Specifications
Prescriptive to Performance

by

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Collaborative Seminar Series on “Responsible Use of SCM’s in Performance-Based Specifications”

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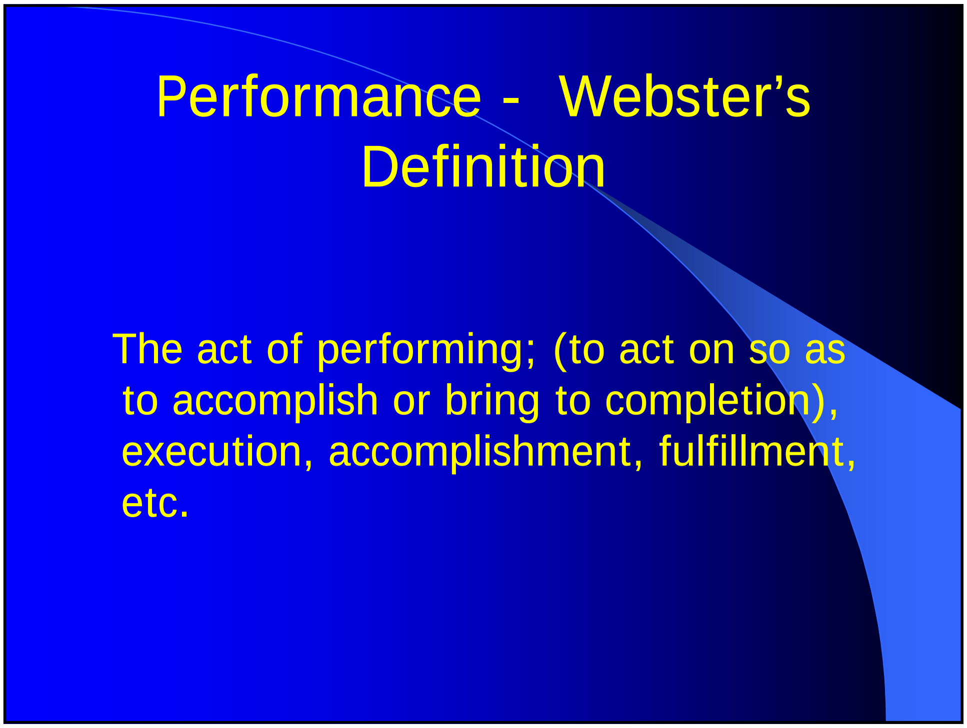
Prescriptive - Webster’s Definition

- that which prescribes;
- based on legal prescription;
- prescribed by custom or long use;



Performance - Webster's Definition

The act of performing; (to act on so as to accomplish or bring to completion), execution, accomplishment, fulfillment, etc.

History

- Specification comes from the Latin verb "*SPECIFICARE*"
  - *To define precisely*
- The need to define precisely is not a new concept; and
- The way requirements are communicated has changed

Chinese

- Specified stone of particular size and quality for the great wall;
- Specified how stones were to be laid;
- Quality control during implementation of work.

Need for Specifications

British Standards BS 5760: Part 4

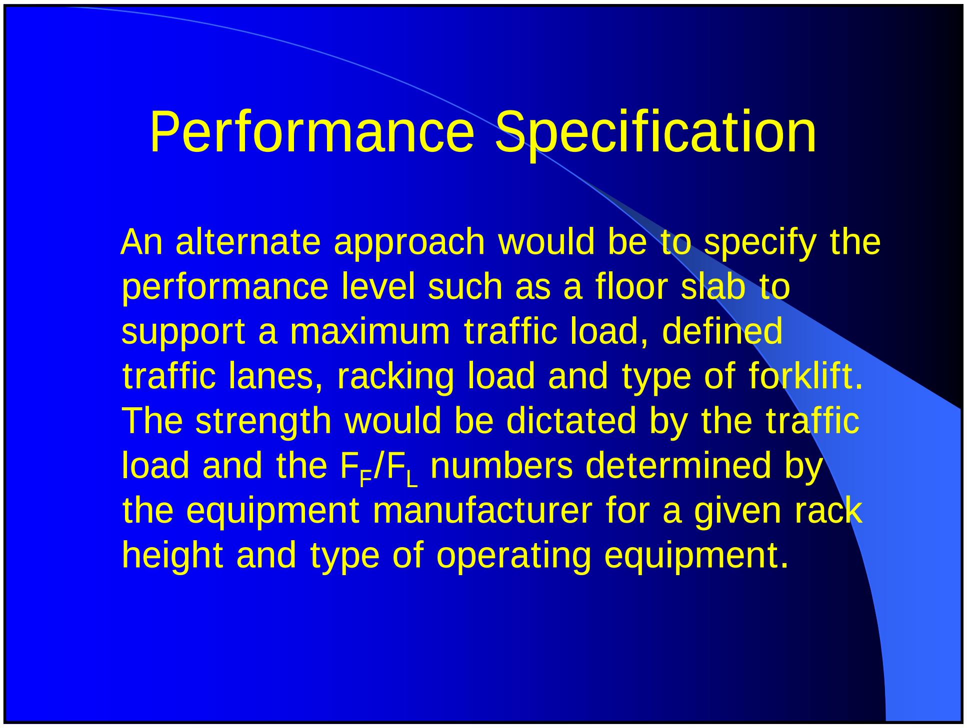
A specification is a means of communication in writing the requirements or intentions of one party to another in relation to a product, service, material, procedure or test.

Communication

- Ancients rarely used written methods;
- Very few tradesmen could read – so why bother;
- One could say, on occasion not much has changed.

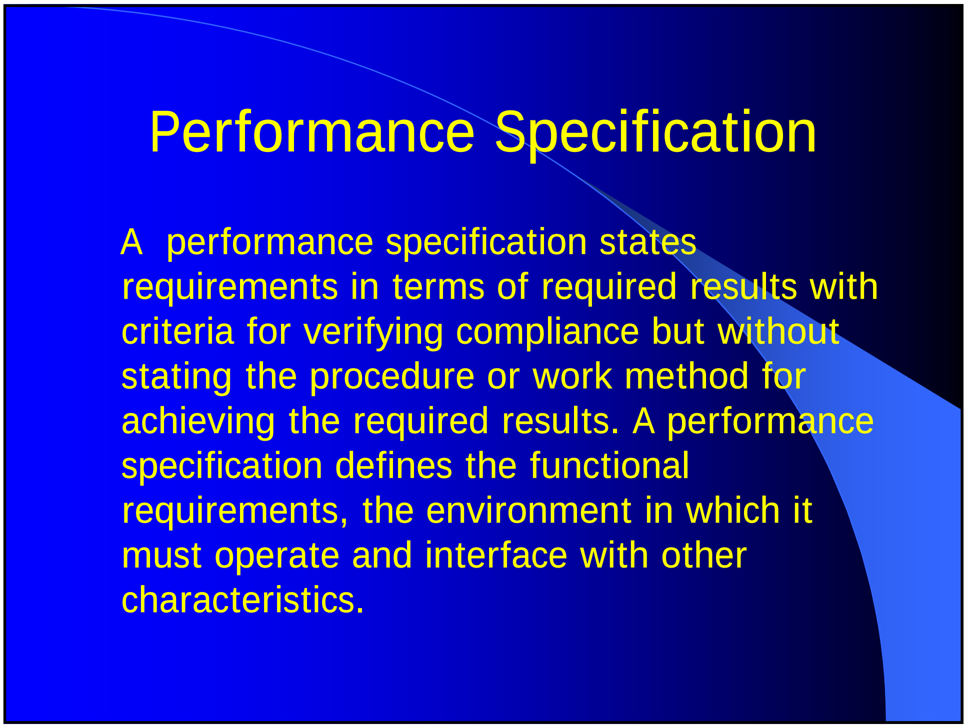
Prescriptive Specification

A prescriptive specification details the materials that must be used and to a certain extent the methods or procedures to achieve the end result. For example, a floor slab might be specified to contain 35 MPa concrete in accordance with CSA and a specified surface finish also in accordance with CSA.



Performance Specification

An alternate approach would be to specify the performance level such as a floor slab to support a maximum traffic load, defined traffic lanes, racking load and type of forklift. The strength would be dictated by the traffic load and the F_F/F_L numbers determined by the equipment manufacturer for a given rack height and type of operating equipment.



Performance Specification

A performance specification states requirements in terms of required results with criteria for verifying compliance but without stating the procedure or work method for achieving the required results. A performance specification defines the functional requirements, the environment in which it must operate and interface with other characteristics.

CSA A23.1 – 04 Prescriptive

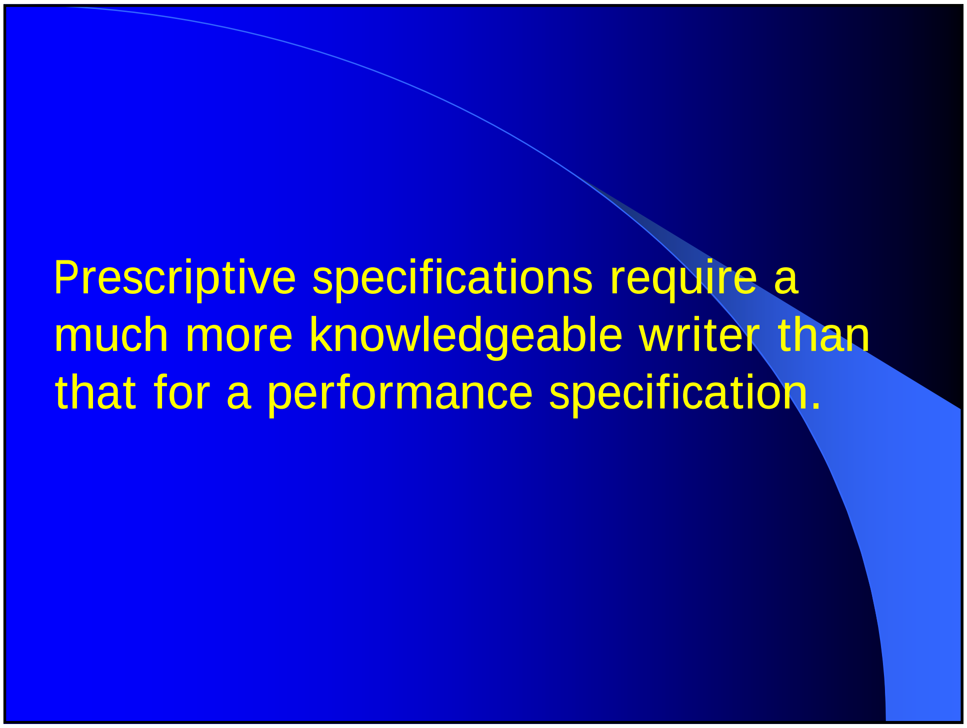
CSA defines a prescriptive specification “as a method of specifying a construction product in which all processes, activities, materials, proportions and methods to achieve a final outcome are specified in mandatory language”.

