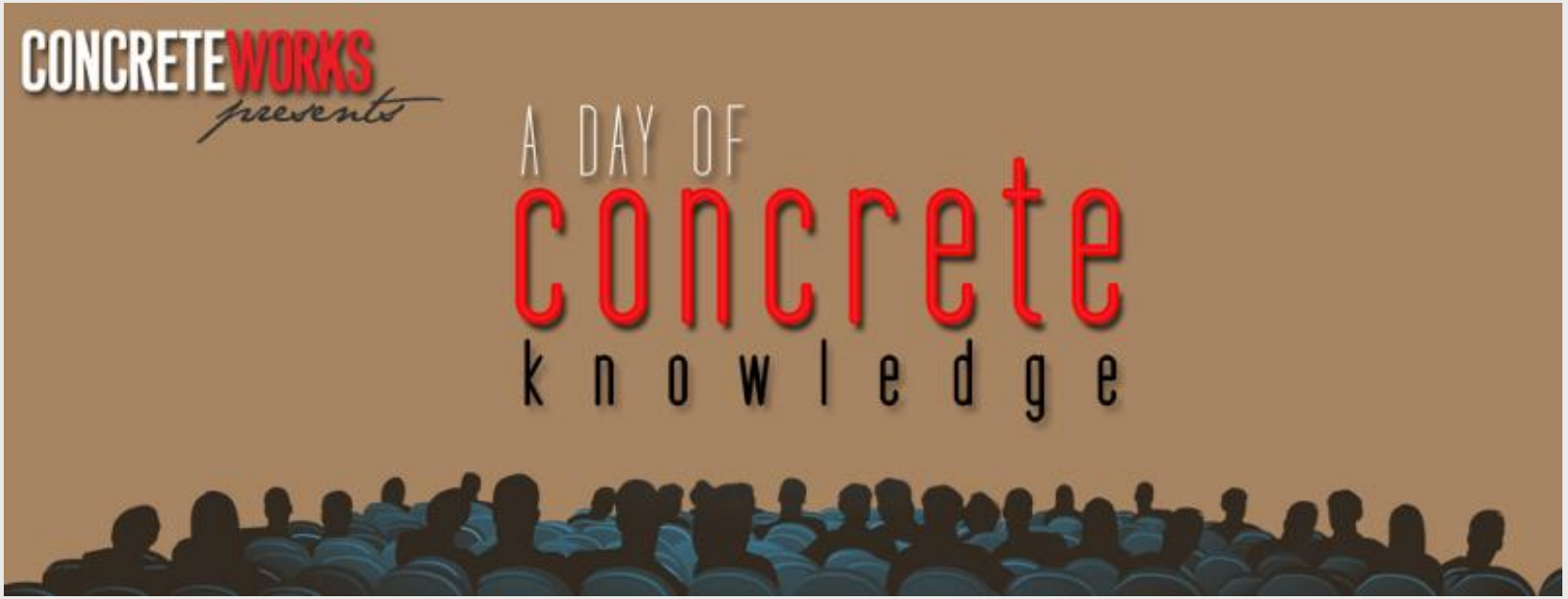


How Poor Mix Designs May Lead to Poor Concrete

What is a “poor” mix design?

One that does not perform
as expected !

What is a “good” mix design?

One that DOES perform as expected !

- No issues in delivery
- Slump and air in specification
- Places and finishes properly
- Sets up in a reasonable amount of time
- Meets design strength
- Performs in service

How do we get a “good” mix design?

General Guidelines

- Use no more cement than necessary for strength/durability
- Minimize water/cement ratio
- Maximize coarse aggregate size and content
- Use mid-range or HRWR for slumps higher than 5 inches
- Avoid entrained air for interior flatwork
- Use normal set, retarders, accelerators as needed for set

How do we proportion a “good” mix design?

