



FHWA COMPASS

(Concrete Mixture Performance Analysis System)

Tennessee Concrete Pavement
Conference

2009

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New Conditions Create New Problems

- State highway agencies are changing the rules to how they award construction projects.
 - Warranties
 - Time constraints
 - Performance specifications
- New rules = more risk for contractors

New Conditions Create New Problems

- Today, we want to know things like, “If I plan to build an 8” JPCP in July in Madison with a 5 year warranty, what properties should I design for?”
- Or, “How can I design a mix using 3 or even 4 aggregates?”
- Or, “What’s the best way to get 550 flex strength at 28 days for the lowest cost, with the least cement?”

Welcome to COMPASS

- Computer-based guidelines for job-specific optimization of paving concrete
- Purposes:
 - For use by concrete pavement designers/engineers, researchers, and concrete suppliers
 - For the purpose of designing with conventional concrete-making materials
 - For JPCP, CRCP, and patch/repair mixtures

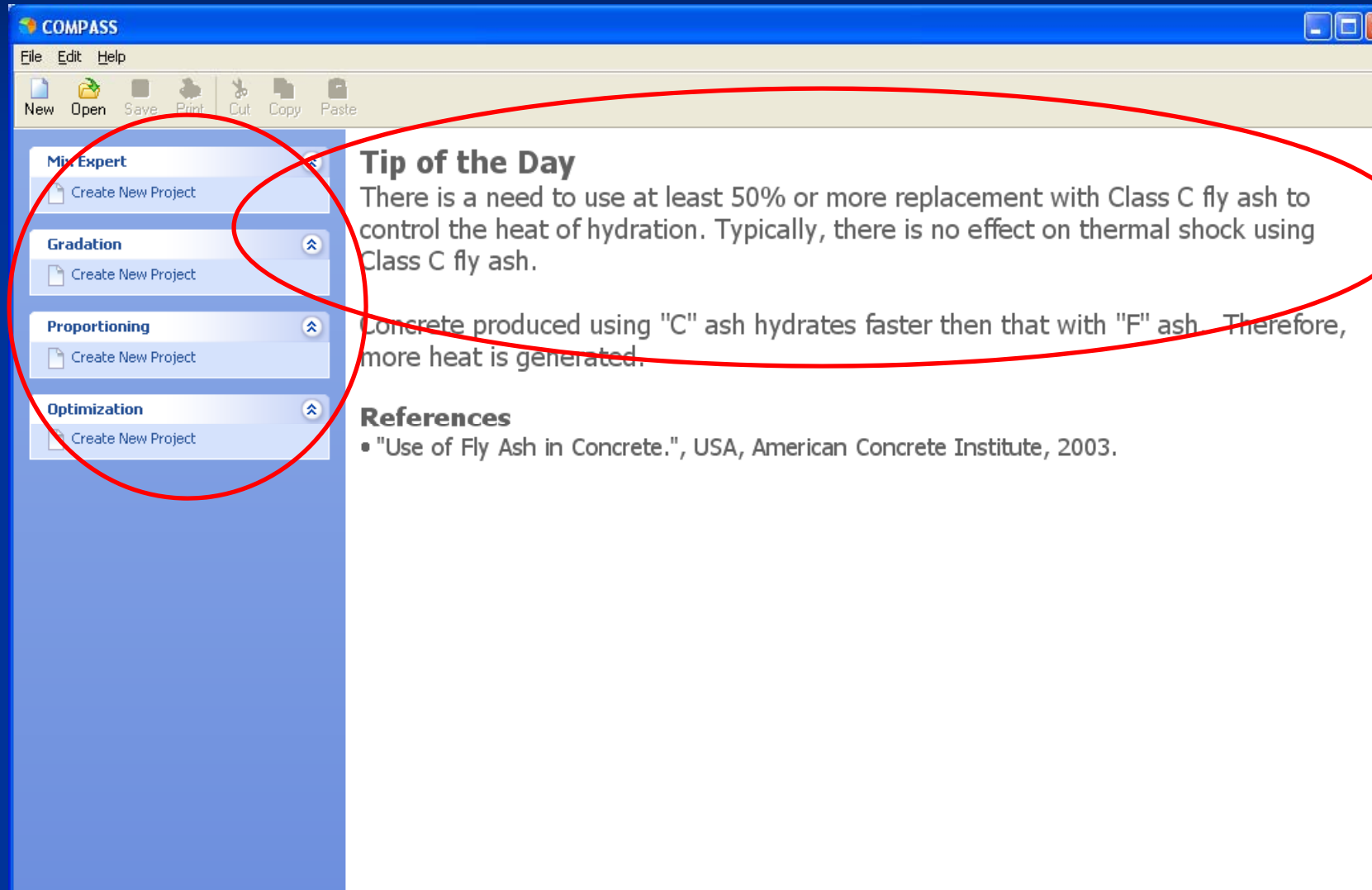
Welcome to COMPASS

- COMPASS does 2 things:
 1. Guides the user through the mix design process.
 1. Guides the user in optimizing mix designs.

