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Engineering and Physical Sciences Research Council

UNIVERSITY OF LEEDS

Optimization of Sustainable Concrete Mixes: Analysis of an Industrial Database

Presented by

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Table of Contents

- We can do data analysis to relate the strength to mix design. → What database?

Industrial database

- We can use machine learning(ML) methods to predict strength.
- We can also use ML models to optimise the strength.

→What method?

Multiple Linear Regression with interaction terms and variable transformations

- Strength is affected by many factors. → What factors?

t, w/b, plasticizer content and type, coarse aggregate content and type, Dmax, C/F

- Those factors have also interactions effects on the strength. → What interactions?

CA content with Dmax and type; water-to-binder ratio with time, Dmax and CA type;
Plasticizer content with water-to-binder ratio and time

- Consistent and big dataset

Standard routine industrial testing provides big dataset of concrete performance.

Dataset is consistent as trial mixes were performed in the laboratory well-controlled environment.

We have used approximately 3000 mixes for our model.

- Complexity, accuracy and interpretability trade-off

With a well-specified multiple linear regression model, high accuracy and interpretability do not have to be a trade-off.

Our model has achieved 90% of R^2 and it has a regression equation to estimate the strength of concrete and optimise the concrete mix design.

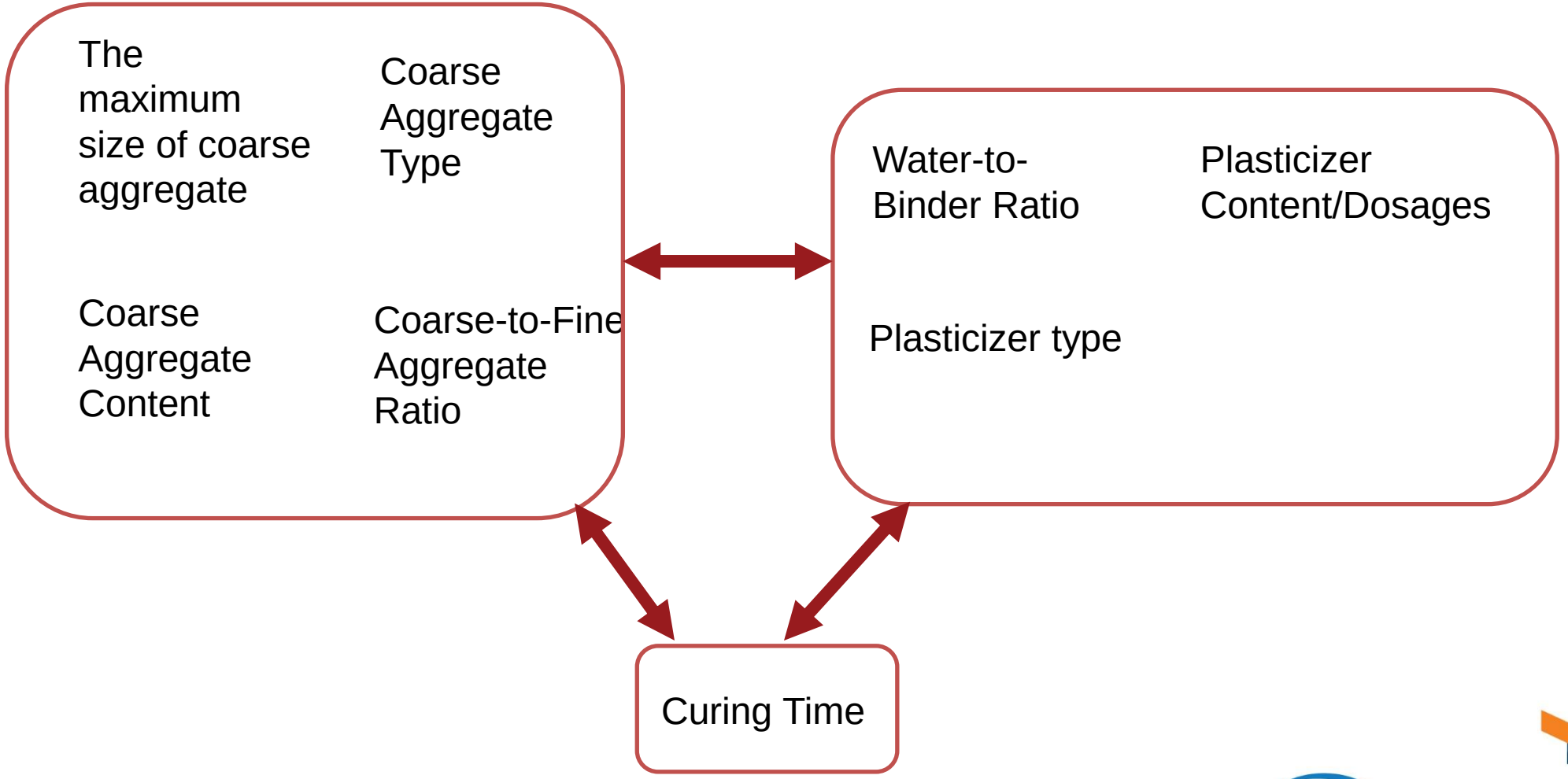
- Model specification

Determination of main factors
and interaction effects based on the knowledge.

