Durability of Concrete using Recycled Aggregates

W.K. Fung

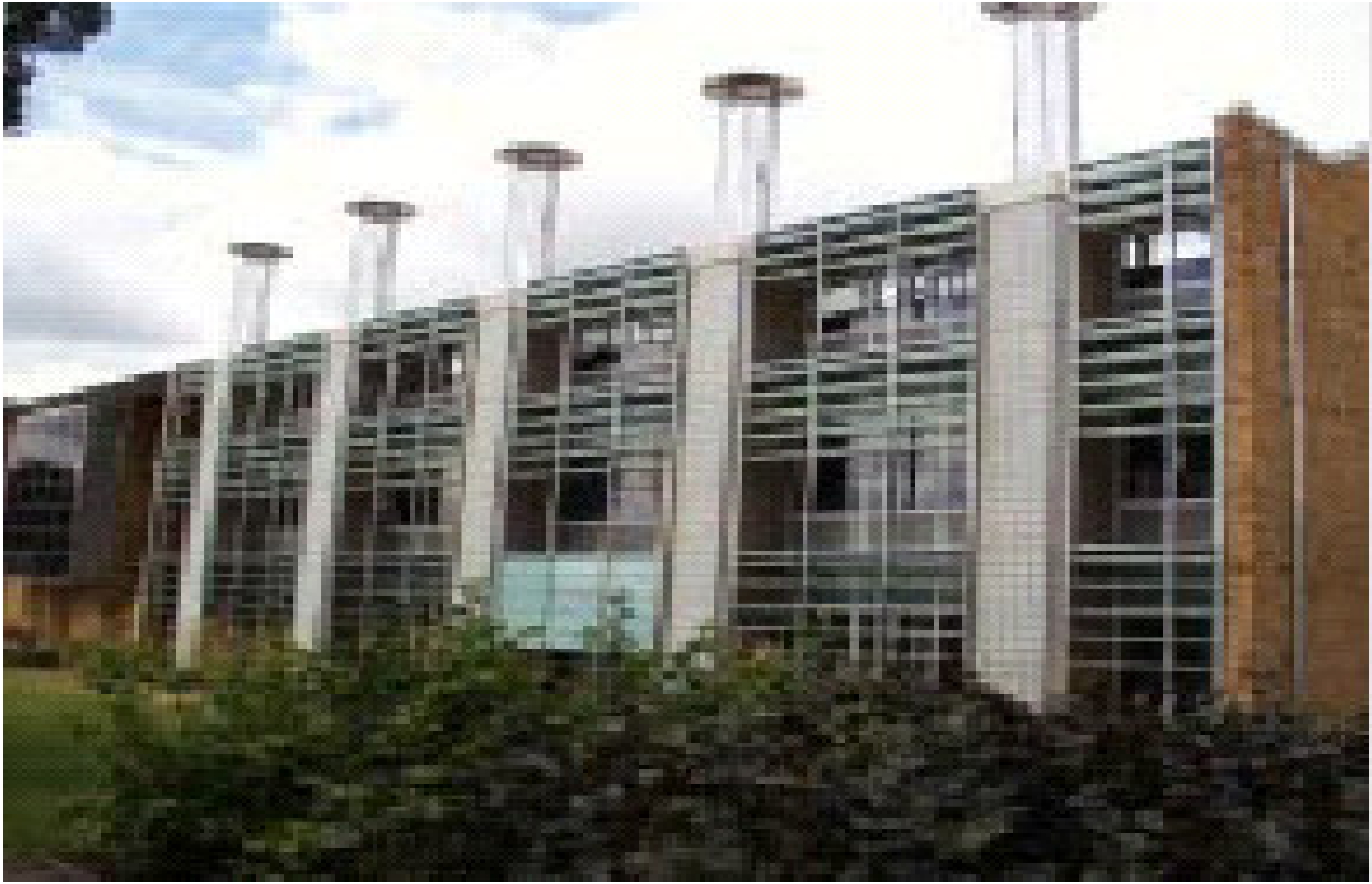
SCCT Annual Concrete Seminar

3 February 2005

Condominium Complex in Hamburg, Germany, built 50 years ago

Berendrecht Lock in Belgium 1987-1988

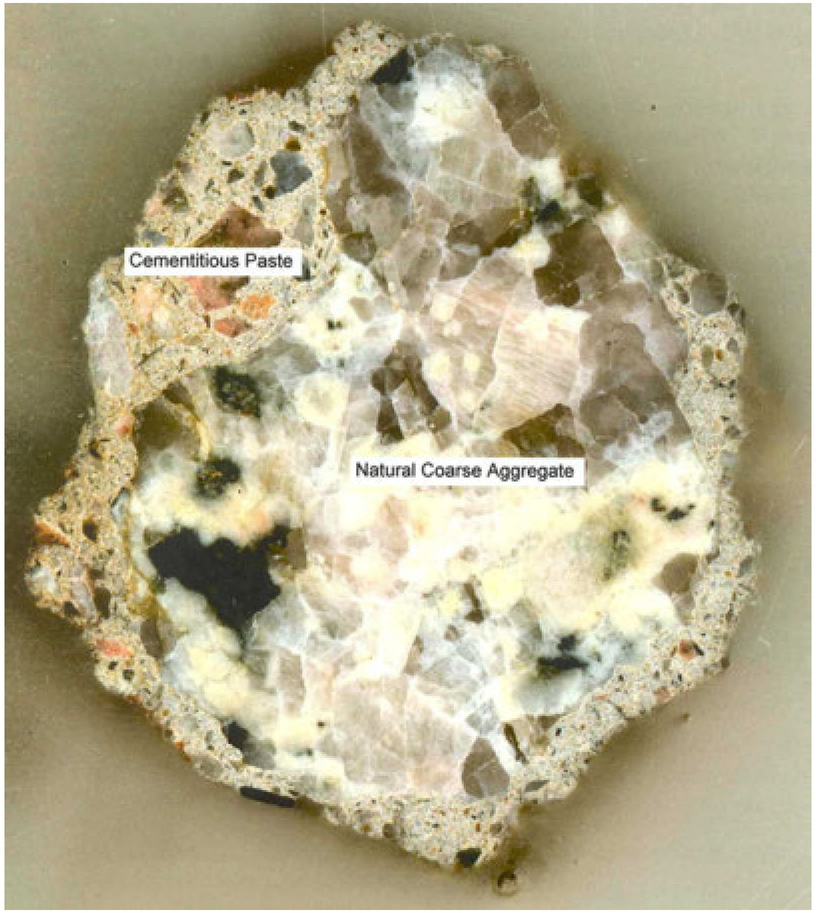
(C 35 recycled concrete)