The COMPASS System

- **COMPASS has 4 tools. You can use one of them, or all of them:**
 1. **Mix Expert (identifies important properties and offers materials advice)**
 2. **Gradation (blends multiple aggregates for the best gradation)**
 3. **Proportioning (ACI 211, with modifications)**
 4. **Optimization (pick the best combination of materials for the specific criteria of your project)**

Mix Expert Module



COMPASS

File Edit Help

New Open Save Print Cut Copy Paste

Mix Expert
Create New Project

Gradation
Create New Project

Proportioning
Create New Project

Optimization
Create New Project

Tip of the Day
There is a need to use at least 50% or more replacement with Class C fly ash to control the heat of hydration. Typically, there is no effect on thermal shock using Class C fly ash.

Concrete produced using "C" ash hydrates faster than that with "F" ash. Therefore, more heat is generated.

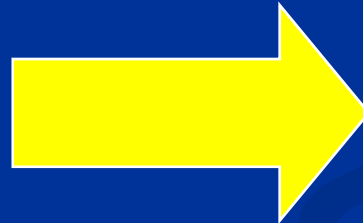
References

- "Use of Fly Ash in Concrete.", USA, American Concrete Institute, 2003.

Mix Expert Module

Site Specific Conditions

- Project Type
- Design & Construction Info
- Climate
- Exposure



Performance Criteria Recommendations

- Important PCC Properties
- Recommended Test Methods
- General Recommendations



Mix Expert Module

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Mix E

1 Intro

2 Design

3 Materials

4 Hydration

5 Proper

Setting

Key Points

- Setting is when concrete loses its workability and becomes hard; it is influenced by the chemistry of the cementitious system.
- Class F fly ash and ground, granulated blast-furnace slag will generally retard setting time.
- Setting is accelerated when the concrete temperature increases.
- Set-accelerating and retarding chemical admixtures in the mixture can control set time.
- Setting affects the time available for

Typically, initial set occurs between two and four hours after batching; final set occurs between four and eight hours after batching. Initial set and final set are arbitrarily determined based on the test methods available, but initial set generally occurs shortly after initiation of the silicate phase of cement hydration (see Portland Cement Hydration in chapter 4, page 88.)

False set and flash set are the stiffening of the mixture in the first few minutes after mixing and are due to uncontrolled reactions of the aluminate/sulfate compounds in the cement (see Potential Materials Incompatibilities in chapter 4, page 97). False set is temporary and can be worked through with continued mixing, but flash set means that the mixture will have to be discarded.

Factors Affecting Setting

A number of factors affect concrete setting time:

Temperature Weather Increasing temperature

134 of 346

Mix Expert Module

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Adobe Reader 7.0

1 Intro
2 Design
3 Materials
4 Hydration
5 Proper

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134 of 346

Mix Expert Module

Untitled * - COMPASS

File Edit Help

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Mix Expert

- General Information
- Job Specific Info
- Environment
 - Location
 - Climate
 - Exposure
- Performance Criteria
- Available Materials
- Materials Advice

Water - 0 Cement - 11 Aggregate - 2 SCM - 11 Admixtures - 14

Recommended Materials

Time of Setting

Use Type III cement in cold weather. [Show Details](#)

Strength

Type III cement helps concrete gain strength faster in cold weather. [Show Details](#)

IP cements can increase ultimate strengths. [Show Details](#)

IS cements can increase ultimate strengths. [Show Details](#)

Type III cement produces early strength in concrete. [Show Details](#)

Permeability

Use of IS cement decreases concrete permeability. [Show Details](#)

Type IP cement reduces permeability. [Show Details](#)

Alkali Silica Reaction (ASR) Susceptibility

Low alkali cements help reduce ASR potential. [Show Details](#)

IP cements decrease concrete's susceptibility to ASR. [Show Details](#)