CSA A23.1 – 04 Performance

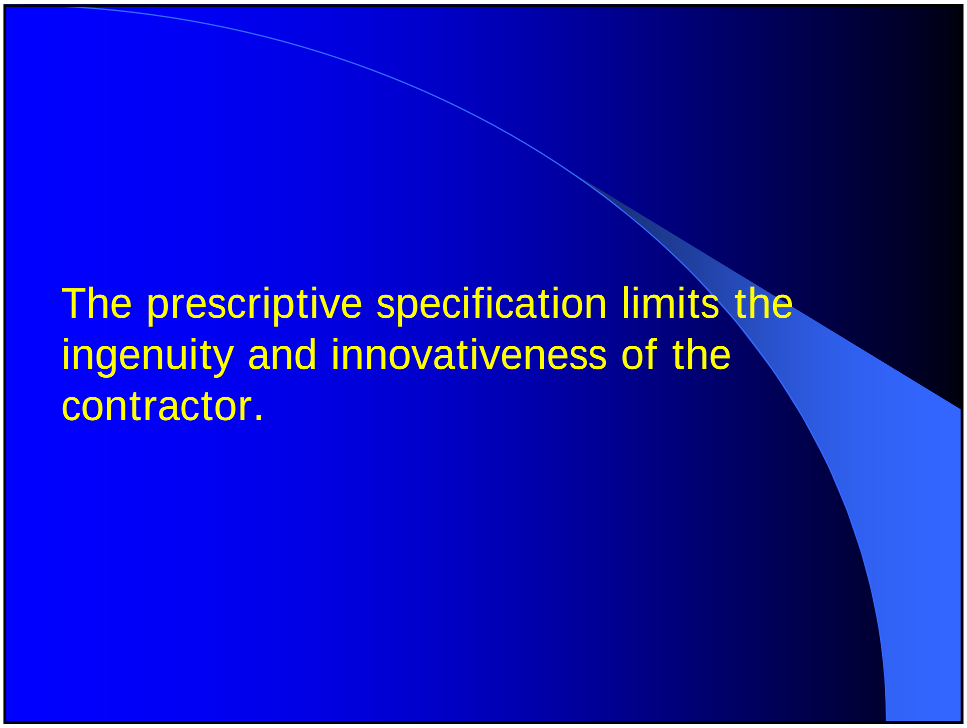
CSA A23.1 defines a performance specification “as a method of specifying a construction product in which the final outcome is given in mandatory language in a manner that the performance can be measured by accepted industry standard and methods”.

Performance specifications are designed to reduce owner risk by transferring responsibility to the contractor. In return the contractor benefits by providing the services requested by innovative methods to achieve performance objectives.

To ensure efficiency, economy and good practice, risk should be allocated to the party best suited to manage them. The allocation of risk must be transparent.



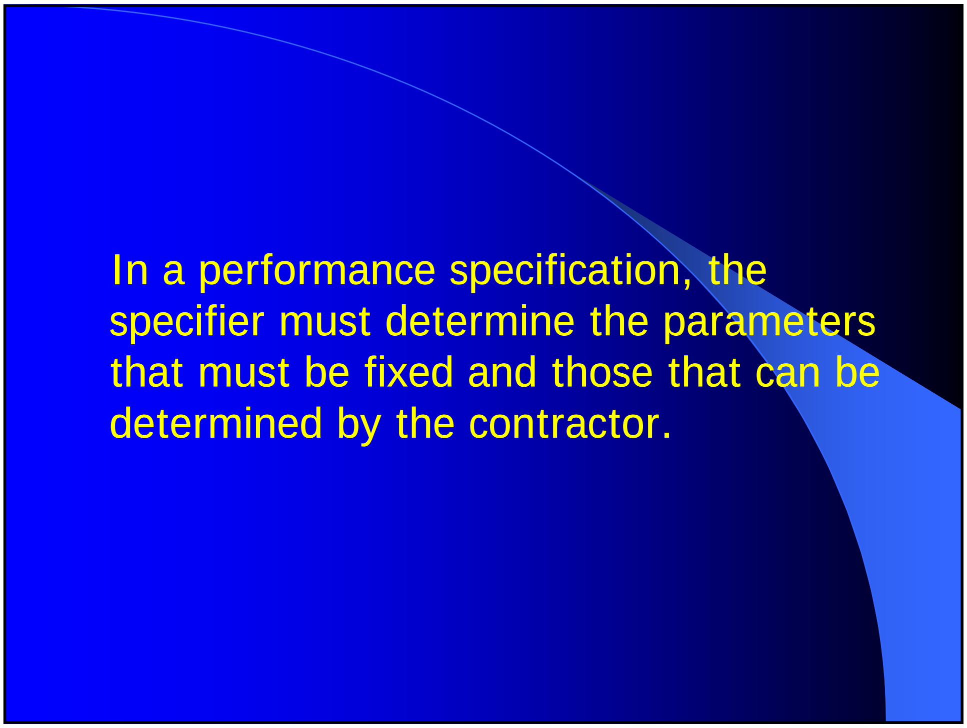
Prescriptive specifications require a much more knowledgeable writer than that for a performance specification.



The prescriptive specification limits the ingenuity and innovativeness of the contractor.

Prescriptive Specification

- Prescriptive specifications are often not precise; they may be ambiguous;
- Requirements are often not sufficiently defined; and
- Prescriptive specifications invite litigation.



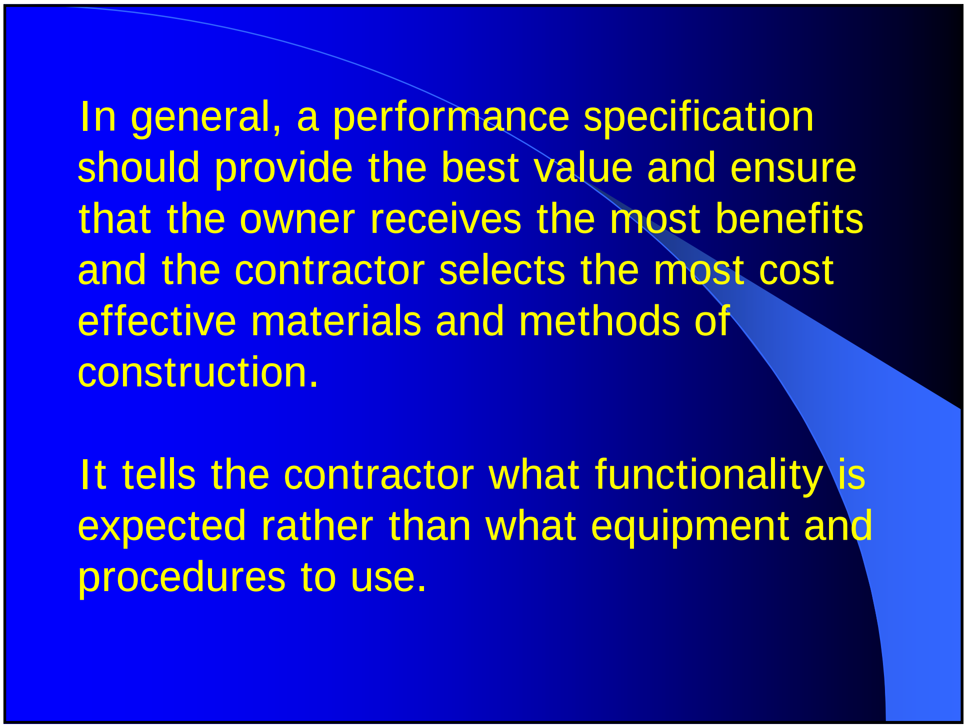
In a performance specification, the specifier must determine the parameters that must be fixed and those that can be determined by the contractor.

Pros and Cons

- Prescriptive specifications
  - Writer has full control
  - Straightforward quantification
  - No proprietary solutions
  - Limited supplier initiative
  - Design responsibility with specifier
  - Certainty of product

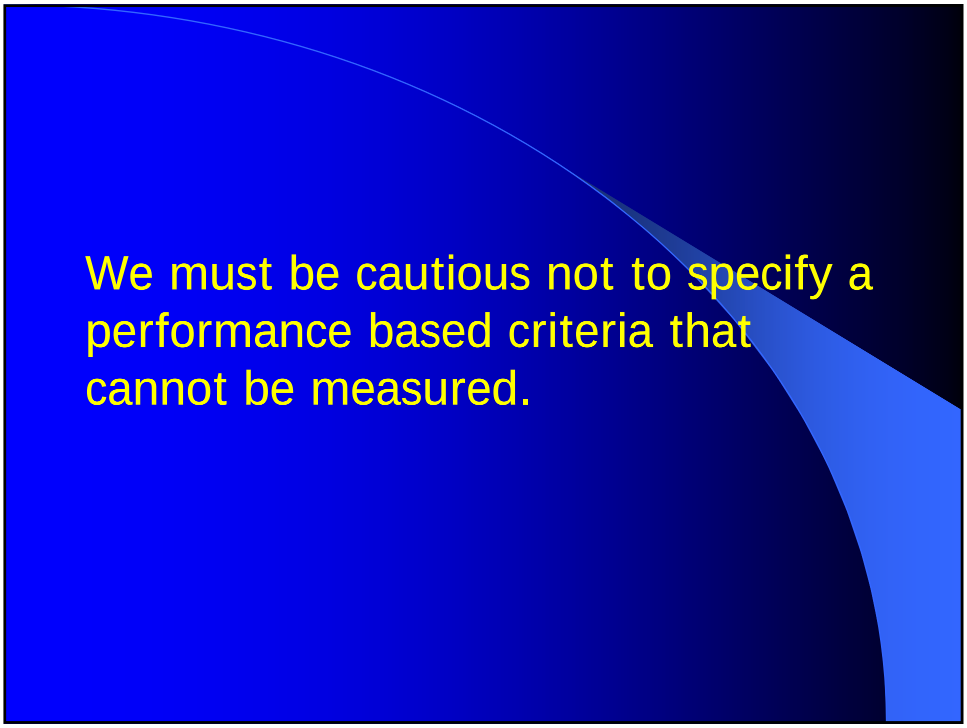
Pros and Cons

- Performance Specification
  - Wide range of design solutions
  - Risk of non-compliance
  - Defining performance may be difficult

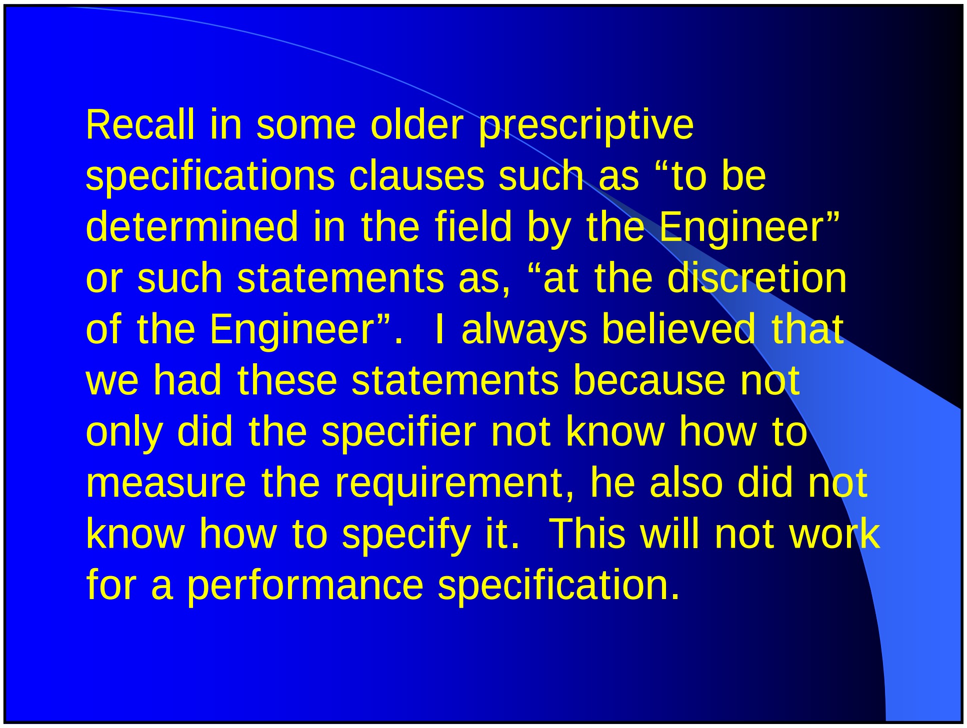


In general, a performance specification should provide the best value and ensure that the owner receives the most benefits and the contractor selects the most cost effective materials and methods of construction.

