Influence of Aggregate Properties on Concrete Mechanical Performance

D. P. Bentz
National Institute of Standards and Technology

Jussara Tanesi
U.S. Department of Transportation

INFLUENCE OF AGGREGATE PROPERTIES ON CONCRETE MECHANICAL PERFORMANCE

TURNER-FAIRBANK HIGHWAY RESEARCH CENTER

Jussara Tanesi[1], Dale Bentz[2], Scott Jones[2], Mengesha Beyene[1], Haejin Kim[1], Ahmad Ardani [3], Joshua Arnold[2], Paul Stutzman[2]
[1]TFHRC/SES Group and Associates; [2]NIST; [3]TFHRC/FHWA

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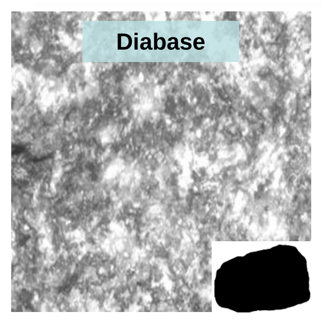
Objective

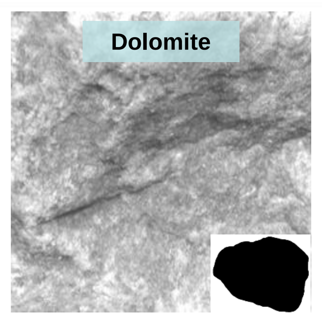
Evaluate the influence of aggregates' mechanical, geometrical characteristics, mineralogy and surface energies on concretes' mechanical performance. Eleven different sources of aggregates were studied in two different concrete binders: OPC and a ternary blend.

Aggregate Sources and Selected Characteristics

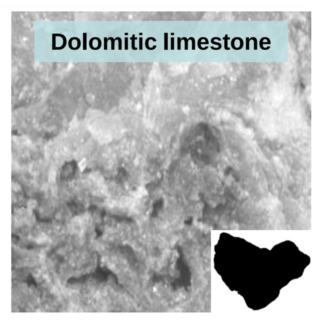
Aggregate Sources



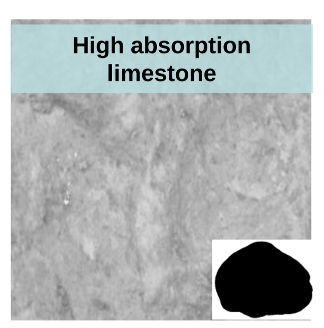
Ang. =2817	Surf. Energy (mJ/m^2)
Text. =724	
CAAT=8806	Disp. = 36.1
Abs.=0.51 %	Polar = 13.3
Emod = 67.6 GPa	
CTE = 4.6 $x10^{-6}/°C$	



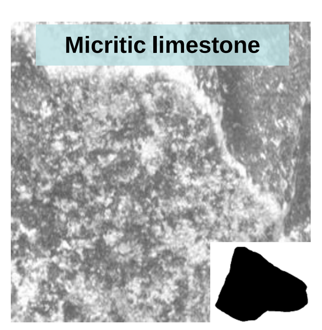
Ang. = 2858	Surf. Energy (mJ/m^2)
Text. = 525	
CAAT= 6680	Disp. = 38.3
Abs.=0.44 %	Polar = 12.4
Emod = 73.4 GPa	
CTE = 8.0 $x10^{-6}/°C$	



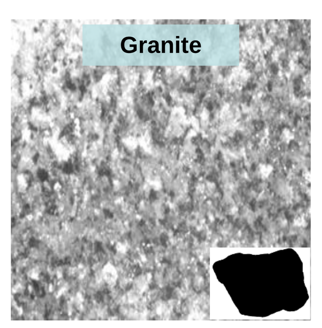
Ang. = 3118	Surf. Energy (mJ/m^2)
Text. = 221	
CAAT =3769	Disp. = 36.7
Abs.=0.59 %	Polar = 3.3
Emod = 79.4 GPa	
CTE = 8.4 $x10^{-6}/°C$	



