



American Concrete Institute

Always advancing

Life Cycle Assessment in Concrete Mix Design: Lessons from the Eco Concrete Competition

Hessam Azarijafari, Ph.D.

Deputy Director, Concrete Sustainability Hub
Massachusetts Institute of Technology (MIT)

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Concrete is the most commonly used building material ... for good reason

- Global cement production ~ 4 billion tons per year.
- Concrete production is about 30 billion tons per year

Versatile

Durable

Constructable

Available

Economical

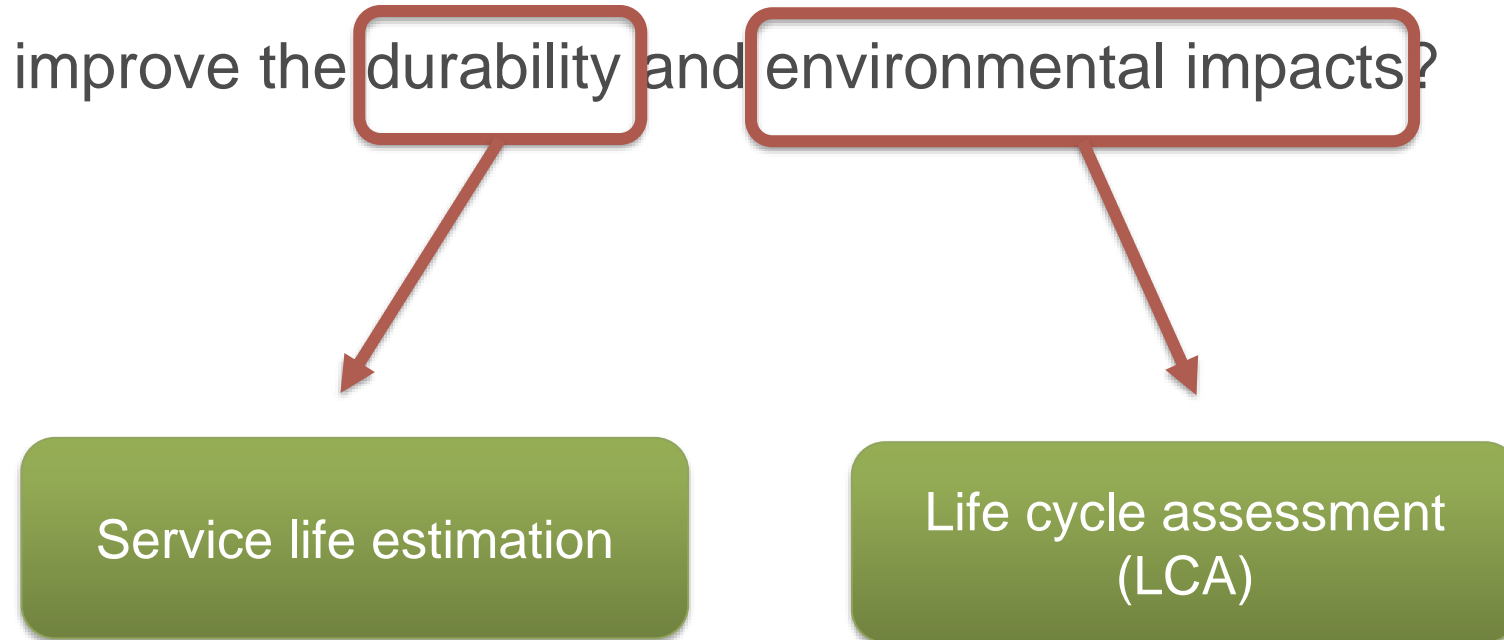
How should we evaluate the sustainability aspect of the of concrete?

How can we mitigate the environmental impacts?

ACI Eco concrete Competition was developed to promote the environmental performance in concrete mix design as an important aspect of sustainability

Objective of the competition:

How can you improve the durability and environmental impacts?

