

Proportioning DCI[®] (and DCI S) Concrete Mixes

This technical bulletin includes mix design guidelines for concrete containing DCI[®] Corrosion Inhibitor. The information should be helpful when preparing for DCI concrete projects and making adjustments during construction.

A Special Note Regarding DCI S and Retarders as They Relate to this Technical Bulletin

DCI S is a corrosion inhibitor which is formulated for concreting situations where accelerated concrete set times are not required or desired. DCI S contains ingredients which provide it with essentially neutral setting characteristics. The dosage rate of DCI S is identical to DCI. The information in this technical bulletin applies equally to both products with the exception that DCI S will require much less retarding admixture to offset acceleration. This should be considered when using this technical bulletin to design concrete mixes containing DCI S.

Pre-Bid Information

Basic to planning any DCI concrete job are the project specifications and the construction requirements. Once these factors are established, a concrete mix should be designed and a test program initiated.

Typical specifications for a DCI project include the following:

- Maximum water/cement ratio 0.40
- Air content 7% + 1%
- DCI dosage rate 10 to 30 L/m³ (2 to 6 gal/yd³)
- Compressive strength at 28 days 31 MPa (4500 psi)

Construction requirements include:

- Slump and slump life
- Travel time to job site
- Early strength requirements (if any)
- Strength required at 28 days
- Methods of placing, finishing and curing
- Set time desired
- Expected weather conditions (temperature, humidity, wind, etc.)

Testing Program

Test the concrete before bidding when possible and always test before actual construction starts. Critical design factors to consider during testing include:

- Water requirement
- Cement content
- Superplasticizer dosage rate
- Retarder or water reducer dosage rate
- Air-entraining agent dosage rate

Water and Cement Requirements

Table 1 gives typical water contents and slumps for various water/cement ratios without adding water reducers. Testing is needed to determine the actual water required for any given set of materials.

Table 1: Cement and Water Required for Slump with DCI Corrosion Inhibitor

SI Units					US Units			
W/C	Cement, kg/m ³	Water, kg/m ³	Slump, mm	Slump, with 20 L/m ³ DCI*	Cement lbs/yd ³	Water lbs/yd ³	Slump, in.	Slump, in. with 4.0 gal/yd ³ DCI*
0.40	356	142	–	–	600	240	–	–
0.40	371	148	–	–	625	250	–	–
0.40	386	154	25	25	650	260	1.0	1.0
0.40	400	160	51	38	675	270	2.0	1.5
0.40	415	166	76	64	700	280	3.0	2.5
0.40	445	178	102	76	750	300	4.0	3.0
0.40	460	184	127	102	775	310	5.0	4.0
0.45	356	160	51	38	600	270	2.0	1.5
0.45	386	174	89	64	650	292	3.5	2.5
0.45	395	178	102	76	665	300	4.0	3.0
0.45	415	187	140	102	700	315	5.5	4.0

As can be seen, the addition of DCI has a negative effect on slump when the water/cement ratio is kept constant. Therefore, a water reducer is needed when designing a DCI concrete mix.

After determining the slump required to place the concrete, simply read across to the corresponding water and cement contents. Adjust these amounts to accommodate high-range water reducers (HRWR), fly ash, slag and other admixtures (see example below).

Test the mix to determine actual slump. Use a high-range water reducer such as ADVA® or a Daracem® family product to increase slump and workability in low water/cement ratio concrete.

Set Acceleration (see note above regarding DCI S)

DCI will accelerate initial set and strength development. Normal or delayed set may be achieved by incorporating water-reducing retarders. Table 2 shows typical dosage rates of Daratard®17 for normal set at 50°, 70° and 90°F. The actual dosage rate will vary with location and weather conditions.

Mix Water Compensation for Water in DCI (DCI S)

Mix water reduction at the batch plant is essential to compensate for the water content of DCI and to maintain the specified water/cement ratio. The water reduction factor for both DCI and DCI S is 0.86 kg/L (7.0 lbs/gal) of DCI admixture added to the mix.

Example: 19.8 L/m³ (4.0 gal/yd³) of DCI is added to a mix containing 163 kg/m³ (275 lbs/yd³) of water. Reduce the water added to the mix as follows:

SI: 19.8 L/m³ x 0.86 kg/L = 17.0 kg/m³ water added to the mix by DCI

Water adjustment: 163 kg/m³ – 17.0 kg/m³ = 146 kg/m³ water added to the mix

US: 4.0 gal/yd³ x 7.0 lbs/gal = 28 lbs/m³ water added to the mix by DCI

Water adjustment: 275 lbs/yd³ – 28 lbs/yd³ = 247 lbs/yd³ water added to the mix

DCI Test Program

Using the cement content from Table 1 and the retarder dosage rate from Table 2, DCI concrete should be adjusted for slump and air content using a high-range water reducer and an air-entraining agent as required. The mix should be tested to verify performance.

