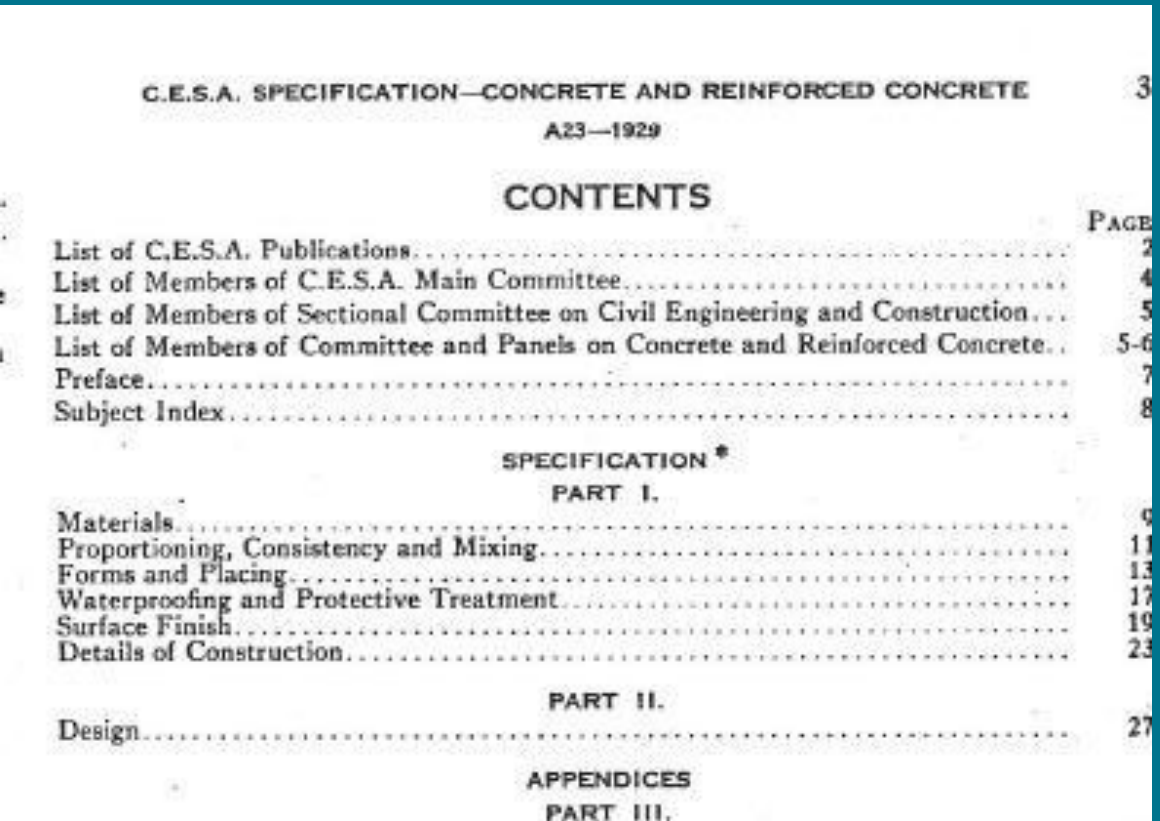
What's new in the 2014 Edition of CSA A23.1 and .2

Chris Rogers

History of CSA Std on concrete

- First std in 1929 – work started in about 1922
- About 18 pages equiv to modern 23.1
- Revisions in 1942, 1960 and 1967



C.E.S.A. SPECIFICATION—CONCRETE AND REINFORCED CONCRETE 3

A23—1929

CONTENTS

W Schnarr

A23—1929

CANADIAN ENGINEERING STANDARDS ASSOCIATION

(INCORPORATED 1919)

STANDARD SPECIFICATION

FOR

CONCRETE AND REINFORCED CONCRETE

—:—

OTTAWA, MAY 1929

More recent standards

- 1973 - 94 pages, 112 on testing
- 1977 – 132 pages, 119 on testing
- 1990 – 115 pages, 151 on testing
- 1994 – 147 pages, 200 on testing
- 2000 – 153 pages, 202 on testing
- 2004 – 180 pages, 266 on testing and standard practices
- 2009 – 211 pages, 343 on testing and standard practices, total 554 p.
- 2014 – 268 pages, 397 on testing and standard practices, total of 668 p.