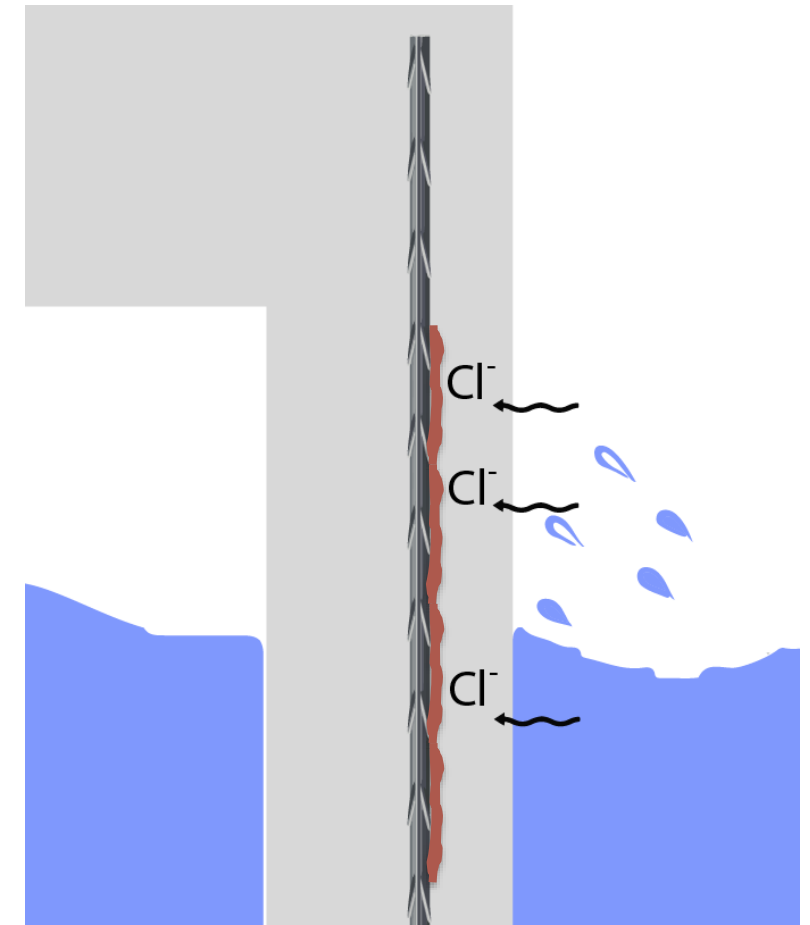


How do we estimate the service life of concrete mixtures?

- Long-term chloride penetration resistance of concrete mixtures is simulated based on their critical chloride content in time.
- Life-365™ software is considered to estimate the service life of concrete mixtures based on the corrosion initiation time.