The sequence of batching the mix materials is critical. It is generally more convenient to batch all the materials, including DCI at the plant. DCI may be added to the plant water discharge line after most material has been batched into the central mixer or truck but before the “tail-end” water, the air-entraining agent should be added with the fine aggregate, and the retarder should be added separately (see technical bulletin “Admixture Line Location and Sequencing for Concrete Batching Operations,” TB-0110). If job site addition of DCI is required, the batching sequence must be altered accordingly. Usually, the air-entraining agent, retarder and often the high-range water reducer are added at the batch plant, with the DCI added at the job site.

Table 2: Retarder Dosage (Daratard 17) Needed to Provide Neutral Set With DCI at Various Dosages

Temperature	10° C (50° F)	21° C (70° F)	32° C (90° F)
DCI dosage rate	Daratard 17 Dosage, mL/100 kg (oz/100 lbs) of Cement		
15–20 L/m ³ (3.0–4.0 gal/yd ³)	130 (2)	261 (4)	326 (5)
20–27 L/m ³ (4.0–5.5 gal/yd ³)	196 (3)	326 (5)	456 (7)
27–30 L/m ³ (5.5–6.0 gal/yd ³)	261 (4)	391 (6)	522 (8)

During testing, actual job conditions should be simulated as nearly as possible. The conditions tested should include:

- Actual production procedures
- Actual travel time to job site
- Actual slump, air, set time required
- Actual ambient temperature and project conditions

Seven Steps to a DCI Concrete Mix Design (an Example)

Step 1: Project Specifications

Gather all information regarding the project specification and special construction requirements.

Maximum W/C ratio	0.40
Air content	7% ± 1%
Compressive strength at 28 days	31 MPa (4500 psi)
Slump	102 mm ± 25 mm (4 in. ± 1 in.)
DCI dosage rate	19.8 L/m ³ (4.0 gal/yd ³)
Estimated ambient temperature	21 °C (70 °F)

Step 2: Start with a Workable Mix

A cement content of 335 kg/m³ (564 lbs/yd³) would produce 31 MPa (4500 psi) in 28 days at a water/cement ratio of 0.40; however, the mix would be very stiff and unworkable even with a high-range water reducer, due to the water content of 134 kg/m³ (226 lbs/yd³) at 0.40 water/cement ratio.

Start with the 102 mm (4 in.) slump required at the job site. From Table 1, at 102 mm (4 in.) slump, 20 L/m³ (4 gal/yd³) of DCI and no other admixtures would require 460 kg/m³ (775 lbs/yd³) of cement and 184 kg/m³ (310 lbs/yd³) of water.

Step 3: Offsetting DCI's Set Acceleration with Retarder (See Earlier Note Regarding DCI S)

Using Table 2, at an ambient temperature of 21 °C (70 °F), 261 mL/100 kg (4 oz/100 lbs) of Daratard 17 is required to offset the accelerating action of DCI.

Step 4: Air Entrainment

7% + 1% air content Darex® or Daravair® dosed as needed.

Step 5: Water Reduction

Incorporating 228 mL/100 kg (3.5 oz/100 lbs) of ADVA plus Daratard 17 at 261 mL/100 kg (4 oz/100 lbs) allows a 15% water reduction. The following calculations will determine the adjusted cement and water contents:

- **Water required:** From Table 1, 184 kg/m³ (310 lbs/yd³) of water are required to provide a 102 mm (4 in.) slump with 460 kg/m³ (775 lbs/yd³) cement and 19.8 L/m³ (4.0 gal/yd³) of DCI. ADVA and Daratard 17 can provide a 15% water reduction.

SI: 184 kg x 15% = 28 kg of water; 184 kg – 28 kg = 156 kg/m³ water required

US: 310 lbs x 5% = 47 lbs of water; 310 lbs – 47 lbs = 263 lbs/yd³ water required

- **Cement adjustment:** The reduction of water allows for a reduction of cement as long as the specified water/cement ratio of 0.40 is not exceeded

SI: 156 kg/m³ / 0.40 = 390 kg/m³ cement required

US: 263 lbs/yd³ / 0.40 = 658 lbs/yd³ cement required

Step 6: DCI Water Compensation

Mix water must be reduced to compensate for the water contained in DCI.

SI: 19.8 L/m³ x 0.86 kg/L = 17 kg/m³ water added by DCI; 156 kg/m³ – 17 kg/m³ = 139 kg/m³ water required

US: 4.0 gal/yd³ x 7.0 lbs/gal = 28 lbs/yd³ water added by DCI; 263 lbs/yd³ – 28 lbs/yd³ = 235 lbs/yd³ water required

Step 7: Test the Mix for Performance and Make Adjustments as Needed Prior to Construction

Materials	Mass/m ³	Weight/yd ³
Cement	390 kg	658 lbs
Water	156 kg	235 lbs
DCI	19.8 L	4.0 gal
ADVA	228 mL/100 kg	3.5 oz/100 lbs
Daratard 17	261 mL/100 kg	4.0 oz/100 lbs
Darex or Daravair	as needed	as needed

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