To illustrate progressive changes in standard content

- Advice on alkali-aggregate reaction
- In 1973 and 1977 appendix of 3 pages and one test method (concrete expansion) total of 5 pages.
- Supplement in 1986, 37 pages
- 1994 24 pages of appendix B and 3 test methods - total 44 pages.
- 2000 addition of 2 standard practices - total 63 pages.
- 2004 as 2000 + 25 pages of new procedure for petrographic examination
- 2009/14 no substantial change

Year	Test Methods	Numbers of pages
1973 and 77	1	5
1986	1	37
1990 / 94	3	44
2000	5	63
2004	6	88

County bridge after 4years

What's new in 2014

- Using blends of Portland-limestone cement and supplementary cementing materials in sulphate exposure conditions.
- Changes to requirements for residential concrete first taken over by A23.1 in 2009
- Clarification of responsibilities for those involved in concrete construction in clause 4. Test results on same sample from multiple qualified labs to be considered by the Owner (4.4.1.6.2)
- Option to use an optimized aggregate grading for the total aggregate rather than individual coarse and fine aggregates in clause 4 with new annex Q
- Modification of some requirements for hot and cold weather conditions in clause 7

What's new in 2014

- In clause 8 new sections deal with controlled low strength concrete (unshrinkable fill) and shotcrete
- Two new exposure classes for interior concrete floors – steel trowelled and reinforced floors for manure or silage
- New annex O on aggregates from recycled concrete
- New Annex P on impact of sulphides in concrete aggregates and how to deal with this issue.
- New annex R gives guidelines for residential concrete construction from old A 438 std
- Two new test methods: 22c on scaling resistance exposed to de-icing salts; 23c chloride ion

Portland limestone cement

- Using blends of Portland-limestone cement and supplementary cementing materials in sulphate exposure conditions. PLC's were first approved in 2009 but not for sulphate exposure.
- S2 and S3 using PLC require max 0.40 w/c and it is mandatory to use minimum amounts of SCM or appropriate blended cement.
- With non-PLC's higher w/c may be used
- Limestone fillers cannot be used in sulphate exposure.

Residential concrete

- Refinement of treatment of residential concrete
- Residential came into A23.1 in 2009.

	CSA A23.1 2009			CSA A23.1 2014		
Class	strength 28d MPa	Max w/cm	Total air %	strength 28d MPa	Max w/cm	Total air %
R 1	15	0.70	3 - 6	25	0.55	4 - 7
R 2	15	0.70	4 - 7	25	0.55	4 - 7
R 3*	20	0.65	-	25	0.55	-

- R- 1 = footings, walls, columns, fireplaces, etc.
- R-2 = foundation walls, grade beams, piers, etc.
- R-3 = interior slabs on ground not exposed to F/T
  (*now the same as other interior concrete floors)

Residential concrete

- Currently used strengths for residential in Canada

Province	Specified or customary strength	comment
Nova Scotia	20 MPa	
PEI	20 MPa	
New Brunswick	25 MPa	
Newfoundland	20 MPa	
Quebec	25 MPa	BNQ
Ontario	20 MPa	
Ontario GTA	15 MPa	
Manitoba	20 some 25 MPa	32 for S2
Saskatchewan	20 MPa	32 for S2
Alberta	32 MPa (S2 exposure)	
British Columbia	25 MPa	BC code

Residential concrete

- Old CSA A 438 3rd edition last published in 2000
- This edition did not consider the issue of life-cycle costs but rather installed cost.
- In 2000 edition - for basements to be used for "… habitation comparable to that above ground" advised that concrete should have 30MPa, 0.50 w/cm, air 4 – 7% and some other requirements.
- Following the 2009 edition there was considerable discussion within the A23.1 committee on the issue.
- The changes in 2014 were the considered opinion of the members of the committee knowledgeable about concrete in Canada.