Exploring how incorporation of those factors into model change the model accuracy.

Selecting the key factors that most significantly influence strength, while emphasizing model accuracy and aligning with the fundamental principles of concrete technology

- Effective main factors



- Effective Interaction terms

Coarse aggregate content **X** Dmax

Coarse aggregate content **X** Crushed/Uncrushed

$\frac{Cement}{water}$ & $\frac{GGBS}{water}$

Water-to-binder ratio **X** Curing time

Water-to-binder ratio **X** Dmax

Plasticizer content **X** Curing time

Ln(curing time)

(Plasticizer Content)^2

Plasticizer content **X** Water-to-binder ratio

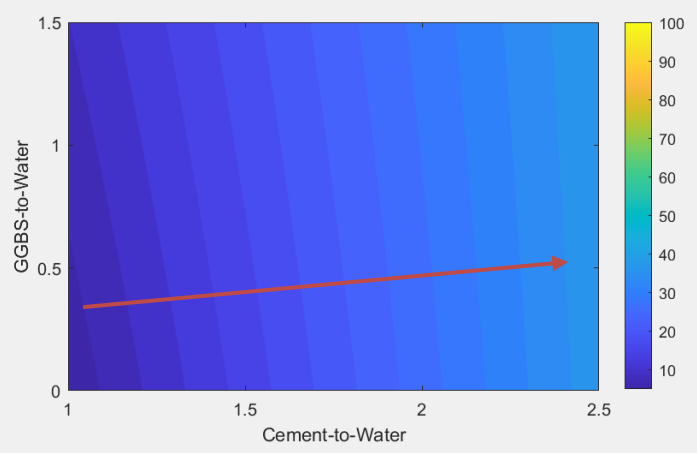
However, if we do not apply some variable transformations we cannot achieve a model with high accuracy.

As we need to catch the nonlinearity of between some variables and the strength.

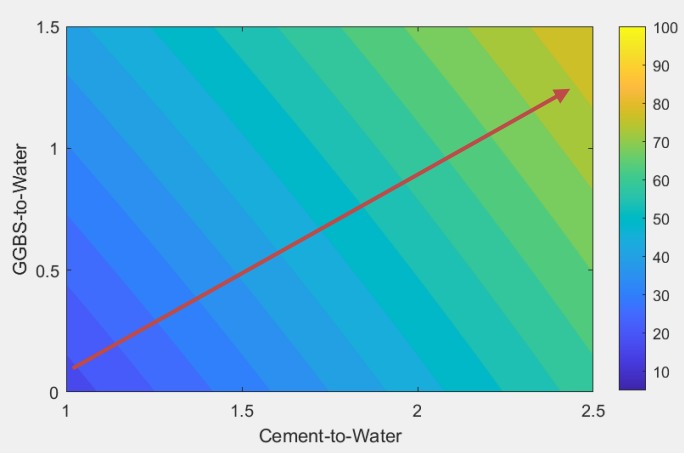
- Descriptive statistics of the dataset

Numeric Variables	Coarse Aggregate	Coarse-to-Fine Aggregate	Dmax	Cement-to-Water	GGBS-to-Water	Plasticizer	Super plasticizer
median	1030	1.23	20	1.2	0.7	1.91	1.99
5th percentile	808	0.85	10	0.50	0.00	1.00	1.05
95th percentile	1175	1.70	20	2.50	1.50	4.1	5.54
Unit	kg/m3	unitless	mm	unitless	unitless	kg/m3	kg/m3

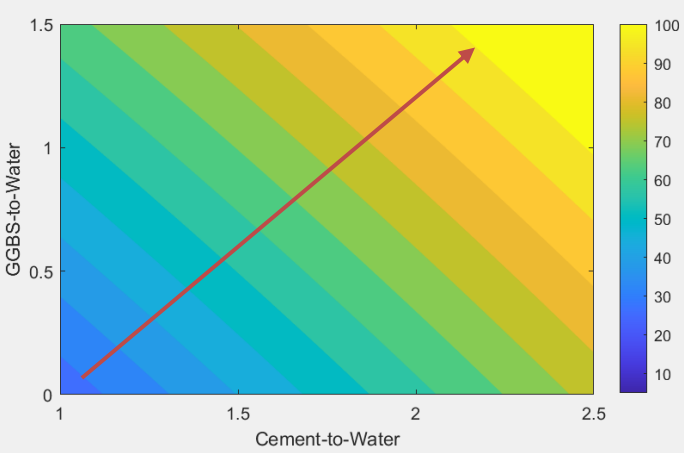
Categorical Variables	
Coarse Aggregate Rock Type	Water-reducers
Crushed (67%)	Plasticizer (23%)
Uncrushed (33%)	Superplasticizer (77%)