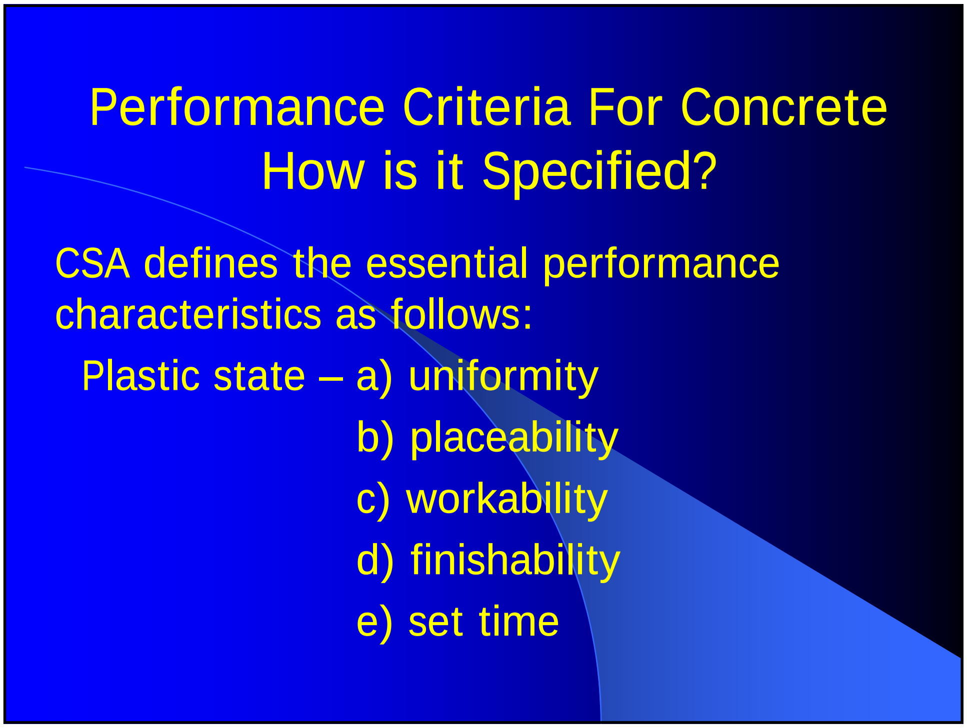
It tells the contractor what functionality is expected rather than what equipment and procedures to use.



We must be cautious not to specify a performance based criteria that cannot be measured.



Recall in some older prescriptive specifications clauses such as “to be determined in the field by the Engineer” or such statements as, “at the discretion of the Engineer”. I always believed that we had these statements because not only did the specifier not know how to measure the requirement, he also did not know how to specify it. This will not work for a performance specification.



Performance Criteria For Concrete
How is it Specified?

CSA defines the essential performance characteristics as follows:

Plastic state – a) uniformity
b) placeability
c) workability
d) finishability
e) set time

Performance Criteria For Concrete How is it Specified?

CSA defines the essential performance characteristics as follows:

Hardened state – a) physical characteristics
b) rate of strength development
c) durability in service environment
d) volume stability
e) geometric requirements
f) appearance

Design Build

The concept of design build is a tendency toward a performance specification. The design build team has wide latitude in choosing the outcome of the structure.

Design Build Specification

Appropriate Level of Design

- Ohio Department of Transportation 10 to 40 percent depending on complexity;
- WisDot 30 to 40 percent;
- NCDoT 25 to 75 percent, with ultimate aim to be 25 percent;
- FLDoT 10 percent;
- AZDoT 10 to 20 percent; and
- CalTrans 30 percent

The Milwaukee 6th Street Viaduct Project was Somewhat Unique in Several Ways:

- Project drawings to 30 percent completion was produced for tendering;
- A clause in the specifications provided for a 50/50 split between owner and contractor for areas of cost saving for more economical design; and
- 30 percent fly ash was used in the concrete for the 1st time with WisDot as part of a requirement for 40 % recycled materials in the overall project.

6th Street Viaduct, WI

Typical Performance Specification Requirements

- The contractor must submit a comprehensive Quality Management Plan;
- Detailed Quality Control Plan; and
- Thermal Management Plan for mass concrete.

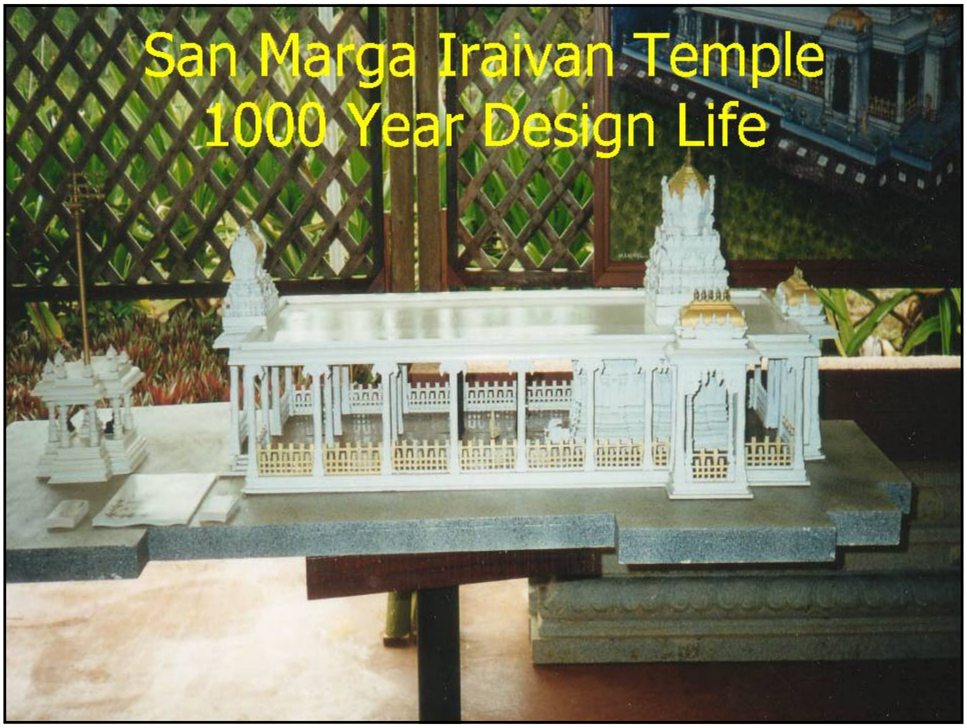
Example of Performance Specification

San Marga Iraivan Temple
Kaua’i

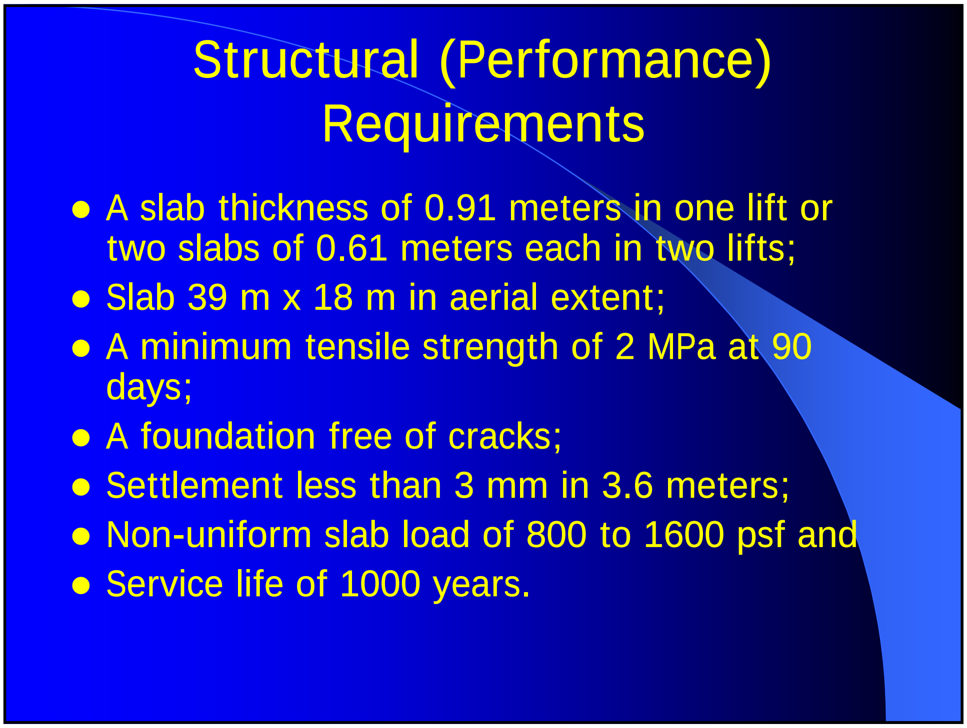
The Construction of a High-Volume Fly Ash Concrete Foundation for a Structure Designed for a 1000-Year Service Life