Optimized aggregate grading

- Option to use an combined (optimized) aggregate grading for the total aggregate rather than individual coarse and fine aggregates in clause 4.2.3.5.3
- This may provide benefits in improve concrete performance and economy
- New annex Q gives examples of how to do this.
- For instance the use of three (or more) different aggregates none of which may meet the current grading requirements may make a good mixture.
- Preparation of aggregate test samples has to change by combining all materials in proportion into coarse or fine fractions by using the 5 mm sieve

Unshrinkable fill and shotcrete

- Clause 8.11 provides specification for unshrinkable fill as a type of CLSM (controlled low strength material)
- Strength typically 0.3 to 1.0 MPa at 28d
- Recycled concrete aggregates are permitted.
- New annex O has a lot of information and advice about types and uses of recycled aggregates. We are soliciting further information to improve on this in the future.
- Clause 8.14 on shotcrete is new and 4 pages long

New test methods

- Revision to many test methods has been done.
  - Addition of new table for classification of structures for determining risk of alkali-aggregate reaction in 27A (a modification of 27A was recently adopted by ASTM as c1778)

- A23.2 - 22c "Scaling resistance of concrete surfaces exposed to de-icing chemicals using mass loss";
  - Note that in clause 4.4.10 the owner can specify which test method he wishes to use: BNQ, CSA or the MTO methods

- A23.2-23c "Electrical indication of concrete's ability to resist chloride ion penetration"
  - very similar to ASTM c1202 (RCP)

NEW Annex P on Sulphides in concrete aggregate on concrete

- Since 1973, CSA A23.1 has alerted users to the risk of using concrete aggregates incorporating expansive materials (iron sulphides) in concrete:

  "Aggregates that produce excessive expansion in concrete through reaction other than alkali reactivity shall not be used in concrete unless preventive measures acceptable to the owner are applied."

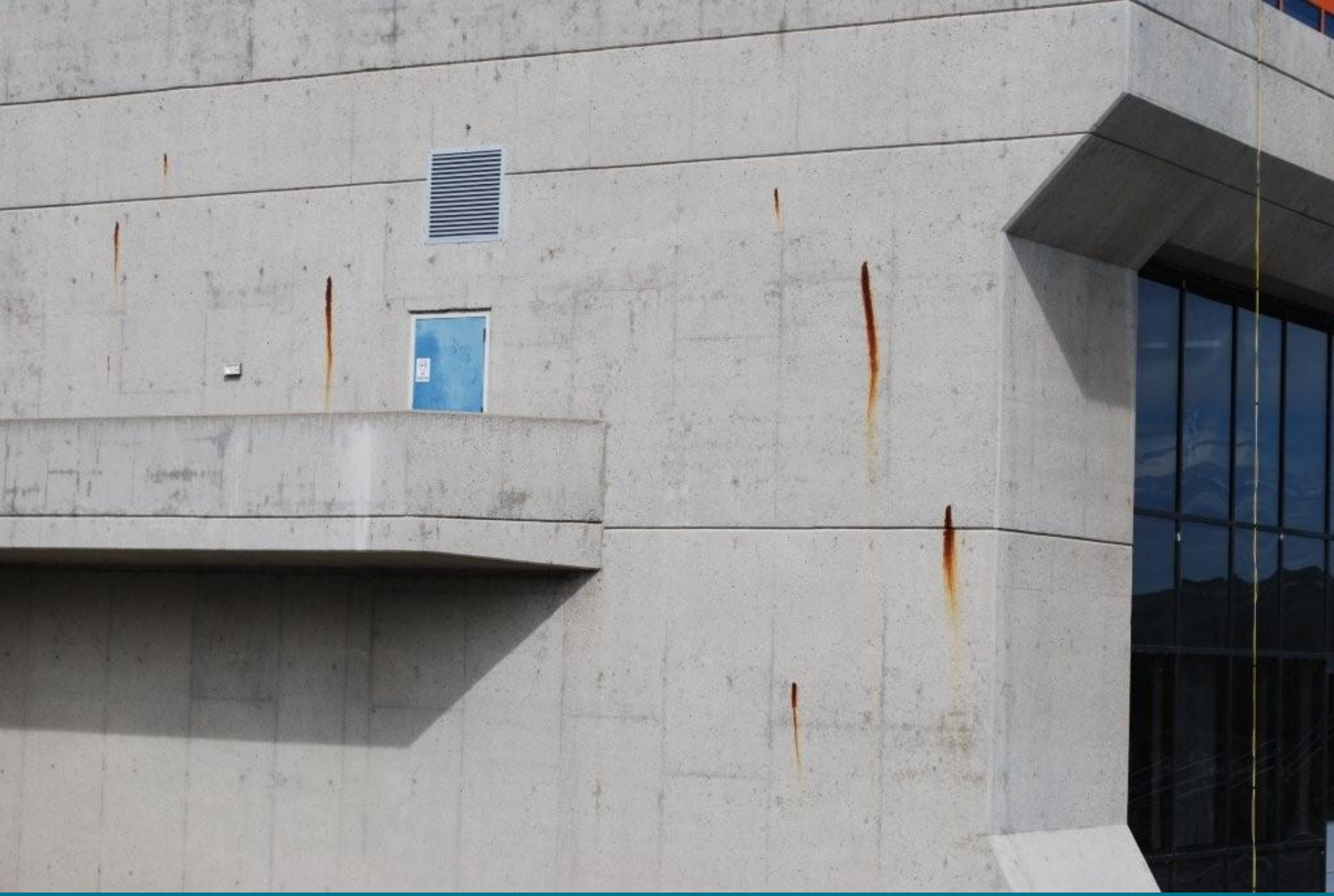
- *Note (added in 1994): Although rare, significant expansions can occur due to reasons other than alkali-aggregate reaction. Such expansions might be due to the following:*
  - *The presence of sulphides, such as pyrite, pyrrhotite, and marcasite, in the aggregate that might oxidize and hydrate with volume increase or the release of sulphate that produces sulphate attack upon the cement paste, or both;"*