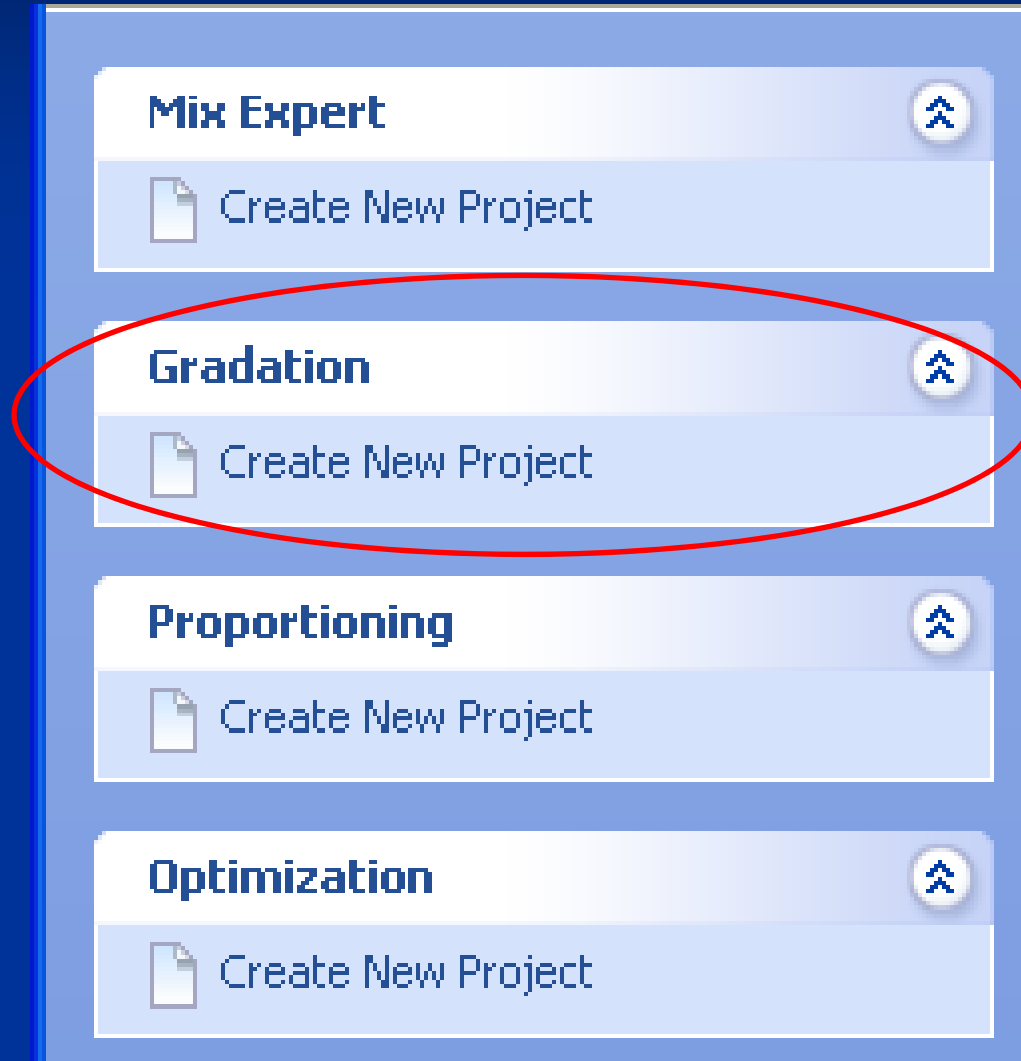
IS cements decrease concrete's susceptibility to ASR. [Show Details](#)

Materials to use with caution

Specification

Cements for mix design must conform to ASTM C 150, ASTM C 595, or ASTM C 1157. [Show Details](#)

Gradation Module



Module purpose:

Optimize blending of aggregates for:

- Durability
- Strength (adequate not max)
- Workability, and
- Cost

Gradation Module

- **Models**
 - De Larrard
 - Dewar
 - Toufar
- **Plots**
 - Coarseness factor chart
 - Power 0.45 chart
 - Percent Retained (8-18 chart)

Gradation Module

Binary * - COMPASS

File Edit Help

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Gradation

Use Custom Proportions

Model: Toufar

Analyze

Proportions as Percentage of Mass

Aggregate	Recommended	Custom
G10 (Intermediate)	25	38
G20 (Coarse)	45	51
Sand 1 (Fine)	30	11
Total	100	100

G10 (Intermediate)

G20 (Coarse) Sand 1 (Fine)

