Insights into Sustainable Concrete Floors

Geoff Kinney
Concrete Floor Contractors Association

What is sustainability?

The ability to be sustained, supported, upheld or confirmed while:

- not being harmful to the environment,
- not depleting natural resources,
- supporting long-term ecological balance
Atmospheric CO2 has now reached 4%, which last occurred more than 1 million years ago when Earth was 3-4 degrees hotter than now.

Increases in GHG emissions are increasing the rate of climate change.

2016:
Record high temperatures
&
Record reduced sea ice concentration
Within the last 40 years alone, 50% of the planet's wildlife population has been wiped out. By 2020, this number will reach 2/3s.

Our impact on nature is undeniable.

“Sustainable Development” is about meeting the needs of the present without compromising the ability of future generations to meet their own needs.”

Between Jan 1- Aug 8 2016, humanity used up all of the physical resources that the Earth can renewably provide in a year known as “Earth Overshoot Day”

Canada ranks 37th by population, but ranks 10th by GHG emissions.
The need for Sustainability is REAL

- We need to make changes at every level (we must not give up).
- Individually we have a moral responsibility to reduce, reuse and recycle every aspect of our lives.

No one wants to change, but we all need to change (now)!

Exposed Concrete Floors are THE Sustainable floor finish

- Concrete floors are a necessary part of every building – their use as an exposed final finish is obviously sustainable.
- Concrete can be very durable and economical in the long term.
- Materials design and selection must be done carefully to achieve enhanced performance & value (doing more with less).
- Workmanship responsibilities need to be focused on quality and problem avoidance to achieve the best results.
Successful Performance can be difficult to achieve!

Private Owners:
• Lowest cost & ROI

Designers:
• Confusing material options; conflicting specification requirements; changing technical standards ...

Tendering:
• Non-compliant “low” bids;

Contractors:
• Fast schedules, divisions of responsibilities; hostile ambient conditions; low technical knowledge; no standards compliance; insufficient quality planning; poor coordination; no inspection.

Materials:
• Cheapest cost focus; unspecified substitutions; cutbacks in thickness/dosage rates etc.; no inspection.

Without a quality planning focus, variable performance should be expected.

Every floor is a unique Opportunity!
Quality planning is essential
For Quality results!

Divided Source Responsibilities are not sustainable

- Divided Source responsibilities are creating and repeating the same problems on many sites.
- Repeated mistakes are being caused by improper “concrete purchasing” which ignore CSA requirements to focus solely on the lowest priced & performance materials - without any consideration for potential problems or future performance.
- Concrete materials must be carefully selected for each application, ambient condition and finish type.
- A lack of responsibility for the overall “concrete floor” assembly is problematic.
- Divisions of responsibility creates the need for coordinated efforts that can only be managed by a concrete floor specialist.
- Single Source responsibilities must be specified to eliminate problems.
Divided source supplies many people to blame!

but this does not stop the problem from happening!

“Single Source” Responsibility is Sustainable

For ALL exposed concrete floor surfaces:
- Architectural finishes
- Rink slabs
- Bonded toppings
- Superflat floors
- Sustainable floors
- higher quality anything

- Undivided responsibility, coordination and focus on quality & performance.
- Warrantee for the concrete floor assembly (not just placing & finishing).
Two Types of Concrete Contractors

- Don’t read specifications or standards.
- Substitute specified materials with whatever was left over from last job.
- May have skills but no technical knowledge.
- Cut corners to make profits.
- Do what they are told whether right or wrong.
- Undertake not quality planning.
- Take no responsibility for the results.

- Use specified methods & materials.
- Understand and comply with Standards.
- Are skilled and experienced.
- Wish to produce high quality results.
- Eliminate problems through preventative preconstruction quality planning.
- Proudly stand behind their product with a written warrantee.

The Choice of Prequalification

High quality results are never an accident

- To ensure that bidders are capable of delivering good quality. Allows a specifier to support industry ethics, quality planning, education, standard practices (or nothing at all).

- Tender naming gives the Concrete Floor Contractor time to schedule specified materials properly and to perform preconstruction quality planning.

- “Shall be performed by a member of the Concrete Floor Contractors Association.”

