

STRUCTURAL ASSESSMENT OF SEABROOK STATION

Role of Concrete Material Testing



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QUESTIONS FROM NRC

Eighteen questions were posed to NextEra and Seabrook Station representatives on April 13, 2012.

The image shows two scanned pages of NRC questions. The left page is labeled 'P. 03' and the right page is labeled 'P. 04'. A red box is drawn across the center of both pages, containing the text: "Technical questions generally reflect concerns related to *performance of concrete materials*." The text on the pages is mostly illegible due to the scan quality, but some fragments are visible.

Page P. 03:

Detailed Questions for Seabrook ASR Public Meeting on April 23, 2012

(1) What other in-scope buildings besides the five noted in the inspection report recently issued are suspected of having alkali silica reaction (ASR) based on initial assessments?

(1a) Where is ASR located at the site?

(1b) If ASR is suspected, how and when will it be confirmed such as examination by petrography of concrete cores?

(1c) If ASR is confirmed, what method will be used to distinguish localized vs. global effects for each building?

Page P. 04:

(8) Corrective Action Plan needs to fully address:

- Condition assessment (extent and characterization of the degradation, including its severity);
- Root cause and corrective action;
- Testing to estimate "expansion to date" and "the current expansion rate";
- Testing to estimate "potential for further expansion";
- Interim and long term structural appraisal under design basis loads and load combinations;
- Monitoring and managing the condition;
- Mitigating and remedial measures, and
- Potential for further deterioration due to other mechanisms.

Red Box Text:

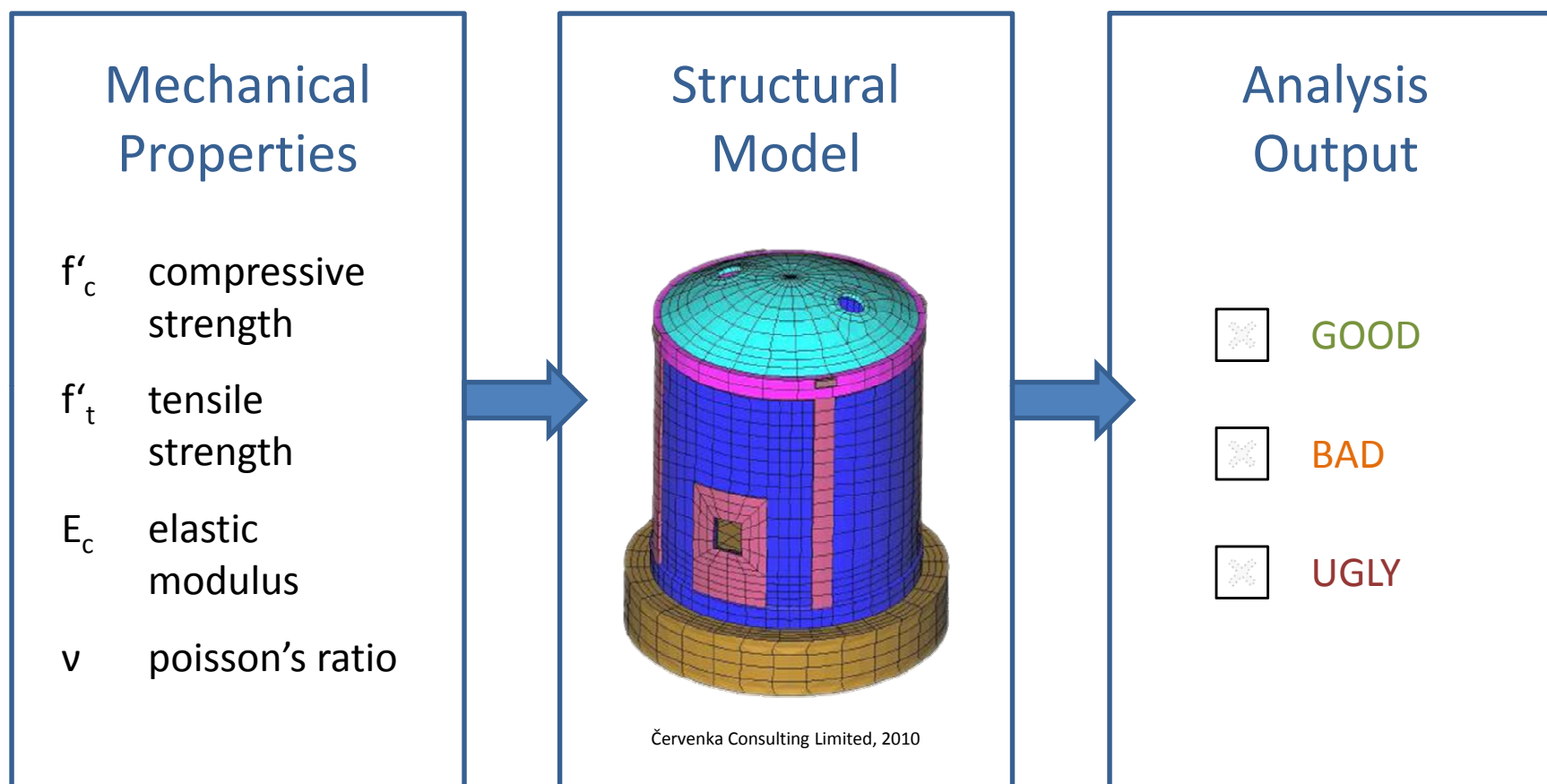
Technical questions generally reflect concerns related to *performance of concrete materials*.

Page P. 04 Footer:

TOTAL P. 04

BASIS FOR CONCERNS

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MECHANICAL PROPERTIES

- Material test data collected from literature

Swamy and Al-Asali, 1988

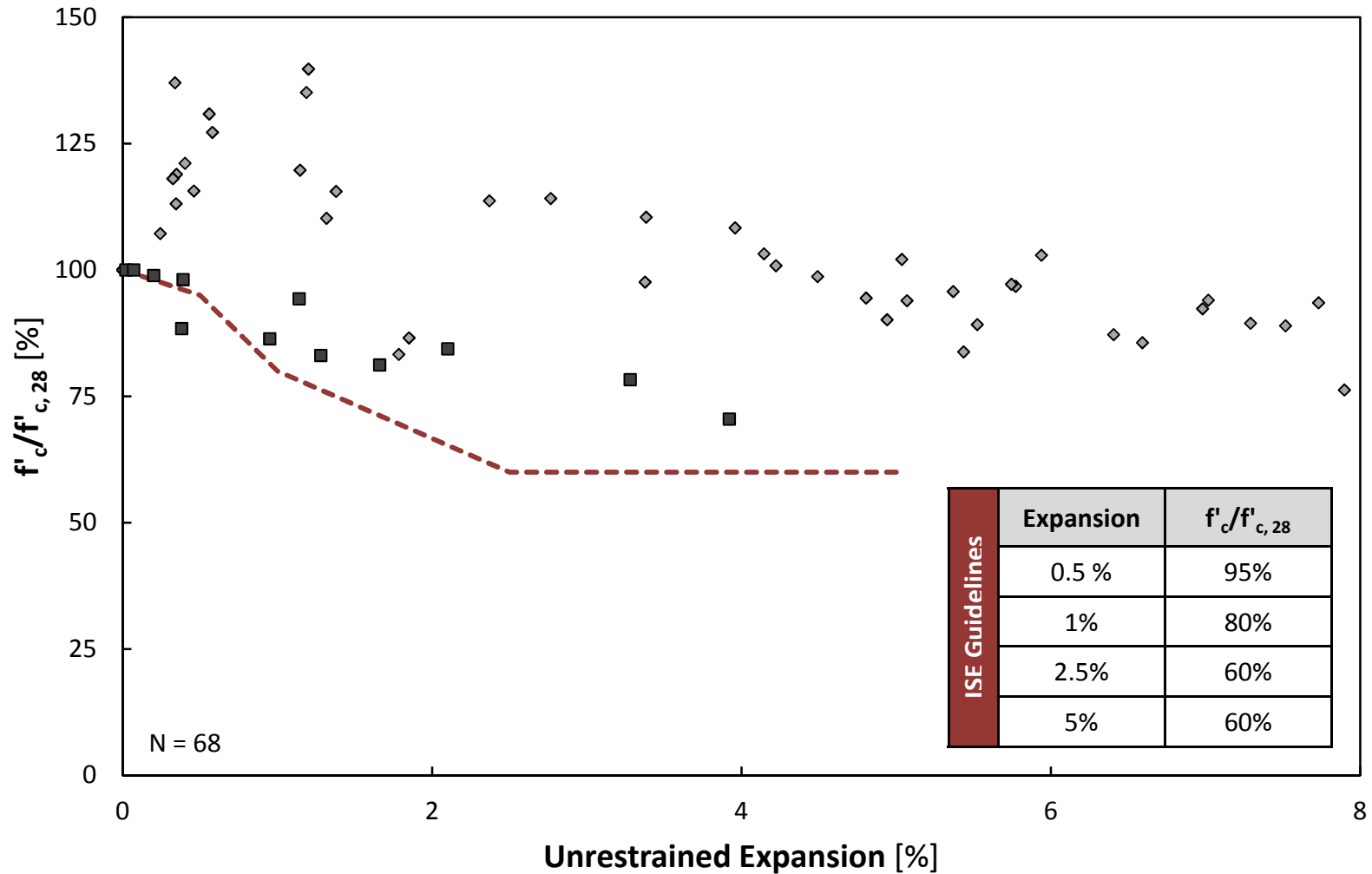
Clark, 1989

Ng and Clark, 1992

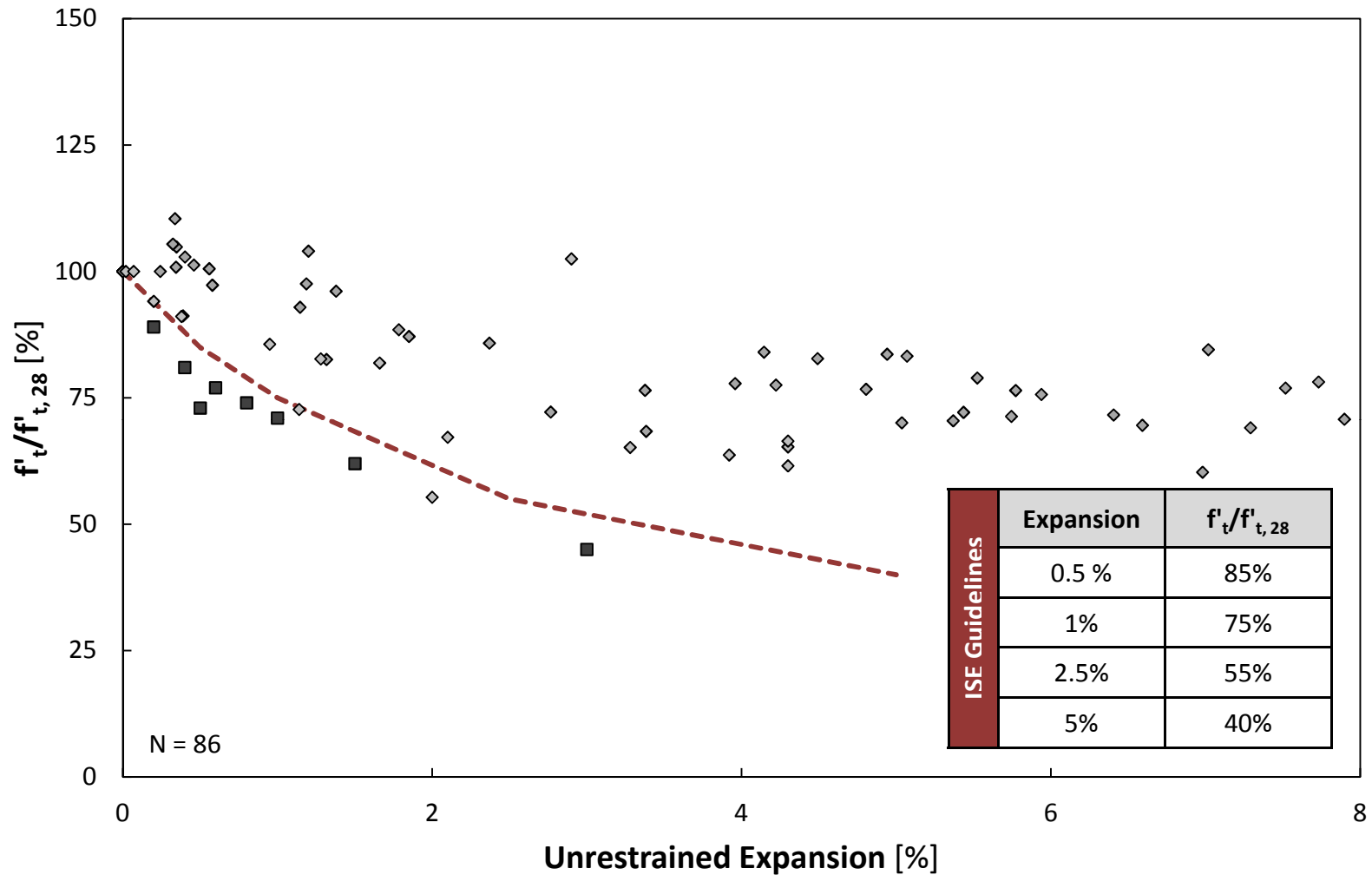
Smaoui et al., 2006

- Strength and stiffness reductions are plotted with respect to *unrestrained* expansions
- Guidelines from Institution of Structural Engineers (ISE) provide a reasonable estimate of lower bound performance