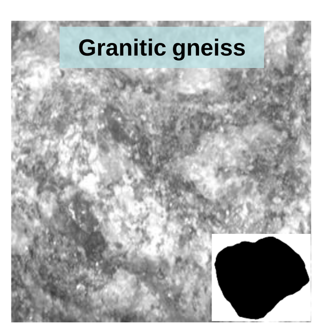
Ang. = 2483	Surf. Energy (mJ/m^2)
Text. = 149	
CAAT =2730	Disp. = 36.6
Abs.=2.98 %	Polar = 7.8
Emod = 44.1 GPa	
CTE = 7.0 $x10^{-6}/°C$	



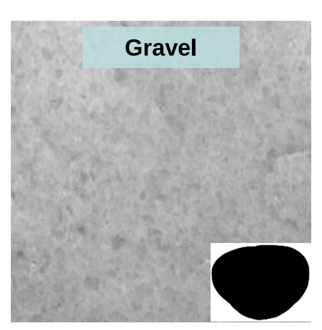
Ang. = 2934	Surf. Energy (mJ/m^2)
Text. = 645	
CAAT = 7992	Disp. = 37.2
Abs.= 0.33 %	Polar = 2.5
Emod = 71.6 GPa	
CTE = 5.0 $x10^{-6}/°C$	



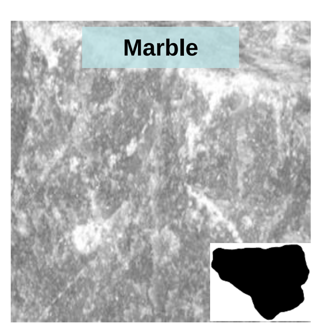
Ang. = 2877	Surf. Energy (mJ/m^2)
Text. = 543	
CAAT = 7113	Disp. = 37.8
Abs.= 0.68 %	Polar = 11.2
Emod = 54.4 GPa	
CTE = 9.2 $x10^{-6}/°C$	



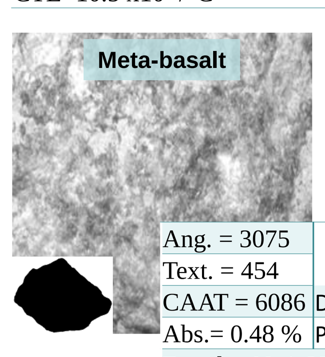
Ang. = 2995	Surf. Energy (mJ/m^2)
Text. = 606	
CAAT = 7788	Disp. = 35.8
Abs.= 0.60 %	Polar = 14.0
Emod = 40.0 GPa	
CTE=10.5 $x10^{-6}/°C$	



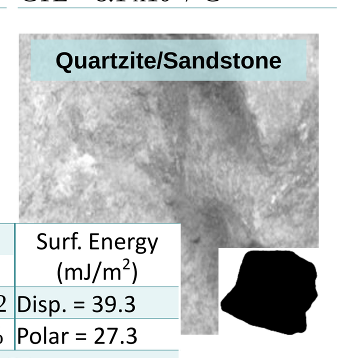
Ang. = 2366	Surf. Energy (mJ/m^2)
Text. = 112	
CAAT = 2246	Disp. = 29.1
Abs.= 1.67 %	Polar = 11.4
Emod = 97.3 GPa	
CTE=11.3 $x10^{-6}/°C$	



Ang. = 2943	Surf. Energy (mJ/m^2)
Text. = 441	
CAAT = 5883	Disp. = 32.5
Abs.= 0.31 %	Polar = 9.2
Emod = 102.1 GPa	
CTE = 8.1 $x10^{-6}/°C$	