Voids Ratio

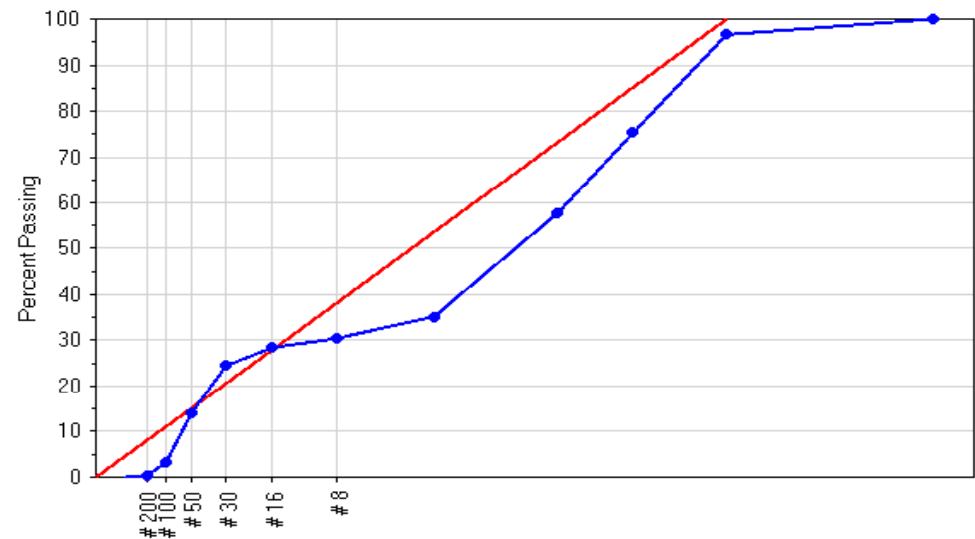
Packing

Coarseness Factor Chart

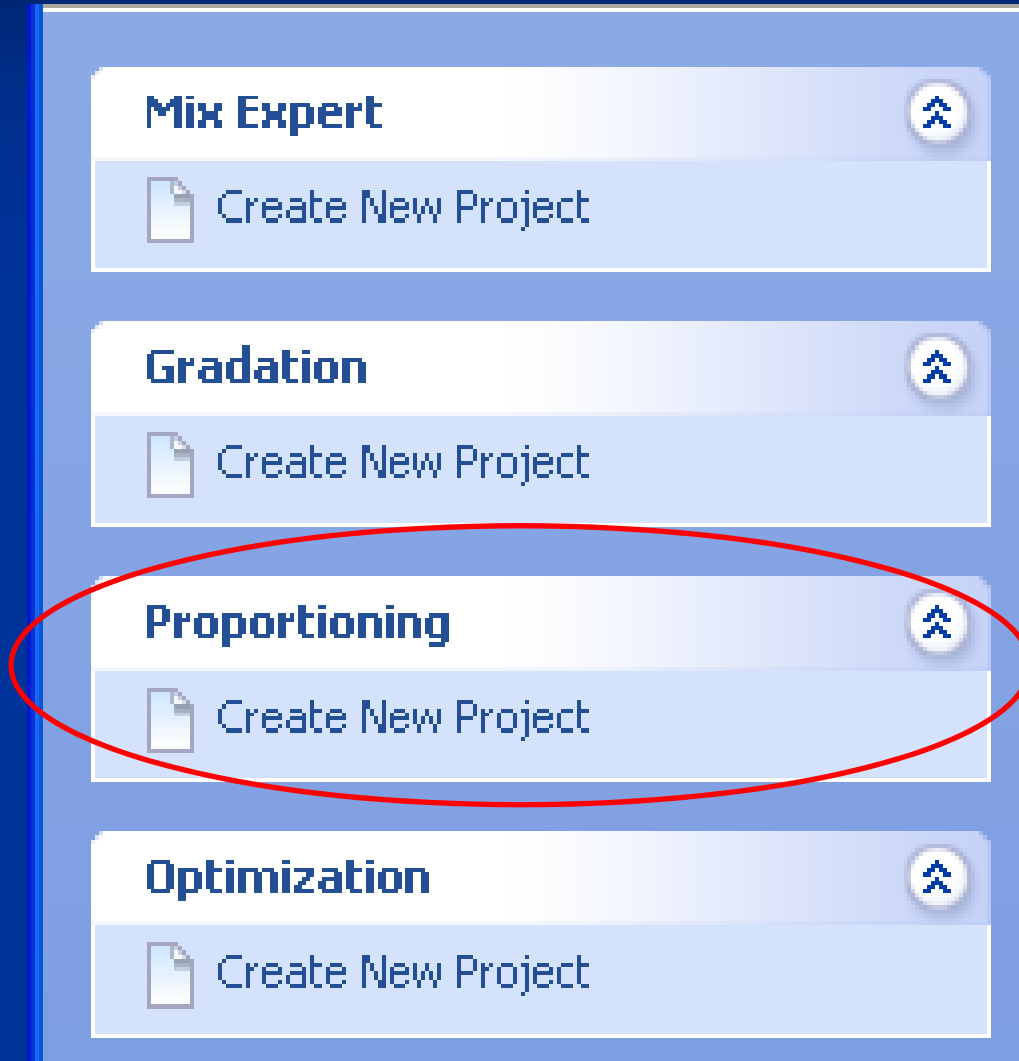
Percent Retained

0.45 Power Chart

0.075 (# 200)	0.4
0.150 (# 100)	3.1
0.300 (# 50)	14.0
0.600 (# 30)	24.5
1.180 (# 16)	28.5
2.360 (# 8)	30.5
5000	35.2
10000	57.7
14000	75.3
20000	96.6
37500	100.0



Proportioning Module



Module purpose:

Allow user to create a mix design based on user-defined criteria. (ACI 211)

Proportioning Module

Proportioning Module

Proportioning

- ▶ General Info
- ▶ Mix Design Criteria
- ▶ Materials
 - ▶ Aggregates
 - ▶ Cementitious
- ▶ Analysis
 - ▶ Initial Mix Proportions
 - ▶ Water Adjustments
 - ▶ Refined Mix Proportions

Characteristics based on conditions

Requirement	Value	Unit
Design 28-day Compressive Strength	5,200	psi
Design Air Content	5.0	%
Design Slump	2	inches