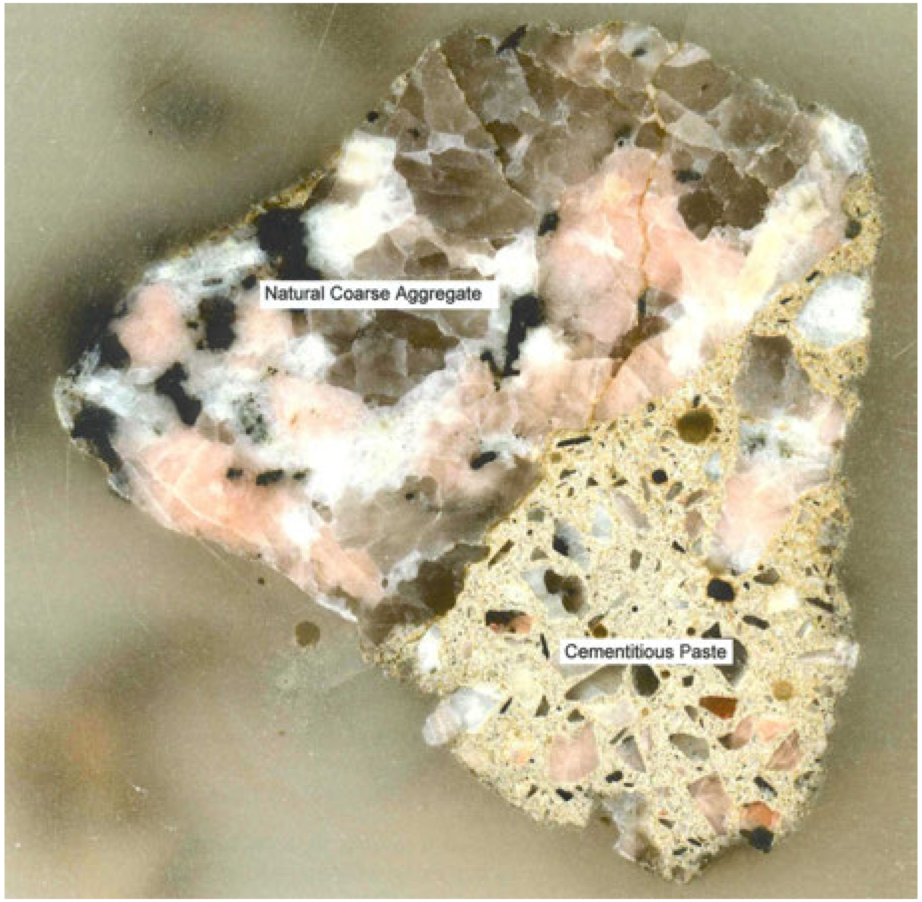


Environmental Building at BRE, 1995-1996
(C25 for foundations, C35 for concrete slabs)

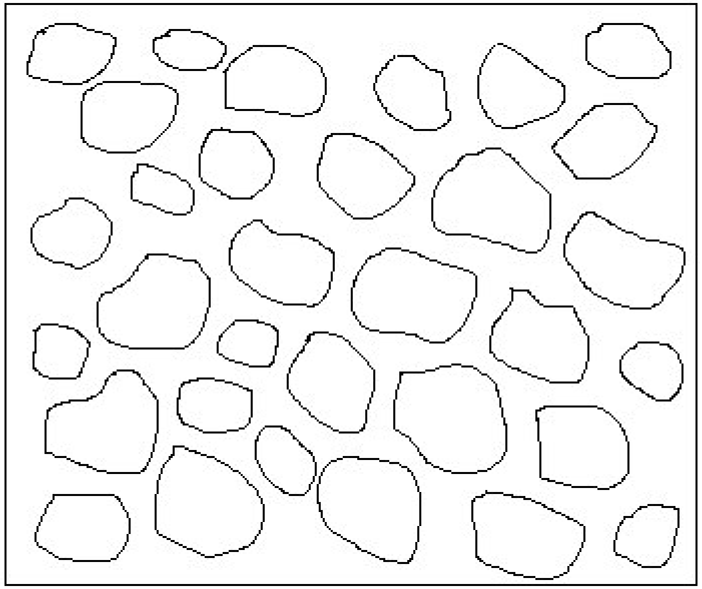
Durability Indicators

- *Carbonation*
- *Resistance to Chloride Penetration*
- *Permeability*
- *Resistance to Corrosion*
- *Fire Resistance*
- *Alkali Aggregate Reaction*