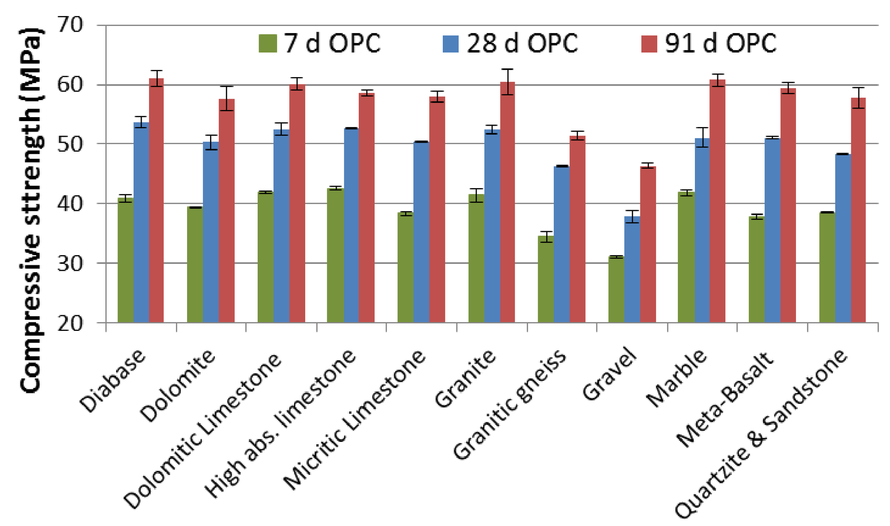
Ang. = 3075	Surf. Energy (mJ/m^2)
Text. = 454	
CAAT = 6086	Disp. = 42.3
Abs.= 0.48 %	Polar = 19.7
Emod = 92.4 GPa	
CTE = 6.3 $x10^{-6}/°C$	

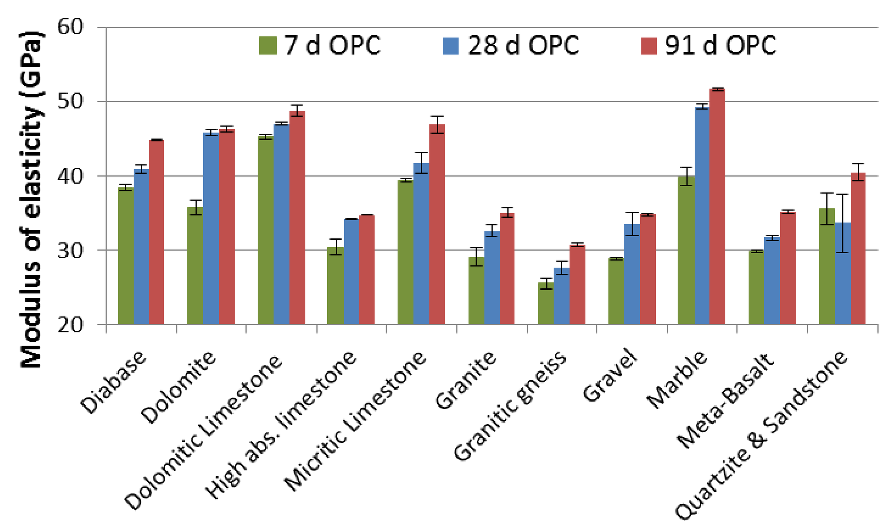


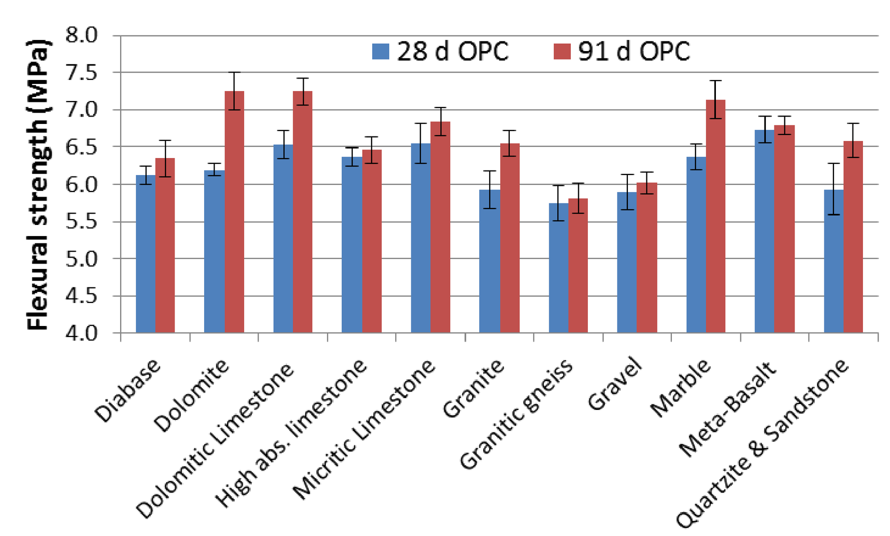
Ang. = 3029	Surf. Energy (mJ/m^2)
Text. = 312	
CAAT = 4632	Disp. = 39.3
Abs.= 0.87 %	Polar = 27.3
Emod = 62.9 GPa	
CTE=10.1 $x10^{-6}/°C$	

