Dosagem do Concreto
Treval Powers

Escola Politécnica
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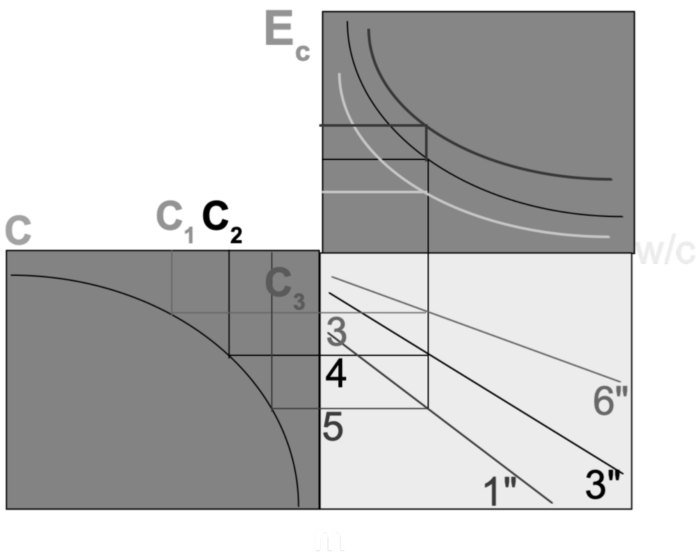
20 de agosto de 2009

MIX DESIGN NOMOGRAM



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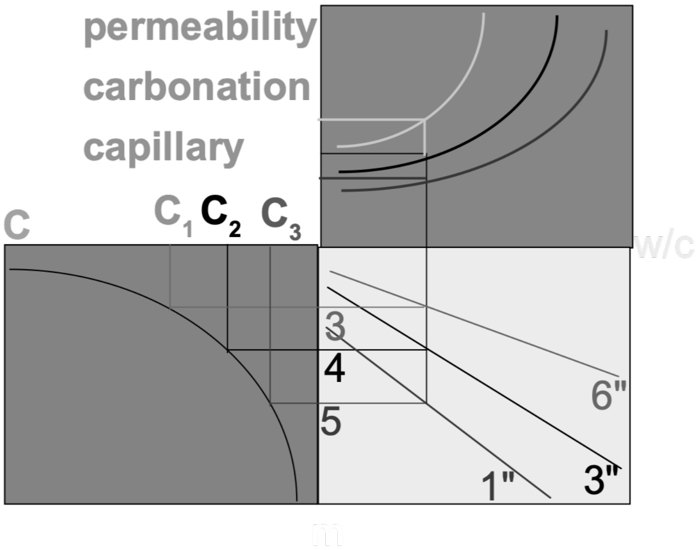

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Quais as águas da pasta hidratada?

?

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Química do Cimento Portland

- (100) C_3S + (24) H_2O —> (74) C-S-H + (49) $Ca(OH)_2$
- (100) C_2S + (21) H_2O —> (100) C-S-H + (21) $Ca(OH)_2$
- (100) C_3A + (80) H_2O —> etringita + aluminato
- (100) C_4AF + (37) H_2O —> aluminato + ferrito
- compostos menores

água capilar

água de gel

água de cristalização

?

Qual a água necessária para hidratar o cimento?

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cálculo da água de cristalização:

C_3S = 51% *C_2S = 23 %* *C_3A = 8 %*

C_4AF = 9 % *CaO livre= 1%* *$CaSO_4.2H_2O$ = 5%*

compostos menores e impurezas = 3 %

C_3S —> 51 • 0.24 = 12
C_2S —> 23 • 0.21 = 4
C_3A —> 8 (0.3•1.73+0.7•0.4) = 6
C_4AF—> 9 • 0.37 = 3

Total H_2O = 25 —> 0.25 da massa cimento

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C_3S —> 27.6% C-S-H ; 18.4% $Ca(OH)_2$

C_2S —> 20.8% C-S-H ; 4.3% Ca(OH)2

C_3A —> estáveis 3.7% ; instáveis = 5.3%

C_4AF —> estáveis = 10%

total:

- C-S-H = 48.8% estáveis = 13.7%
- $Ca(OH)_2$ = 22.7% instáveis = 5.3%

...a reação de hidratação se dá com redução de volume equivalente a 25.4% do volume de água que reagiu...