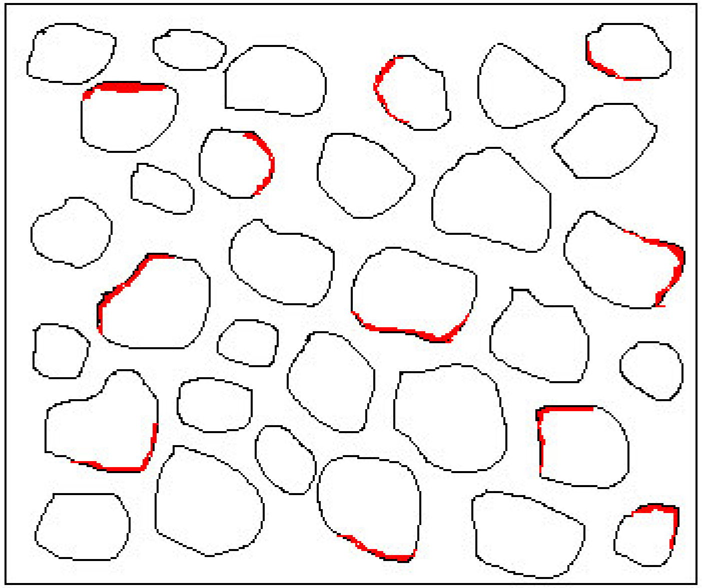




The Recycled Aggregate

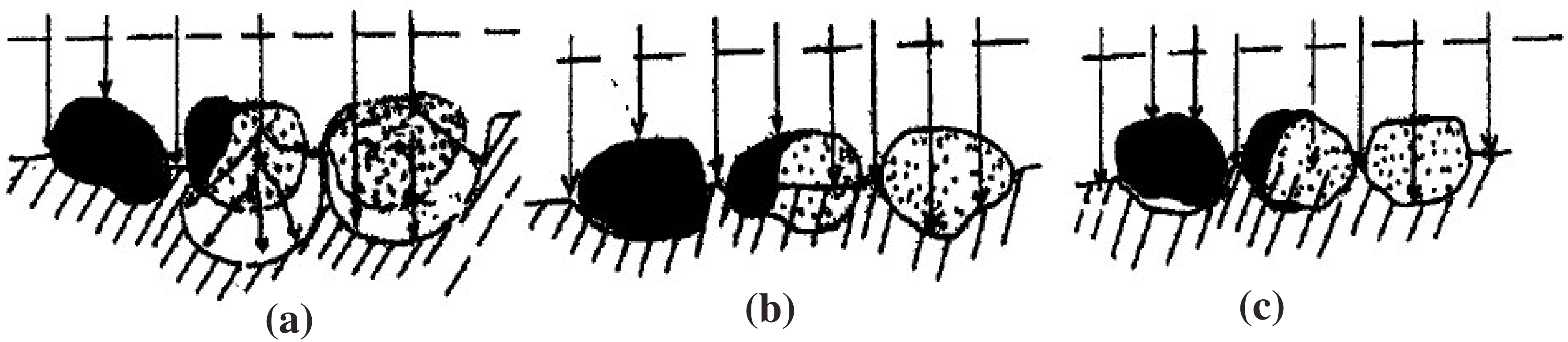


Ordinary Concrete



Recycled Concrete

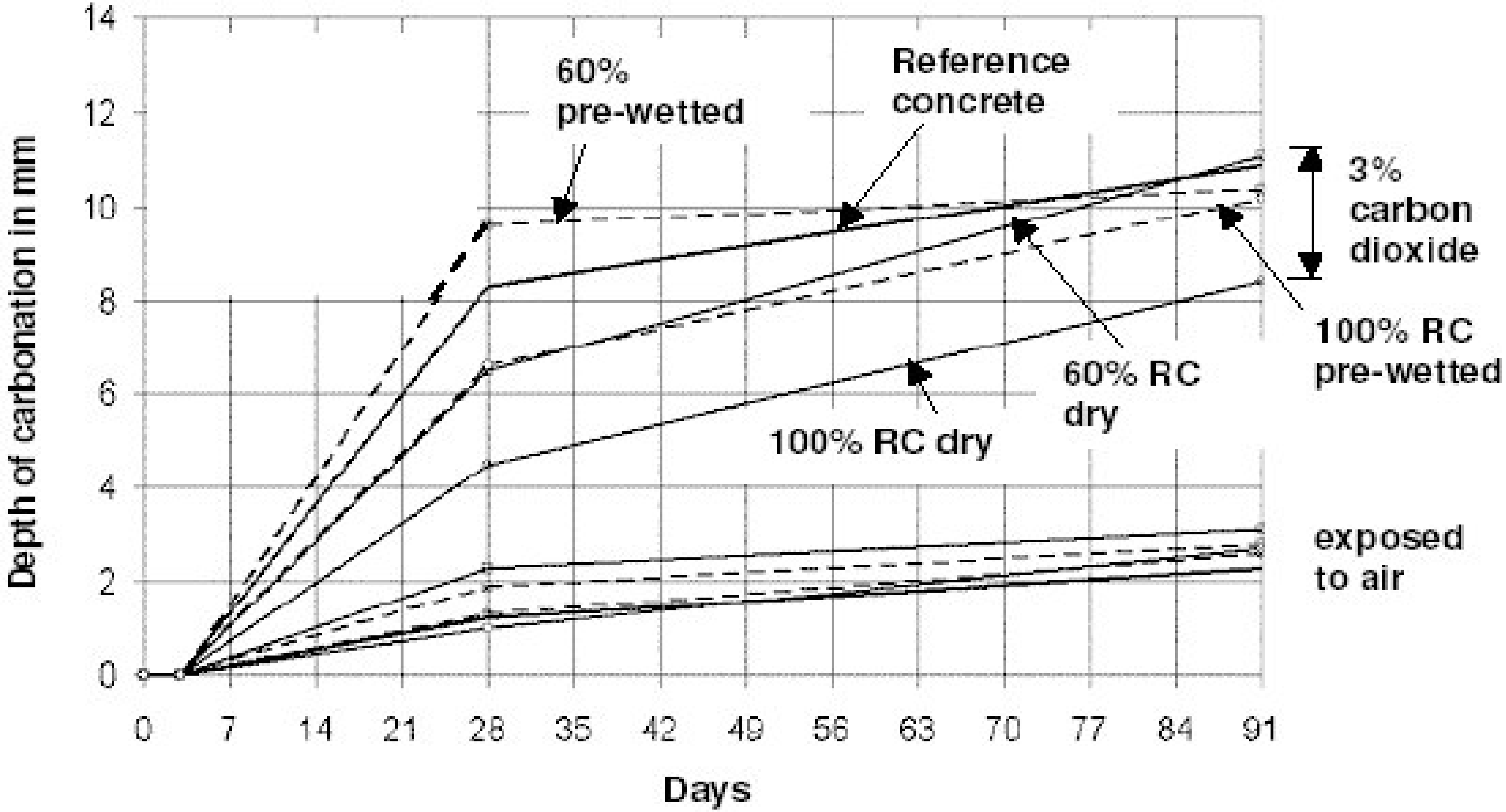
Carbonation front in relation to permeability of the recycled aggregate and the new mortar