No qualification = variable quality & performance
Qualification = better finished products
What is the CFCA?

www.concretefloors.ca

- A voluntary not-for-profit association of quality oriented concrete floor contractors and materials suppliers.
- Promotes good quality concrete floor construction by standardizing skills, knowledge, safety & ethics across the concrete floor industry.
- Provides industry education on CSA A 23.1 and Quality Planning.
- Provides technical information & support to members and design professionals.

The Best Floor Start With Our Finish!

Sustainable ethics

1. Make every effort to meet, and exceed when possible, the specified quality expectations of our clients.
2. Perform our work as helpful and respectful members of the project team at all times.
3. Provide our employees with a safe and healthy workplace
4. Supply and install all specified methods and materials without unapproved substitutions.
5. Perform our work to meet the requirements of the Canadian Standard CSA A23.1 Concrete Materials and Methods of Concrete Construction.
6. Install all materials in accordance with the materials manufacturer’s written instructions.
7. Support an environment of individual initiative and free enterprise while respecting each other’s contractual rights and privileges.
8. Participate in the future progress of the concrete floor industry through continuing research, education and the transfer of knowledge to Owners, specifiers and users of concrete floors.

A good attitude and sincere efforts are necessary for success!
Doing more with less

- The cement and ready mixed concrete industries have been working for decades to reduce CO2 emissions with innovations such as GUL cement and cement replacements like flyash (coal) and slag (steel) and silica fume (silicon).

- Cement properties and contents have been optimized and minimized to achieve compressive strengths as efficiently as possible.

- The traditional business model of “minimizing costs to maximize profit” ignores the hidden value of performance engineering. High performance concrete and fibre materials can optimize hardened performance while minimizing costs and materials consumption.

Every Fibre Type is Unique in Performance

20 kgs SFR ≠ 3 kgs Marco synthetic fibre

- Designs are NOT transferable. Do not substitute fibres without a design review!

- Each floor loading condition must be analyzed based on the specific fibre type, its capacities and hardened performance qualities.

- Reverse design to determine load capacities (make sure this considers future change of use).

- Perform a cost / performance analysis to save money!

Drawn Steel Wire is NOT equal to Mill Cut Steel is NOT equal to Macro Synthetic
Fibre Type Performance

Steel Fibre Performance Chart Example

Example

40%

Performance Value Engineering

• For any given set of loading conditions there are a variety of slab thickness solutions.

• Comparing combinations of concrete materials, fibre type, dosage rate and slab thickness to determine the lowest marginal cost.

Lowest cost materials approach: $3.48/sf
Lowest cost performance approach: $3.23/sf
Net result: $<0.25>/sf

The lowest cost per sf performance solution:
1. used a premium performance/higher cost concrete material
2. used a premium performance/ higher cost fibre
3. No change to methods of construction

Purchasing materials based on “low price” may be misleading and cost you more!
Quality Planning & Coordination

- There are 50+ items to coordinate for each concrete floor placement (complicated).
- Site conditions & attitudes vary significantly between employers and projects.
- Too little planning time due to last minute awards of trade work.
- Divided responsibilities are a problem.
- A lack of inspection is a problem.

Divided Responsibilities:
- good workmanship
- low quality materials
- poor planning/coordination

= quality & performance problems

Concrete Floor Pre-Construction Meetings are critical

- To ensure that the Owner’s expectations are clearly understood and can be met.
- Must include participation concrete floor contractor and ready mixed concrete producer!
- A last chance opportunity to address any concerns, questions, incompatibilities, tolerances, vapour retarders, drying shrinkage curling etc.

Review:
- Specified methods & materials.
- Responsibilities of parties
- Work of other trades.
- Affect of building envelope and ambient conditions.
- Concrete mix design.
- Mock-ups.
- Joint details and layout.
- Inspection procedures.

Minimum 4 weeks prior to placing!
Lack of Inspection is a Problem

- **There is too little inspection!**
- A lack of inspection causes reductions in quality and variable hardened concrete performance.
- A lack of inspection encourages unethical behaviours.
- **Inspection supports honest contractors, stop cheaters, stops mistakes and ensures value for your client!**
- Inspect the source, quantity and application of all materials.

*Many will cheat so long as they think they won't get caught!*

Joint Layouts

Must be carefully reviewed by concrete floor contractor.