cimento = 1 kg

água de cristalização = 0.25 kg

vol. cimento = 1 / 3.10 = 0.32 dm^3

vol. água cristalização = 0.25 dm^3

total 0.57 dm^3

efetivo —> 0.32 + 0.746 • 0.25 = 0.51 dm^3

Powers' Model

gel 100% hidratado

tem 28 % de vazios

para água de cristalização = 0.26 —> água de gel = 0.19 da massa cimento

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água mínima para hidratação a 100%

cristalização + gel

—> 0.25 + 0.19 = 0.44

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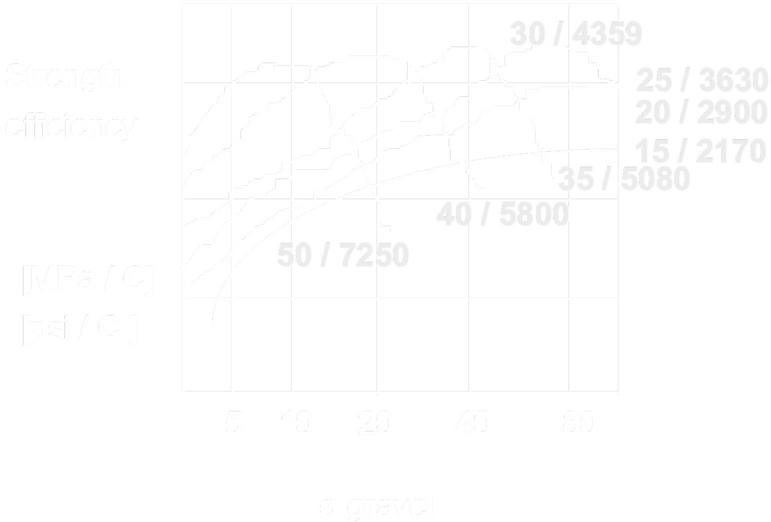
PRINCIPLES



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POWERS' MODEL

three water : crystallization, chemical or non-evaporable

gel water (interlawer + adsorbed)

capillary water (capillary + free)

voids : entrapped air

entrained air

empty pores

capillary water pores

solids products of hydratation :

anhydrous cement + chemical water

cement gel :

solid products + gel water

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POWERS' MODEL

cement paste :

cement gel + capillary water + air + empty pores

porosity of cement gel : cte (by volume)

gel water / [gel water + solids products] = 27 / 28%

volume of solids products of hydratation is less than sum of volume of anhydrous cement + chemical water :

contraction equivalent 25.6% of reduction

of volume the chemical water

POWERS' MODEL

1 : 2 : 3 ; 0.55

type of cement : C_3S = 50% C_2S = 22% C_3A = 13%

C_4AF = 9% others = 6% -> w_{ch} = 0.22

solid products :

by weight : 1 + 0.22 = 1.22

by volume : 1 / 3.12 + 0.22 / 1.00 = 0.54 WRONG

= 0.32 + 0.22(1 - 0.256) = 0.48 RIGHT

gel water (from porosity 27%) : w_{gel} = 0.18

POWERS' MODEL

absolute volume of cement	= 1/0.32 = 0.32	-> 11.6%
absolute volume of sand	= 2/2.65 = 0.75	-> 27.1%
absolute volume of gravel	= 3/2.70 = 1.11	-> 40.0%
absolute volume of water	= 0.55/1 = 0.55	-> 19.8%
entrapped air	= 1.50% = 0.04	-> 1.5%
Total volume of concrete	= 2.77	-> 100%

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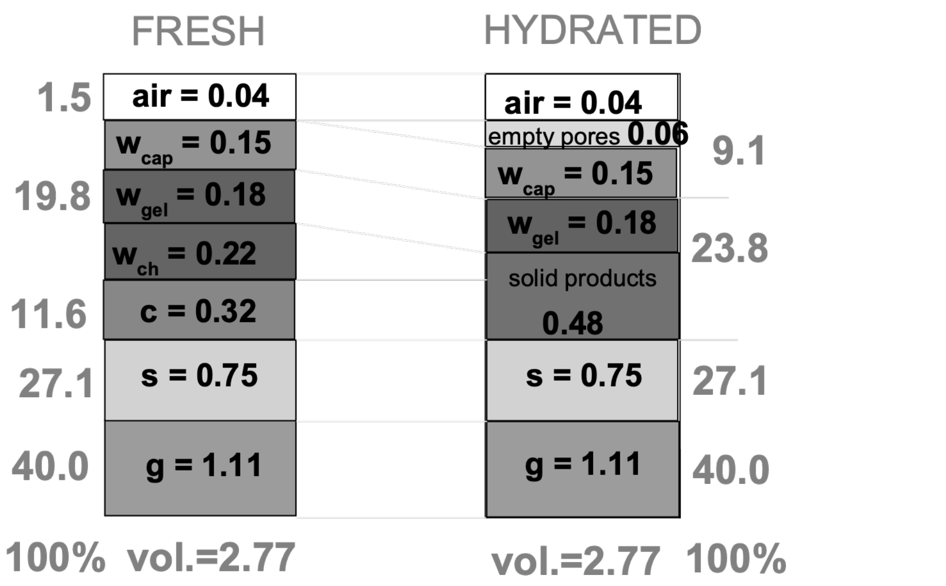
1 : 2 : 3 ; 0.55 C = 360 kg/m3 - 600 lb/yd3