by

Dr. P.K. Mehta & Dr. W.S. Langley

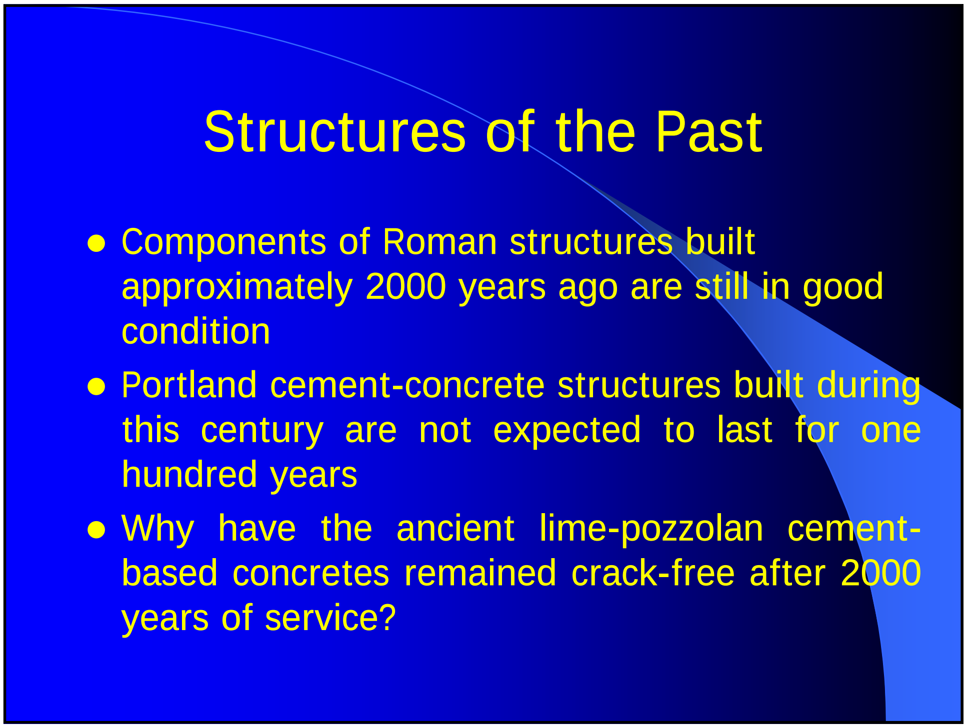


San Marga Iraivan Temple 1000 Year Design Life



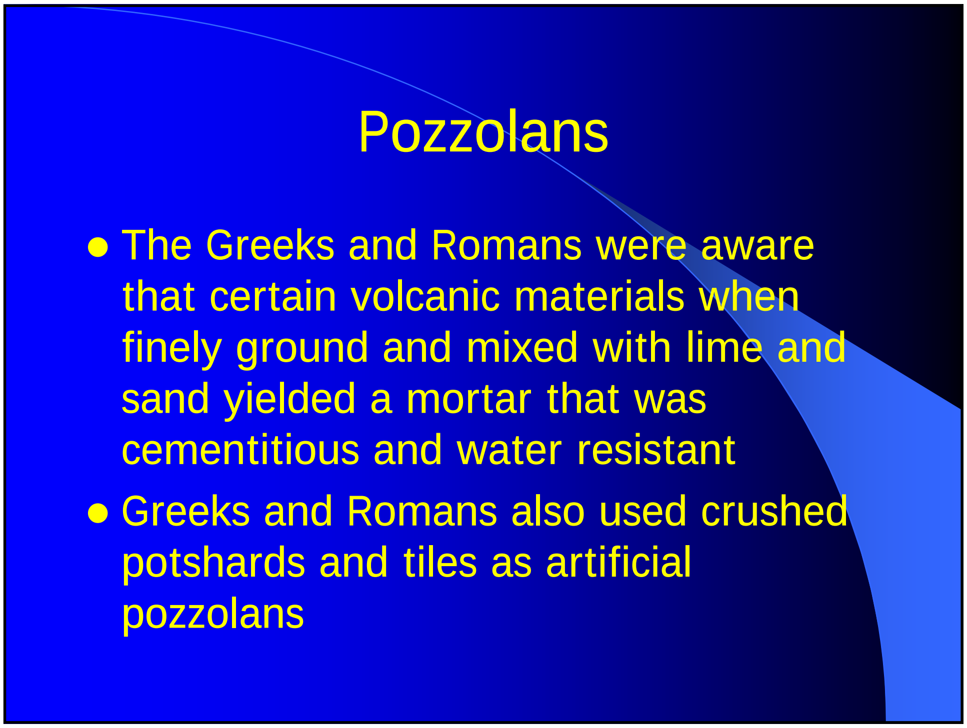
Structural (Performance) Requirements

- A slab thickness of 0.91 meters in one lift or two slabs of 0.61 meters each in two lifts;
- Slab 39 m x 18 m in aerial extent;
- A minimum tensile strength of 2 MPa at 90 days;
- A foundation free of cracks;
- Settlement less than 3 mm in 3.6 meters;
- Non-uniform slab load of 800 to 1600 psf and
- Service life of 1000 years.



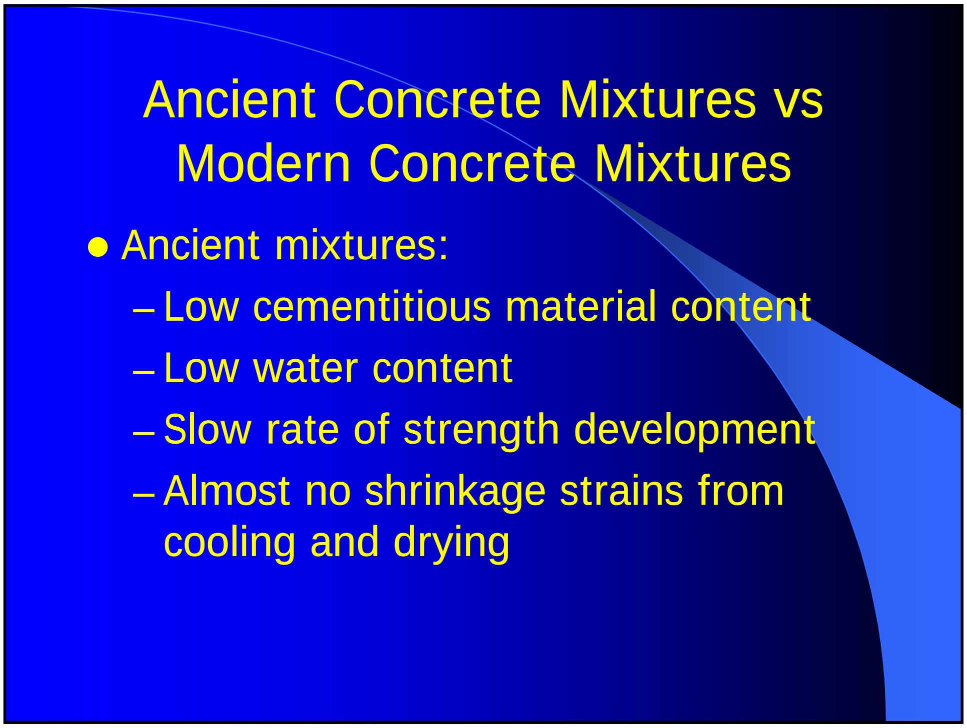
Structures of the Past

- Components of Roman structures built approximately 2000 years ago are still in good condition
- Portland cement-concrete structures built during this century are not expected to last for one hundred years
- Why have the ancient lime-pozzolan cement-based concretes remained crack-free after 2000 years of service?



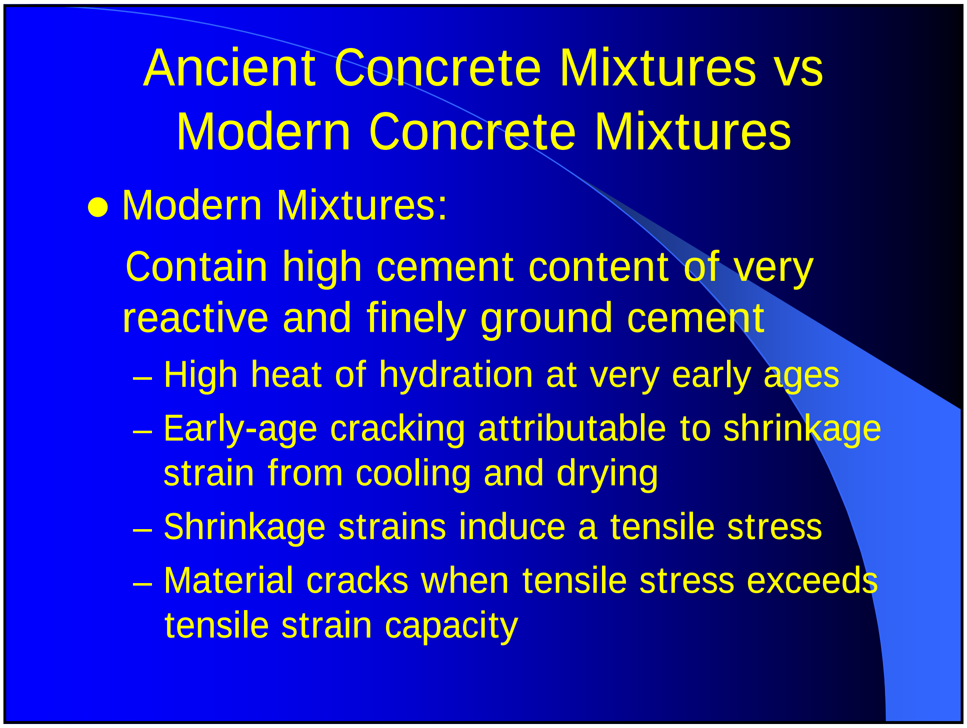
Pozzolans

- The Greeks and Romans were aware that certain volcanic materials when finely ground and mixed with lime and sand yielded a mortar that was cementitious and water resistant
- Greeks and Romans also used crushed potshards and tiles as artificial pozzolans



Ancient Concrete Mixtures vs Modern Concrete Mixtures

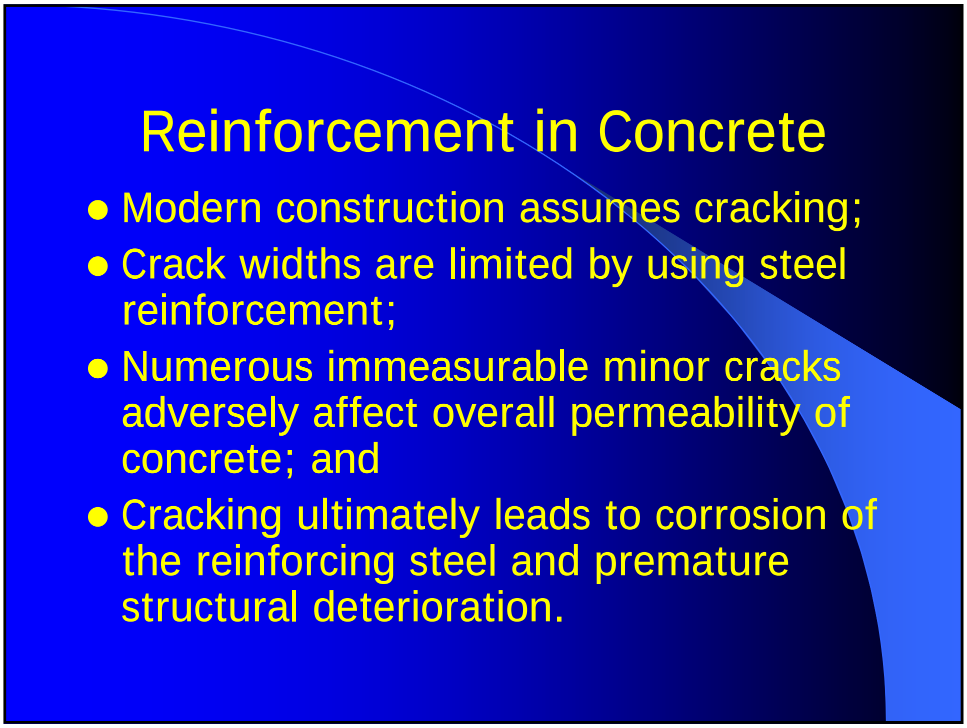
- Ancient mixtures:
  - Low cementitious material content
  - Low water content
  - Slow rate of strength development
  - Almost no shrinkage strains from cooling and drying