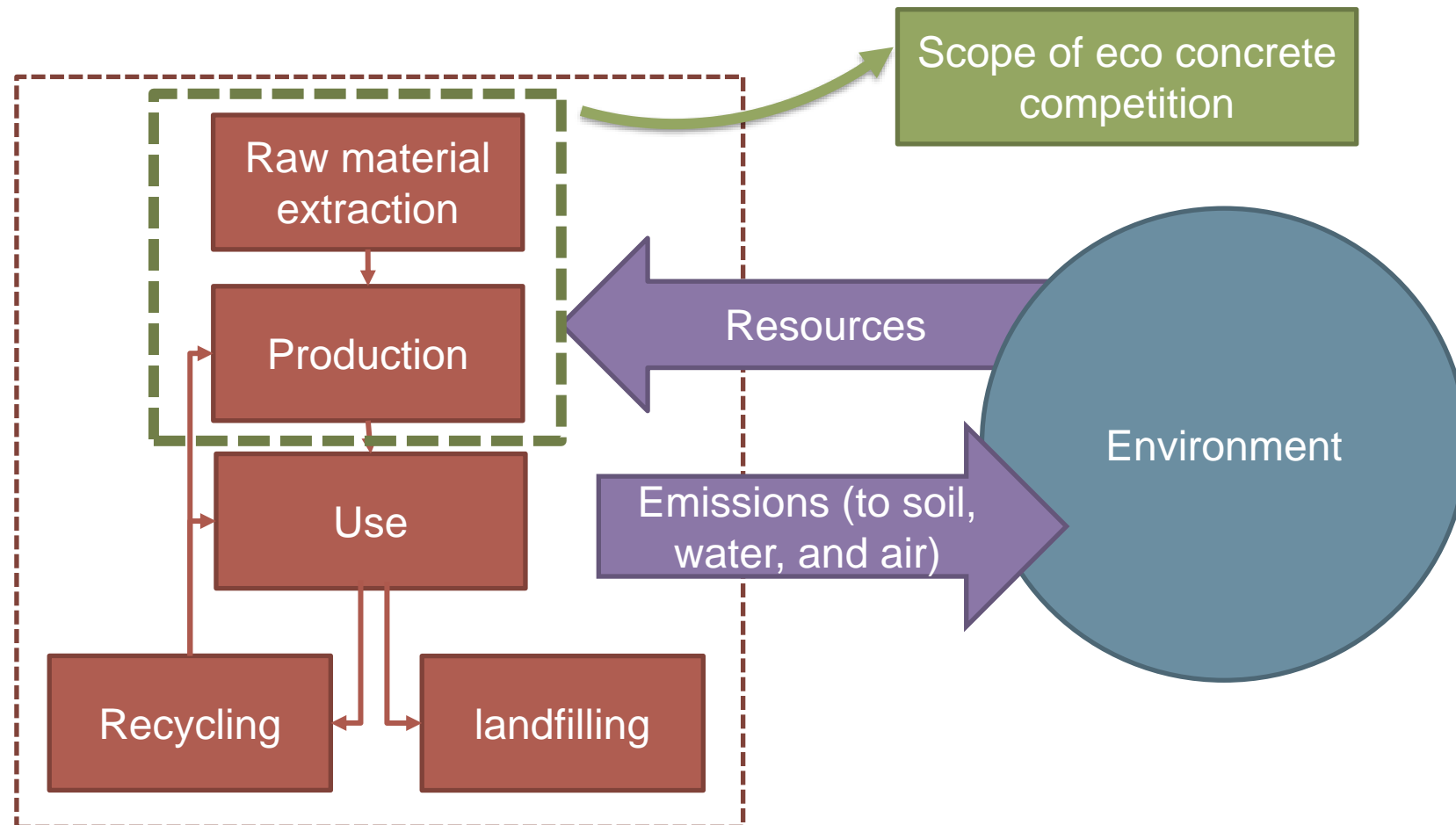


Software download: <http://www.life-365.org/>



How do we calculate the environmental impacts of concrete?

Life cycle assessment (LCA) is a quantitative method for assessing of the potential environmental impacts of any products (e.g., concrete) during its life cycle.

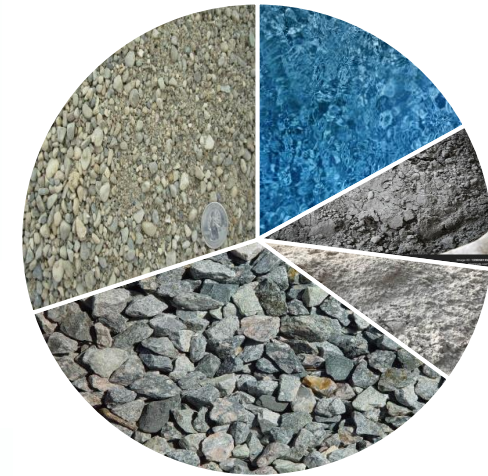


What should we design and evaluate in the eco concrete competition?

Base-case scenario
(BCS)



Alternative-case scenario
(ACS)



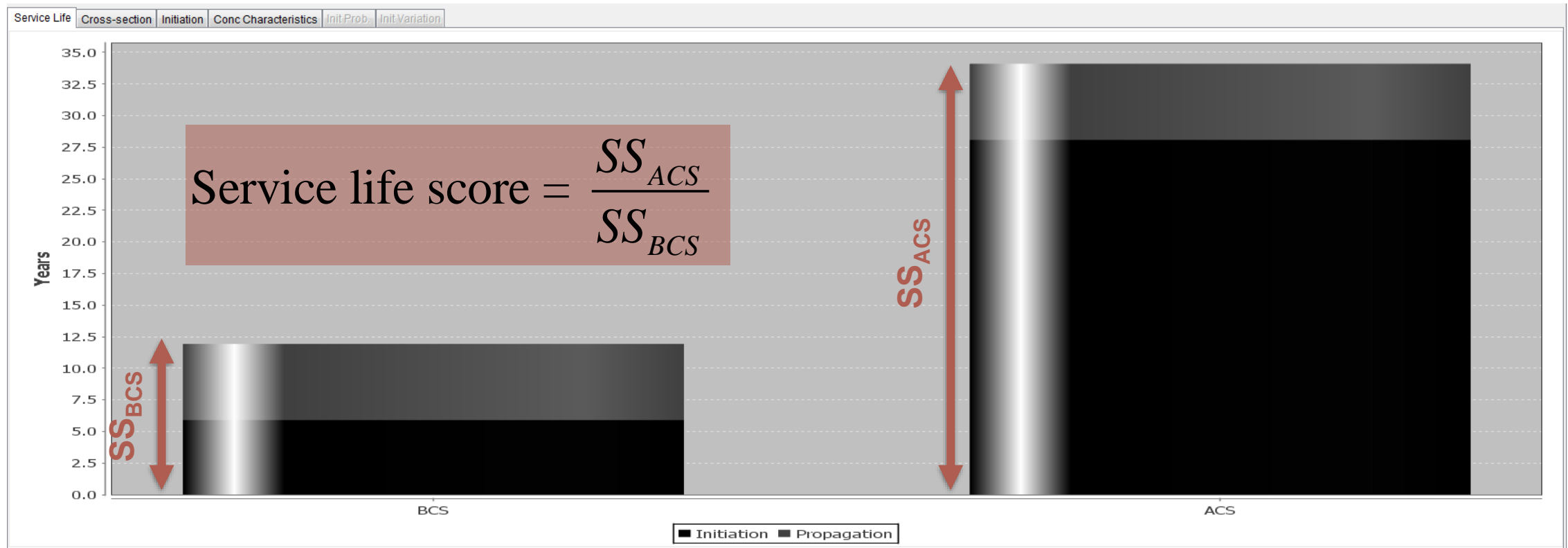
Service life
prediction (Life365)