a) **Permeability of the recycled aggregate > permeability of the new mortar**

b) **Permeability of the recycled aggregate = permeability of the new mortar**

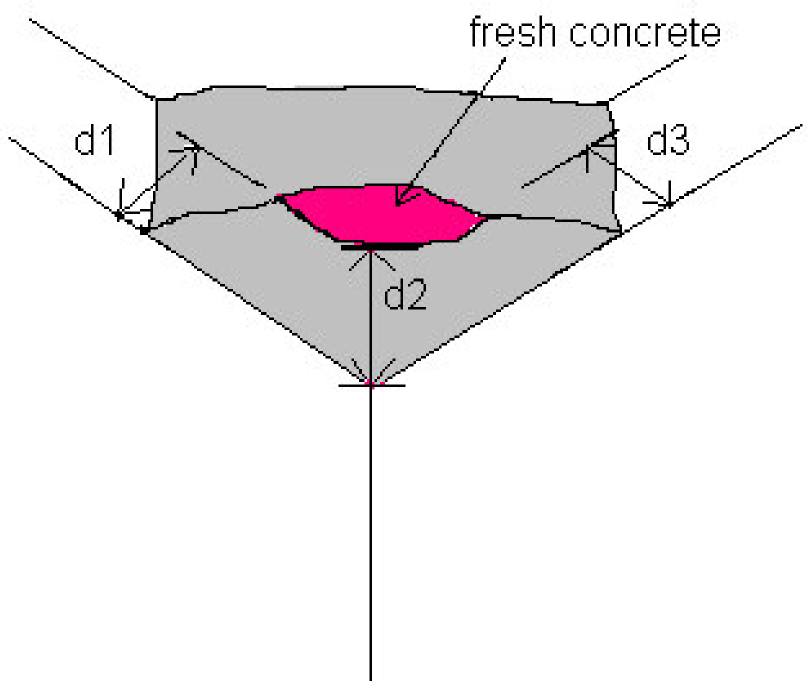
c) **Permeability of the recycled aggregate < permeability of the new mortar**



Carbonation of concrete with different recycled aggregate content, used wet or dry in air and in 3% carbon dioxide (Second Series of Tests)

(Philipp Holzmann, 1998)

The 5% Carbon Dioxide Chamber



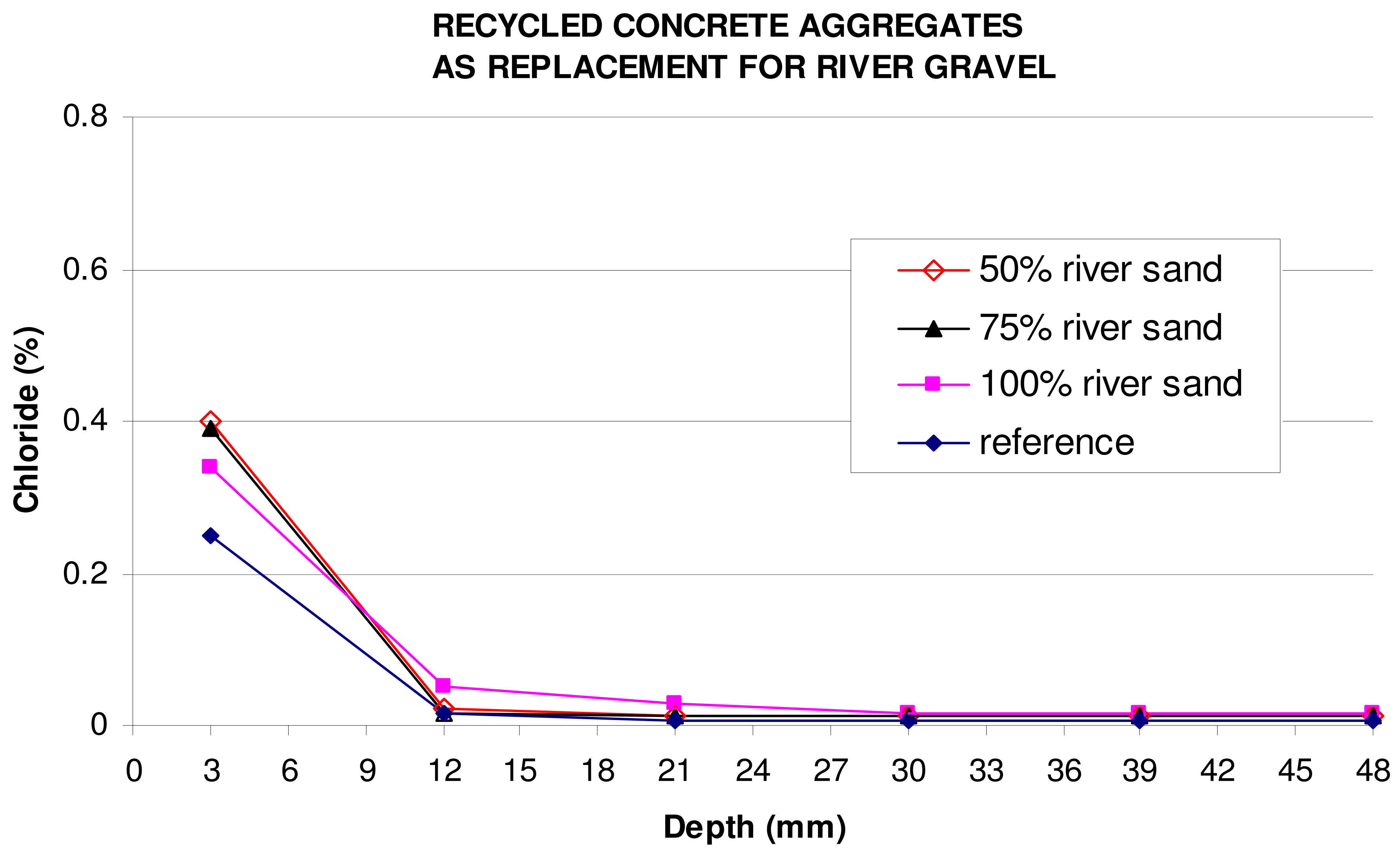
Measured Carbonation Depth

Uncarbonated concrete turning into pink color

Table 11.4(a) Carbonation Depths (mm)

Concrete Grade	Recycled Coarse Aggregates (%)	Sample	Corner 1			Corner 2		
			d_1	**d_2**	**d_3**	**d_1**	**d_2**	**d_3**
30/20	Control 0	G	11	20	10	17	26	21
		H	12	20	15	**10**	**24**	**23**
	20	G	0	0	0	**9**	**10**	**11**
		H	0	0	0	0	0	0
	20	G	20	21	7	16	20	13
		H	11	17	13	**13**	**21**	**19**
	40	G	0	0	0	0	0	0
		H	0	0	0	0	0	0
	60	G	0	0	0	0	0	0
		H	**20**	**27**	**16**	**20**	**25**	**6**
40/20	0	G	16	28	20	**12**	**20**	**16**
		H	22	25	9	0	0	0
	20	G	10	14	12	12	23	17
		H	8	10	5	15	15	6
	40	G	4	8	3	6	15	5
		H	10	9	10	5	10	7
	60	G	7	9	7	9	10	6
		H	6	17	8	12	13	9
30/20 25% PFA	60	G	0	0	0	0	0	0
		H	0	0	0	0	0	0
40/20 25% PFA	60	G	8	24	19	13	17	8
		H	10	18	6	5	7	5