Ancient Concrete Mixtures vs Modern Concrete Mixtures

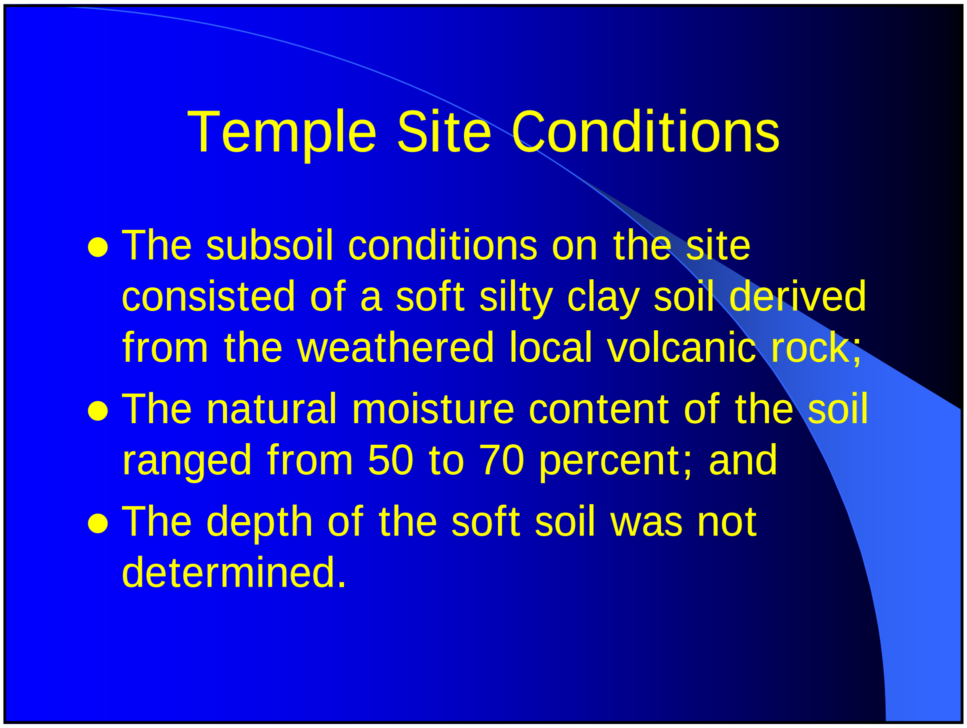
- Modern Mixtures:

  Contain high cement content of very reactive and finely ground cement
  - High heat of hydration at very early ages
  - Early-age cracking attributable to shrinkage strain from cooling and drying
  - Shrinkage strains induce a tensile stress
  - Material cracks when tensile stress exceeds tensile strain capacity



Reinforcement in Concrete

- Modern construction assumes cracking;
- Crack widths are limited by using steel reinforcement;
- Numerous immeasurable minor cracks adversely affect overall permeability of concrete; and
- Cracking ultimately leads to corrosion of the reinforcing steel and premature structural deterioration.



Temple Site Conditions

- The subsoil conditions on the site consisted of a soft silty clay soil derived from the weathered local volcanic rock;
- The natural moisture content of the soil ranged from 50 to 70 percent; and
- The depth of the soft soil was not determined.

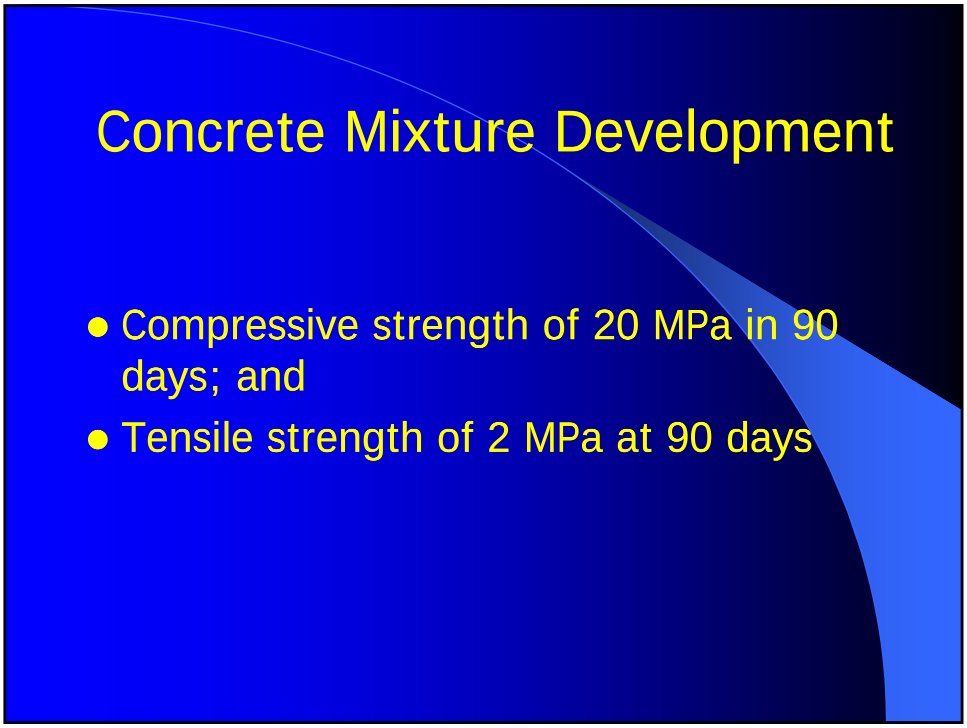
Base Course Preparation

- Approximately one meter depth of soft clay/silt subgrade soil was removed and replaced with compacted granular material
- Granular base used to spread loads over a wider surface area, provide a dense working surface and provide drainage around the temple perimeter

Foundation Surcharge

- Surcharged with 2.5 m of native soils;
- Remove any residual settlements prior to placing stonework;
- Opportunity to inject cracks should they occur prior to stone placement; and
- Surcharge placed 6 months after concrete placement- left 3 months.

Finished Foundation

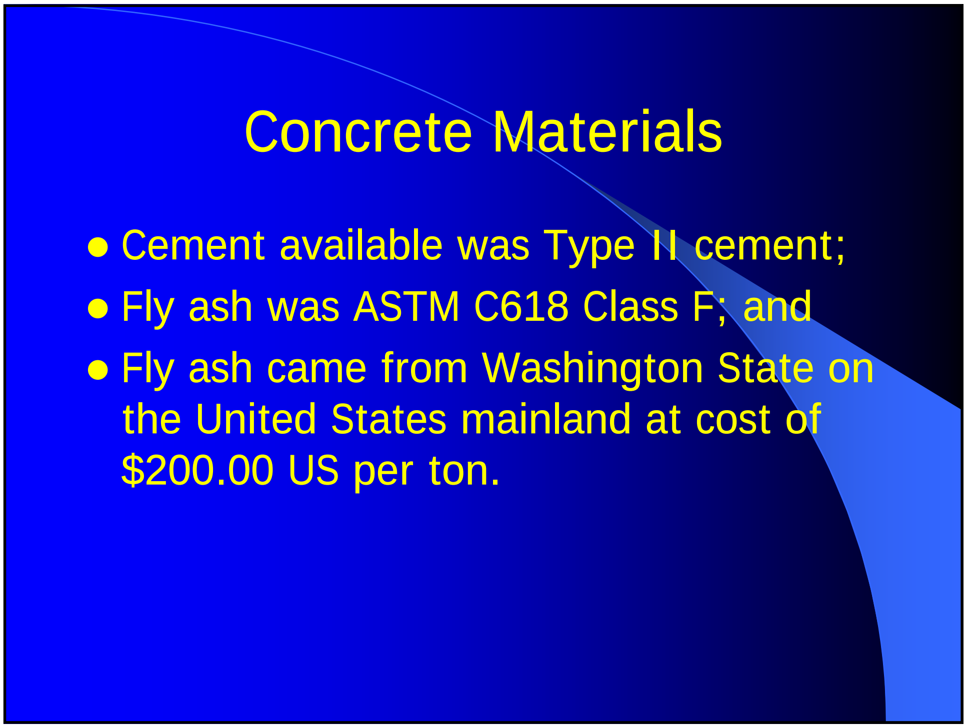


Concrete Mixture Development

- Compressive strength of 20 MPa in 90 days; and
- Tensile strength of 2 MPa at 90 days

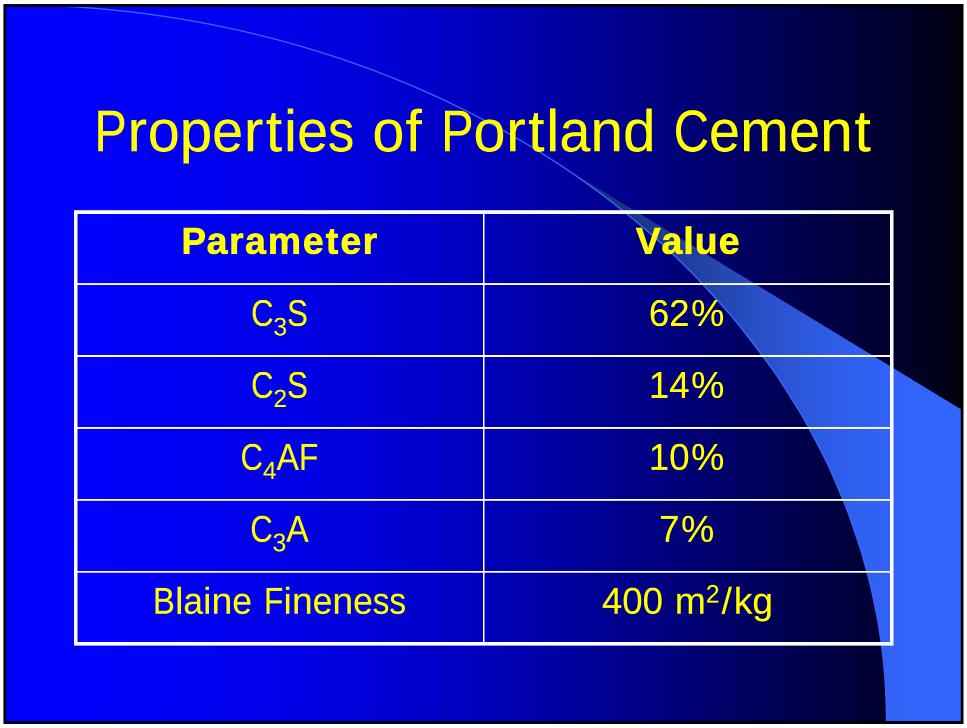
Concrete Making Materials for Temple Slab

- Choices limited as there is only one ready-mixed concrete plant able to supply 380 m^3 of concrete in an 8 to 10 hour period
- Crushed basalt used as the coarse aggregate, 25-mm and 10-mm
- Sand made from crushed calcareous stone used as the fine aggregate, FM = 2.83.