Some common iron sulphide minerals

Left to right:

- Chalcopyrite ([FeCu]S_2)
- Pyrite (FeS_2)
- Pyrrhotite (FeS)

Some kinds of pyrrhotite are magnetic



Iron sulphide stains, Peace Canyon Dam, Peace River, Northern BC, 2011

"Pyrrhotite dans la région: environ 400 millions $ de dégâts" (damage)

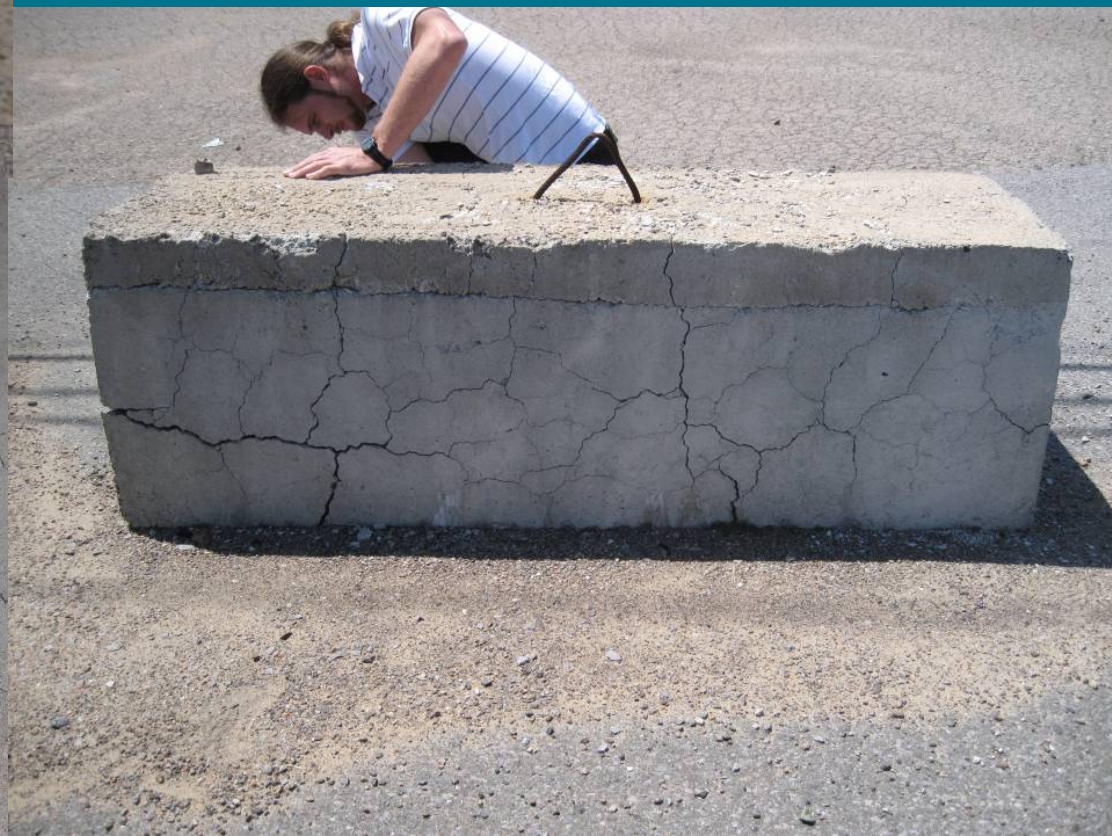
Le Nouvelliste (Trois-Rivières) 30 mars 2013