Streamlined
LCA tool

Service life prediction shall be conducted for the BCS and ACS mixtures

Service life simulation and Ratio calculation



How do we do LCA in the eco concrete competition?

Streamlined LCA tool was developed in 2017 for this competition

Eco Concrete Student Competition Designing Base-Case Scenario concrete

Developed by ACI Sherbrooke Student Chapter

Run calculations

Go!

Last calculation update:

2017-03-13

1) Input insertion

Base-Case concrete mix design

Components	Category	Subcategory	Amount kg/m ³
Cementitious Materials and fillers			
Type 1 (GU) Portland Cement	Cement	Main-Product	400
+ Aggregates			
Sand	Fine aggregates	Crushed	900
- 5-10mm aggregate	Coarse aggregates	Crushed	1000
+ Water			
Water#1		Tap water	170
+ Admixtures			
Admixtures #1			

¹Amount required for the production of 1 kg of material

²Distance between the origin of the material and the batching plant (your university)

Total amount	2470
Total binder content	400
Water-to-binder ratio	0.40
Cement substitution rate	0%

EcoConcrete Student Competition

Summary

Developed by ACI Sherbrooke Student Chapter

2) results

Table 1 : Base- and Alternative-Case

Mix characteristics	Unit	Base-Case Scenario	Alternative-Case Scenario	Note
Density	kg/m ³	2470	2470	
Total binder content (b)	kg/m ³	400	400	b _{BCS} = b _{ACS}
Water-to-binder ratio (w/b)		0.40	0.40	w/b _{BCS} = w/b _{ACS} = 0.43
Cement substitution rate	%	0%	40%	Maximum 40%

Table 2 : Details of the potential environmental impact scores and variation

Impacts categories	Units	Base-Case Scenario	Alternative-Case Scenario	Potential environmental impact reduction
Global warming	kg CO ₂ eq	366.973	231.749	36.8%
Carcinogenic	CTUh	0.000	0.000	33.3%
Ozone depletion	kg CFC-11 eq	1.55E-05	9.10E-06	41.5%
Ecotoxicity	CTUe	596.460	392.430	34.2%
Fossil fuel depletion	MJ	142.815	83.578	41.5%

Average: 37.5%

Figure 1: Your improvements in a glance

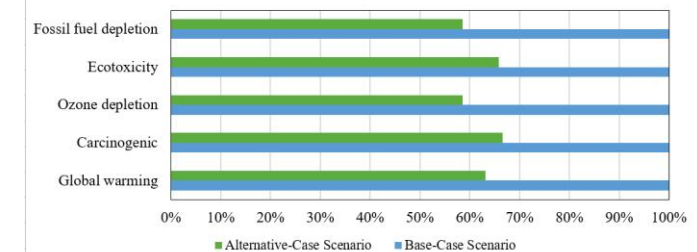


Table 3 : Sensivity analysis and estimation of your final score

Performances	Units	Weighing factor	Results
Written report	%	0.30	100.0%
Poster presentation	%	0.10	100.0%
Compressive strength	MPa	0.15	50.0
Electrical resistivity	kΩ*cm	0.20	254.0
Environmental impact reduction	%	0.25	37.5%
Final score	/100		84.4%

Life cycle assessment shall be conducted by the streamlined LCA tool designed for this competition

Step 1) After mixtures definition:

- A. Materials suppliers shall be identified in your city.
- B. Transportation distances shall be presented on a map.
- C. Transportation distances from the supplier to university shall be calculated.