Maximum Aggregate Size	0.75 inches (19 mm)	
Water to Cement Ratio	0.38	
Water to Cementitious Ratio	0.38	
Paste Content	7.93	ft ³
Mortar Content	15.72	ft ³
Fine to Coarse Aggregate Ratio	0.45	
Design Yield	141	lb/ft ³

Volumetric (%)

- Water
- Cement
- Coarse Aggregate
- Fine Aggregate
- Air

Recommended Mix Proportions (SSD)

Mix Component	Mass (lb/ycf)	Volume (ft ³)	Volume (%)
Water	268.2	4.30	15.9
Cement	714.0	3.63	13.4
Coarse Aggregate	1,957.8	11.88	44.0
Fine Aggregate	879.3	5.84	21.6
Air	N/A	1.35	5.0
Total	3,819.3	27.00	100.0

Mix Adjustments

Account for Moisture

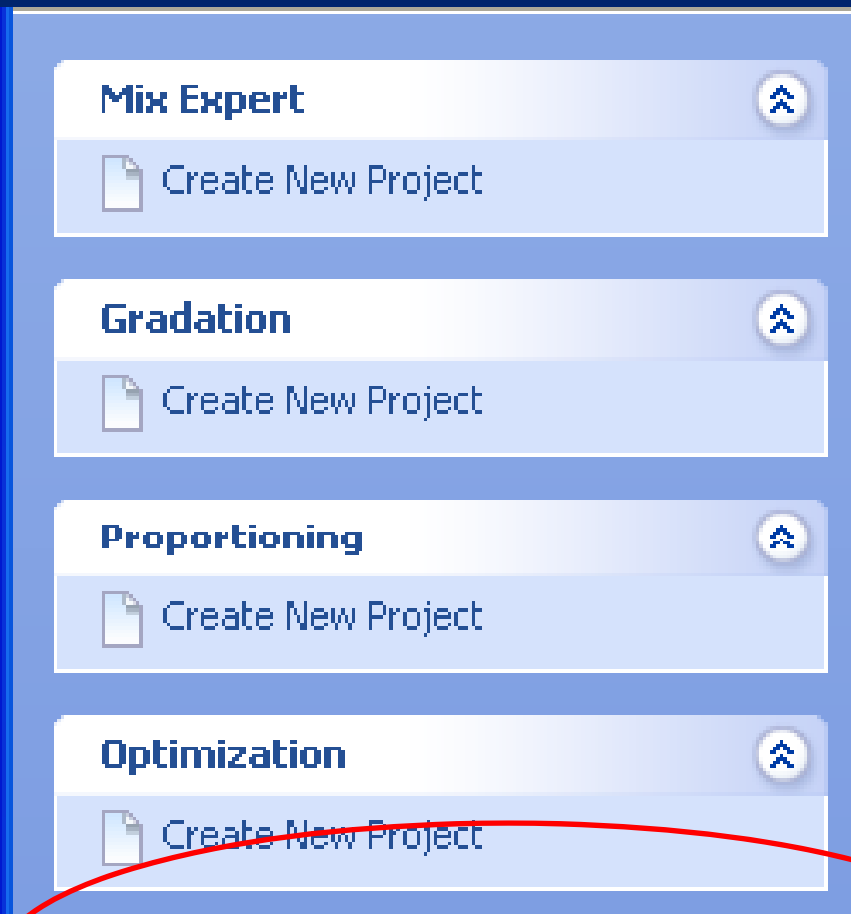
Batch Size (yard³) yard³

Mix Adjustment Type

Water to Cementitious Ratio

Cement (lb/ycf)

Optimization Module



Module purpose:

To create a list of alternative mix designs that meet job-specific criteria.