1-day Strength in MPa

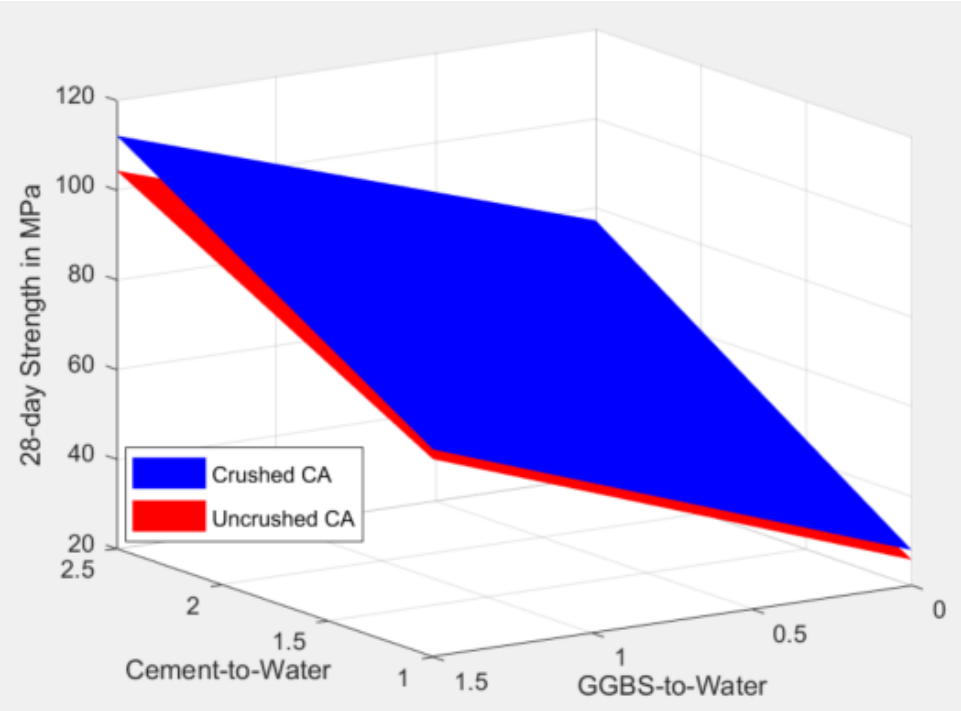


7-day Strength in MPa

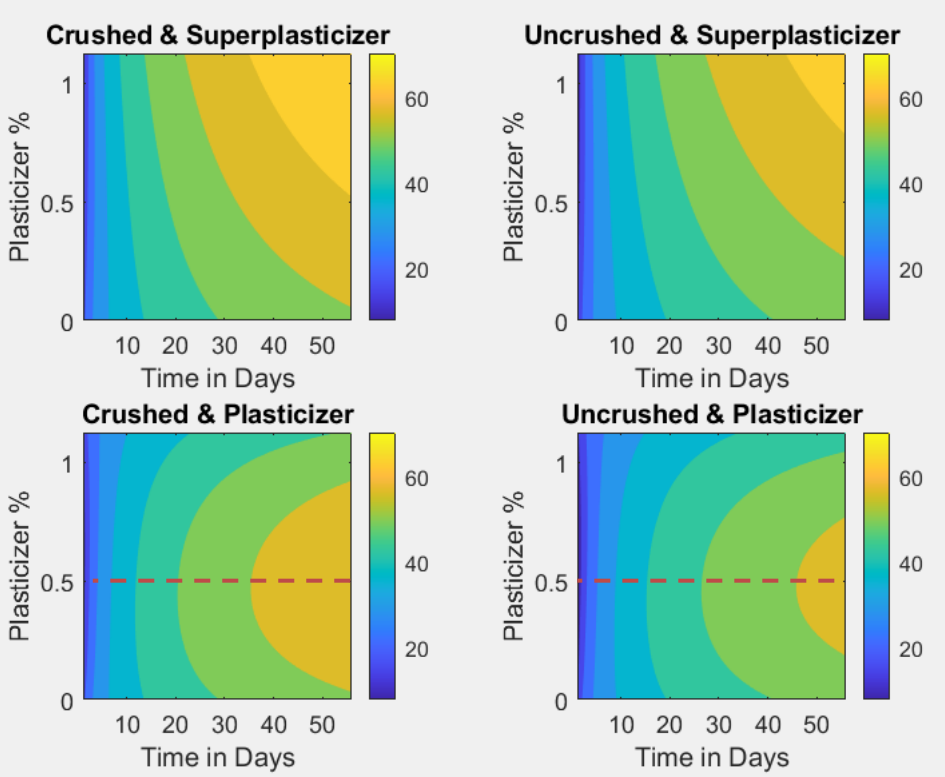


28-day Strength in MPa

The model reproduces the latently hydraulic feature of Ground-Granulated Blast Furnace Slag(GGBS).



- The model demonstrates that concrete with crushed coarse aggregates gains higher strength than that with uncrushed aggregates.
- The strength difference of concrete with coarse aggregate being uncrushed and crushed is approximately 5-10%.



At the early stages of strength development;

- increasing water-reducer agent dosage does not affect strength development for both superplasticizers and plasticizers, **but**

for later ages;

- increasing superplasticizer dosage increases the strength.
- Increasing plasticizers dosage increases the strength up to 0.5% of plasticizer dosage.

~ THANKS FOR LISTENING ~

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