Analysis and Design Issues in Liquid-Containing Concrete Structures

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Steven R. Close has 40 years experience designing both post-tensioned and conventionally reinforced water containment and treatment structures of all shapes and sizes. His designs are located all over the US, Canada, the Caribbean, as well as Asia, and the Middle East. He was a long-time Principle of Jorgensen & Close Associates, and now is with minority-owned WHPacific.

Proposed Changes to Shrinkage and Temperature Reinforcement Requirements in ACI 350

Steven R. Close, PE

Toronto, Fall 2012 ACI Convention
Or is the Solution New Thinking on Shrinkage and Temperature Reinforcement for Environmental Structures (ACI 350)?

This Thinking is Not New
- It's been a part of 350 documents since the mid 1990s (350.2R-95 Hazardous Materials)

This is Not New
- Has not been introduced because of the “rules”
- For developing the original C&C 350-01
  - Must reflect 350R-89
- And the first revision, 350-06
  - No new business – catch up to 318 only

Where Does This “New Thinking” Come From?
- Field Observations
  - Vertical wall cracks much closer than the presently indicated “distances between movement dissipating joints” (30, 40 and 50 ft)

This is Not New
- 350 C (Reinforcement) has been working on this since before 2006
- Balloted by Main Committee in 2009

Where Does This “New Thinking” Come From?
- Field Observations
  - Cracks in “checkerboard” placed SOGs
Field Observations

"Corner cracks" in suspended slabs

Field Observations

Cracks ending at construction joints

Field Observations

No cracks in walls to be prestressed, even after months until application of horizontal or circumferential prestressing

Research

Dr. Reza Kianoush
Shrinkage Cracks can’t be prevented in all cases, but they may be able to be “controlled” to where we have a larger number of cracks small enough to not seep (0.1mm).

Tie reinforcement levels to “amount of restraint”
Not distances between movement joints (except 20 ft and under).

“Reduced Restraint”
* For vertical wall reinforcement (except near Construction Joints)
* Where measures are taken to reduce restraint of shrinkage and temperature shortening

“Maximum Restraint”
* Where shrinkage and temperature shortening is prevented by ties to previously placed concrete
**What is the New Thinking?**

“Normal Restraint”
- Anywhere not defined as “Reduced” or “Maximum” Restraint
  - Slabs on soil away from construction joints
  - Horizontal reinforcement in walls, away from bottom construction joints

**What Are The New Amounts?**

Similar to the prior amounts, “depending”...

**What Are The New Amounts?**

Normal Restraint
- Designed around 0.42%
  - #5s at 12 inches o.c. each face in a 12-in. section
  - 15mm bars at 300mm o.c. each face in a 300mm section

Maximum Restraint
- Double the “Normal Restraint” values

**What Are The New Amounts?**

Reduced restraint
- Starting at 0.28%
  - #4s at 12 inches o.c. in a 4-inch slab
  - 13mm bars at 300mm o.c. in a 100mm slab

**What Are The New Amounts?**

Varies with Bar Size
- Smaller bars closer together “control” crack widths better than the same percentage with bigger bars farther apart
Examples of the Varying Restraint Conditions in Everyday Construction

Restraining Slab Penetrations

NOTE: REINFORCEMENT SHOWN IN ONE DIRECTION ONLY FOR CLARITY.

VAULT, LARGE PIPE, OR OTHER RESTRAINING SLAB PENETRATION.
POTENTIAL CRACKS

ADDITIONAL S.A.F. REINFORCEMENT

SLAB-ON-SOIL

FIG. R12.13.2.4

Restraint areas in Walls

REINFORCEMENT BASED ON "NORMAL RESTRAINT" (CONTINUOUS THROUGH VERTICAL CONSTRUCTION JOINT)

REINFORCEMENT BASED ON "MAXIMUM RESTRAINT"

NOTES:
1. ONLY ONE LAYER OF REINFORCEMENT SHOWN FOR CLARITY.
2. MORE REINFORCEMENT THAN INDICATED MAY BE NEEDED FOR FLEXURE AND AXIAL TENSILE

FIG. R12.13.2.4(a)

Temporary Reduction of Restraint in Walls

PLASTIC LAYERS OR OTHER FRICION REDUCES MEASURES. NO DOWELS PASS THROUGH THIS JOINT.

"CURVES" OR OTHER STRUCTURAL CONNECTIONS PLACED AFTER THE PERIOD OF INITIAL SHRINKAGE

NOTE: THIS IS AN EXAMPLE OF ONE WAY TO TEMPORARILY REDUCE THE RESTRAINT WITH RESPECT TO HORIZONTAL (LATERAL), OR CIRCUMFERENTIAL RESTRAINT IN WALLS. WATERSTOP AND OTHER REINFORCEMENT ARE NOT SHOWN.

FIG. R12.13.2.4(b)

Typical Circular Floor Example

REINFORCEMENT FOR REDUCED OR NORMAL RESTRAINT (DEPENDING ON SEPARATION FROM SUBGRADE)

REINFORCEMENT FOR MAXIMUM RESTRAINT (TWO DIRECTIONS)

REINFORCEMENT FOR MAXIMUM RESTRAINT (ONE DIRECTION); REINFORCEMENT FOR REDUCED OF NORMAL RESTRAINT IN THE OTHER

FIG. R12.13.2.6(a)
Thank you for your attention!

Questions?

Discussion?