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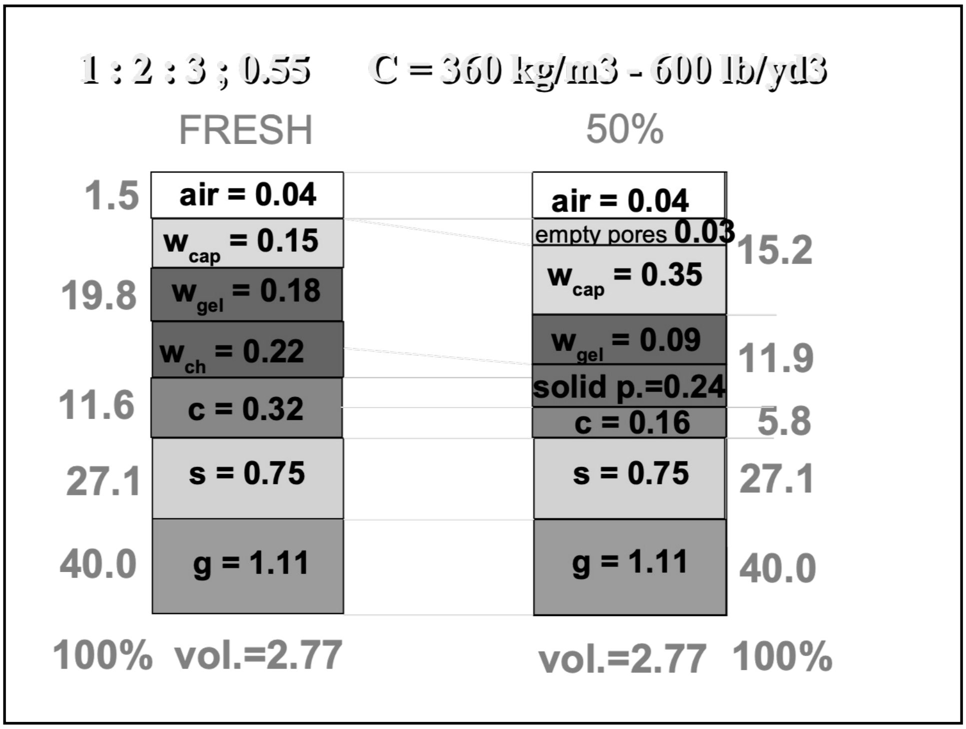
1 : 2 : 3 ; 0.55 C = 360 kg/m3 - 600 lb/yd3
FRESH
50%
1.5
air = 0.04
w_{cap} = 0.15
19.8
w_{gel} = 0.18
w_{ch} = 0.22
11.6
c = 0.32
27.1
s = 0.75
40.0
g = 1.11
100% vol.=2.77
air = 0.04
empty pores 0.03
15.2
w_{cap} = 0.35
w_{gel} = 0.09
11.9
solid p.=0.24
c = 0.16
5.8
s = 0.75
27.1
g = 1.11
40.0
vol.=2.77 100%

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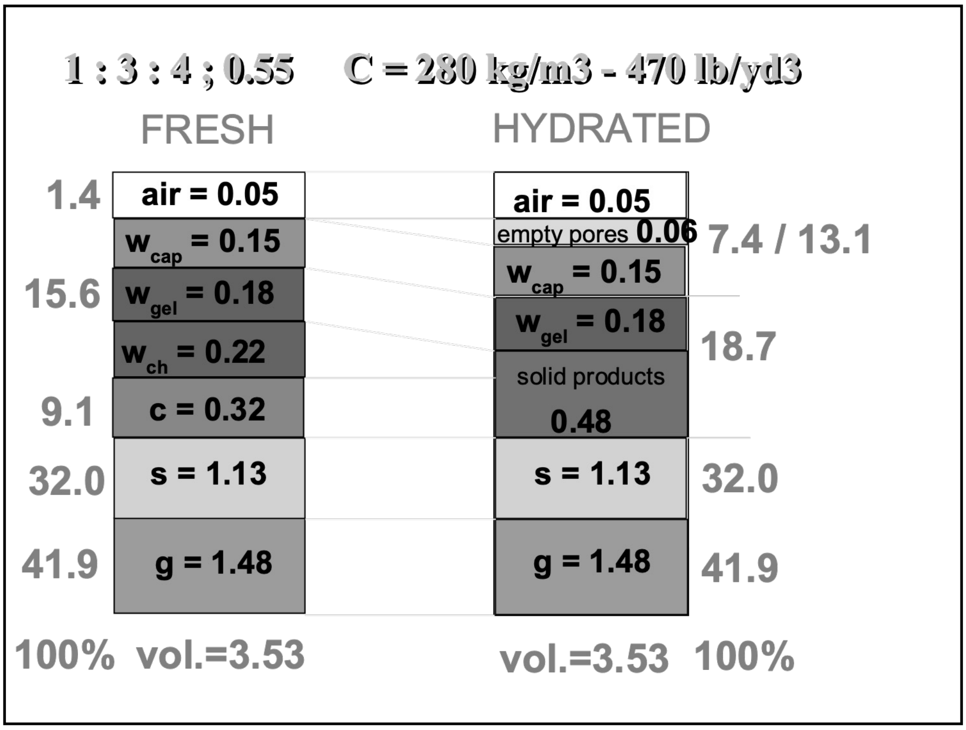
1 : 3 : 4 ; 0.55 C = 280 kg/m3 - 470 lb/yd3
FRESH
HYDRATED
1.4
air = 0.05
w_{cap} = 0.15
15.6
w_{gel} = 0.18
w_{ch} = 0.22
9.1
c = 0.32
32.0
s = 1.13
41.9
g = 1.48
100% vol.=3.53
air = 0.05
empty pores 0.06
7.4 / 13.1
w_{cap} = 0.15
w_{gel} = 0.18
18.7
solid products
0.48
s = 1.13
32.0
g = 1.48
41.9
vol.=3.53 100%