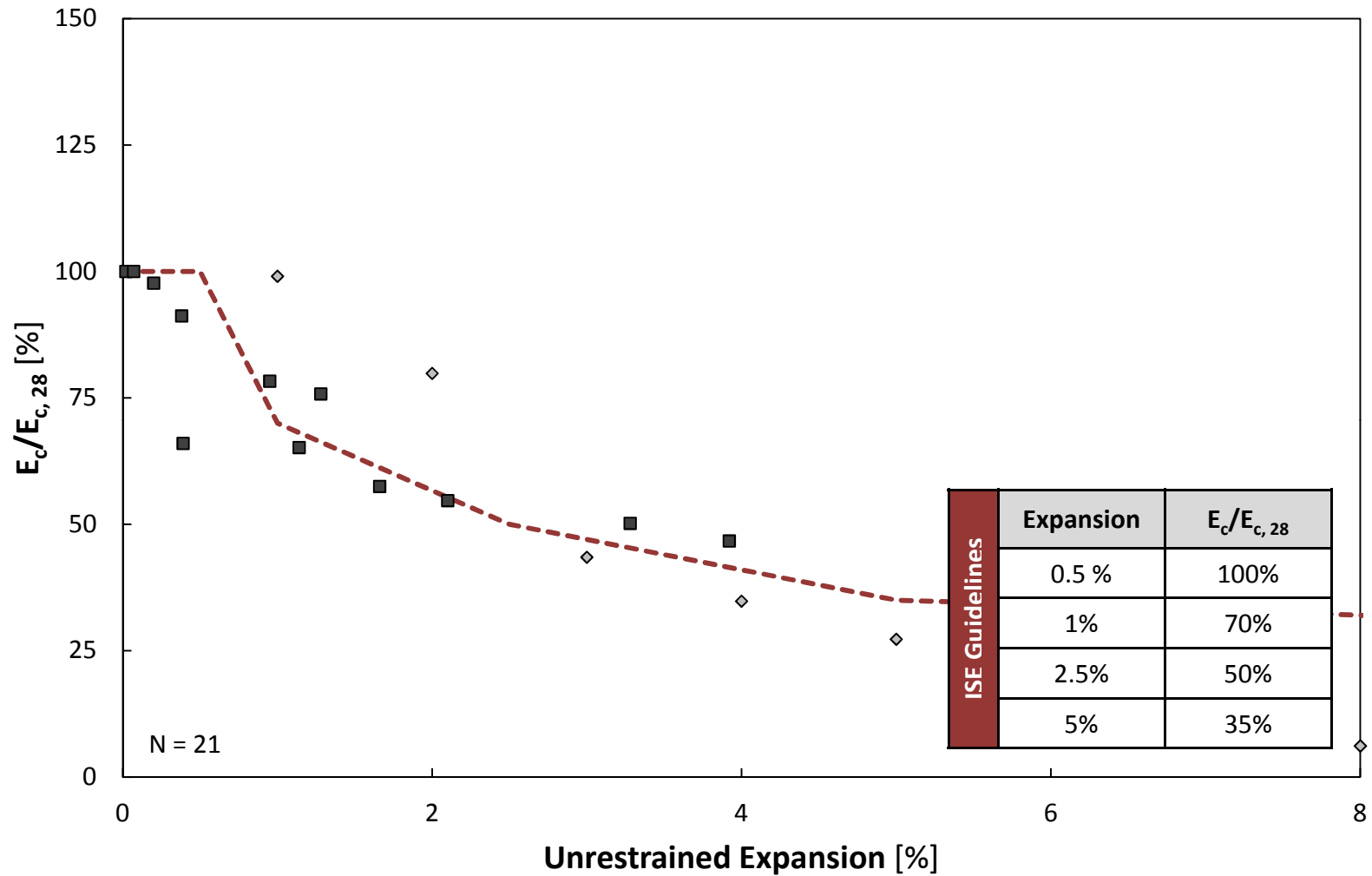
COMPRESSIVE STRENGTH | f'_c



SPLITTING TENSILE STRENGTH | f'_t



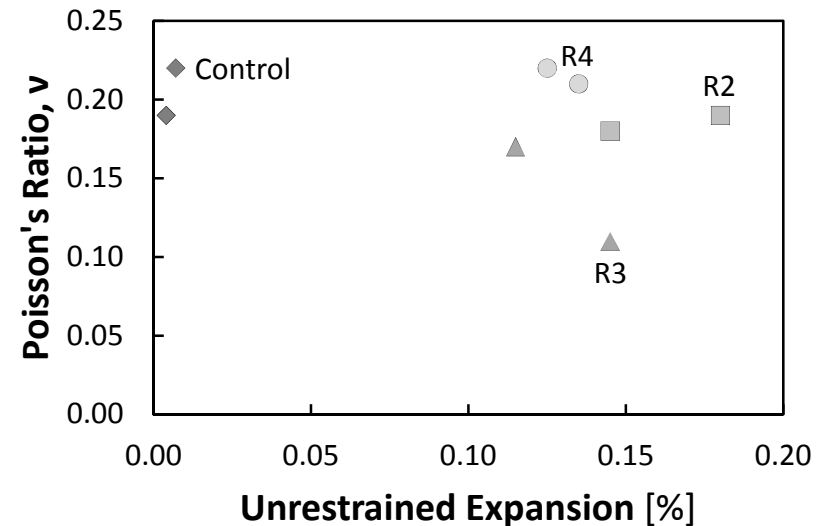
ELASTIC MODULUS | E_c



POISSON'S RATIO | ν

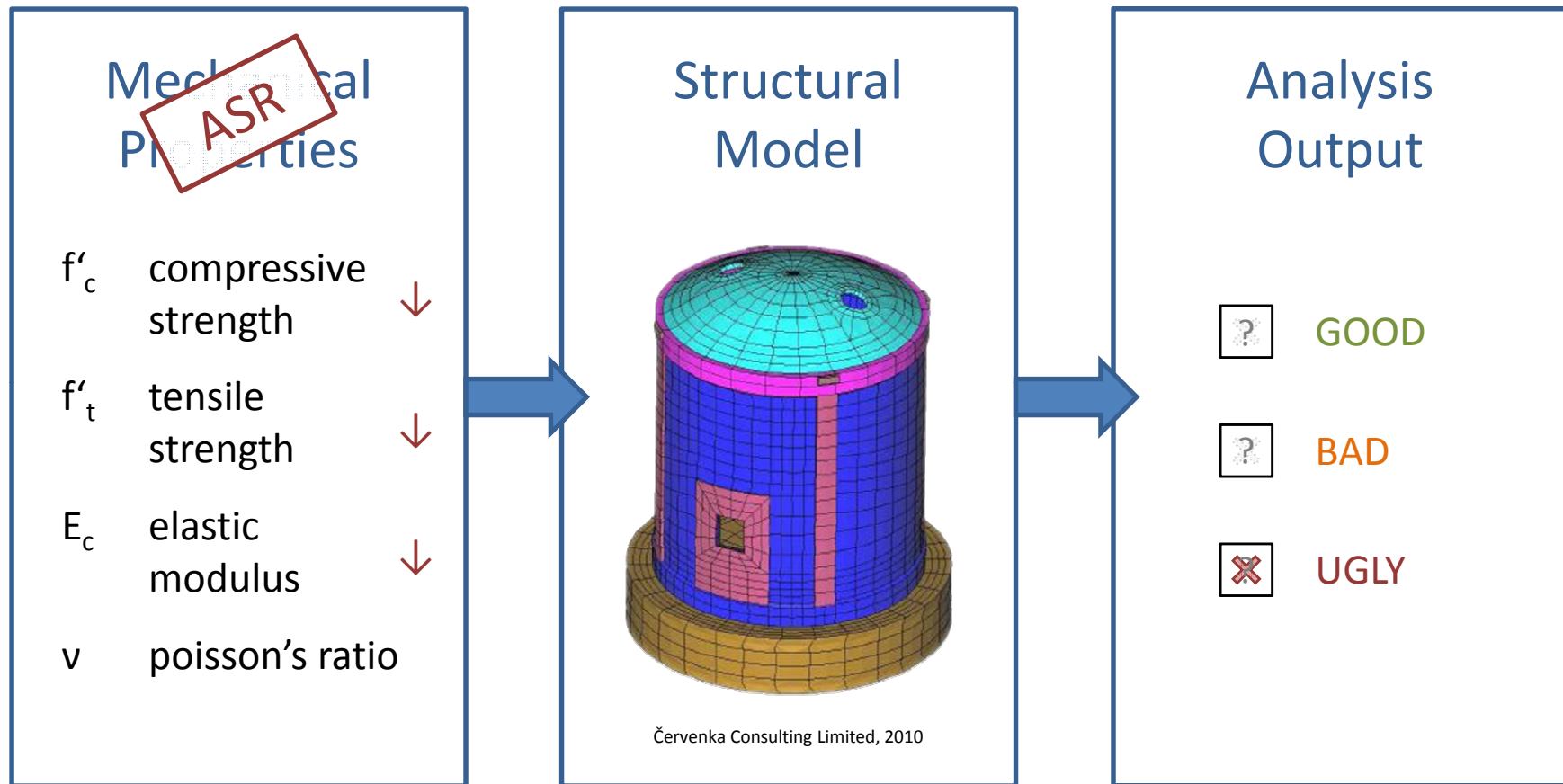


- Literature review yielded one relevant study
- Limited correlation between ν and measured expansions



Giaccio, G., Zerbino, R., Ponce, J.M., and Batic, O.R. "Mechanical behavior of concretes damaged by alkali-silica reaction." *Cement and Concrete Research* Vol. 38 (2008): 993-1004.

PERCEPTION



REALITY

*It has to be realized that any strength test conducted on a specimen quantifies the performance of the material in relation to that method of test only and does not necessarily reflect the performance of the material in its **structural context**. The significance of this for the assessment of structures [subject to ASR] is that no reliance should be placed on the values obtained from any one test and that commonly accepted procedures, such as the cube crushing test, may not indicate the value to be used in a normal design check.*

Clayton et al., 1990

STRUCTURAL CONTEXT

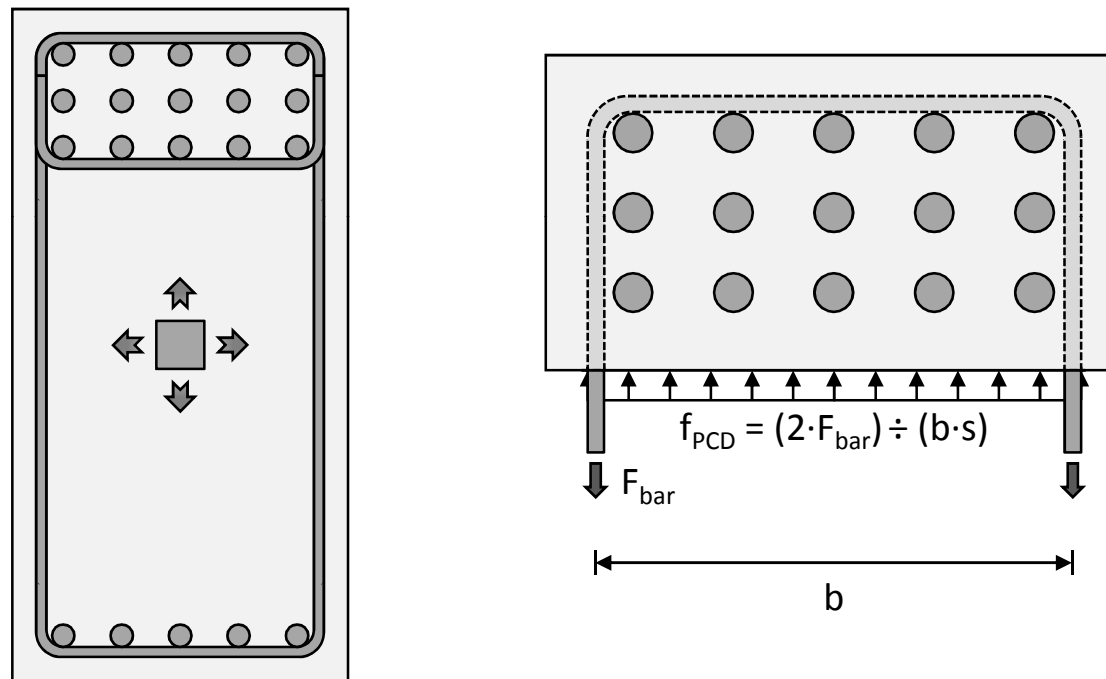
INSIGHTS FROM FSEL RESEARCH

Full-scale study conducted to establish effects of ASR on shear strength of beams with transverse reinforcement.



RESTRAINED EXPANSION

Transverse reinforcement restrained ASR-related expansions, resulting in the development of confining stresses.



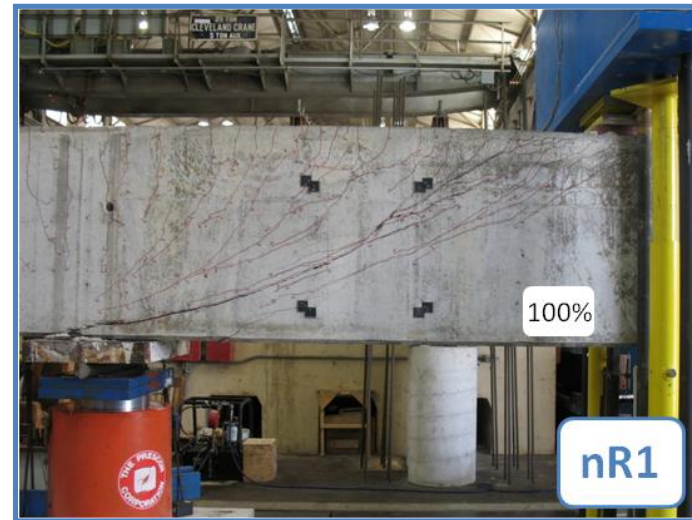
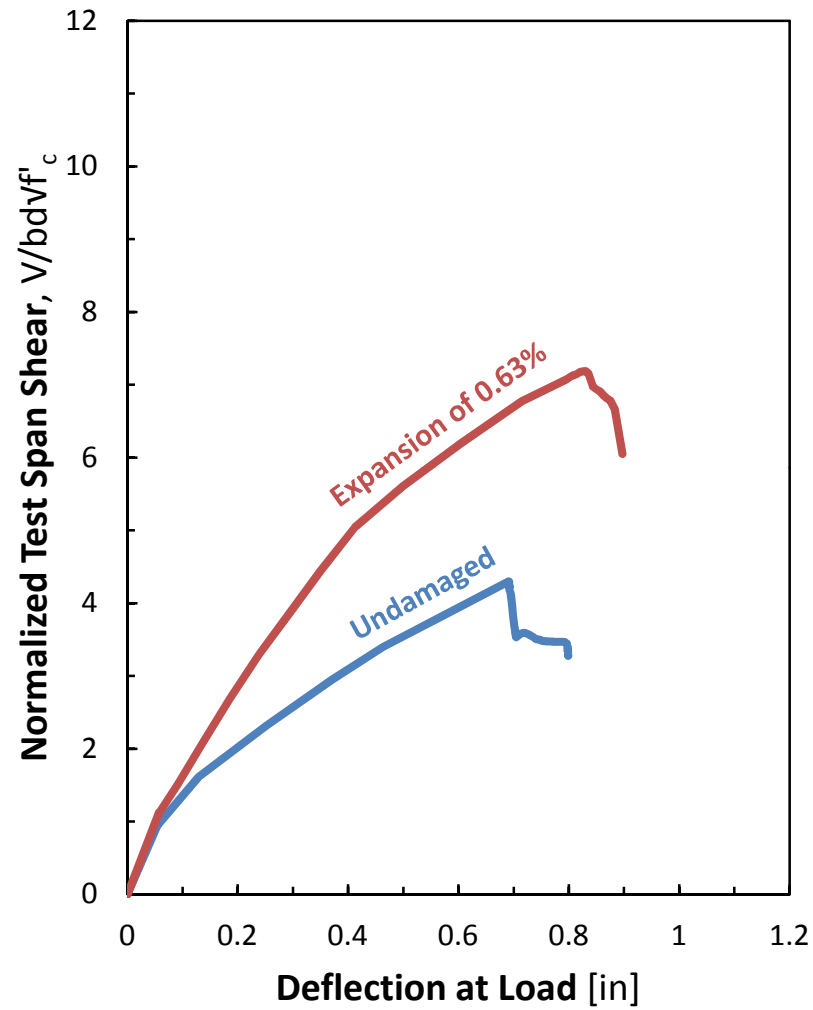
RESTRAINED EXPANSION