- Including:
  - 1200 houses – government of Quebec financial assistance of $15 million, to demolish basements and to replace
  - 30% of surface of the new sports arena
  - 2 new buildings for Quebec police
  - Ambulance station
  - Hospital
  - At least 15 commercial buildings (supermarket, pharmacy) – can they be underpinned and concrete removed or is demolition necessary?
  - Bridge widening and repair (about 10) for MTQ
  - New addition to palais de justice

- The lawsuit, with 70 lawyers, 20,000 documents of 250,000 pages, was one of largest in Canada with hearings from Nov 2012 – Aug 2013

Trois-Rivières showing signs of deterioration

Concrete near Trois-Rivières showing signs of deterioration



House jacked up to replace concrete foundation

Concrete placement

What happened?

- On October 23, 2003, Laurentide Concrete and B & B joint owners of the quarry wrote to Terratech to require a petrographic examination of the stone which was in their quarry. The two companies said: "We need to know the risks of use of this stone, in the manufacture of concrete."

- On December 2, 2003, A.B. a geologist with Terratech (SNC Lavalin) reported the presence from 3% to 5% of iron sulphide (pyrite and pyrrhotite) in the crushed stone.

- A. B. concluded that "The crushed stone coming from the quarry B & B of Saint-Boniface represents a good aggregate for concrete and that it can be used without risk of development of noxious reaction."
- English translation from Brigitte Trahan
  Le Nouvelliste, May 6, 2013

What happened?

- A.B. had been a corresponding member of CSA sub-committee on AAR where issues of sulphide oxidation were discussed in early 1990's. He was also a member of a Quebec committee formed to resolve issues with iron sulphide heave of shales under buildings.

- Coarse aggregate was used from 2003 until about 2007 in ready mix concrete in the region of Trois-Rivières.

- Every year A.B. conducted petrographic examination and reported various amounts of iron sulphide from about 3% to as high as 7%. A.B. continued to recommend use in concrete.