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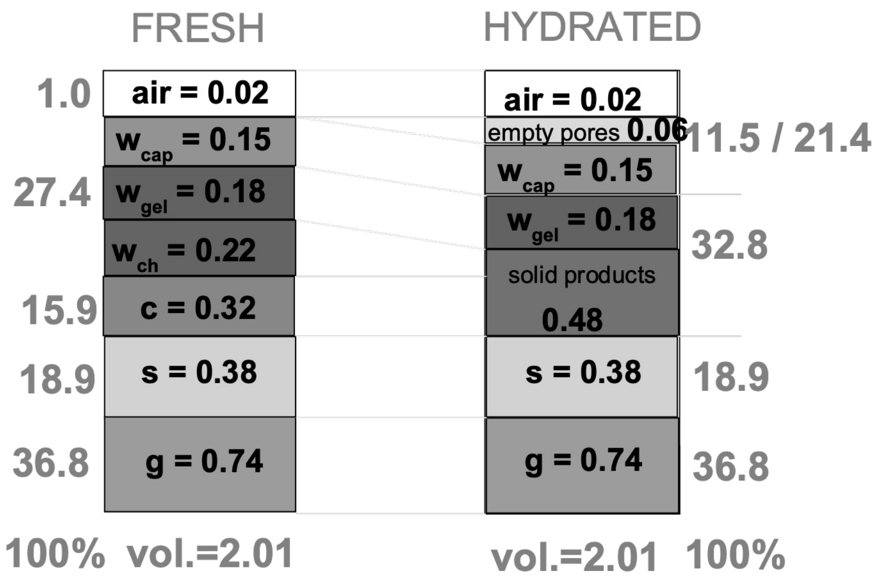
1 : 1 : 2 ; 0.55 C = 500 kg/m3 - 850 lb/yd3



POWERS' MODEL w/c = cte = 0.55 slump variable

Mix proportions	Cement content	Aggregate	Cement paste	
(by weight)	(kg/m³) (lb/yd³)	s + g	cement gel	voids
1 : 1 : 2	500 / 850	55.7%	32.8%	11.5%
1 : 2 : 3	360 / 600	67.1%	23.8%	9.1%
1 : 3 : 4	280 / 470	73.9%	18.7%	7.4%

How about strength? Permeability? Carbonation? Ions permeability? Creep? Modulus?Drying shrinkage? Durabilit

POWERS' MODEL w/c variable slump = cte

Mix proportions	Cement content	Aggregate	Cement paste	
(by weight)	(kg/m³) (lb/yd³)	s + g	cement gel	voids
1 : 1 : 2 ; 0.37	540 / 900	61.2%	35.0%	3.8%
1 : 2 : 3 ; 0.55	360 / 600	67.1%	23.8%	9.1%
1 : 3 : 4 ; 0.73	270 / 450	70.3%	17.9%	11.8%

How about strength? Permeability? Carbonation? Ions permeability? Creep? Modulus?Drying shrinkage?Durability?