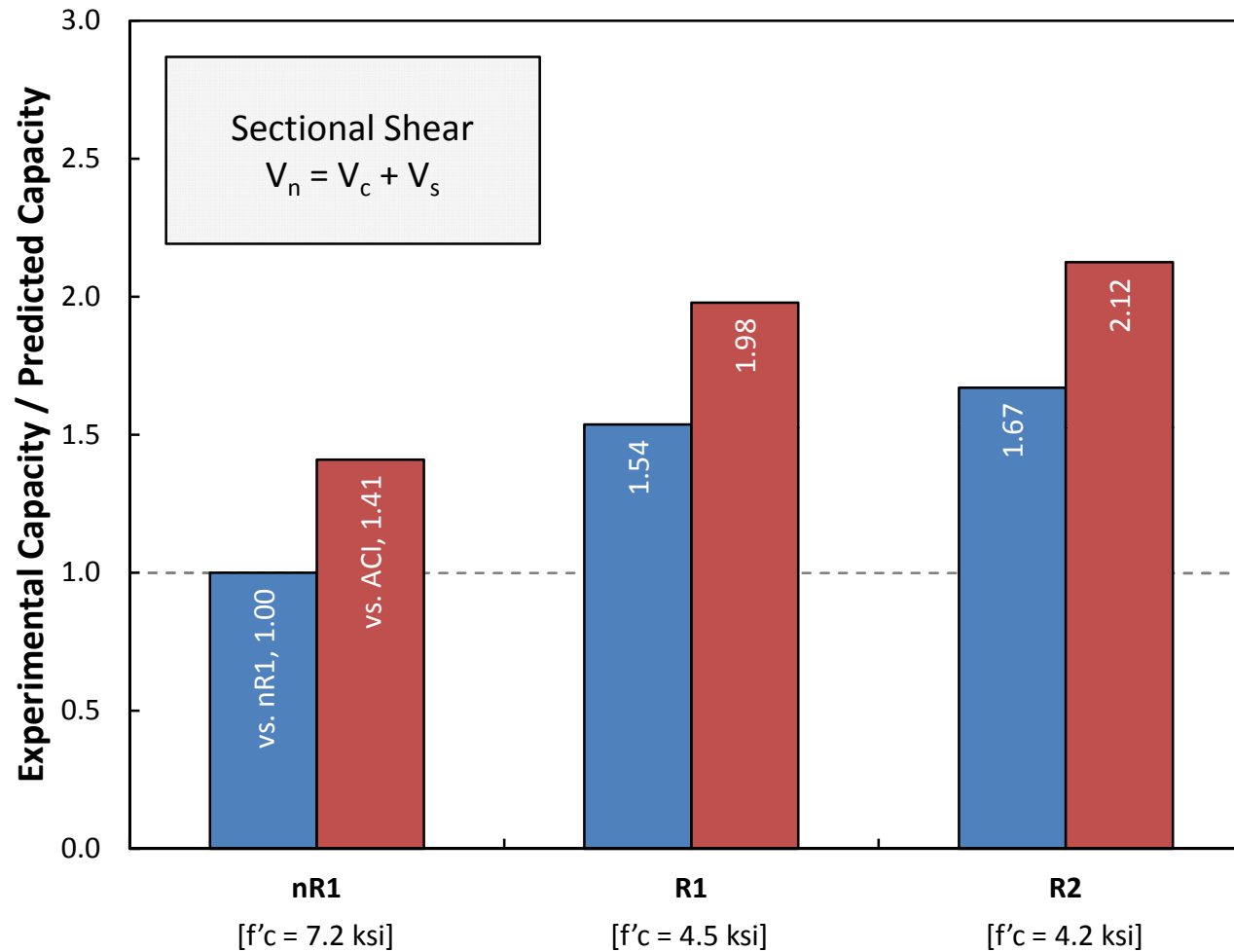
UNRESTRAINED EXPANSION




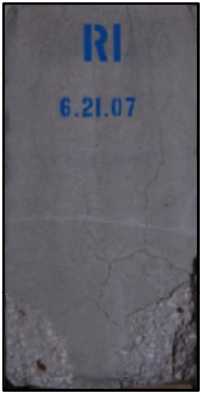
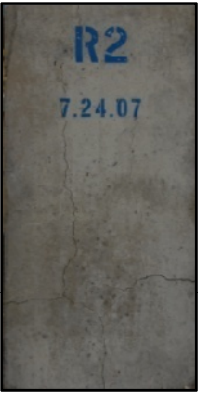
STIFFNESS IMPLICATIONS



STRENGTH IMPLICATIONS



CORRELATION TO MATERIAL TESTS

	nR1	R1	R2
			
$\epsilon_{t,max}$	0.0%	0.2%	0.7%
f'_c	7.2 ksi	4.5 ksi	4.2 ksi
f'_t	640 psi	430 psi	-
V_{test}	276 kips	336 kips	353 kips

RELEVANCE OF MATERIAL TEST DATA

The behavior of *plain concrete* affected by ASR is not necessarily indicative of structural performance.