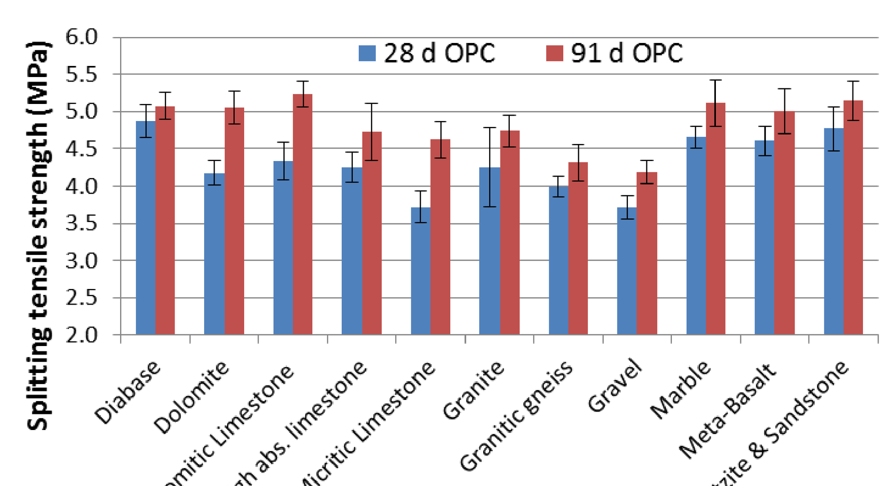
Coarse aggregate angularity texture value (CAAT): It is a combination of the angularity and texture values computed as 10 times the texture + one half of the angularity