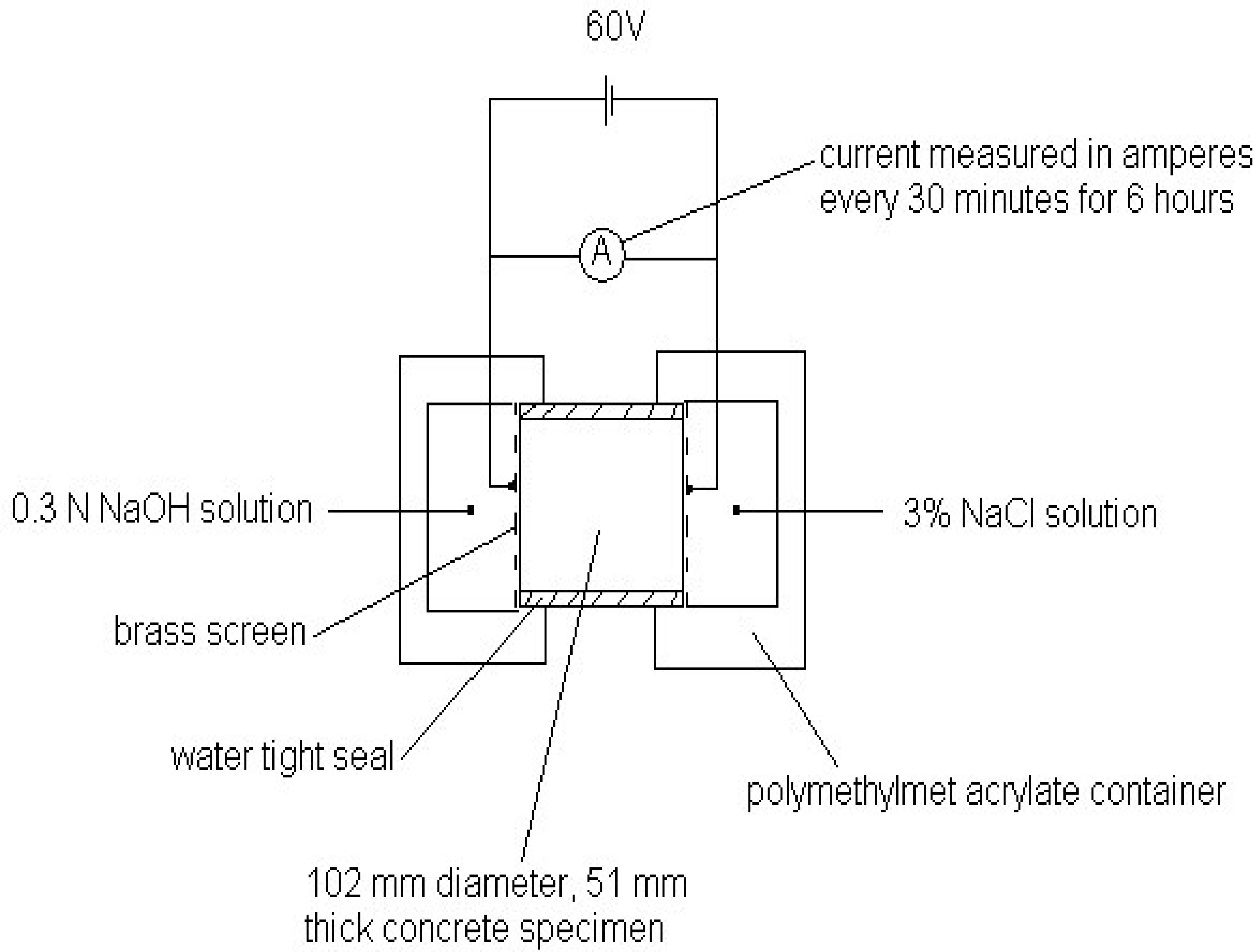
Note: d_1, d_2 & d_3 are defined in the previous slide