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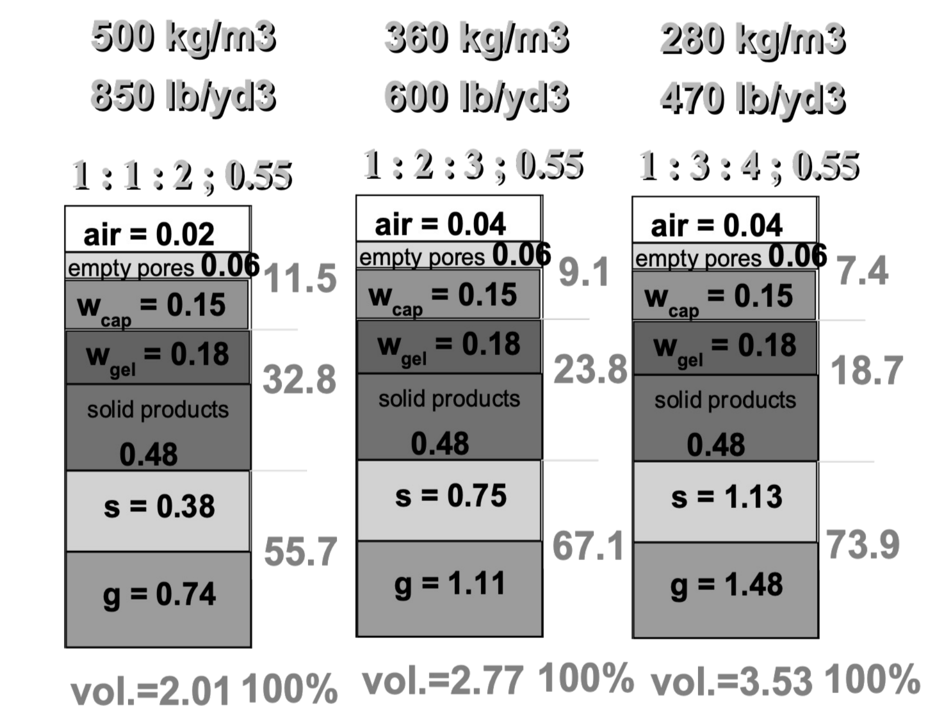

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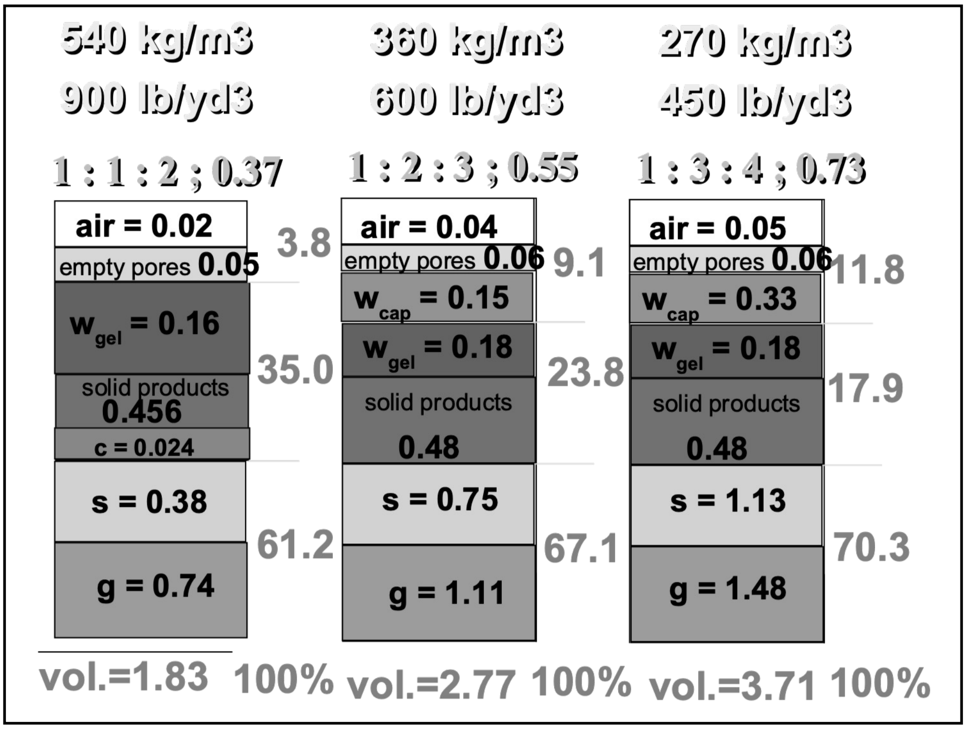

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HISTORY

- 1824 -> Joseph Aspdin
- 1896 -> Férèt
  $f_c = K [c / (c+w+air)]^2$ (volume)
- 1918 -> Duff Abrams
  $f_c = K_1 / K_2^{w/c}$ (volume)
  *fineness modulus
  *slump test