Concrete Properties - OPC

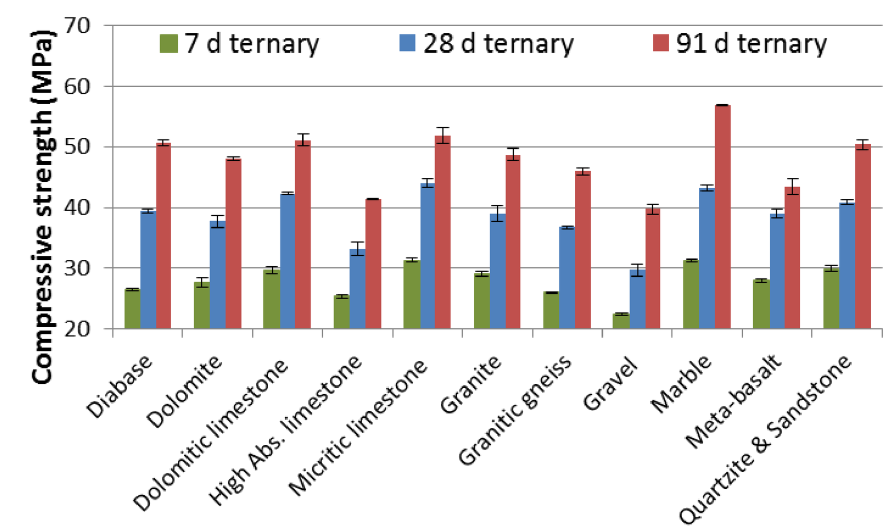


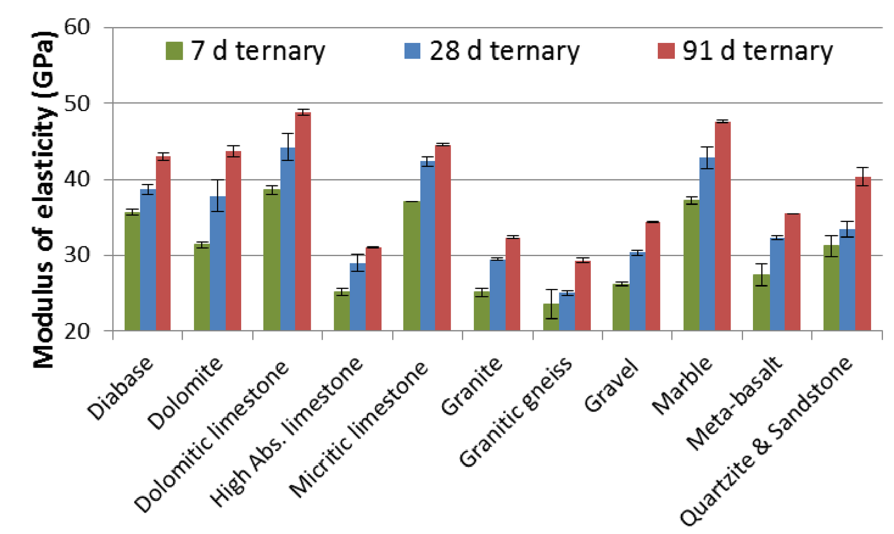


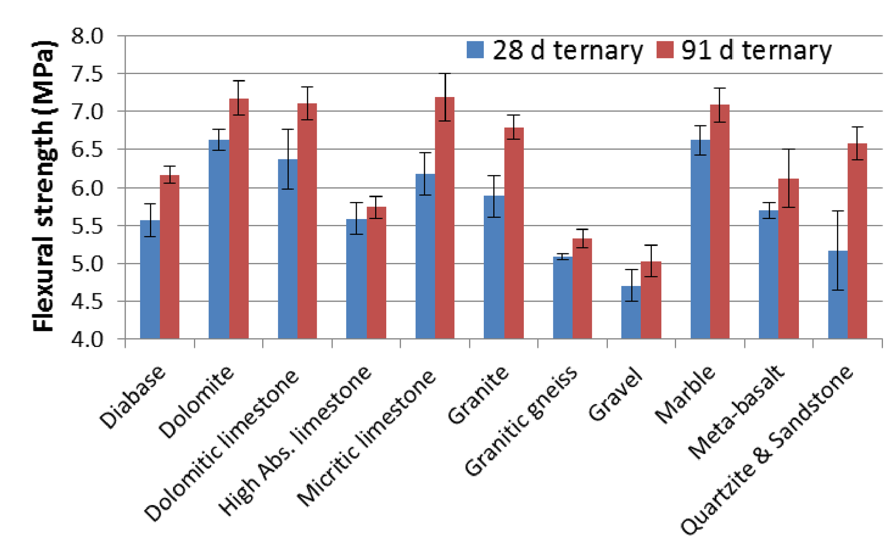


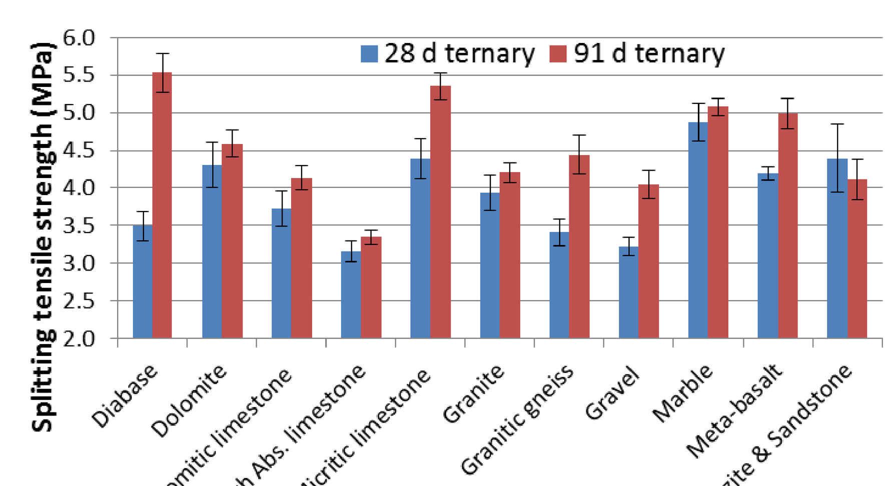


Concrete Properties - Ternary