Mix design definition

Eco Concrete Student Competition
Designing Base-Case Scenario concrete
Developed by ACI Sherbrooke Student Chapter

Run calculations Go!
 Last calculation update: 2017-03-13 00:29

Base-Case concrete mix design

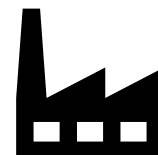
Components	Category	Subcategory	Amount kg/m ³
Cementitious Materials and fillers			
Type 1 (GU) Portland Cement	Cement	Main-Product	400
+ Aggregates			
Sand	Fine aggregates	Crushed	900
- 5-10mm aggregate	Coarse aggregates	Crushed	1000
+ Water			
Water#1		Tap water	170
+ Admixtures			
Admixtures #1			
Total amount			2470
Total binder content			400
Water-to-binder ratio			0.40
Cement substitution rate			0%

¹Amount required for the production of 1 kg of material
²Distance between the origin of the material and the batching plant (your university)

Transportation definition

Transport²

Road	Rail	Waterway	Footpath
km	km	km	km
			3
			2
			3
			0
			3
0	0	0	3



Calculation of relative environmental improvement score

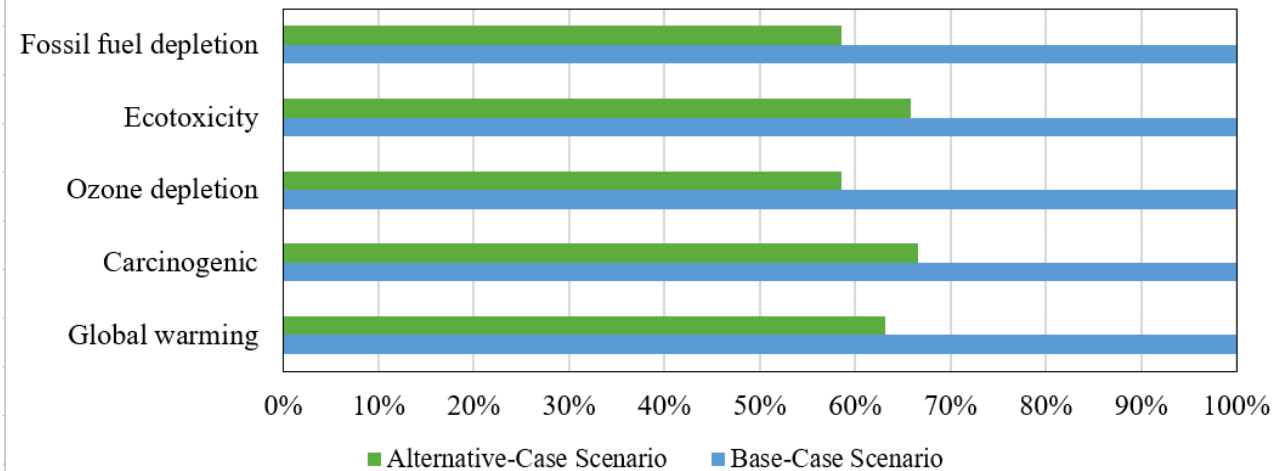
Step 3) Check if all the parameters were inserted correctly (all the boxes are green)

Table 2 : Details of the potential environmental impact scores and variation

Impacts categories	Units	Base-Case Scenario	Alternative-Case Scenario	Potential environmental impact reduction
Global warming	kg CO ₂ eq	366.973	231.749	36.8%
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Average: **37.5%**

Figure 1: Your improvements in a glance



Score calculation and Question and answer interview

Score = 20% report + 30% presentation + 25% durability + 25% LCA

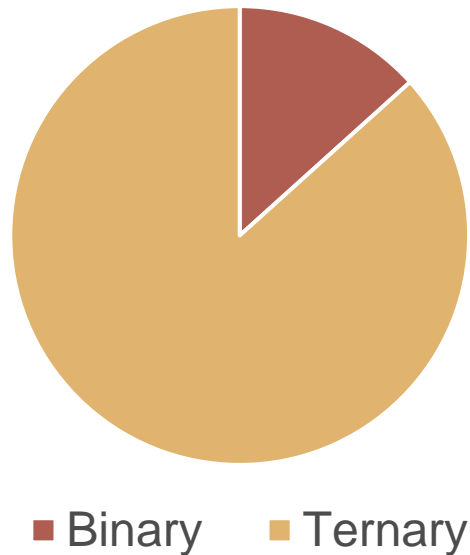
Submission requirement by the deadline:

- PDF report
- YouTube link of the recorded video
- Excel tool (including the calculated LCA results)
- Saved file of the Life-365 results (JSON format)

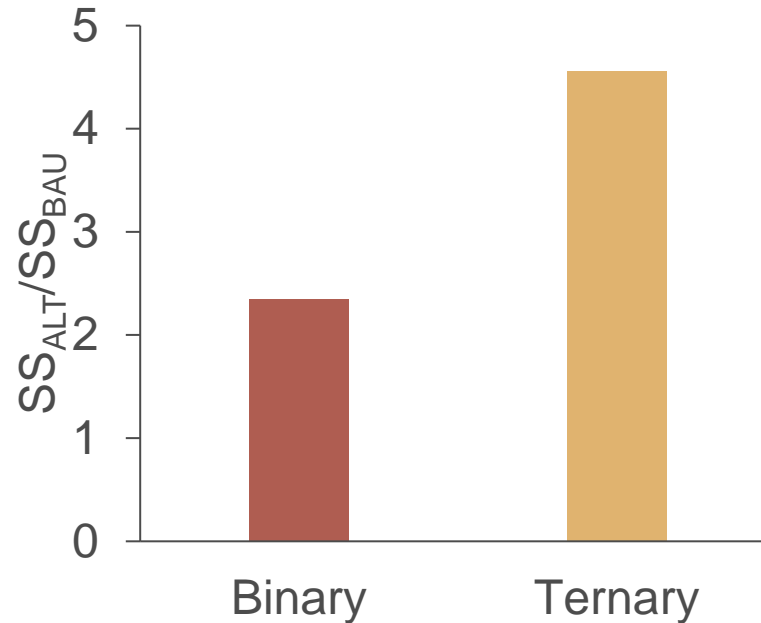
Lessons learned: Ternary mixtures considerably improve the durability and environmental performance of mixtures

Combination of Fly Ash, Slag, and Silica Fume

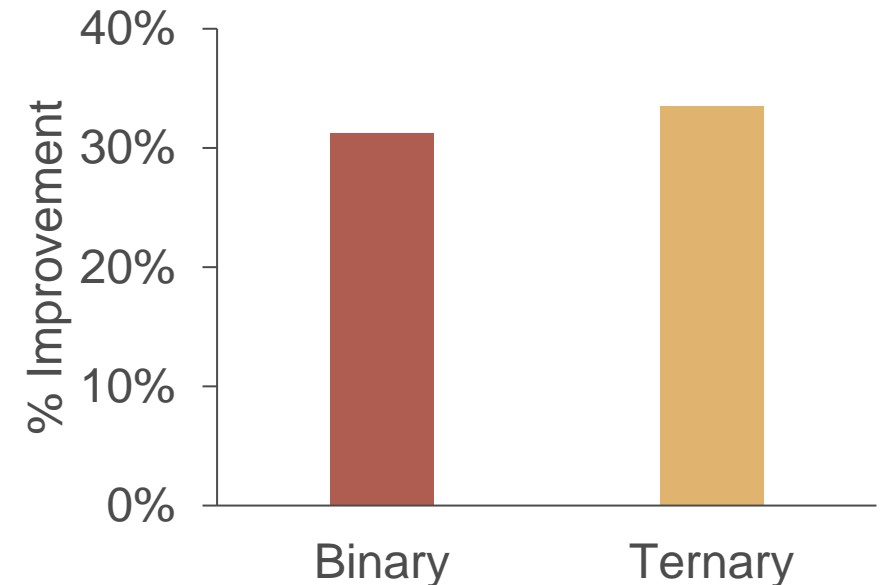
Binder composition selection



Durability improvement



Environmental impact improvement



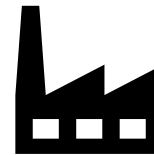
Lessons learned: Recycled materials and transportation needs to be

1) Neglecting the energy consumption of recycled materials (crushing, grinding, and sieving the materials)

2) Overlooking the transportation of material from the quarry to the plant

3) Not satisfying the minimum content of aggregates in both mix designs

Quarry

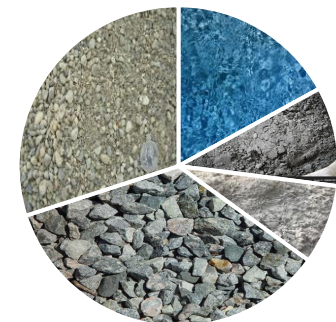


X km

Plant



Rule: Similar aggregate volume shall be considered



Part of the last winners' video recording



Three version of this competitions has happened so far because of the following

- ACI Staff:
 - Student, Faculty & Young Professional Activities Coordinator
- ACI Committee Chairs:
 - S801 – Student Competition
 - 130 – Sustainability of Concrete
- Tens of volunteers:
 - Report and Video Reviewers
 - Interview Judges