- Construction Joints
- Isolation Joints
- Contraction Joints
- Expansion Joints

Floors with extended joint spacings using shrinkage compensating concrete are becoming more popular.
Mock-up Samples

- **Must be specified** if desired.

- *Is necessary for all architectural finishes to ensure expectations can be met.*

- Must be representative of the final product (using same methods and materials).

Quality Materials

- Good quality materials are an **essential** part of good concrete floor *performance*.

- *All materials are not equal in cost, performance or workability and require careful analysis - beware of unequal substitutions and alternatives.*

- CFCA material & equipment suppliers are major manufacturers and suppliers to the concrete floor industry globally.
CSA A23.1-2014

- We have a national mandatory concrete standard that defines mandatory compliances.

- All materials and workmanship MUST comply with CSA A23.1 to avoid all kinds of problems (call if you need assistance !)

- A23.1 is part of all project documents, building codes, but it is often ignored due to a lack of inspection.

**Seeking public input for 2019 Edition**

Most trade & GC’s have not read this standard
You cannot comply with requirements that you have not read!

CSA A23.1 “N-CF”

**Interior Concrete Floor Mix**

### 8.12 Concrete mixes for interior concrete floors

#### 8.12.1 General

Interior concrete floors with a steel-bonded finish, other than residential concrete floors (Class II-15 exposures, Table 3), are designated as N-CF class of exposure (Table 2) and shall be designed to a minimum 0.55 MPa and a minimum compression strength of 2.5 MPa at 28 d (as specified in Table 2), as well as designed for placing methods, finishability, and workability, as required for intended service.

**Notes:**

1. See N-114 for further information on concrete mixes and exposure areas.
2. The water content of the concrete mix should be minimized to reduce the effects of shrinkage and the slump increased using a normal setting plasticizing admixture.
3. Most mortars for floors should have a minimum slump of 100 mm at the point of placement. Higher workability or flow should be achieved with the addition of plasticizing admixture only.
4. A bond and water reduction, or concrete water content in the mix may be used to achieve a minimum 0.55 MPa and a minimum compression strength of 2.5 MPa at 28 d (as specified in Table 2), as well as designed for placing methods, finishability, and workability, as required for intended service. See Clause 7.5.

5. The use of an anti-carbonation concrete mix in the concrete floor slab or floor is recommended to protect the concrete from carbonation. See Clause 7.5.

**It is critical to define a minimum quality of concrete materials to achieve consistent results with good performance.**
Concrete purchasing is complex

• Many slab on grade failures relating to purchasing the wrong concrete materials.

• Some ready mixed concrete producers “ship what is ordered” without being supplied the project specifications or exposure conditions.

• “Concrete purchasers” must:
  1. Comply with specification requirements.
  2. Comply with CSA A23.1.
  3. Design for hardened performance requirements.
  4. Manage the compatibility of methods and materials (including plastic protection).

Mixes must be compatible with methodology & site temperatures

Low Temperature Lab Test Study

All concrete mixes bled less in quantity (retained more water) at 5°C than at 20°C – low temperature water retention is abnormal
Granular base & concrete materials temperatures

- It is essential that concrete mixes be maintained at no less than 10°C from the time of placing through to the end of the curing period in order to avoid abnormal concrete set problems.

Table 14 Permissible concrete temperatures at placing
(See Clause 5.2.3.1, 5.13.1, 7.4.13, and 8.4.3.)

<table>
<thead>
<tr>
<th>Thickness of section, m</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.3</td>
<td>10</td>
<td>32</td>
</tr>
<tr>
<td>0.3-1</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>≥1</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>≥2</td>
<td>3</td>
<td>20</td>
</tr>
</tbody>
</table>

Notes:

(1) The placing temperature for high performance concrete should be at least 20°C.
(2) The placing temperature should be kept as close as possible to the suggested minimum temperatures shown in this Table. Higher temperatures result in an increase of mixing water, internal slump loss, and an increase in thermal expansion.

Table 19 Allowable curing regimes
(See Clause 4.1.1.1, 4.1.1.2, 5.2.3.1, 7.4.13, 6.2.3.2, and Table 2.)