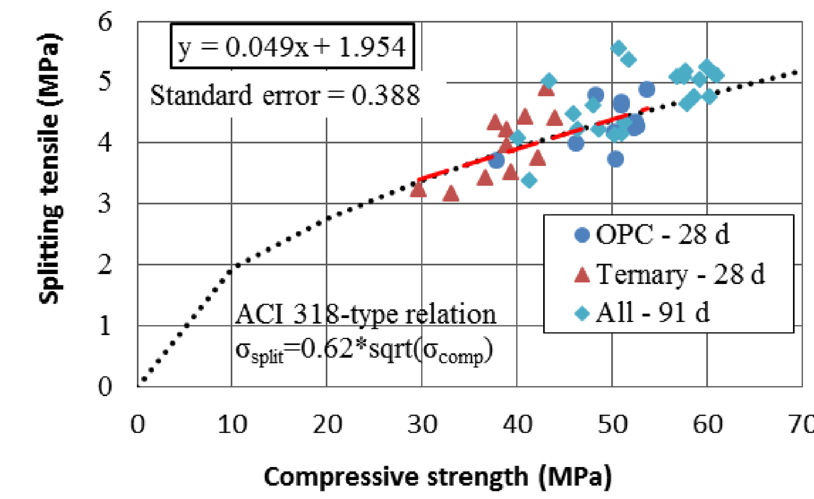




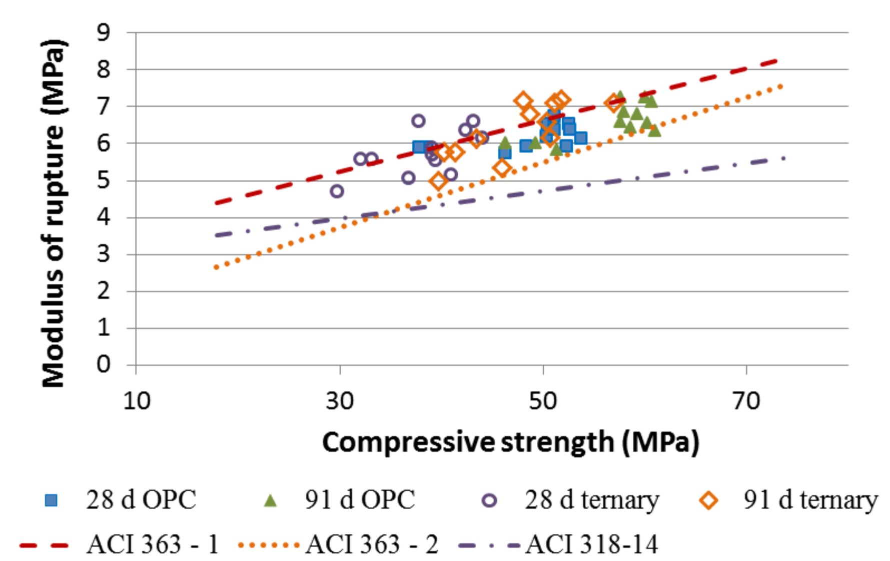




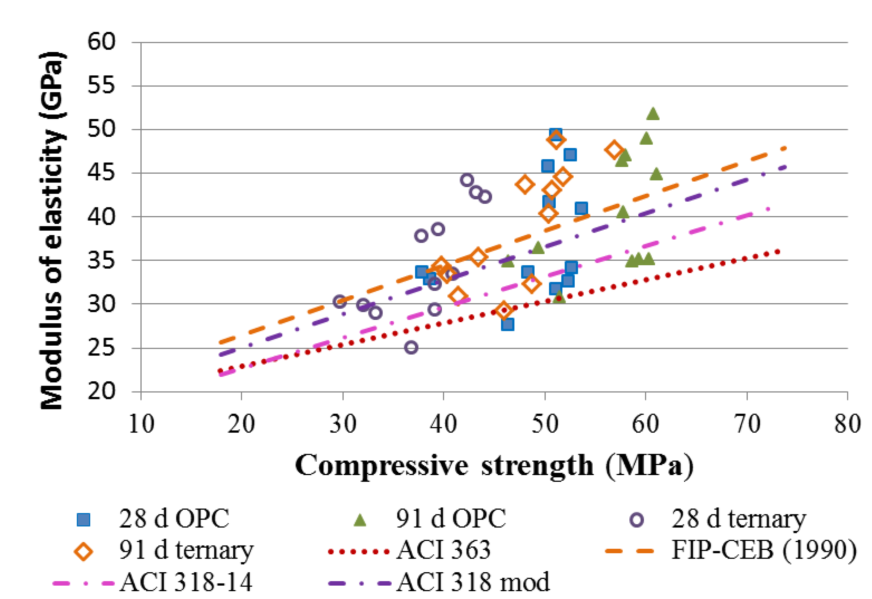
Relation Between Concrete Properties



28-d and 91-d splitting tensile strength vs. compressive strength. Recommended ACI coefficient