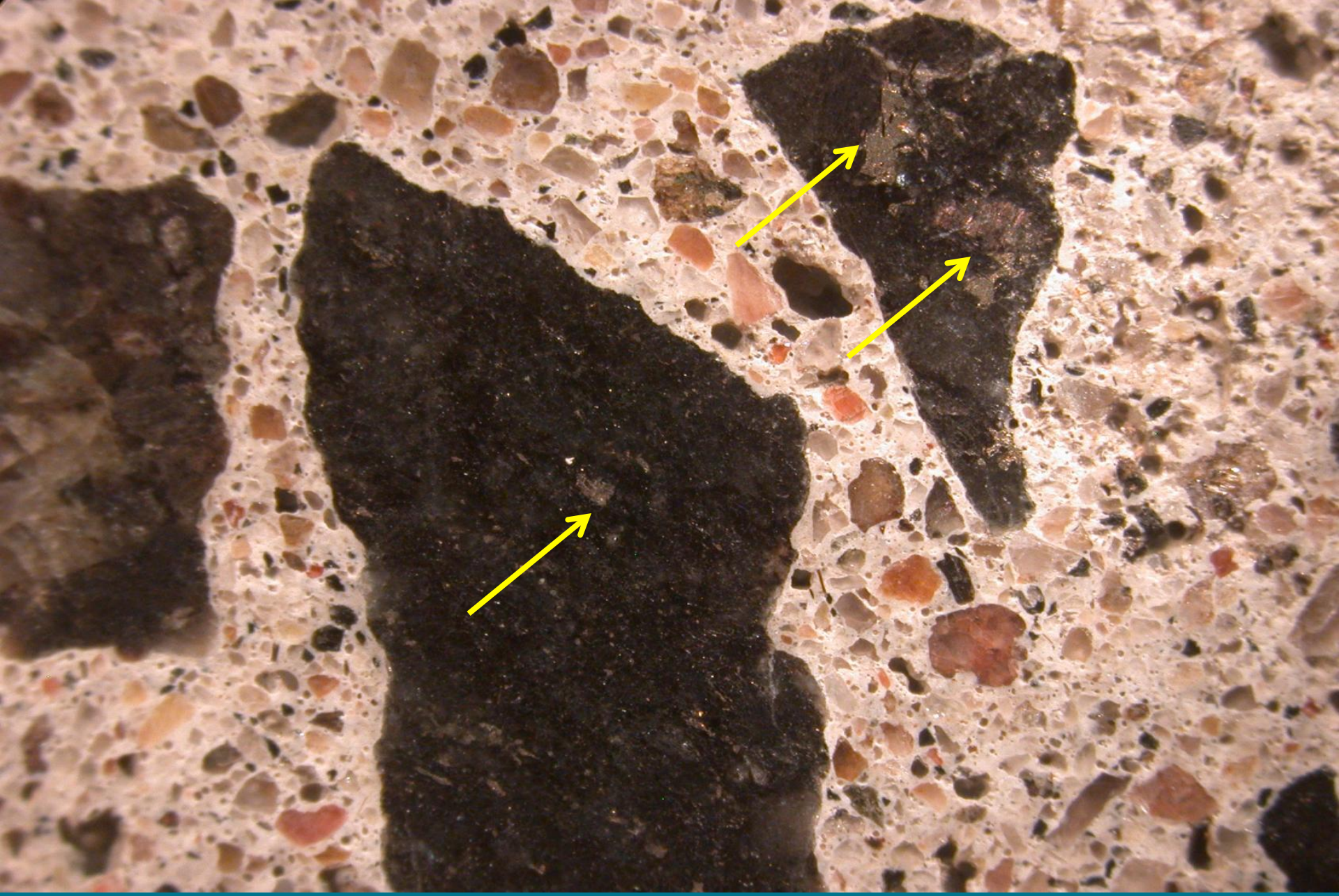
- Because of increasing reports of damage, the aggregate stopped being used in late 2007

St. Boniface quarry
"Quality by the tonne"
Trois-Rivières, Quebec
June 2011

Old oxidized stockpile and weathered surface rock
St. Boniface quarry
Trois-Rivières, Quebec
June 2011

Another quarry (Maskimo) near the St. Boniface qry also contains pyrrhotite

Maskimo quarry crushed stone
Showing oxidation after several years
Trois-Rivières, Quebec



Main iron sulphide mineral is pyrrhotite – FeS, Pyrite is FeS_2

Mechanism of expansion

- FeS oxidizes to iron hydroxide and sulphuric acid
- Sulphuric acid attacks cement to produce gypsum [$CaSO_4 \cdot 2H_2O$] and eventually ettringite [$C_3A \cdot 3CaSO_4 \cdot H_{32}$] and also thaumasite – this causes expansion of concrete

Existing European Standards

- French Standard
  - NF P18-301 (1983) → Total « S » < 0.4% as SO_3
  - NF P18-541 (1994) → Total « S » < 1% SO_3 (0.75% pyrite)
- European Standard (NF EN 12 620 2003)
  - < 1% of S (aggregate)
  - < 2% of S (air-cooled slag)

Note : if pyrrhotite is present, reduce total « S » to < 0.1%

Note : 1% S = 2.5% in SO_3
1.87% pyrite
2.65% pyrrhotite

What is a safe level of pyrrhotite?