Based on FHWA and NIST's COST software

Optimization Module

Create Trial Batches...

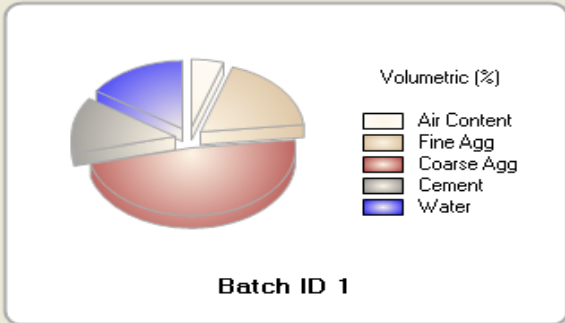
Optimization1 example - COMPASS

File Edit Help

New Open Close Save Print Cut Copy Paste

Optimization

General Information
 Trial Batches
 Materials
 Analysis
 Mix Optimization
 Mix Design Criteria
 Batching
 Desirability
 Analysis



Factor	Value	Unit
W/CM Ratio	0.37	
Coarse Agg	47.86	% Volume
Fine Agg	18.31	% Volume
Air Content	5.00	% Volume

Batch ID 1

View

Batch ID	Water (lb/ycf)	Cement (lb/ycf)	Coarse Agg (lb/ycf)	Fine Agg (lb/ycf)	Total (lb/ycf)	Total Cost (\$/ycf)
1	263.1	701.9	2,178.1	833.4	3,976.5	44.04
2	256.9	703.9	2,252.7	773.7	3,987.2	44.20
3	256.9	703.9	2,252.7	773.7	3,987.2	44.20
4	256.9	703.9	2,252.7	773.7	3,987.2	44.20
5	279.5	765.6	2,139.0	773.7	3,957.7	45.80
6	256.6	722.4	2,178.1	833.4	3,990.5	44.80
7	257.1	685.9	2,327.4	714.0	3,984.4	43.63
8	287.0	765.8	2,178.1	714.0	3,944.9	45.69
9	250.7	706.0	2,327.4	714.0	3,998.1	44.37
10	251.9	719.7	2,252.7	773.7	3,998.0	44.79
11	275.0	753.3	2,252.7	682.6	3,963.6	45.48
12	256.9	703.9	2,252.7	773.7	3,987.2	44.20
13	279.9	788.2	2,178.1	714.0	3,960.2	46.51
14	261.7	688.8	2,252.7	773.7	3,976.9	43.64
15	233.2	622.0	2,327.4	833.4	4,015.9	41.98
16	234.4	642.2	2,366.5	773.7	4,016.7	42.60
17	256.9	703.9	2,252.7	773.7	3,987.2	44.20
18	256.9	703.9	2,252.7	773.7	3,987.2	44.20
19	227.4	640.2	2,327.4	833.4	4,028.4	42.65
20	238.9	654.5	2,252.7	864.7	4,010.8	42.92

Optimization Module

Identify Criteria for optimization...

The screenshot displays the 'Optimization1 example - COMPASS' application window. The interface includes a menu bar (File, Edit, Help) and a toolbar with icons for New, Open, Close, Save, Print, Cut, Copy, and Paste. The main area is divided into a left-hand tree view and a right-hand configuration panel.

Optimization

- General Information
- Trial Batches
- Materials
- Analysis
- Mix Optimization
 - Mix Design Criteria**
 - Batching
 - Desirability
 - Analysis

Criteria List:

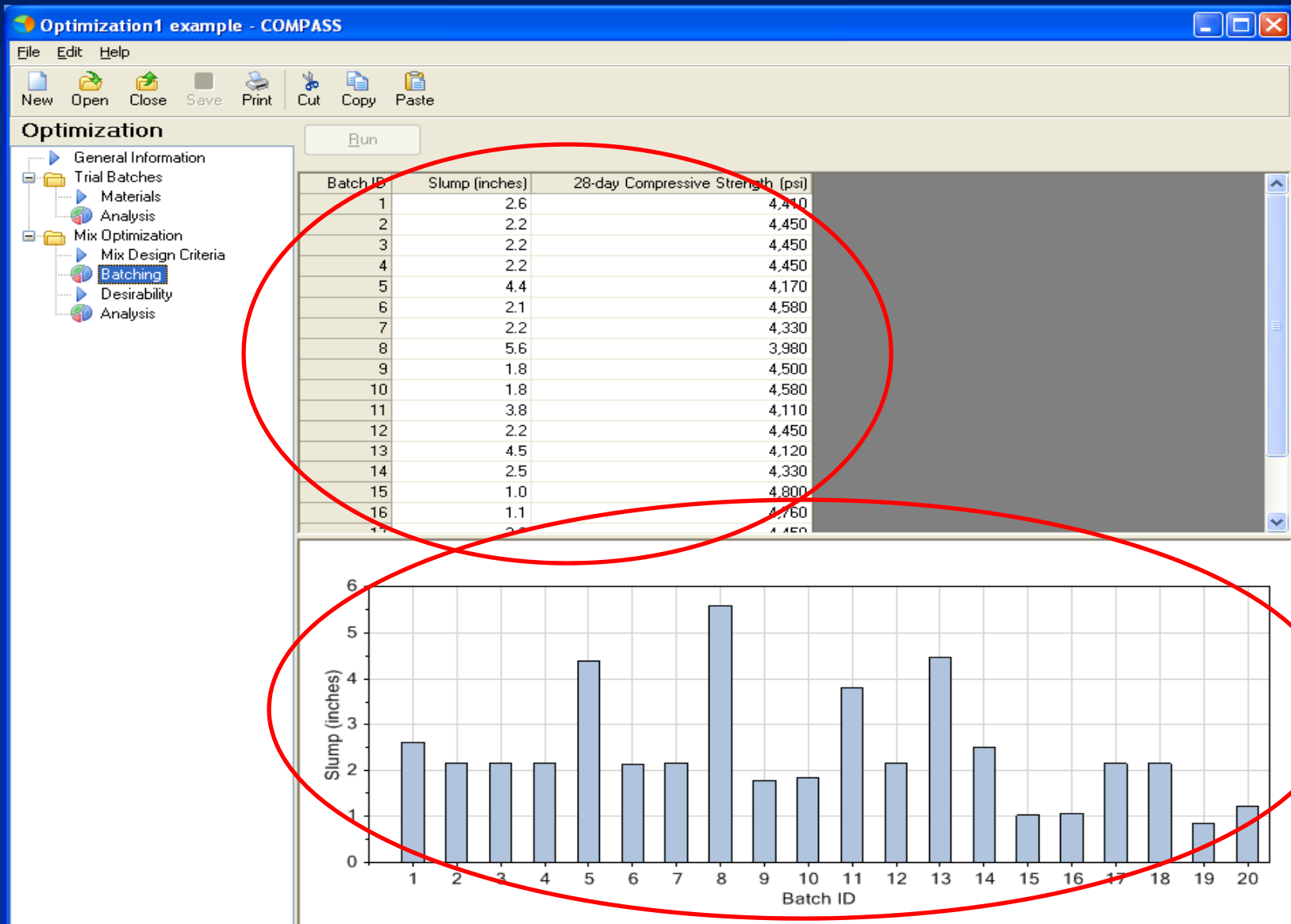
Name	Source
<input checked="" type="checkbox"/> 28-day Compressive Strength	Virtual Batching
<input checked="" type="checkbox"/> Slump	Virtual Batching

Configuration Panel:

- New...** **Remove**
- Source:** Virtual Batching (dropdown menu, circled in red)
- Maximum Aggregate Size:** 1.5 inches (37.5 mm) (dropdown menu)