1.) *By experience* – familiarity with the materials and their performance

An Experienced Designer Will Know:

- Specific gravity of materials
- PSI per lb of cementitious
- Water Content for given slump
- Coarse aggregate content
- Admixture dosage
- How to adjust sand for yield

How do you calculate absolute volume?

Vol (cu.ft.) = weight / sp.gr. / 62.4*

400 lbs cement / 3.15 / 62.4 = **2.04**

Weight = vol. x sp.gr. x 62.4

2.04 cu.ft. x 3.15 x 62.4 = **400**

*Weight of one cubic foot of water

Example:

In this area, proportions for a typical 3000 psi mix design might be:

Material	lbs/yd	Cu.ft./yd
Cement	400	2.04
Fly ash	100	0.64
Stone	1850	10.82
Sand	1315	8.01
Water	275	
Air	4.0%	4.41
Total	***3940***	
AEA	2.0 oz/yd	1.08
Water red.	20 oz/yd	***27.0***

How do we proportion a good mix design?

1.) *By experience*

2.) ***By ACI 211*** *- Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete*

This method may be appropriate if there is no mix design history or experience with the materials

Proportion Mix Design Based on ACI 211 - Step by Step Method

1. Choice of slump
2. Choice of maximum size of aggregate
3. Estimation of mixing water and air content

All are selected from Table 6.3.3

4. Determine water/cementitious ratio from Tables 6.3.4(a) and Tables 6.3.4(b).
5. Calculate cement content from water content and w/c ratio.
6. Estimation of coarse aggregate content from Table 6.3.6

7. Estimation of fine aggregate content

- By weight method
- By absolute volume method

8. Adjustments for moisture content of aggregates

9. Trial batch adjustments

How do we proportion a good mix design?

1.) *By experience*

2.) *By ACI 211 - Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete*

3.) *By project specification*

- Strength
- Maximum w/c ratio
- Minimum cement content
- Aggregate type and size
- Slump and air limits

A good mix design should have history:

- Laboratory data
- Field data
- Producer data
- Independent laboratory data
- Appropriate strength overdesign
- ACI 318 laboratory overdesign
- ACI 318 field overdesign based on standard deviation

Poor Concrete?

Why did it not perform?

Poor Mix Design Could Be Due to:

- Design Proportion Issues
- Material Issues
- External issues – mix not appropriate for application / conditions
    - Weather
    - Placement method
    - Forms

Design Proportion Issues

- Cementitious too low / too high
- Aggregate ratio
- Specific gravities incorrect
- Air content too low / high
- Under / over yield

Material Issues

- Cement - strength, water demand, set time
- Fly ash – entrained air, set time, strength
- Slag Cement – strength, set time, color
- Aggregates – grading, durability, shape
- Admixtures – compatibility

A good mix design becomes a poor mix design with poor materials

External Issues

A good mix design can become a poor mix design if it used at the wrong time, the wrong place, or the wrong situation

External Issues - examples

- 30 – 40% slag cement mix in cold temps.
- Mix with #57 c.a. for tight re-bar spacing
- Normal slump mix / high slump application
- Mix with 5% entrained air for interior slab
- SCM content vs. strength age requirements

CASE STUDIES

#1 – Paving Project Placed in Winter with 30% Slag Cement, 3000 PSI Mix

Cement	341
Slag Cement	141
#57 Granite	1825
Granite sand	1300
Water	240
AEA	3.0
Normal WR	19.0

Weather conditions at placement:

Night time lows - 25 to 30 degrees F
Daytime highs - 45 to 50 degrees F
Subgrade cold/frozen, damp, no base

Four placements made over 10 day period. Right after the last placement, the first several started to deteriorate.

Cores obtained from the pavement broke less than 1000 psi at 21 days.

Laboratory strength results at 72 degrees F:

6% air

5.0 in slump

7 day compressive strength = 1400 psi

28 day compressive strength = 3400 psi

Mix design was reproduced in the lab at 50 degrees and cylinders stored at 45 to 50 degrees.