- 223 houses were studied
- The basements were between about 3 to 9 years old at the time of the study.
- Damage to basement concrete had occurred when the pyrrhotite content was as low as 0.23% by mass of coarse aggregate
- Highest amount of pyrrhotite was 2.92% by mass of the coarse aggregate
- All concrete exceeded the European standard by 3x to 30x
- Much of the pyrrhotite in the damaged concrete had yet to oxidize
- *Source: Tremblay - data presented at a court appearance in Trois-Rivières on May 2, 2013.*

Test method situation

Present

- No accelerated performance test to assess the potential for expansion of concrete due to the oxidation of iron sulphides.
- Petrographic examination combined with
  - Measure of S content using an induction furnace (e.g. LECO furnace) in which the sample is burnt and the gas analyzed using infrared absorption spectroscopy.
  - identify sulphides esp. Pyrrhotite by X-Ray diffraction on concentrates (electro magnetic, density).
  - Apply European Std of 1.0 or 0.1%

Future

- Probable chemical test for S content as a screening test
- Work is underway in Canada (Benoit Fournier at Laval and Medhat Shehata at Ryerson) to develop a performance test for the potential for expansion caused by the presence of iron sulphides – Mortar/concrete expansion test
  - This is not an easy test to develop
- An oxygen consumption test that was developed originally for evaluating the sulphide mineral content of mine tailings is also being evaluated and initially shows promise.

Discussion

- Many aggregates contain very small amounts of sulphides; specifying that there be no sulphides present in the aggregate is not realistic.
- Insufficient data to provide unequivocal advice as to amount of sulphide likely to be harmful, or safe to use. But experience in Quebec indicates < 0.1% S.
- Pyrrhotite, even in very small amounts, is potentially deleterious. Pyrite and marcasite can probably be present in small amounts without causing deleterious expansion although staining can be caused.
- Currently used concrete aggregates: Confirm the satisfactory field performance of concrete. Normally, concrete suppliers will be aware of reports of objectionable staining or other problems with the use of their concrete/aggregate combinations.

Discussion given in annex P

- New and unproven sources of concrete aggregates should be tested for sulphur content. If the sulphur content is less than 0.10%, the aggregate may be used without further investigations. If the sulphide sulphur content is more than 0.10%, the nature of the sulphide mineral present should be determined. If pyrrhotite is detected, the aggregate should not be used.
- If other sulphide minerals are detected, and the sulphur content is no more than 1.0%, the material may be used provided that the sulphide minerals are not susceptible to oxidation and that satisfactory field performance is established. Field performance should be based both on the issue of sulphate attack and resultant expansion and cracking and risk of exterior staining.
- Examples of rocks where the sulphur content may possibly exceed 0.10% and have satisfactory field performance (excluding potential alkali reactivity) include Ordovician limestones and dolostones of the St.Lawrence Lowlands (Quebec) and Lake Ontario. These contain small amounts of minute cubic pyrite. And also some Silurian dolomites in Ontario.

The future of sulphides in Canadian concrete standards

- Considerable dissatisfaction in Quebec with failure of existing standards and Federal Government to prevent this.
- The existing concrete standard warned of the problem. The advice was not followed.
- There will probably be changes in the next CSA std (2018/9) that may apply to all concrete aggregates
  - Chemical analysis?
  - Performance expansion test?
  - Establish field performance of existing sources?
  - Oxygen consumption test?

Final Remarks

- Standards change to serve the people using them
- When developed intelligently they promote commerce and serve our society
- There has to be a balance between too rapid change of standards and not changing soon enough to recognize new materials and techniques
- We need a wide variety of people, experience and outlooks in the standards development process
- Discussion - do we need to develop a guide (advice) to using the standard? It is a complex document for the non-specialist.