Free Expansion

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Restrained Expansion

ASSESSMENT APPROACHES

ASSESSMENT APPROACHES

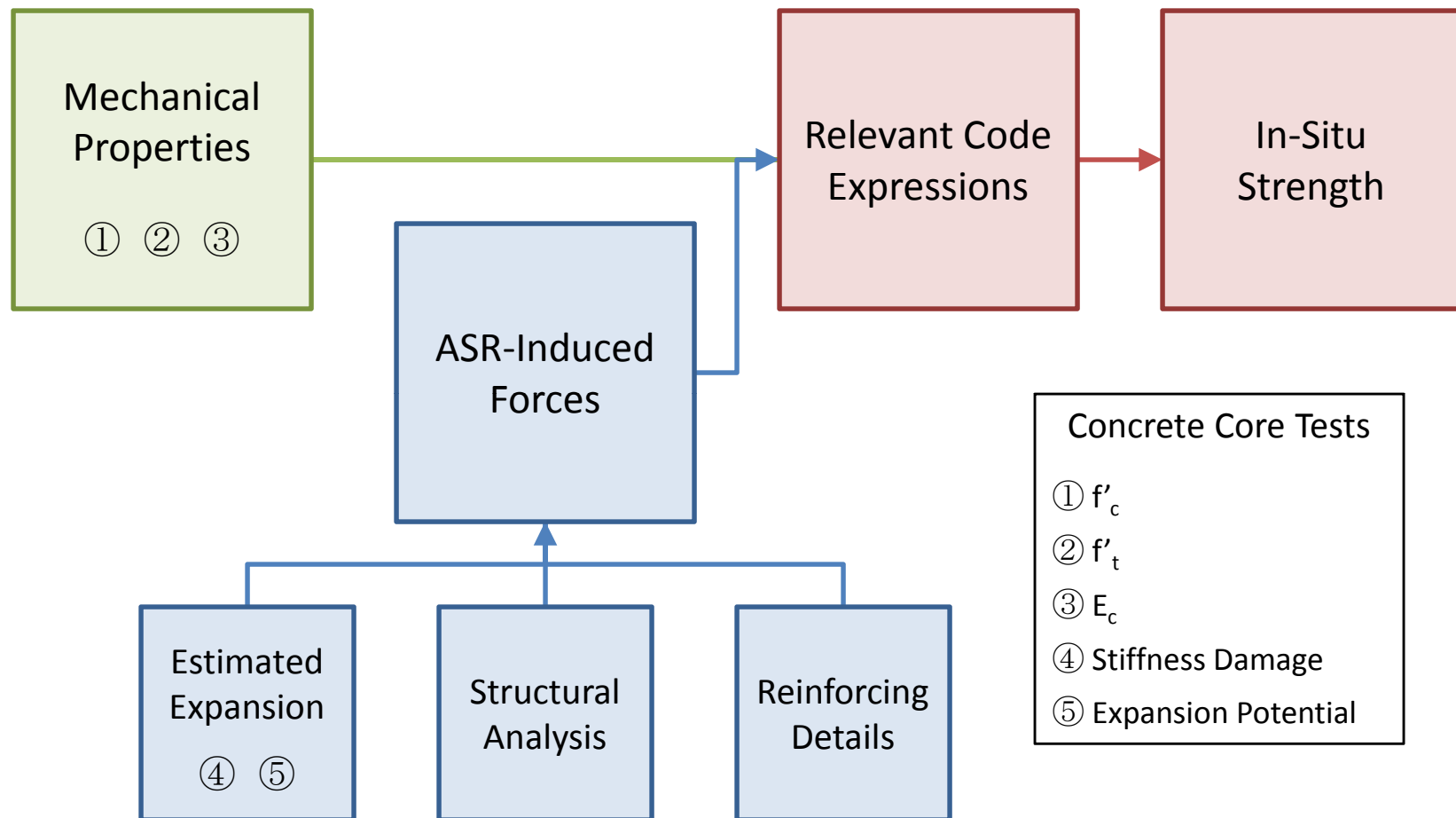
CORE-BASED ANALYSES



FULL-SCALE TESTING

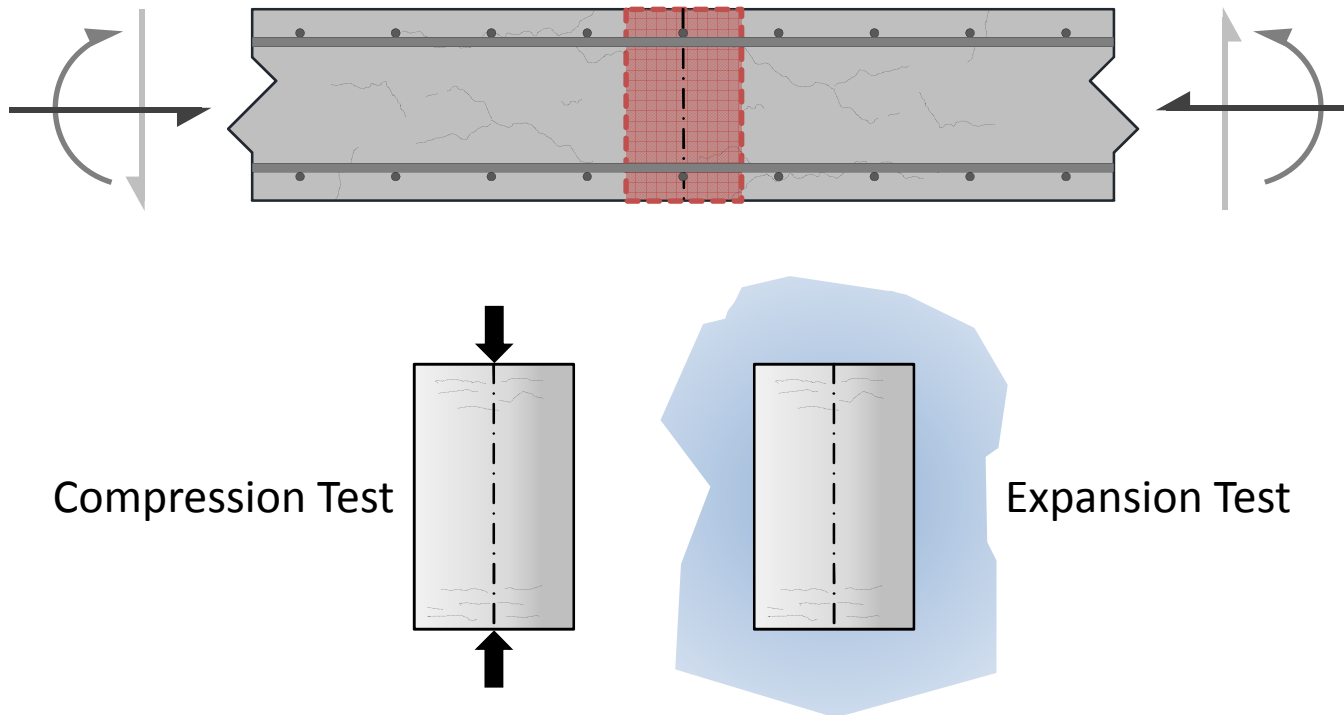


CORE-BASED ANALYSES



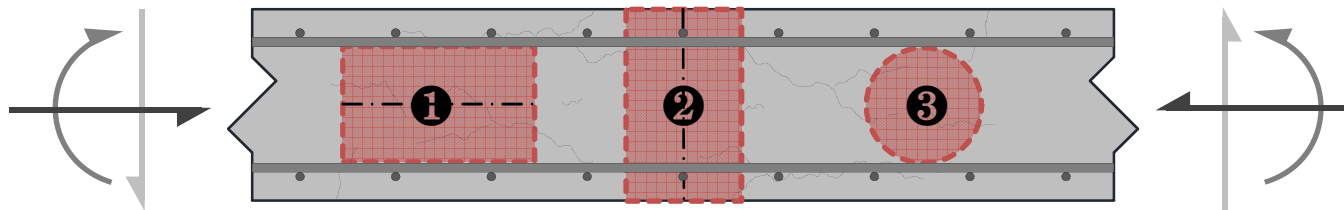
APPLICABILITY OF CORE TESTS

Cores extracted from a reinforced concrete structure are not representative of in-situ conditions.