Set time - 9.0 hours

1 day cylinder - 160 psi

2 day cylinder - 460 psi

3 day cylinder - 595 psi

Over 500 yards of concrete was removed

Marginal mix design + wrong conditions
= *poor concrete*

#2 – Interior Slab Placed with Air Entrained Mix

Cement	525
#67 Granite	1800
Granite sand	1340
Water	270
AEA	2.0
Normal WR	21.0

Field tests indicated air contents of 5 to 6%

What can happen on finished slabs with entrained air mixes?

DELAMINTION !

Good mix design + wrong application
= *poor concrete* surface conditions

#3 – Poor Quality Sand

Cement	575
#67 Granite	1800
Granite sand	1350
Water	342
AEA	1.0
Normal WR	23.0

Excessive water demand ! 41 gallons per yard.

The ready mix producer had concrete in the field failing to meet 3000 psi design strength.

Laboratory testing for the mix produced 28 day compressive strengths of 3600 psi at 4 in slump.

There were numerous cracking complaints.

Sand Gradation

	% Passing	C33 Spec	
-3/8 "	100%	100	
#4	99.7%	95 - 100	
#8	81.9%	80 - 100	
#16	63.3%	50 - 85	
#30	51.4%	25 - 60	
#50	39.9%	5 - 30	FAIL
#100	25.6%	0 - 10	FAIL
#200	13.3%		EXCESSIVE

A washed sample indicated 18% passing #200 screen.

The mix also over yielded at 27.8 cu.ft. per yard due to the additional water demand from the excessive fines.

High w/c ratio, low strengths, low durability

Poor materials = *Poor concrete*

#4 – Proportion issues

Producer changed coarse aggregate in a mix without making specific gravity adjustments

Original Mix

Material	Lb/yd	Sp.gr.	Cu.ft.
Cement	414	3.15	2.11
Fly ash	103	2.50	0.66
#67 Gravel	1790	2.63	10.91
Sand	1258	2.62	7.69
Water	267	1.00	4.28
Total Wt.	3832		
Air	5.0%		1.35
Total Volume			27.00

#67 River Gravel Replaced with #57 Crushed Stone

Material	Lb/yd	Sp.gr.	Cu.ft.
Cement	414	3.15	2.11
Fly ash	103	2.50	0.66
#57 Stone	1790	2.81	10.21
Sand	1258	2.62	7.69
Water	280	1.00	4.49
Total Wt.	3845		
Air	3.5%		0.95
Total Volume			26.10

Mix design under yields by 0.90 cubic feet per yard.

Approximately 300 yards was placed before the mix was corrected.

300 yards x 0.90 cu.ft. / 27 = 10 yards short

Under yielding mix design
= poor concrete

#5 – Material compatibility issues

25% Fly Ash Mix

Cement	398 lbs/yd
Class C fly ash	132 lbs/yd
Normal WR	21 oz/yd *(4oz/100wt cementitious)*

A ready mix producer had a successful history with a mix using these proportions of cement, fly ash, and admixture