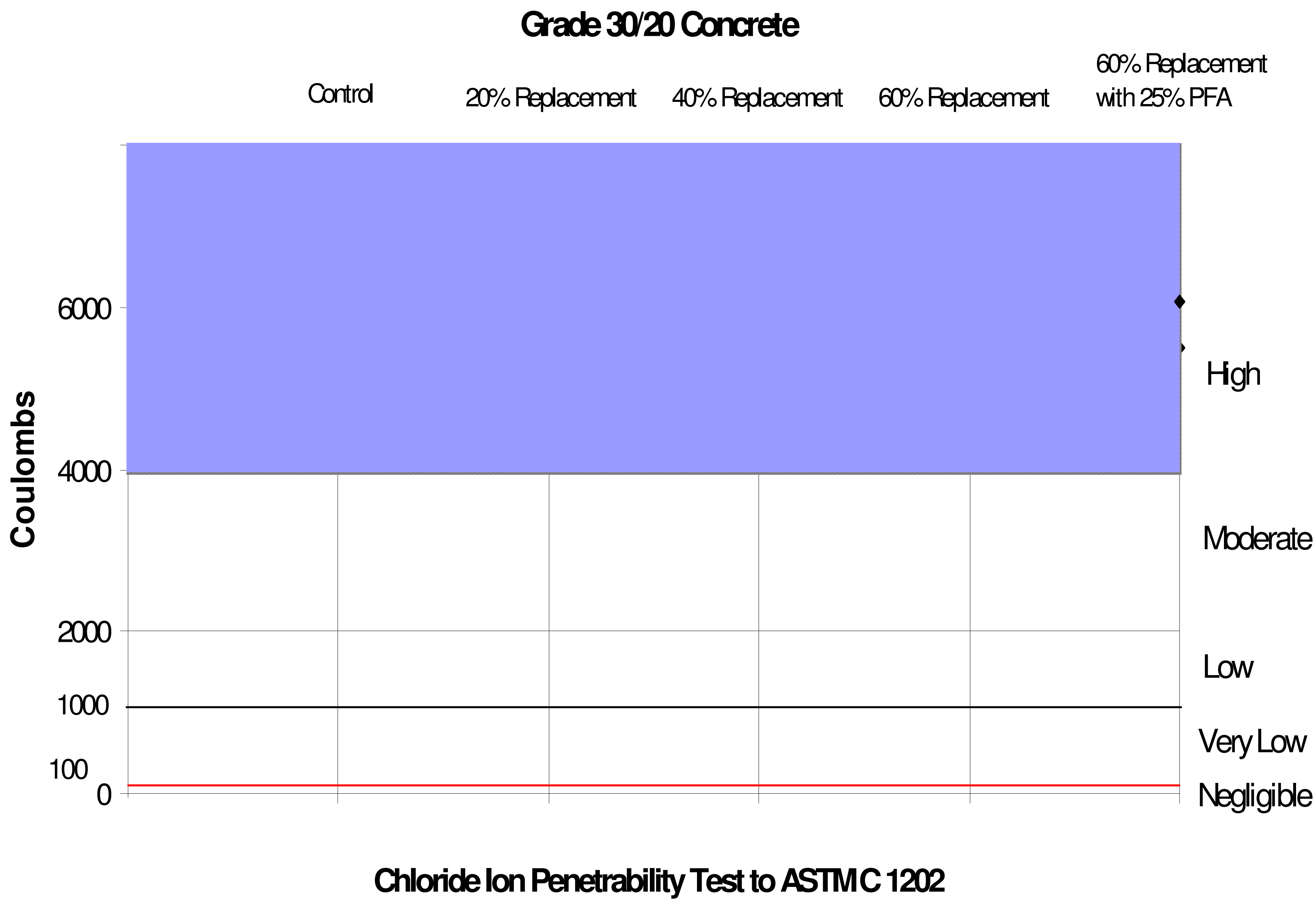
Chloride penetration in concrete mixtures with W/C of about 0.45.
In case of 75% river sand or 50% river sand in the fraction < 4mm the amount of recycled material is 25% or 50% respectively (vol/vol)

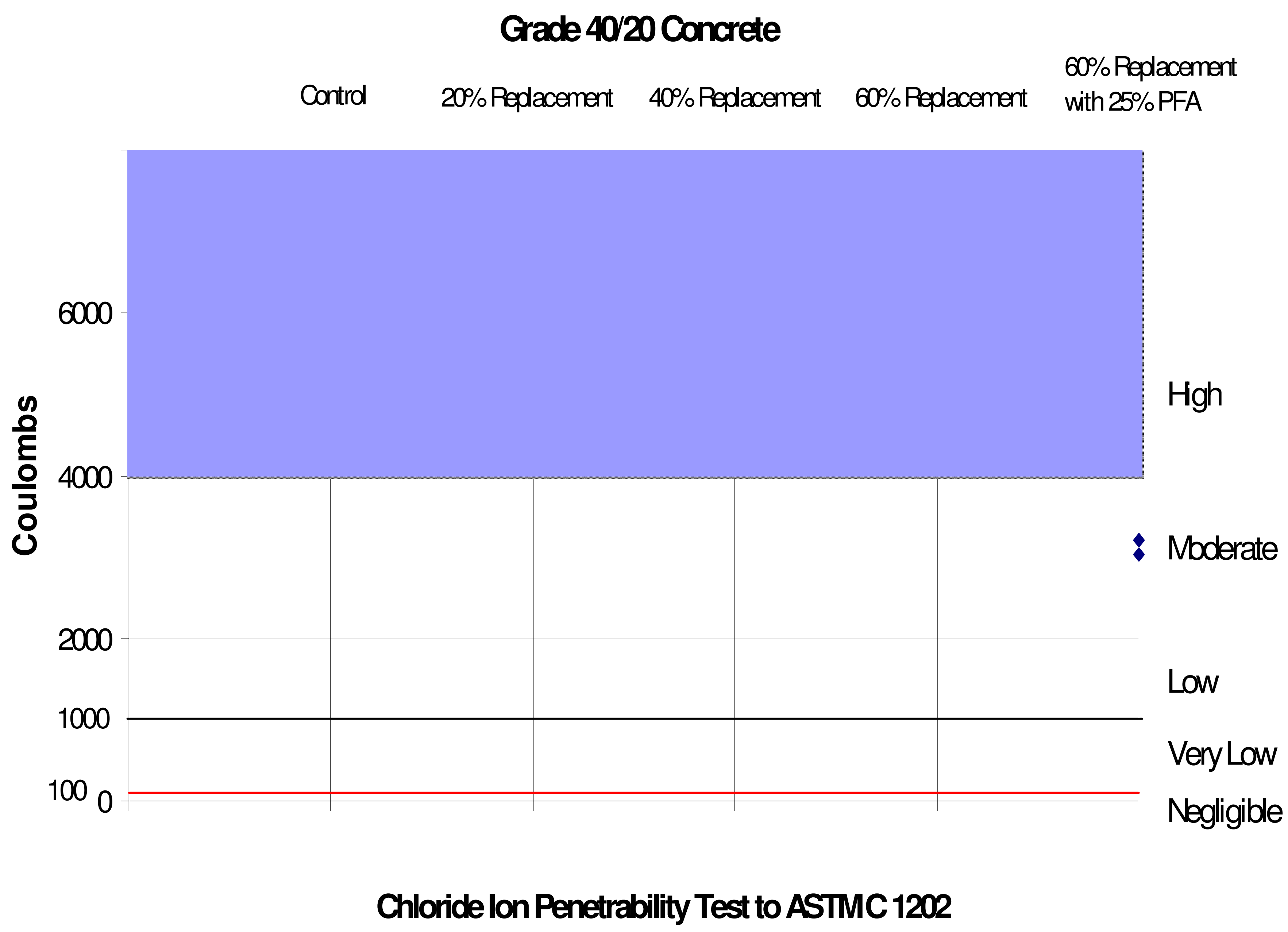
(Fraaij et al, 2002)