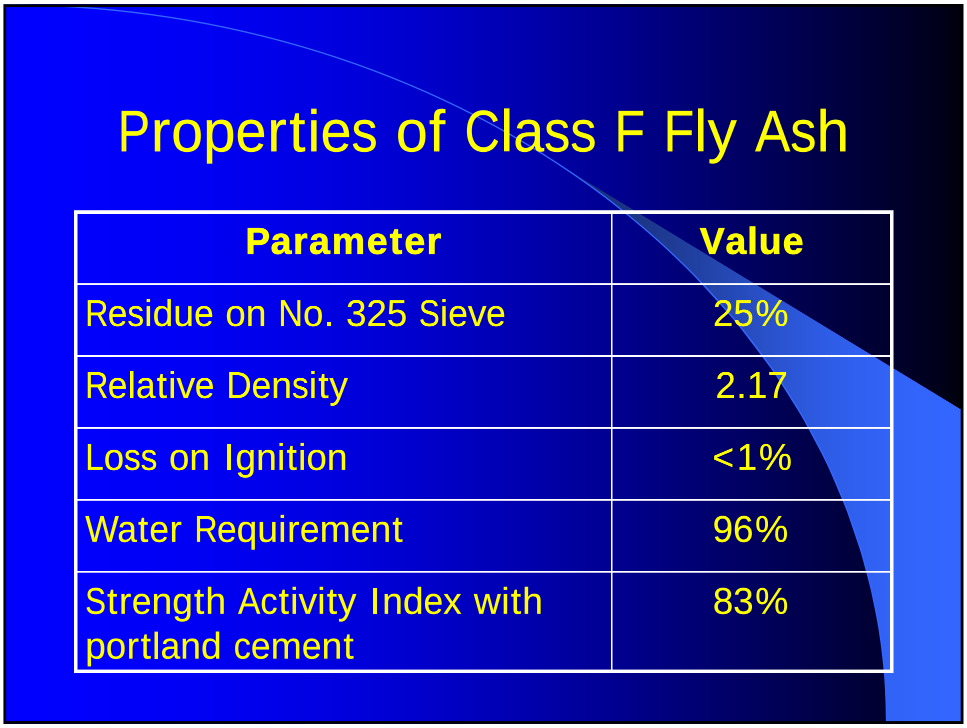
Concrete Materials

- Cement available was Type II cement;
- Fly ash was ASTM C618 Class F; and
- Fly ash came from Washington State on the United States mainland at cost of $200.00 US per ton.



Properties of Portland Cement

Parameter	**Value**
C_3S	62%
C_2S	14%
C_4AF	10%
C_3A	7%
Blaine Fineness	400 m^2/kg



Properties of Class F Fly Ash

Parameter	**Value**
Residue on No. 325 Sieve	25%
Relative Density	2.17
Loss on Ignition	<1%
Water Requirement	96%
Strength Activity Index with portland cement	83%

Typical HVFA Concrete Mixture Proportions – Earlier Studies

W/C+F	Mixture Proportions, kg/m^3			
	Cement	Fly Ash	Sand	Stone
0.49	100	125	800	1100
0.35	150	100	750	1100
0.28	180	220	760	1110
0.20	250	352	850	900
0.46*	290	0	800	1020
0.39*	340	0	855	1020

* Denotes control mixtures

San Marga Iraivan Temple Concrete Mixture Proportions

● Type 2 Cement	106 kg/m^3
● Class F Fly Ash	142 kg/m^3
● Concrete Sand	945 kg/m^3
● 25-mm Gravel	690 kg/m^3
● 10-mm Gravel	430 kg/m^3
● Water	100 kg/m^3
● Microair	116 ml/m^3
● Superplasticizer	3.48 L/m^3

Foundation Construction

- First lift placed on smooth granular base course;
- End formwork left open temporarily to enable trucks to back in the forms;
- Slump adjusted to 150-200 mm on site to facilitate placement; and
- Temperature monitored at three depths in each slab.

Placing Concrete

Concrete Curing

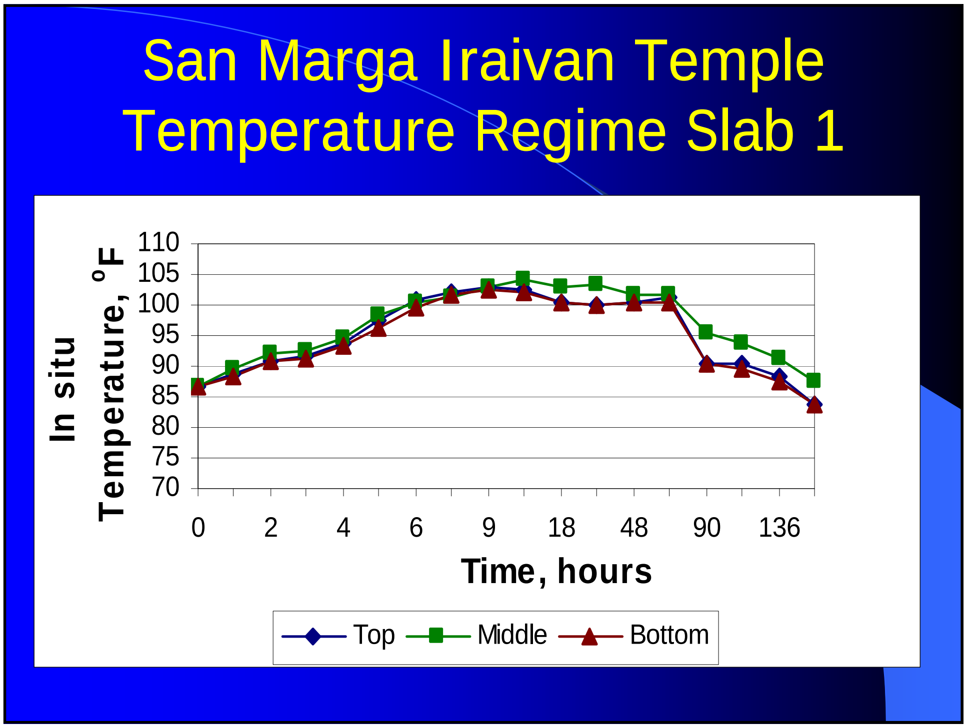
Curing Temple Slab

Immediately after placement and strike-off, 1st concrete slab was covered with 2 layers of burlap, wetted and covered with 6-mil visqueen. The second layer was placed one week later over two layers of 6mil visqueen and water cured for about one month.

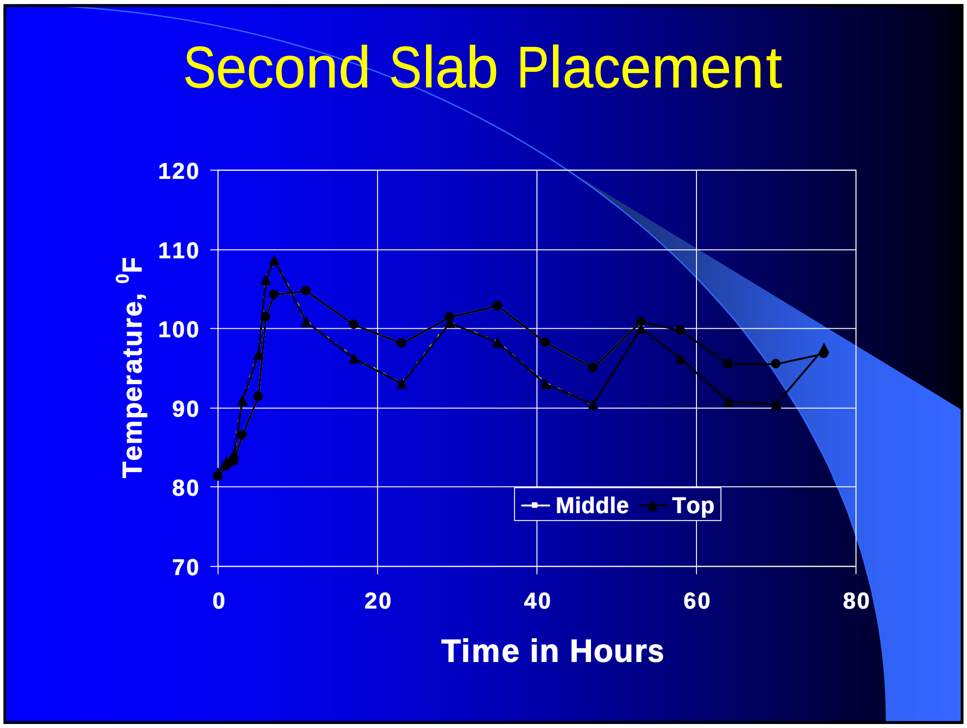
Curing Temple Slab

Removing Stone From Quarry


Carving Tools

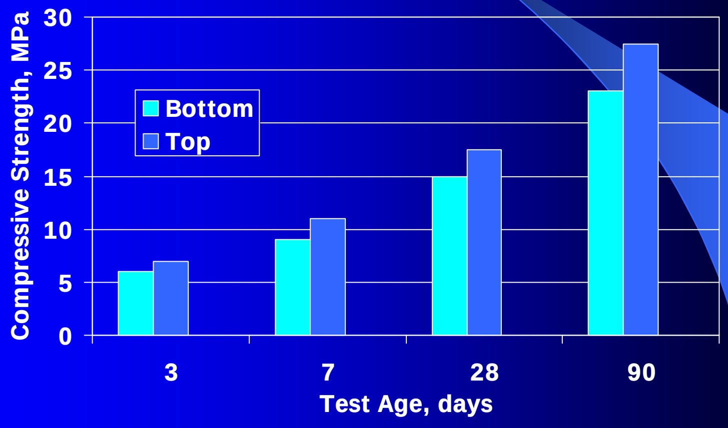


San Marga Iraivan Temple Temperature Regime Slab 1



Second Slab Placement

Strength Testing on Site



Results of concrete Placement

- Low portland cement content of 106 kg/m^3 maintained low temperature rise and insignificant thermal gradients;
- Temperature regime, slow strength gain and good curing ensured a crack-free foundation;
- After a surcharge on the foundation for 3 months, settlement ceased; and
- Uniform settlement less than 25-mm.

Thermal Cracking

W.S. Langley
Concrete & Materials Technology Inc.