A contribution from ACI Committee 130, Sustainability of Concrete

The Eco Concrete Competition

Lessons learned by (and from) students

by Hessam Azarijafari, Julie K. Buffenbarger, and Sean Monkman

Previous experiences of eco concrete competition

<https://www.concrete.org/students/studentcompetitions/ecoconcretecompetition.aspx>

Thank you!
Hessam@mit.edu

Service life prediction shall be conducted for the BCS and ACS mixtures

Step 1) Definition of concrete element geometry in the “Project” tab in Life-365™

Life-365 v2.2.3 <new project> - December 17, 2020

Project Settings

Current Project

- Save project
- Save project as...
- Close project
- Export project data...

Steps

- Define project...
- Define alternatives...
- Define exposure...
- Define mix designs...
- Compute service life...
- Define project costs...
- Compute life-cycle cost...

Settings

- Help for this window...
- Set default values...
- About Life-365™...

Tips

This is the description of each alternative.

To modify a description shown, double-click on the description itself.

Project Exposure Concrete Mixtures Individual Costs Life-Cycle Cost Service Life Report LCC Report

Identify Project

Title "TEAM NAME" 1

Description Default settings for a new project

Select Structure Type and Dimensions

Type of structure slabs and walls (1-D) 2

Thickness (mm) 200.0

Reinf. depth (mm) 50.0

Area (square m) 5

--> Volume of concrete 1.0 cub. met.

Chloride concentration units % wt. conc.

Life-365 will model service

Define Economic Parameters

Base year 2020 Analysis period (yrs) 100 Inflation

Define Alternatives (up to 6)

Add a new alt Delete

Name (double-click to edit)	
BCS	A project that uses the normal mix of concrete
ACS	A project that uses the a new mix of concrete

Software download: <http://www.life-365.org/>

Section 2.5 of the ECOCONCRETE STUDENT COMPETITION 2021 rules:

<https://www.concrete.org/Portals/0/Files/PDF/EcoConcrete-RulesFinal.pdf>

Service life prediction shall be conducted for the BCS and ACS mixtures

Step 2) Definition of local condition in the “Exposure” tab in Life-365™

The screenshot displays the 'Life-365 v2.2.3 <new project> - December 17, 2020' software interface. The 'Project Settings' window is open to the 'Exposure' tab. The 'Select Method for Setting External Concentration and Temperature Profile' section has 'Use defaults' selected. The 'Location' is set to 'Florida', 'Sub-location' to 'TAMPA', and 'Exposure' to 'Marine spray zone'. The 'Chloride Exposure (automatically set)' section shows 'Max Concentration' set to 'Manual' at '1.000 % wt. conc.' and 'Time to Max' set to '10.0' years. A graph titled 'Surface Concentration' plots '% wt. conc.' on the y-axis (0.0 to 1.0) against 'Year' on the x-axis (0 to 80). The graph shows a linear increase from 0% at year 0 to 1.0% at year 10, then remains constant at 1.0% for the rest of the 80-year period.

Year	% wt. conc.
0	0.0
10	1.0
80	1.0

Service life prediction shall be conducted for the BCS and ACS mixtures

Step 3) Definition of mix design in the “Concrete Mixtures” tab of Life-365™

Life-365 v2.2.3 <new project> - December 17, 2020

Project Settings

Current Project

- Save project
- Save project as...
- Close project
- Export project data...

Steps

- Define project...
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- Compute life-cycle cost...

Settings

- Help for this window...
- Set default values...