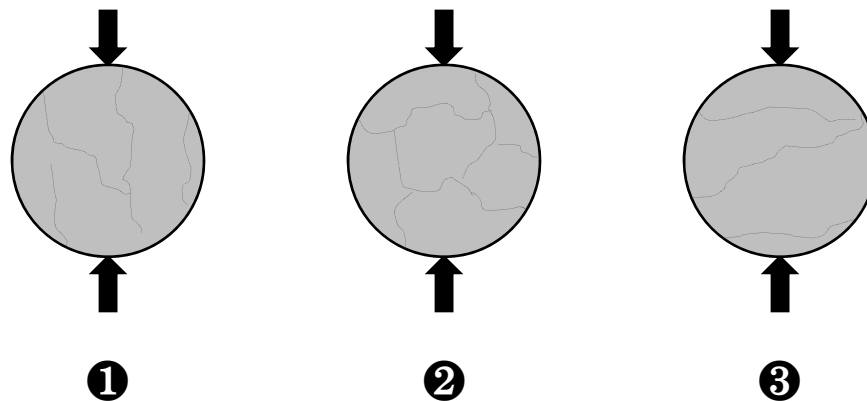


APPLICABILITY OF CORE TESTS

Test results will be influenced by the coring direction as it relates to structural geometry and sources of restraint.

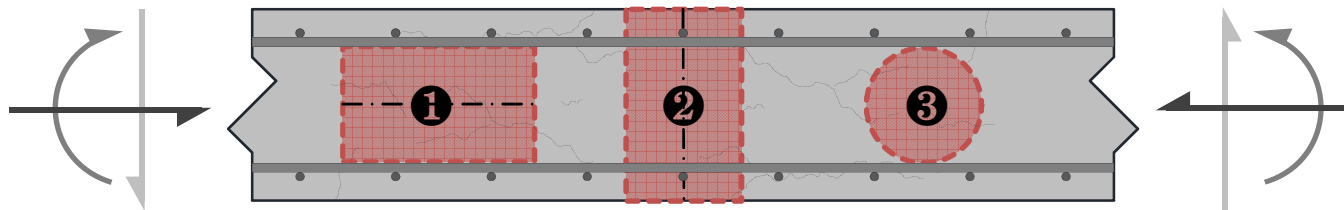


Splitting Tensile Tests

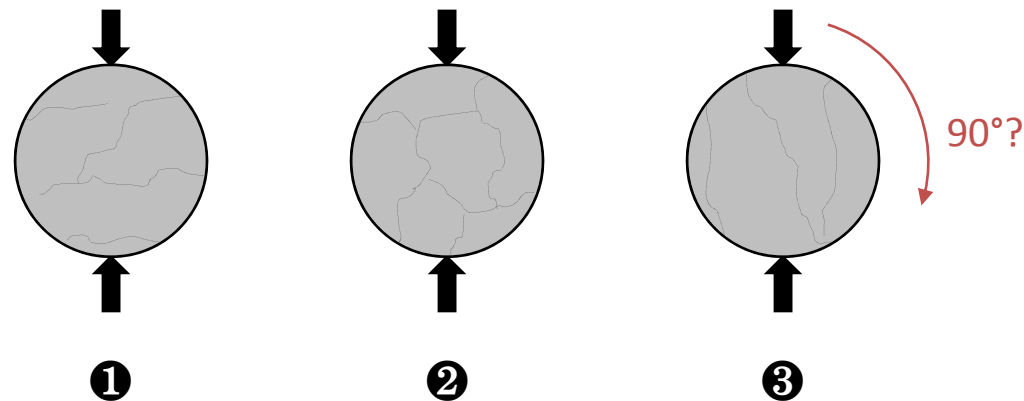


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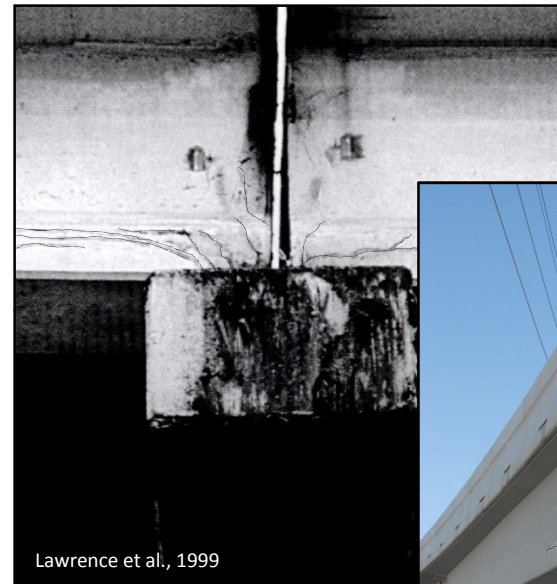
Splitting Tensile Tests



NON-ISOTROPIC EXPANSION

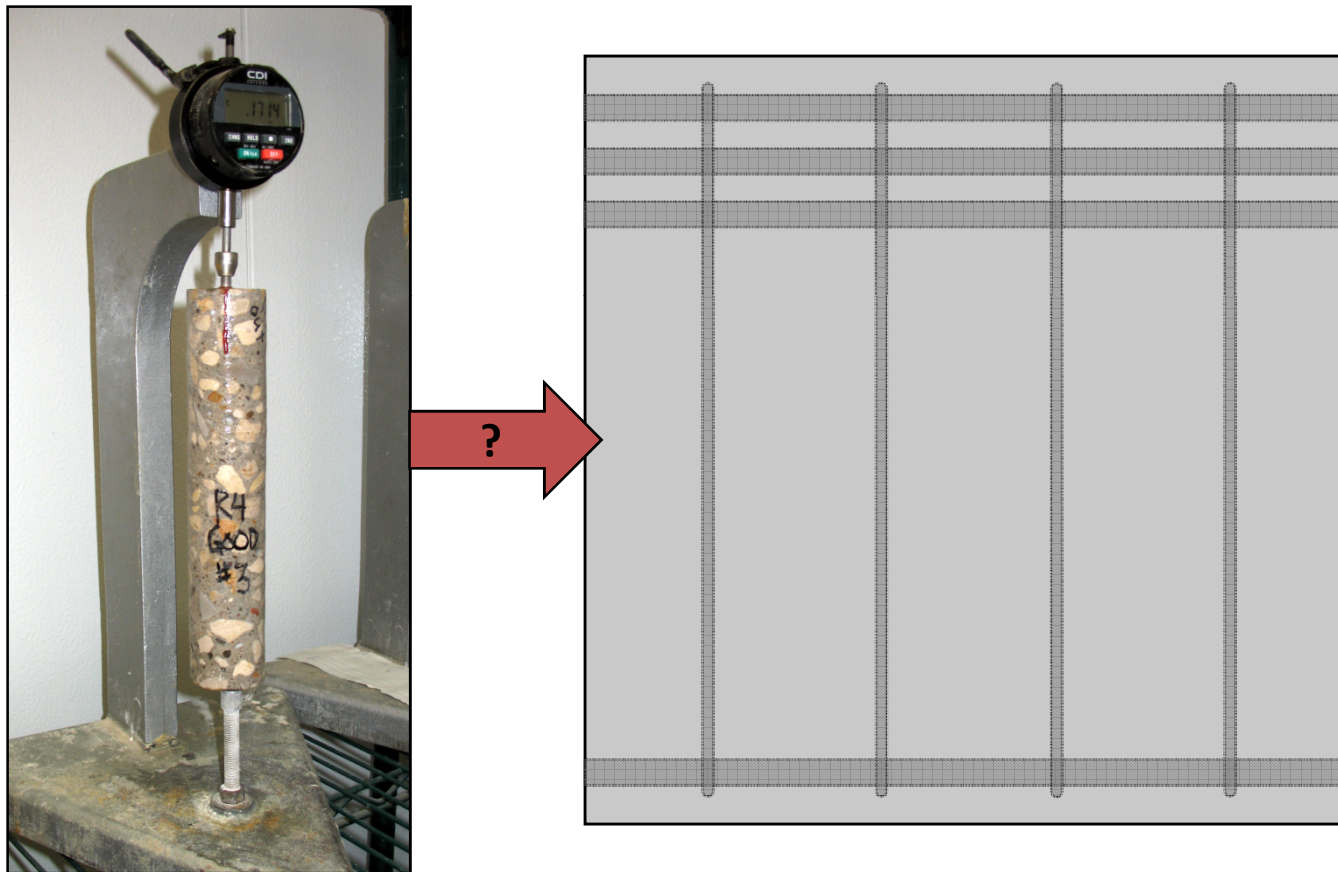
Magnitude and direction of ASR-related cracking in structures is strongly influenced by a number of factors.