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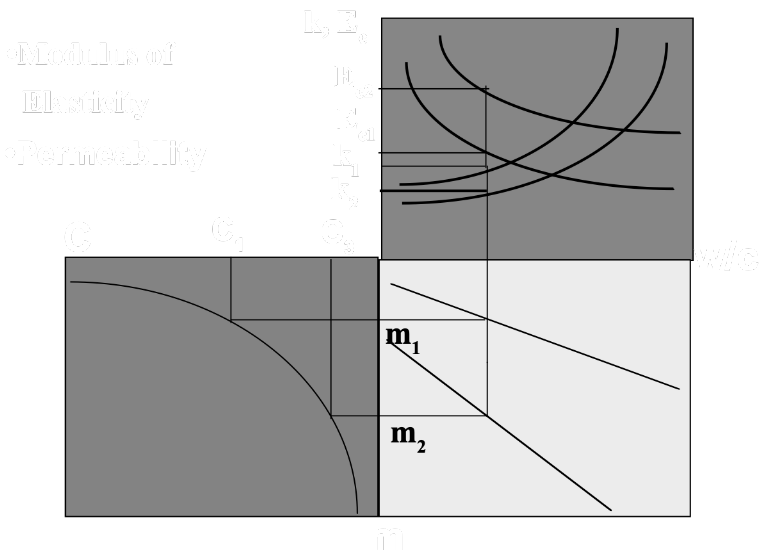
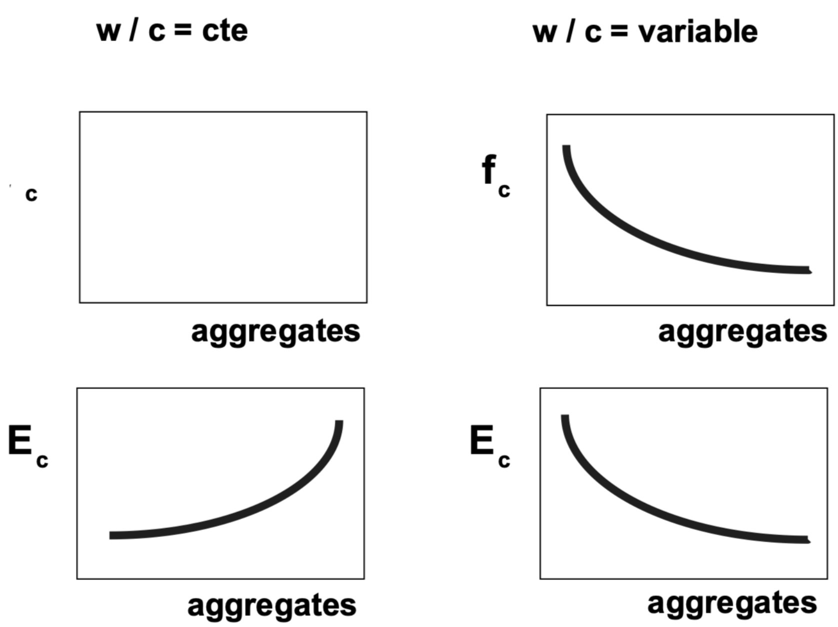
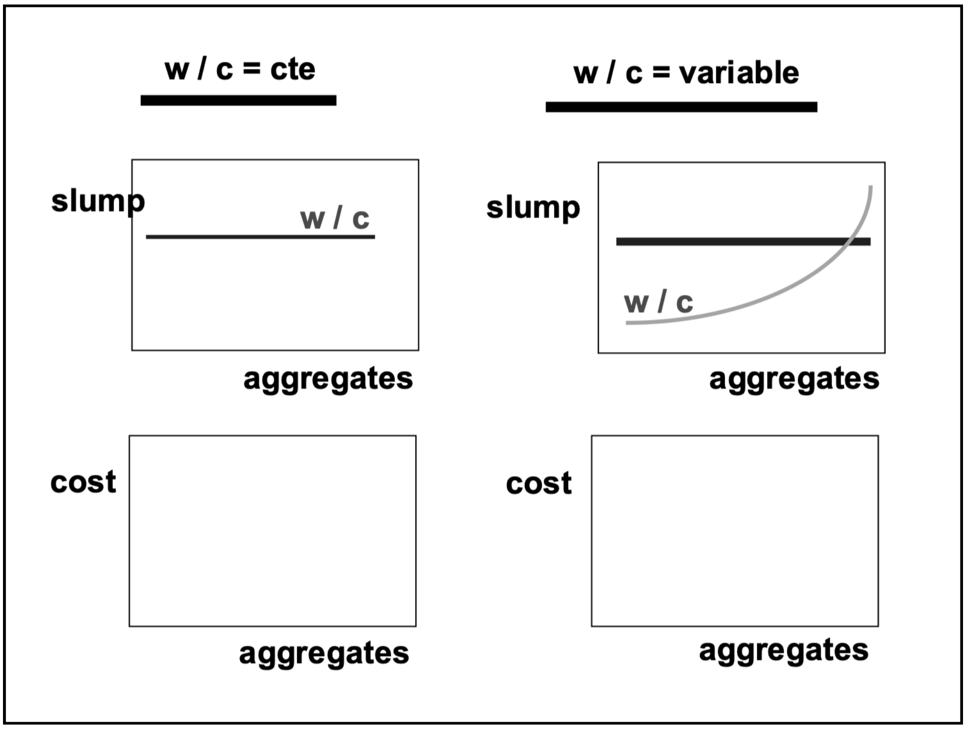
MIX DESIGN NOMOGRAM






w / c = cte
w / c = variable
slump
w / c
aggregates
slump
w / c
aggregates
cost
aggregates
cost
aggregates