ASTM C 1202-97 Test Set-up

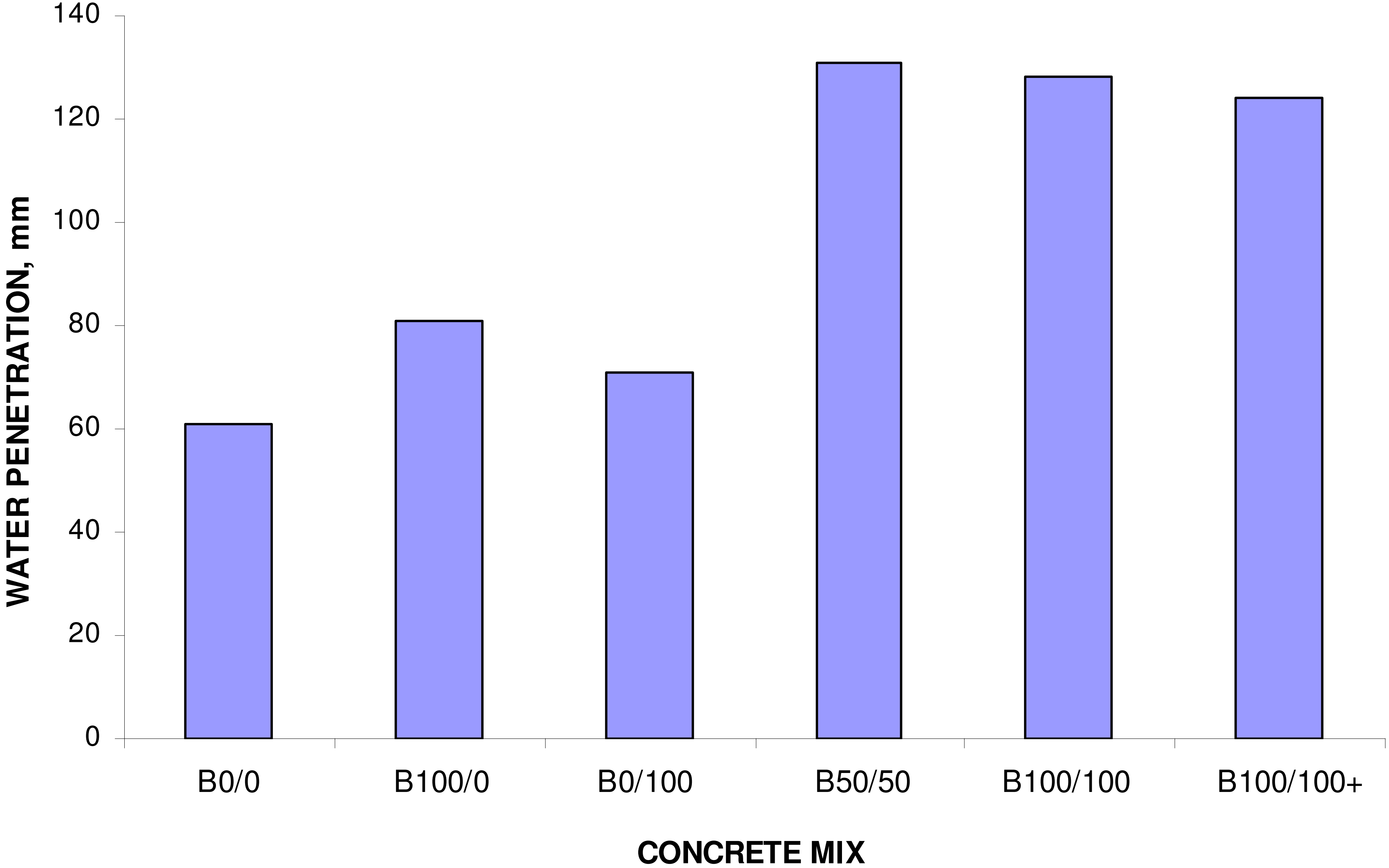


Schematic Diagram of the ASTM C 1202 – 97 Test


Grade 30/20 Concrete
Control
20% Replacement
40% Replacement
60% Replacement
60% Replacement with 25% PFA
Coulombs
6000
4000
2000
1000
100
0
High
Moderate
Low
Very Low
Negligible
Chloride Ion Penetrability Test to ASTM C 1202