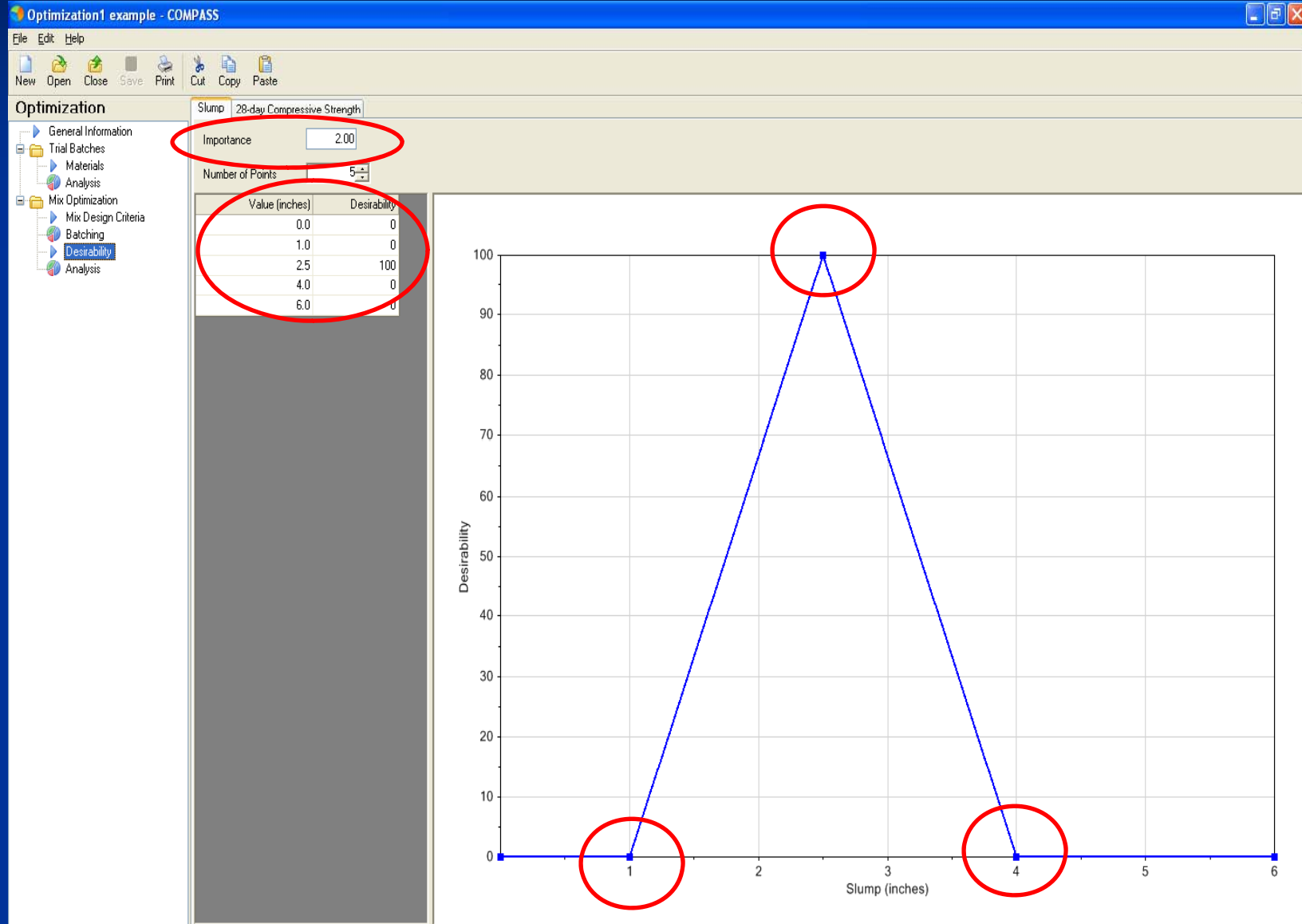
Optimization Module

Identify Criteria for optimization...



Optimization Module

Assign Desirability and Importance...



Optimization Module

Analyze for List of Alternate Optimized Mixes ...

The screenshot displays the 'Optimization1 example - COMPASS' application window. The interface includes a menu bar (File, Edit, Help), a toolbar with icons for New, Open, Close, Save, Print, Cut, Copy, and Paste, and a tree view on the left under the 'Optimization' heading. The tree view shows a hierarchy: General Information, Trial Batches, Materials, Analysis, Mix Optimization, Mix Design Criteria, Batching, Desirability, and Analysis. A red circle highlights the 'Optimize' button. Below the tree view, there are tabs for 'Gravimetric', 'Volumetric', 'Factors', 'Responses', and 'Model Fit'. The 'Responses' tab is active, showing a table with the following data:

Mix ID	Slump (inches)	28-day Compressive Strength (psi)
14	2.5	4,326
75	2.5	4,389
56	2.5	4,464
26	2.6	4,401
90	2.6	4,401
29	2.4	4,376
93	2.4	4,376
45	2.6	4,327
72	2.6	4,413
1	2.6	4,409

Summary

COMPASS consists of 4 modules

1. **Mix Expert** - first cut of material choices
2. **Gradation** - optimize aggregate blends for best packing
3. **Proportioning** - make initial attempts at mix designs
4. **Optimization** - find the best alternatives for specific criteria

The four modules can work as stand alone tools.

OR...

Used together, make a powerful optimization system.



You can download the **FREE** unofficial version of
COMPASS:

www.PCCmix.com

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