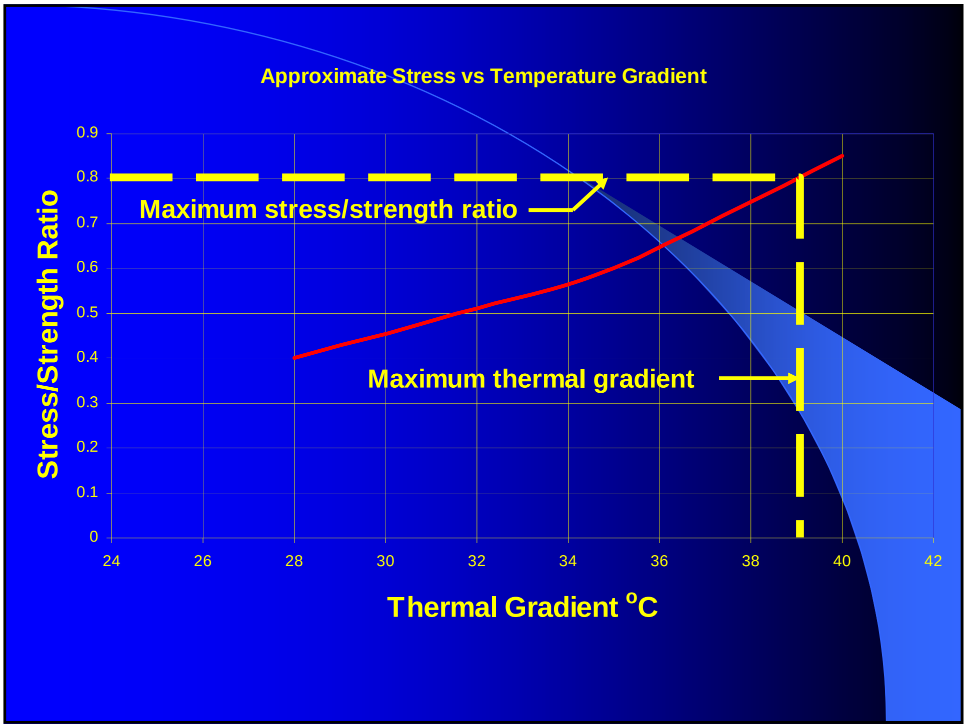
Bridge in California
Mass Concrete – Thermal Control Plan – 31.5 MPa Footing Concrete

Thermal Control Plan

The purpose of the Thermal Control Plan is to provide concrete for mass placements free of cracking from thermal gradients and excessive temperature rise.

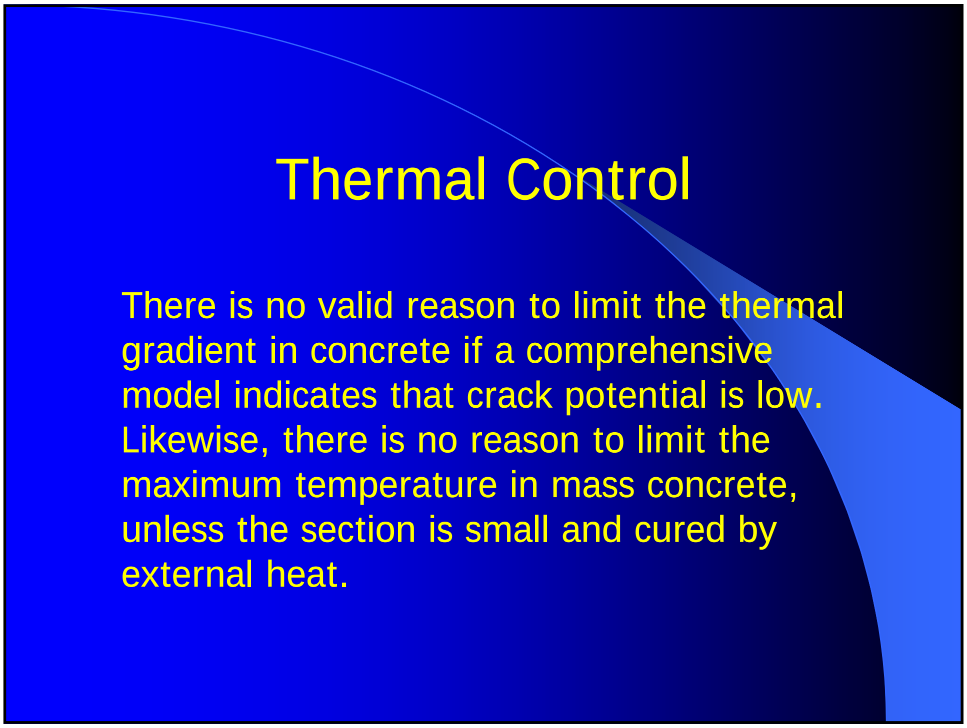
Elements of a Thermal Control Plan

- Materials
  - Cementing materials
  - Aggregates
  - Admixtures
- Development of concrete mixtures
- Thermal modeling
- Field monitoring
- Curing
- Temperature non conformance
- Recommendations


Approximate Stress vs Temperature Gradient

Maximum stress/strength ratio

Maximum thermal gradient



Thermal Control

There is no valid reason to limit the thermal gradient in concrete if a comprehensive model indicates that crack potential is low. Likewise, there is no reason to limit the maximum temperature in mass concrete, unless the section is small and cured by external heat.

Various Mixtures for Temperature Control

	Portland	Silica Fume	Fly Ash	Slag	Adiabatic kJ/kg
ND 6000 psi (3 mixes)	85%	-	15% (C)	-	385
	50%	-		50%	281
	75%	-	25% (F)	-	240
Ohio 10,000 psi	50%	-	-	50%	285
East Asia 60 MPa	30%	-	-	70%	214
California	75%	-	25%	-	311

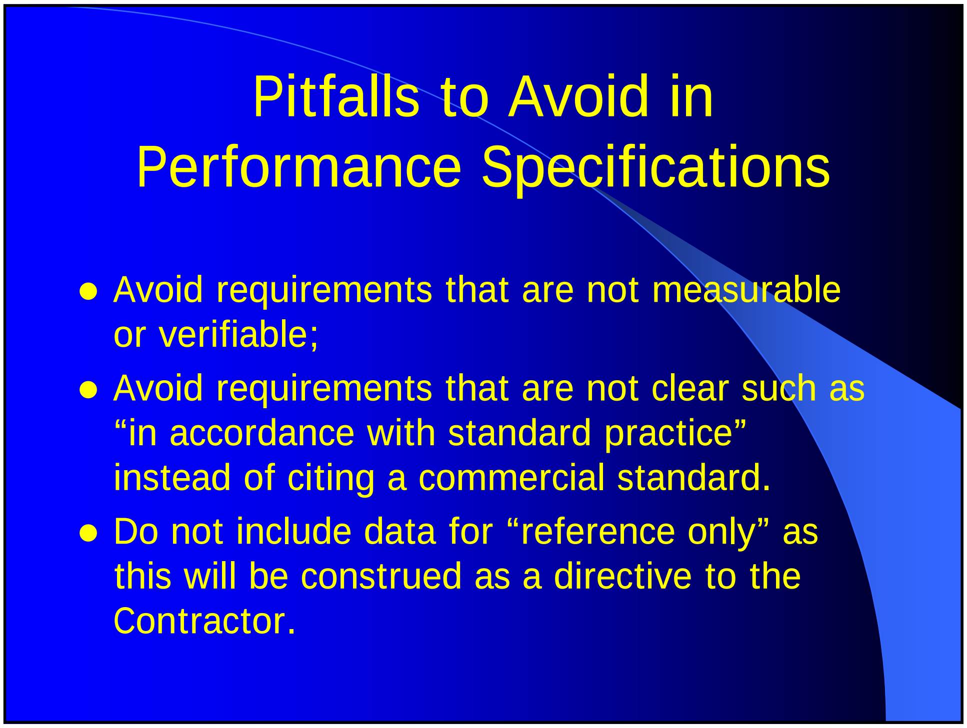
A common problem with a performance specification is how to measure a required performance criteria. For example, if a contractor is to build a bridge for a service life of 100 years, by what criteria do we assess how well he met the objective?

Does the Measurement of the Following Common Parameters Adequately Determine Long Term Performance?

- Air void parameters
- Water-to-cementitious materials ratio
- Mixture proportions including admixtures
- Rapid chloride permeability tests
- Minimum cement contents
- Specifying minimum/maximum levels of alkalis, sulphates, etc. of mixture components

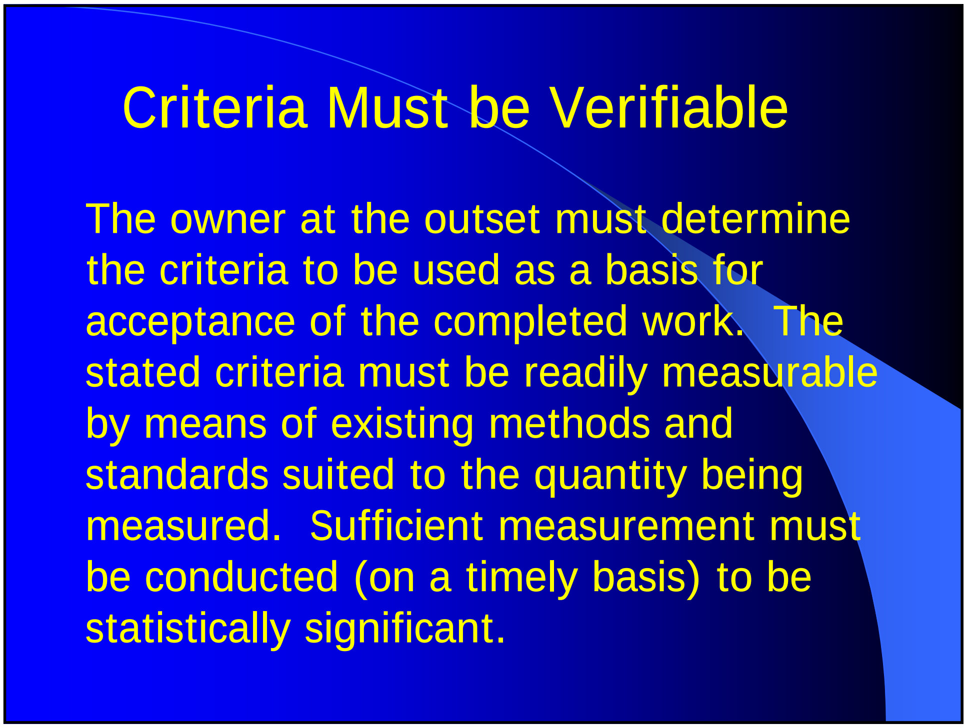
While important, these parameters likely do not form a basis for adequate assessment.

Common physical tests conducted on concrete are conducted on concrete between cracks or on non-cracked concrete at least. Deterioration most likely will occur at cracks first. We do not adequately address this issue in concrete assessment for durability.



