C)R_{OC}^2}{(R_{OC}^2 - R_{OS}^2)} \right) \]

- The Degree of Restraint plays an important role in controlling the resistance to shrinkage, and thus the creep exhibited by the concrete and the time to cracking.

- The DOR is typically in the range 50-80%.
Previous work with small ASTM C1581 ring beams for repair applications has shown that fibres influence the age at cracking and the width of cracks that occur once a crack is initiated.
Current work with large 1600 mm diameter ring beams for FRC slab on ground applications has shown that large fibres do not influence the age at cracking or the strain at cracking, but strength of concrete does.
However, fibres have a significant influence on the development of crack width in the ring once the ring has cracked. Macro-synthetic fibres and steel fibres have a similar beneficial effect on restraining crack growth.
Potential Applications for Ring Beams

- Ring beams provide a much more realistic representation of shrinkage in slabs than beamlets,
- They permit engineers to study the effect of numerous parameters on shrinkage and cracking in a manner that is more closely related to behaviour in the field,
- The effect of mix design, admixtures, reinforcement configuration, curing regime, and DOR can all be examined realistically and in a controlled and reproducible environment,
- The strain at cracking and crack width growth can both be measured, this cannot be done using other test procedures.
Summary

- Ring Beams represent an exciting new means of studying restrained shrinkage behaviour in concrete,

- Ring beams at TSE are large enough to realistically represent concrete used in slabs on ground and pavements

- Ring beams can be used to study the effects of mix design, reinforcement, admixtures and other parameters on the time to cracking, strength at cracking, and crack width growth after cracking.