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Meta-Analysis on PET Plastic as Concrete Aggregate using Response Surface Methodology and Regression Analysis

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Students: Beng Wei Chong, Texas States University, hdn31@txstate.edu
Advisor: Xijun Shi, Texas States University, xijun.shi@txstate.edu

Introduction

- Polyethylene Terephthalate (PET) plastic is a common domestic waste that can be reused as concrete aggregate.
- Replacement of concrete aggregate with PET plastic improved the ductility and durability performance of concrete but compromised concrete compressive strength.
- However, huge discrepancy existed between each study as PET plastic might be used as either or both fine and coarse aggregate replacement with varying effect on concrete performance.
- Meta-analysis on PET aggregate studies was conducted using Response Surface Methodology (RSM) and regression analysis to thoroughly study the effect of PET aggregate on concrete strength.

Objective

- To develop mathematical expressions for concrete with PET coarse aggregate (PET-CA) and PET fine aggregate (PET-FA)
- To investigate the effect of PET aggregate replacement on the compressive strength of concrete for both expressions.

Database & Methodology

- Literature on concrete with PET aggregate replacement was gathered.
- Input factors were the replacement percentage, nominal aggregate size (for PET-CA expression), and concrete mix designs.
- Aggregate size was not taken as a factor in PET-FA expression as studies used the standard fine aggregate size passing 5mm sieve.
- Output factor was 28-day compressive strength of concrete.

RSM Expression	No. of Data	Input Factors	Output Factor
PET-CA	42	PET replacement (%) Nominal aggregate size (mm) Cement content (kg/m^3) Coarse aggregate content (kg/m^3) Fine aggregate content (kg/m^3) Water-to-cement ratio	28-day compressive strength
PET-FA	60	PET replacement (%) Cement content (kg/m3) Coarse aggregate content (kg/m3) Fine aggregate content (kg/m3) Water-to-cement ratio	28-day compressive strength

- Regression analysis was conducted by plotting the strength index (SI) of all data.

$$SI = \frac{CSR}{CSC}$$

where:

CSR = 28-day compressive strength of concrete with PET plastic aggregate
CSC = 28-day compressive strength of control mix without PET aggregate

Mathematical Expression

Notation	Factor
CS_{28}	28-day compressive strength (MPa)
A	Cement content (kg/m^3)
B	Coarse aggregate content (kg/m^3)
C	Fine aggregate content (kg/m^3)
D	Water-to-cement ratio
E	PET replacement (%)
F	Maximum nominal size (mm)

PET-CA Expression

$$CS_{28} = -122.3 + 0.311B + 0.020C - 29.77D - 0.383E + 2.232F - 0.000152B^2 - 0.00156BF + 0.000311CE - 0.00138CF$$

$R^2 = 0.9479$

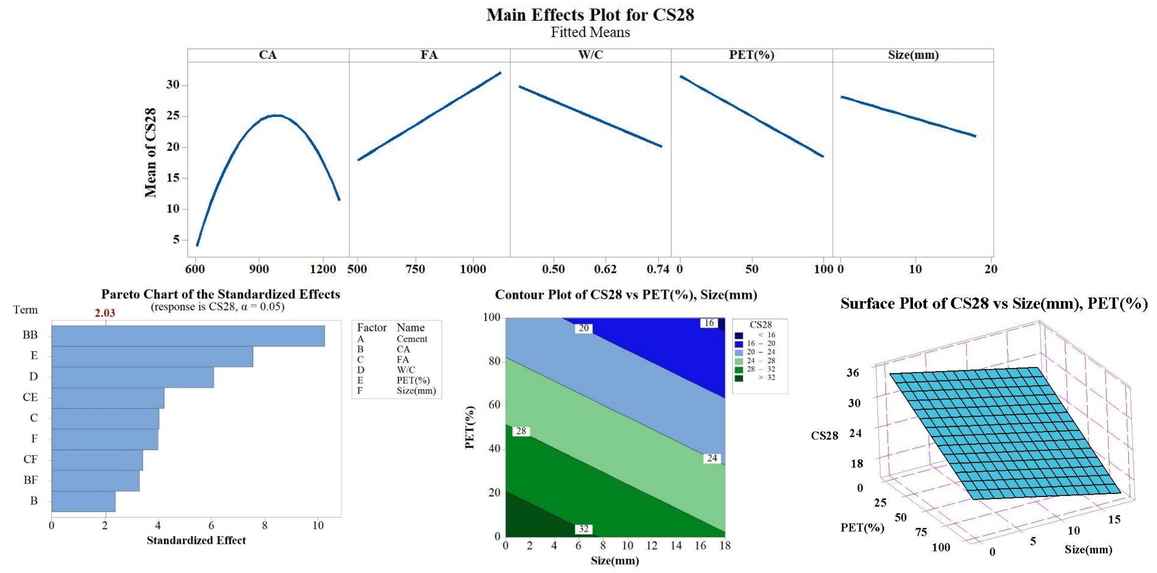
PET-FA Expression

$$CS_{28} = -311.4 + 0.4A + 0.288B + 0.0823C + 157.6D + 1.522E - 0.000106B^2 - 56.5D^2 - 0.000109AB - 0.000156AC - 0.002249AE - 0.000299BE - 0.000803CE$$