<table>
<thead>
<tr>
<th>Curing Type</th>
<th>Water:Cement Ratio</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Bulk curing</td>
<td>3 days at 20°C or for the time necessary to attain 80% of the specified strength.</td>
</tr>
<tr>
<td>2.</td>
<td>Additional curing*</td>
<td>1 day at 20°C and for the time necessary to attain 80% of the specified strength.</td>
</tr>
<tr>
<td>3.</td>
<td>Extended wet curing</td>
<td>A curing period of 7 days at 15°C and for the time necessary to attain 80% of the specified strength. This curing type is allowed to continue in an area protected from drying shrinkage, thermal expansion, or frost, kept continuously wet.</td>
</tr>
</tbody>
</table>

Notes:

(1) When applying other curing methods, additional curing provisions shall be used. See Clause 5.3.1.
(2) Curing of placed concrete prior to concrete shall be in accordance with Clause 4.2.8.4.
(3) Curing of placed concrete prior to concrete shall be in accordance with Clause 4.2.8.4.
(4) The use of compressive strength gain in concrete is significantly reduced below 70°C.

Water:Cement Ratio = Hardened Performance

- The ratio of water:cement is the principal indicator of hardened concrete performance.
- Range: 0.4 (high performance) to 0.55 (medium) to 0.65 (lowest performance).

- When W/C ↑:
  - Hardened performance ↓
  - Drying shrinkage ↑
  - Drying Shrinkage Curling ↑
  - Moisture permeability ↑
  - Drying time for applied finishes ↑
  - Compressive strength ↓
  - Wear resistance ↓
  - Freeze-thaw durability ↓
  - Finishability ↓
  - Materials price ↓
Drying Time for Applied Finishes

- Many site reports of extended waiting time for concrete to dry sufficiently to receive moisture sensitive applied finishes.
- **Concrete Drying time is directly correlated to water:cement ratio**
- Use a plasticizer to reduce water contents, cement contents, drying shrinkage & drying time!

<table>
<thead>
<tr>
<th>Time in days to reach 3 lbs/000sf/24hr *</th>
</tr>
</thead>
<tbody>
<tr>
<td>W/C: 0.4 0.5 0.6 0.7 0.8</td>
</tr>
<tr>
<td>In contact with:</td>
</tr>
<tr>
<td>Wet base (SOG):</td>
</tr>
<tr>
<td>Dry base /VR (SOG):</td>
</tr>
<tr>
<td>Suspended Slab:</td>
</tr>
</tbody>
</table>

High w/c, cold, damp, thick concrete on a vapour retarder takes much longer to dry!

Plasticizers are Sustainable!

**CSA A23.1 “N-CF” Floor Mixes**

- Mix type: CSA -W+P
- f’c: 25 25
- Water: 165 150
- GU Cement: 290 272*
- w/c: 0.55 0.55
- Slump workability: ≥100 130

The use of plasticizers can:
- ↓ water consumption
- ↓ cement consumption
- ↓ drying shrinkage
- ↓ Drying time for finishes
- ↓ CO2 emissions
- ↑ workability

* Cold temperature modifications required

Specify a maximum 80mm “initial water slump” and a 130mm “plasticized final slump” at the point of concrete placement.
**Exterior Joint Reinforcing**

*Uneven joints are a typical exterior failure*
*Reinforce all architectural pavements with steel!*

- Exterior unreinforced concrete is failing at joints and cracks due to frost heave and settlement.
- Use steel dowels, wire mesh or rebar to keep joints connected.

Reinforce exterior joints to avoid differential joint settlement/movement

---

**Air >3% + Steel Trowel Finish = Surface Delaminations**

- Plastic air content shall be checked with compressive cylinder tests per CSA.
- Should be check at the start of every concrete placement.
- Beware that ‘some’ polycarboxylate mid-range plasticizers can increase plastic air contents in non-air entrained concrete above 3%.
- Check at the truck and at the point of placement (even for non-air entrained concrete mixes!).
- Entrained air is not required for interior freezers or rink slabs (or interior floors constructed in the winter).
- While entrained air is required for exterior concrete, exterior refrigerated slabs have performed well without air. Unrefrigerated areas exhibit pitting and freezing damage (change finish and concrete type).