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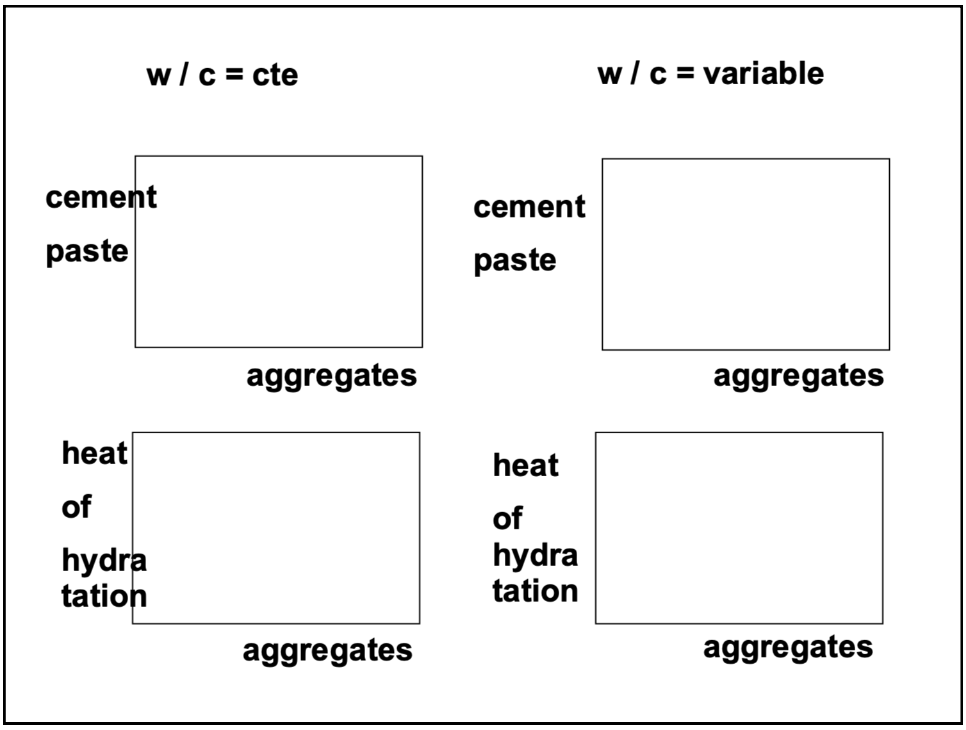
w / c = cte
w / c = variable
cement
paste
aggregates
cement
paste
aggregates
heat
of
hydra
tation
aggregates
heat
of
hydra
tation
aggregates

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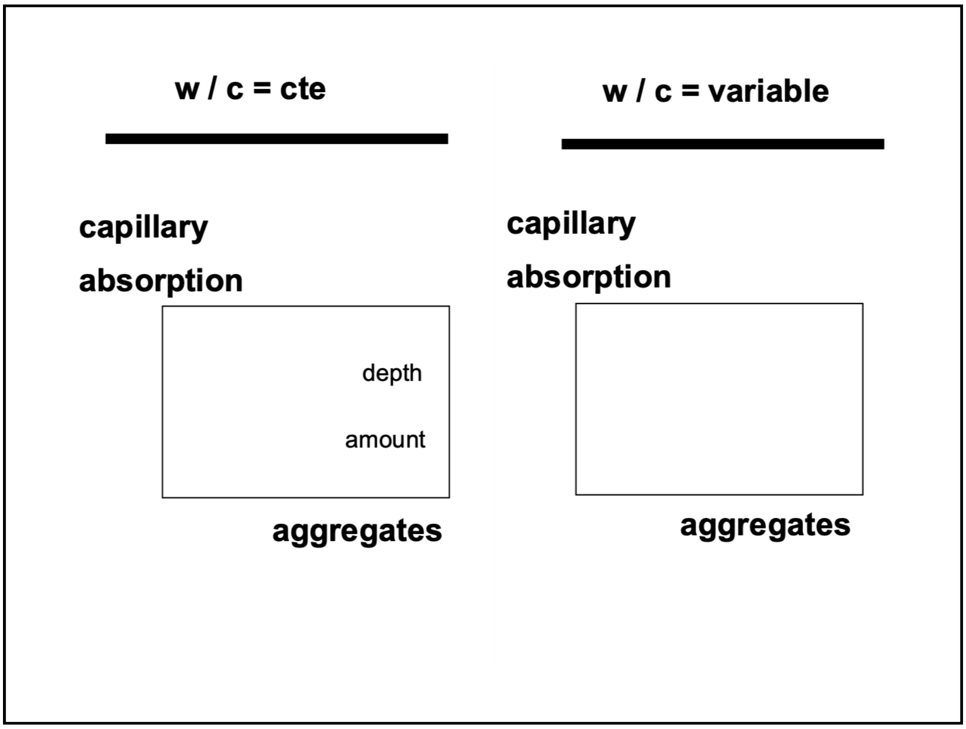
w / c = cte
w / c = variable
capillary
absorption
depth
amount
aggregates
capillary
absorption
aggregates