is 0.56 (instead of 0.62). Linear relation shown in box is for 28-d data for both ternary and OPC mixtures.

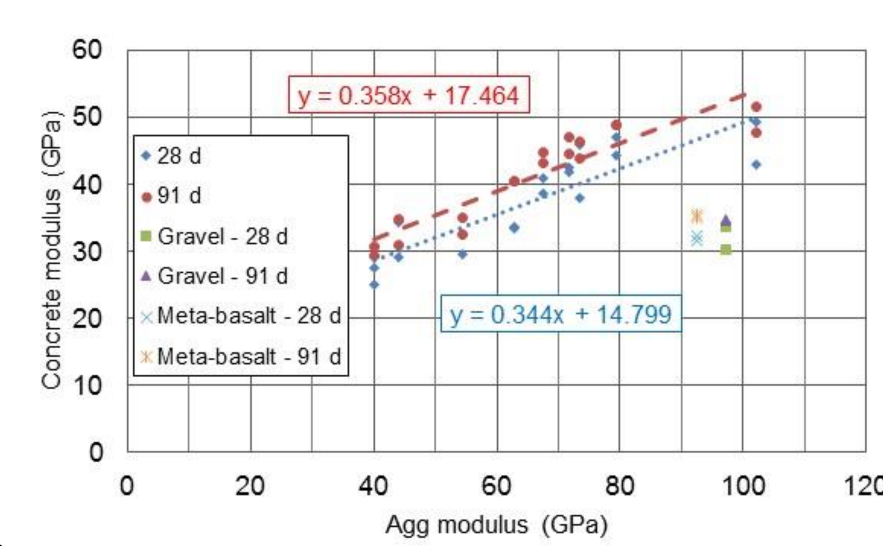


Modulus of rupture vs. compressive strength at 28 d and 91 d for the 22 concrete mixtures.