Recent core inspection of a “trowel finished air entrained concrete” indicates the following:

1. Percentage of air in the top 4mm of slab surface: 0%
2. Depth at which the air content is incorrect: up to 25 mm
3. Depth at which the air bubble spacing is incorrect: up to 85 mm

Even if air entrained concrete could be trowel finished without delaminations, the resulting concrete could not be qualified as freeze thaw resistant any longer.
Warnings about Trowel Finishing & maximum 3% plastic air contents

CSA A23.1

ACI 301 “Specification for structural concrete”

ACI 302 Guide to concrete floor construction

ACI 306 Cold weather concreting

High W/C = Lower Performance

- Fire hall’s require a smooth surface finish for ease of cleaning to trench drains. Slush deposits cause saturated micro freezing resulting in pitting of non-air entrained concrete.

- Although an interior exposure (N-CF), the equipment wheel path is subject to localized freezing & chlorides in a saturated condition (C-2 exposure = 0.45 w/c with 5-7% air).

- Do not combine steel trowel finishing and air entrained concrete or surface delaminations will occur.

- Use N-CF with traditional pigmented dry shake hardener OR epoxy floor system OR a modified N-CF 0.45 w/c concrete mix (with qualifications).

- Do not use sub-standard concrete mixes which have low freezing, wear resistance, high moisture permeability ...

7.6.6.3.1 Interior or non-air-entrained concrete:

Check plastic air contents at the start of every concrete placement !

ACI 306 Cold weather concreting

4.6—Slab finishing

If during construction, but after the cold weather protection period, the concrete is likely to be exposed to freezing-and-thawing cycles while saturated, air entrainment may be necessary even through the concrete will not be exposed to freezing and thawing cycles in service. Where a hard-troweled finish is specified, the addition of air entrainment may lead to finishing difficulties or problems with blisters, delaminations, or other surface defects. These finishing problems also develop when the total air content is greater than 3 percent (ACI 302). In this case, magentic ...

1 year old:
25 MPa “compressive strength” mix used
(≈ 0.67 w/c)

Freezing damage from road slush
Surface Hardeners are Sustainable

- Dry shake surface hardeners increase wear resistance and durability economically.
- Floors without hardeners wear faster and exhibit more fibres and surface crazing.
- Different hardness aggregates for different applications (natural and pigmented).

Vapour Retarders

- Prevents moisture vapour transmission through the concrete to eliminate the future delamination of non-breathing finishes.
- Must be at least 10 mils thick and have ASTM E1745 Class A puncture resistance with all joints, terminations & punctures sealed!
- Extend at least 1m past applied finish edges.
- Located directly under the concrete slab causes one sided drying = longer drying time (↓ water content & plasticize).

Requires concrete mix adjustment for one sided drying (use lower w/c and plasticizer)
Granular Bases

- Inspect elevations and compaction to ensure specified thickness and support.

A good level base

Unacceptable tire rutting

CHECK Fibre contents by Washout Testing (A23.2-16C)

- Synthetic and steel fibre concentration MUST be checked by washout testing!

- Samples collected as the truck discharges.

- Fibre washed out from concrete and weighed.

The washout test should be considered acceptable if:
1. The average of three test samples is no more than 10% less than specified dosage, and
2. No individual test sample is more than 20% less than the specified dosage rate.
Floor Tolerances

- Tolerances are not measured often enough resulting in variable results.

- Tolerance compliance is an Owner’s choice & cost (3rd party) – check the first placement on every job!

- Shall be measured within 72 hours of each placement to quantify “as-built” tolerances.

- Levelness tolerances are not applicable to suspended slabs due to camber & deflection.

- Tolerance losses caused by drying shrinkage curling must be calculated into the slab design (or restrained with reinforcing).

www.concreteslabs.ca
Summary

- Act now to change the future – everyone needs to help.
- Specify “Single-Source” responsibilities for slabs on grade.
- Pursue value engineering to obtain better performance and value.
- Specify pre-construction meetings to increase quality and value (and avoid common problems).
- Use plasticizing admixtures to enhance hardened performance and minimize materials consumption.
- Inspect everything.
- Prequalify CFCA contractors for better quality results and to support industry improvement.
Questions?

Please leave your card for a copy of the presentation

www.concretefloors.ca