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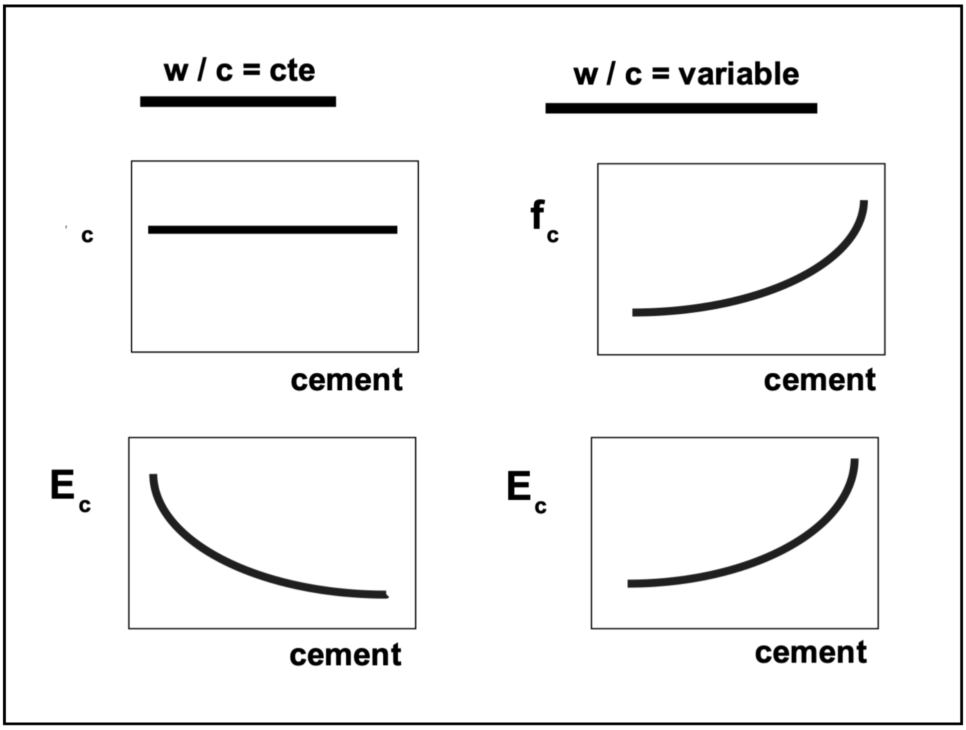
w / c = cte
w / c = variable
c
cement
f_c
cement
E_c
cement
E_c
cement

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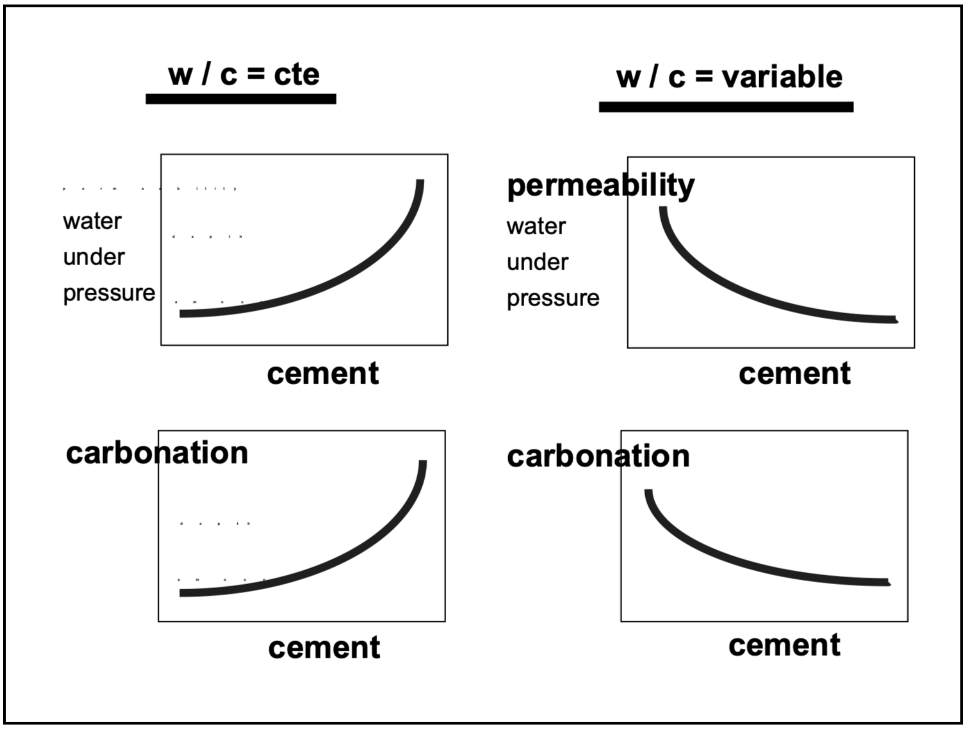
w / c = cte
w / c = variable
water
under
pressure
cement
permeability
water
under
pressure
cement
carbonation
cement
carbonation
cement