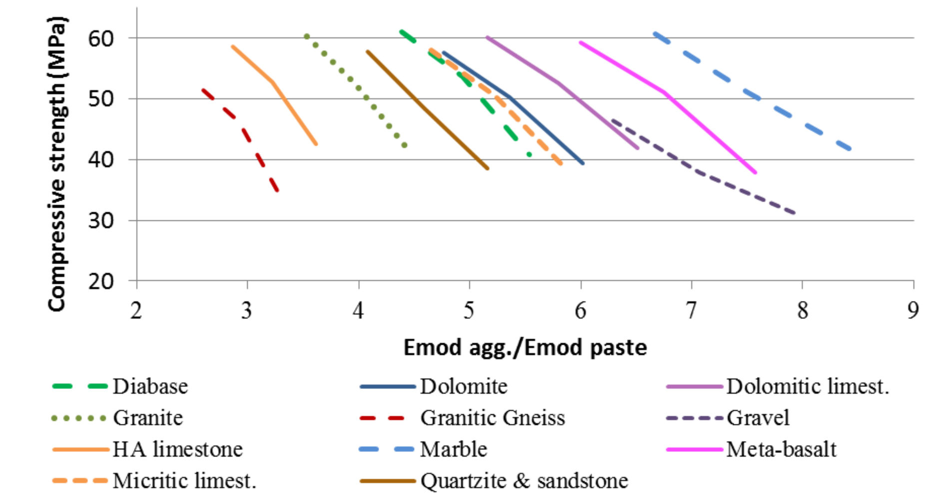


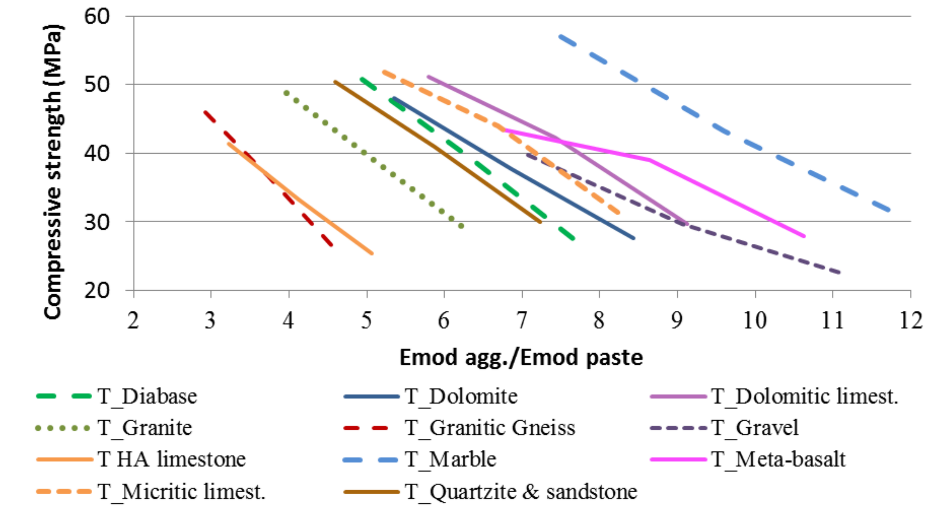
Modulus of elasticity. ACI 363: E = 6900 + 3320 x $f_c^{0.5}$, FIB-CEB E = 22,000 x $(f_c/10)^{0.33}$, ACI 318-14: 4700 x $f_c^{0.5}$ and "ACI mod" series indicates ACI 318 model with a coefficient of 5174 instead of 4700.

Relation Between E_{agg} and $E_{concrete}$



Modulus Mismatch (E_{agg}/E_{paste}) and Compressive Strength





Conclusions

- For the eleven aggregates studied, the aggregate properties that varied the most were absorption, texture, CAAT, polar surface energy and dynamic elastic modulus.
- Common models (ACI 318, ACI 363 and CEB-FIP 1990) for prediction of concrete modulus of elasticity, splitting tensile strength or modulus of rupture from compressive strength, were not able to provide good estimations since they don't take into account different aggregates, nor that aggregates' properties influence concrete compressive strength and modulus of elasticity, tensile strength or modulus of rupture differently.
- It was not possible to identify a single aggregate property that is responsible for the concrete mechanical behavior, but rather a combination of aggregate properties.
- Exception to this was the good correlation between the aggregate and the concrete moduli of elasticity.
- The extent of the influence of each aggregate property depends mainly on the concrete property analyzed, as well as the cementitious materials used.
- The ratio between the aggregate and the paste moduli of elasticity was the factor that influenced the concrete properties the most, since it affects the bond between paste and aggregate.
- Other aggregate properties (texture, porosity and absorption) also affected the bond between aggregate and paste and consequently the concrete properties (aggregate texture, modulus of elasticity, porosity and absorption and paste modulus).
- Aggregate morphology and mineralogy also played a significant role, as they affect the aggregate strength and the chemical reaction with the paste.
- Concrete made with aggregates with the same rock type but from different sources presented different mechanical behavior.

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