Project | Exposure | Concrete Mixtures | Individual Costs | Life-Cycle Cost | Service Life Report | LCC Report

Type: slabs and walls (1-D) Calculate service life Compute unce

Define Concrete Mixtures (select a mix to edit its properties)

Name	User Defined	D28 (m*m/sec)	m	Ct (% wt. conc.)
BCS	no	7.9433E-12	0.20	0.050
ACS	no	3.4810E-12	0.43	0.050

Selected mixture: BCS (A project that uses the normal mix of concrete)

Mixture

w/cm	0.40
Class F fly ash (%)	0.00%
Slag (%)	0.00%
Silica fume (%)	0.00%

Rebar

Rebar steel type	Black Steel
Rebar % vol. concrete	3.00%
Inhibitor	<none>

Binder percentage shall be exactly defined based on constituents of BCS and ACS mixtures

Results should be presented in two format: written report and Video recording

1. Written Report

- PDF format (check the due date from the competition rule documents)
- No more than 20 pages
- Don't forget the illustration of maps and results!
- Discussion of results and how they can be applied in large scale

2. Video recording

- No longer than 7 minutes
- Presentation of all team members is a plus
- Slides should innovatively discuss the results and calculation process

Results validation should be done to assure satisfying all the competition criteria

Step 2) Check if all the parameters were inserted correctly (all the boxes are green)

EcoConcrete Student Competition

Summary

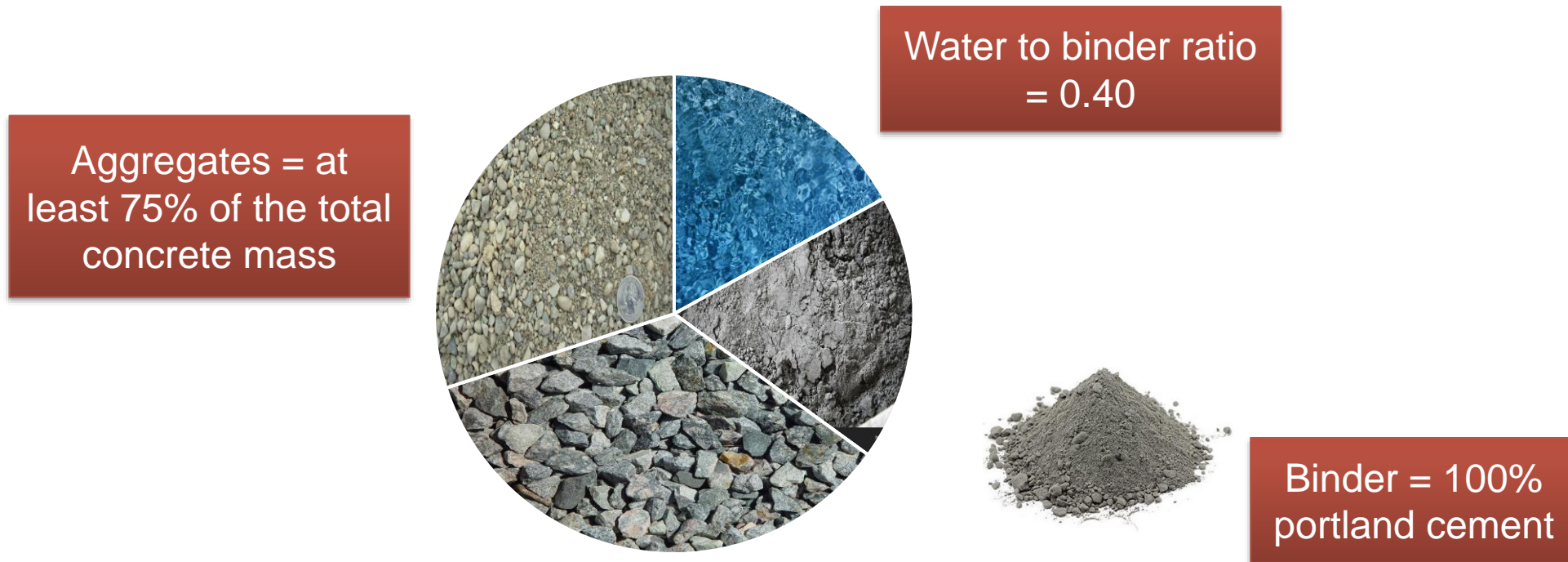
Developped by ACI Sherbrooke Student Chapter

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Water-to-binder ratio (w/b)		0.40	0.40	$w/b_{BCS} = w/b_{ACS} = 0.40$
Cement substitution rate	%	0%	40%	Maximum 40%

Rules of competition for material selection and mix designs for the Base-case scenario (BCS)

The design should correspond to a local structural concrete practice.



Rules of competition for material selection and mix designs For the Alternative-case scenario (ACS)

The volume of aggregates and binders shall be equal to those in the BCS mixture

Water to binder ratio
= 0.40

Similar aggregate
volume shall be
considered



Similar binder volume to
shall be considered

40% maximum binder
replacement by
supplementary cementitious
materials (SCM)

Only SCMs predefined in
Life-365™ software shall
be included.

Multiple types of SCMs
are allowed.