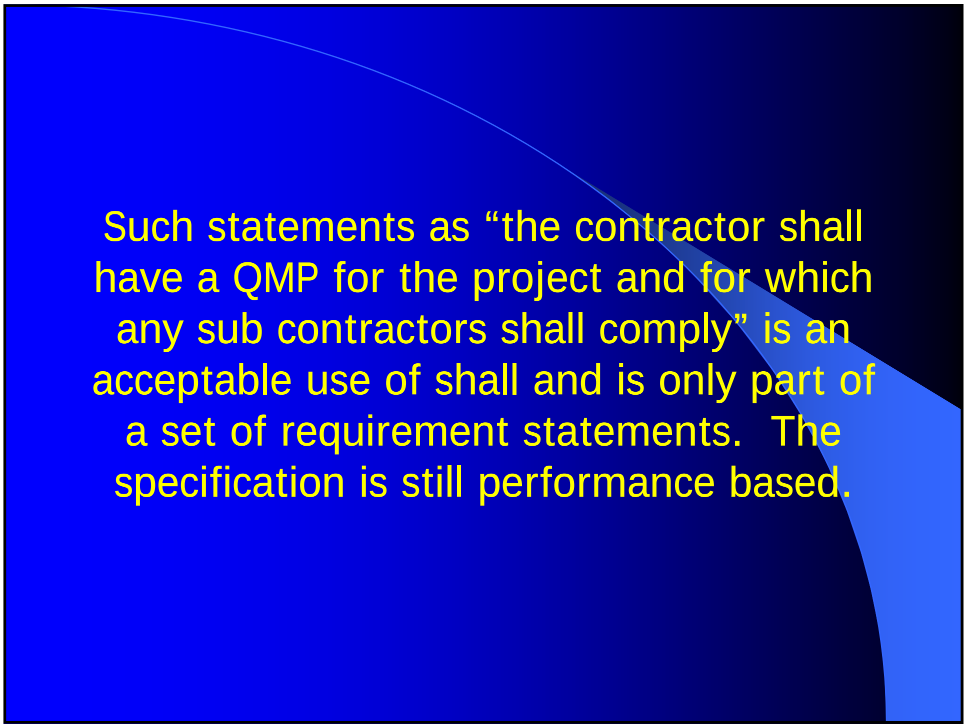
Pitfalls to Avoid in Performance Specifications

- Avoid requirements that are not measurable or verifiable;
- Avoid requirements that are not clear such as “in accordance with standard practice” instead of citing a commercial standard.
- Do not include data for “reference only” as this will be construed as a directive to the Contractor.

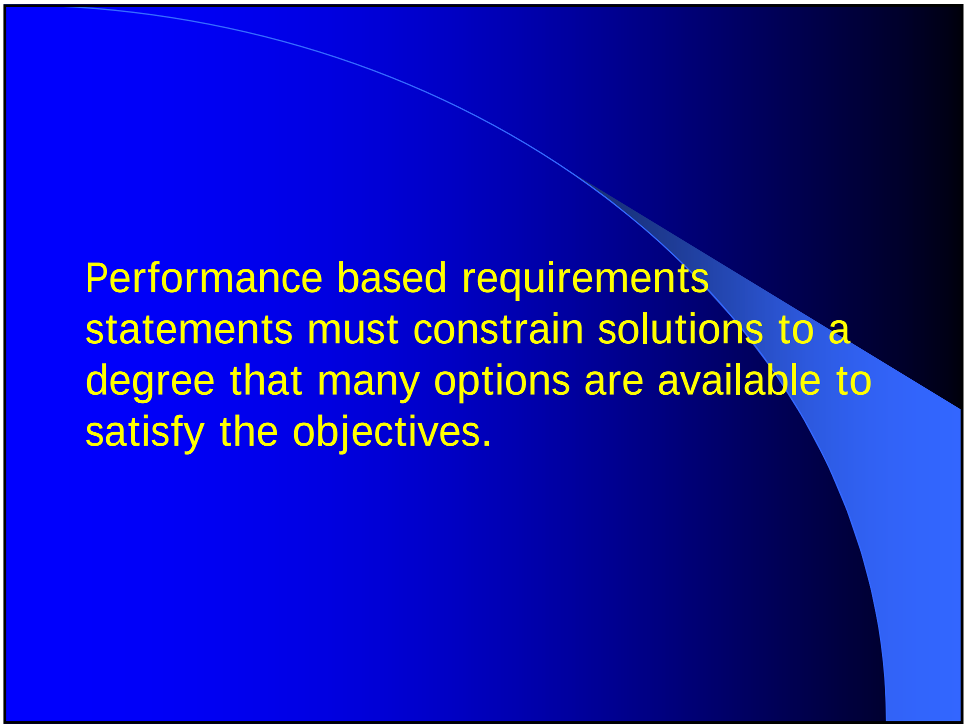


Criteria Must be Verifiable

The owner at the outset must determine the criteria to be used as a basis for acceptance of the completed work. The stated criteria must be readily measurable by means of existing methods and standards suited to the quantity being measured. Sufficient measurement must be conducted (on a timely basis) to be statistically significant.



Such statements as “the contractor shall have a QMP for the project and for which any sub contractors shall comply” is an acceptable use of shall and is only part of a set of requirement statements. The specification is still performance based.



Performance based requirements statements must constrain solutions to a degree that many options are available to satisfy the objectives.

Performance Specifications and Penalty Clauses

- Penalty clauses should only be placed on parameters that affect the performance of the structure (not color for example).
- Penalty clauses should not apply while production is within accepted levels of standard deviation. Too costly otherwise.
- Penalties should be offset by bonuses. If the owner is disadvantaged by a penalty item, then he should also be advantaged by a bonus item.

Fick's Second Law of Diffusion

$$\frac{C_x - C_o}{C_s - C_o} = \left[1 - erf \frac{x_t}{2\sqrt{D_a t}}\right]$$

where: C_x = chlorides at depth X
C_0 = background chloride level
C_s = surface chloride concentration
erf = standard error function
D_a = diffusion coefficient
t = time of chloride measurement

Penalty Clauses

If you consider that Fick’s Second Law of Diffusion applies to chloride ingress (and it does) then if one was going to penalize a significant parameter, why would it not be cover over the reinforcing steel? New Hampshire is currently the only jurisdiction that I know of that does penalize this parameter.

Performance Specifications and Penalty Clauses

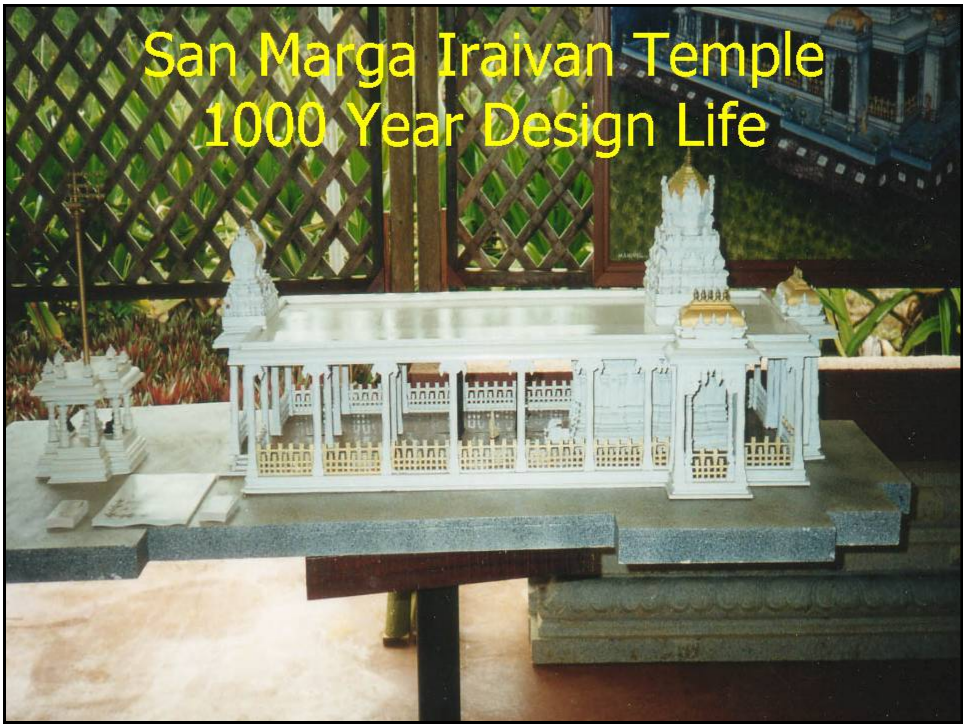
In a performance specification, there should be a direct relationship between the penalty and the loss suffered due to a breach of the specification. For example, if a temperature gradient is exceeded in concrete, and no visible cracking or micro cracking is apparent, why would we have a penalty? How do we assess this to indicate that the owner has been disadvantaged?

Performance Specifications – What Should we Include

- Include a requirement for verification of the identical parameters that was used to qualify the structure characteristics;
- Include the requirement for a comprehensive QMP stating acceptable statistical limits on measured values;
- Define the responsibility for project QC; and
- Define the elements of a thermal control plan.

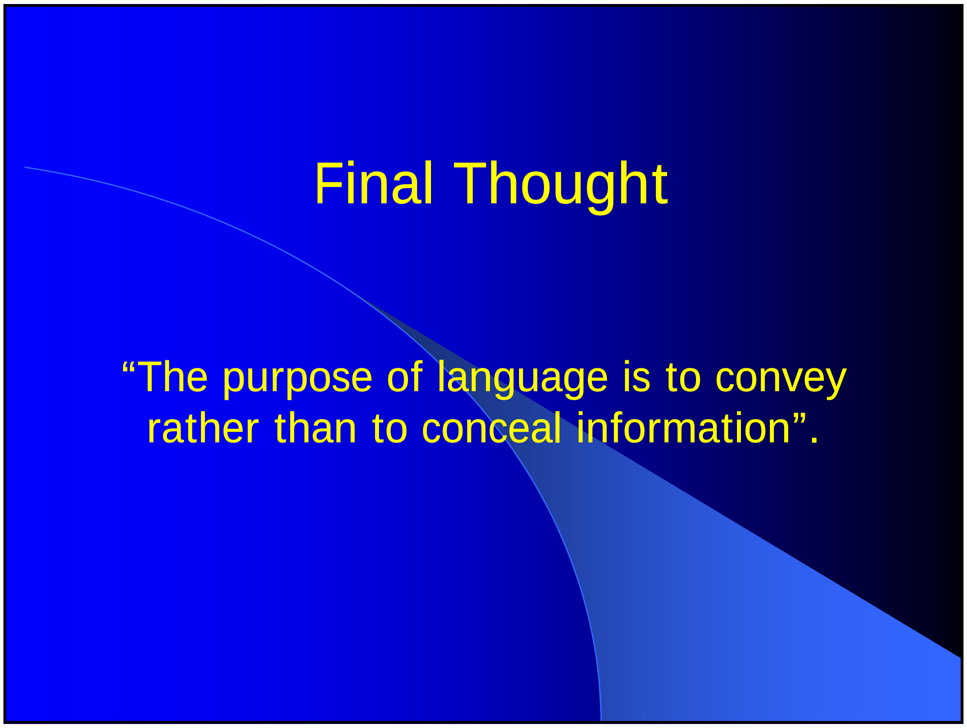
Sungai Prai Bridge - Specifications

- Design for 120 years
- Water/cementitious materials 0.303
- AASHTO T277 Coul @28 days ‹500
- Drying shrinkage ‹ 0.06%
- ISAT (sorptivity) ‹0.05 ml/m^2/s
- Compressive strength (28 days) 70 MPa



San Marga Iraivan Temple
1000 Year Design Life

No Performance Requirements Stated



Final Thought

“The purpose of language is to convey rather than to conceal information”.

Thank You