$R^2 = 0.9787$

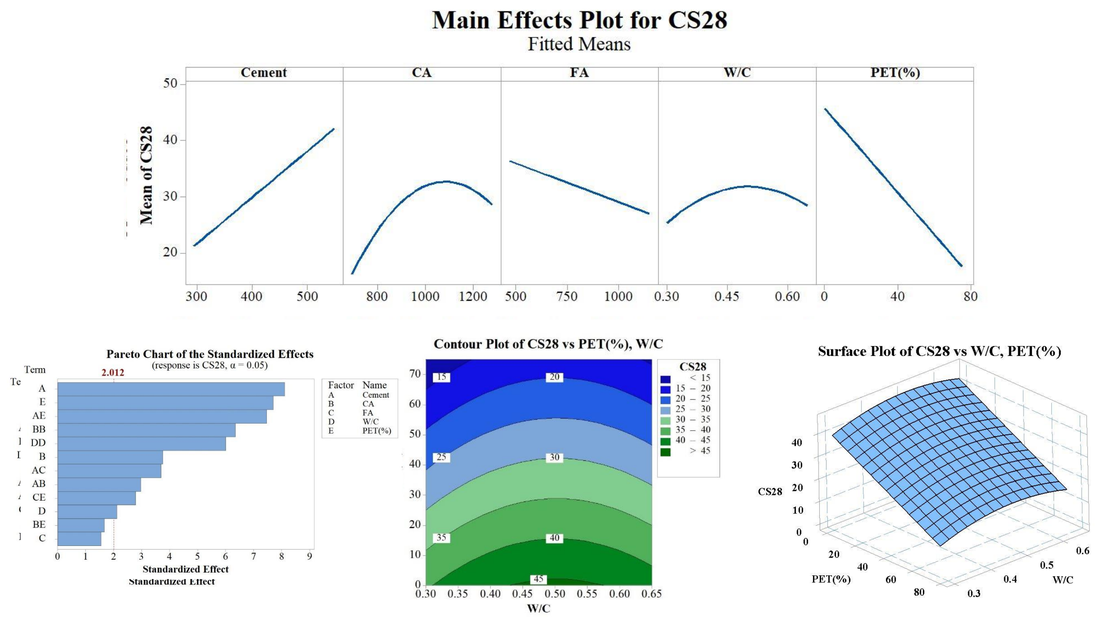
Results and Discussion

- **RSM of PET-CA Expression**



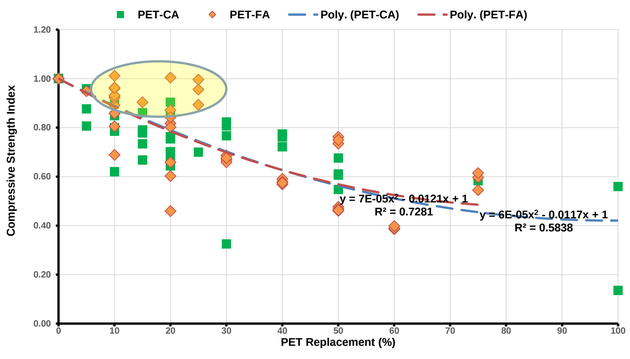
- Concrete strength decreases linearly with higher percentage of replacement.
- Concrete strength decreases linearly with larger maximum nominal aggregate size.
- Morphology of PET aggregate is smooth, causing poor adhesion with cement paste and resulting in compromises at the interfacial transitional zone (ITZ).
- PET aggregate with greater size caused greater weakness at ITZ.

- **RSM of PET-FA Expression**



- Concrete strength decreases linearly with higher percentage of replacement at a steeper rate.
- Significant strength loss was observed at high replacement level. Water-cement ratio has a curvilinear effect on compressive strength.
- Reduction of strength occurred because PET plastic had a lower density and load-bearing capacity compared to river sand.

- **Regression Analysis**



- For both expressions, compressive strength of concrete reduced with the introduction of PET aggregate
- However, for PET-FA, fine or granular size PET aggregate below 30% replacement may produce concrete with comparable or slightly increased strength (see highlighted zone).

Conclusions

- PET aggregate replacement (either coarse or fine) reduced the compressive strength of concrete.
- The reduction of strength is proportional to percentage replacement as well as the maximum nominal size of PET aggregate
- PET plastic as coarse aggregate replacement generally produces concrete with lower compressive strength.
- PET plastic as fine aggregate replacement could produce concrete with comparable strength through finer grinding, the usage of superplasticizer, and a judicious selection of replacement level (< 30%).