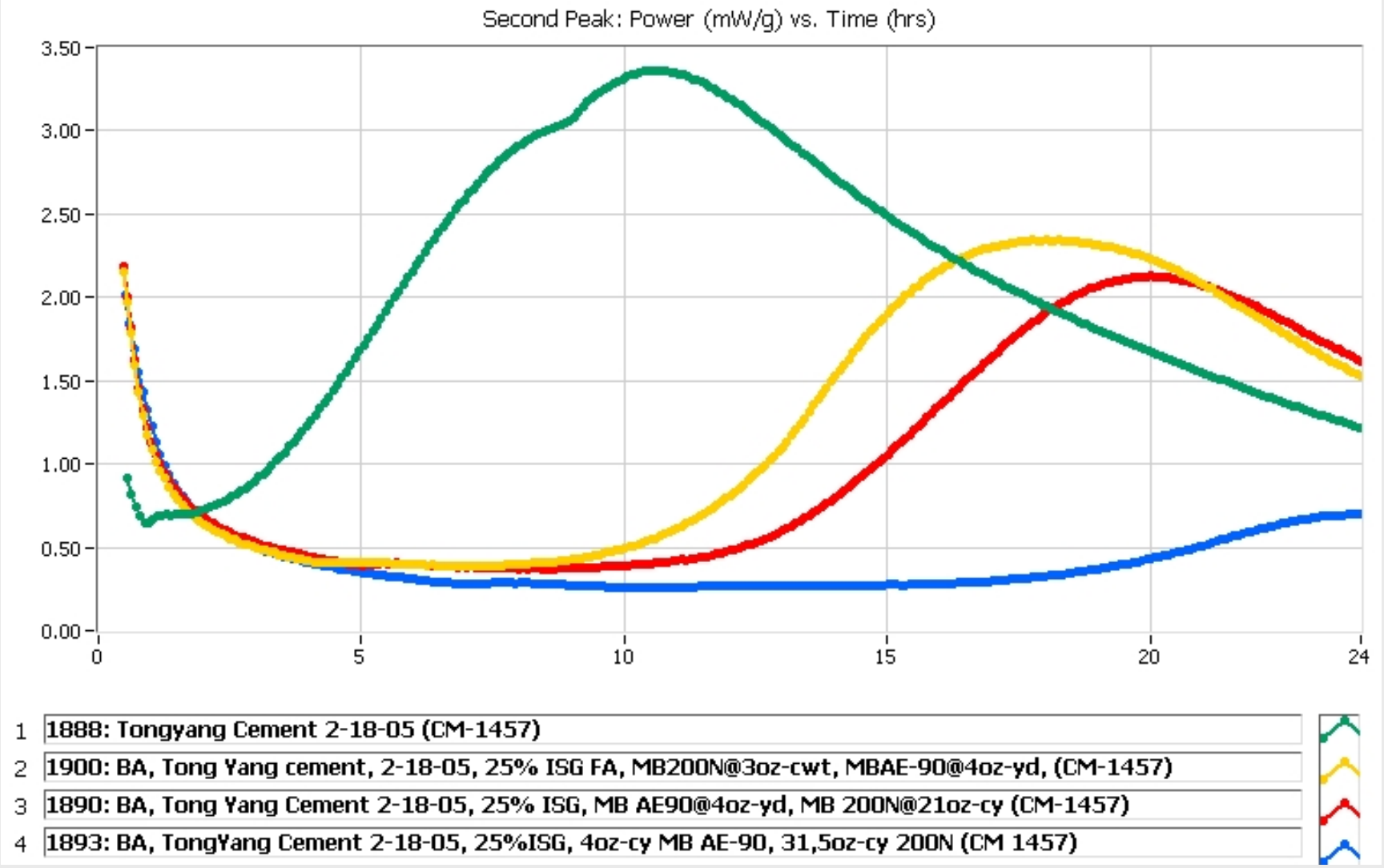
For a particular project, they increased the water reducer dosage from 4 to 6 oz/100wt to allow for a longer set time. They used this dosage rate for all the concrete they supplied that day with the mix, 460 yards.

They had no experience with this mix at a higher water reducer rate than 4 oz/100wt

This was two days later

For this set of materials, a dosage rate of 6 oz/100wt was too much, causing extended delayed set.

Materials tested by isothermal calorimetry



Untested change in mix design proportions
= extended delayed set = poor concrete

Summary

To avoid poor mix designs:

- *Know your materials*
- *Follow recommended guidelines for mix proportioning*
- *Do not use untested mix designs*
- *Follow ACI 318 overdesign*
- *Maintain correct yield*
- *Communicate with project on weather, placing, and formwork*

QUESTIONS ?