- Internal Restraints
 - Reinforcement Pattern
 - Prestressing
 - Post-Tensioning
- External Restraints
 - Superimposed Loads
 - Boundary Conditions
 - Geometric Discontinuities



APPLICABILITY OF CORE TESTS

Field implementation of test results requires development of correlation between free and restrained expansions.



FULL-SCALE TESTING

Definitive assessments may be obtained by replicating critical structural details and deterioration within the laboratory.



Accelerated Deterioration



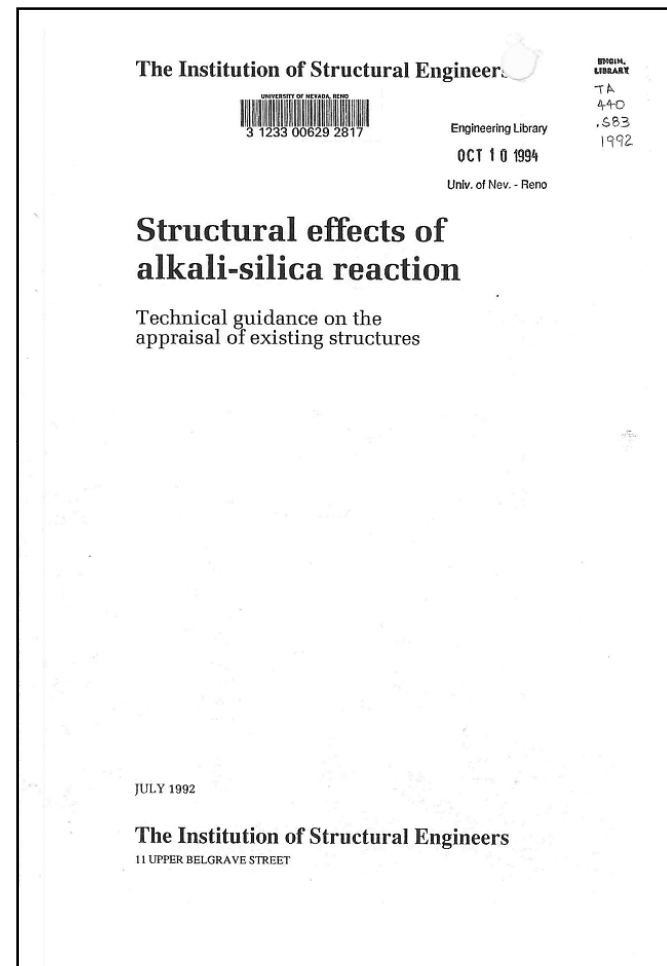
Continuous Monitoring



Current and Future Damage

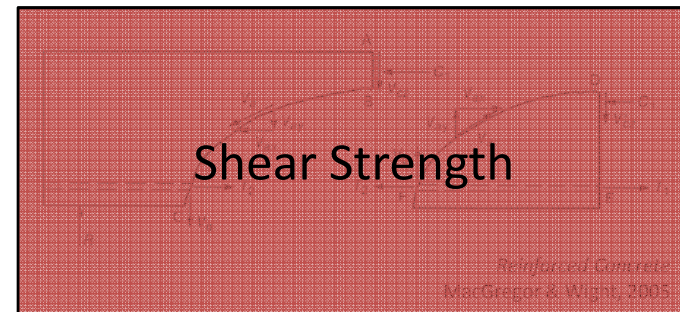
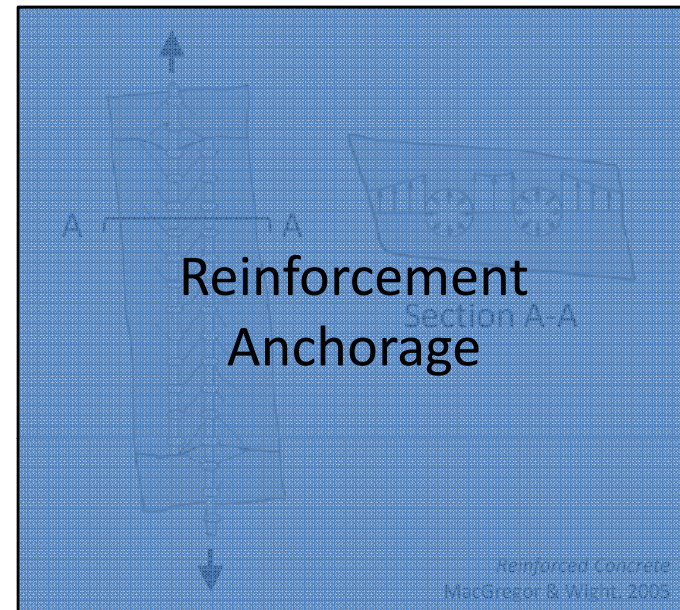
FULL-SCALE TESTING

- ISE structural assessment guidelines were developed on the basis of accelerated laboratory tests



FULL-SCALE TESTING

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- Proof testing will provide the most meaningful assessment of critical structural details



FULL-SCALE TESTING

- ISE structural assessment guidelines were developed on the basis of accelerated laboratory tests
- Proof testing will provide the most meaningful assessment of critical structural details
- Full-scale structural testing is the most definitive form of structural assessment



from "Containment Integrity Research at Sandia National Laboratories"
Nuclear Regulatory Commission, 2006

QUESTIONS