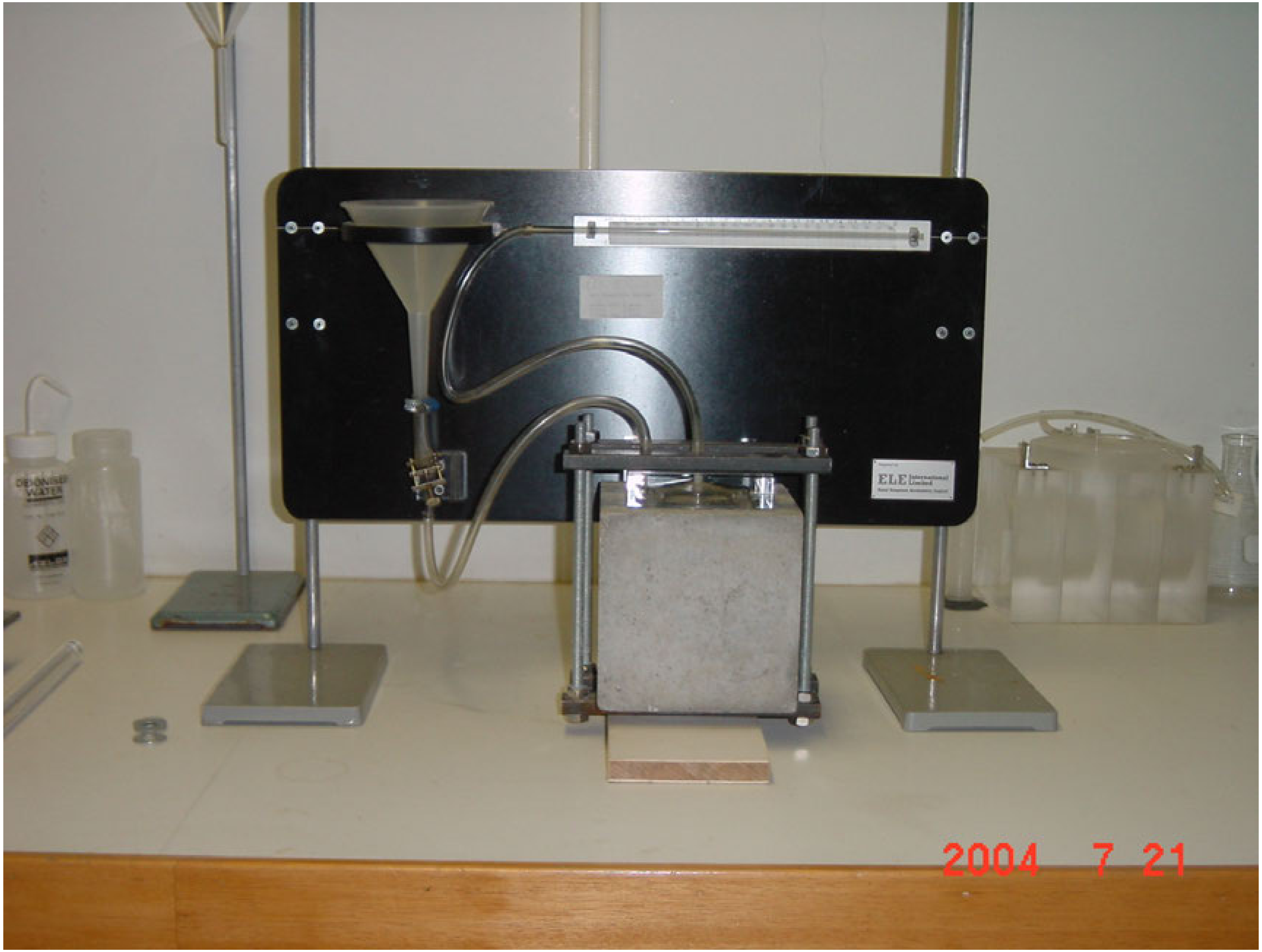


Grade 40/20 Concrete
Control
20% Replacement
40% Replacement
60% Replacement
60% Replacement with 25% PFA
Coulombs
6000
4000
2000
1000
100
0
High
Moderate
Low
Very Low
Negligible
Chloride Ion Penetrability Test to ASTM C 1202

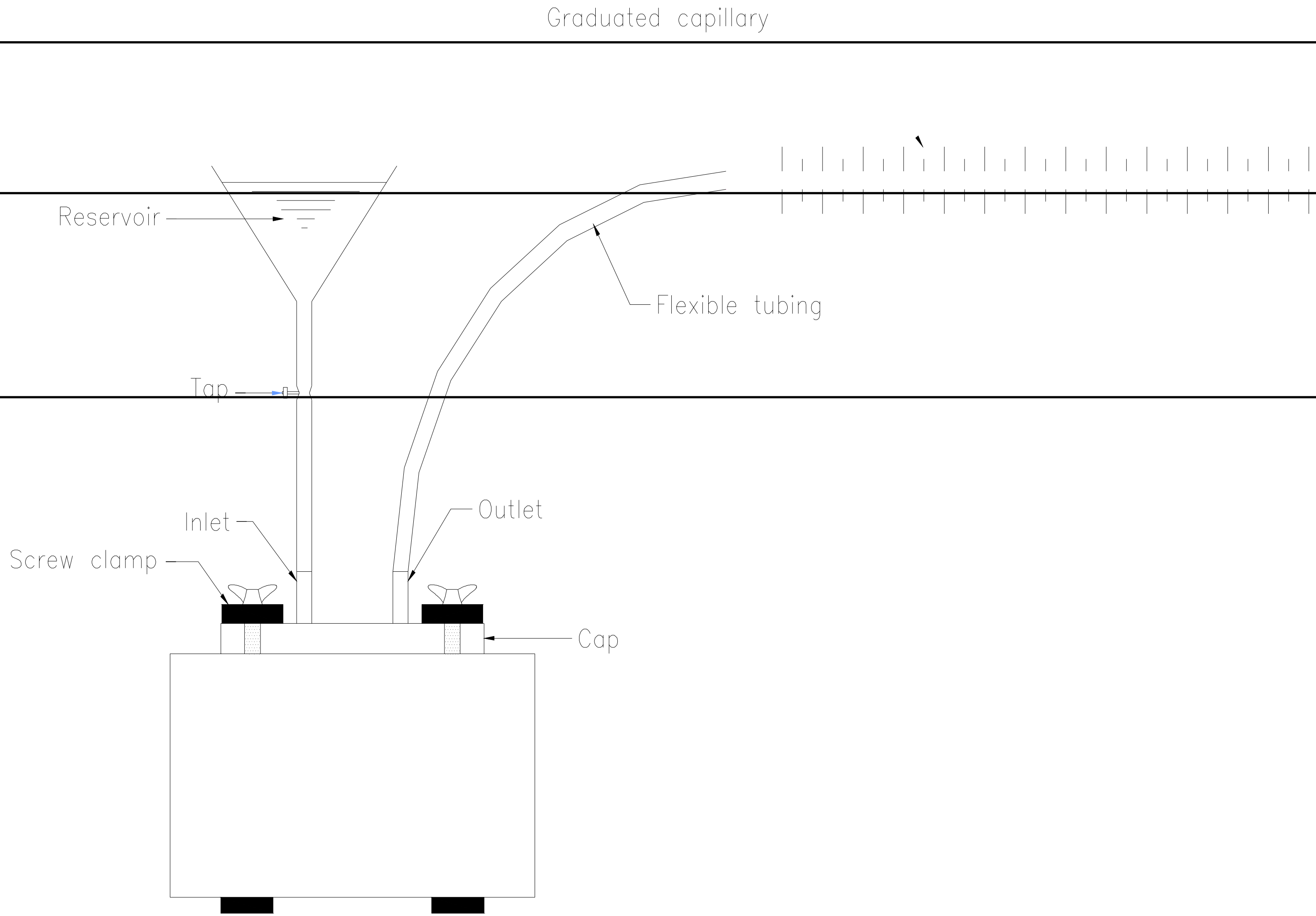


Variation of water permeability for different mixes

(Kenai et al, 2002)



Initial Surface Absorption Test



Schematic layout of the ISAT equipment

Concrete Society Technical Report 31 (1987)

Reading taken	Low	Average	High
10 min	<0.25	0.25-0.50	>0.50
30 min	<0.10	0.10-0.35	>0.35
60 min	<0.07	0.07-0.20	>0.20

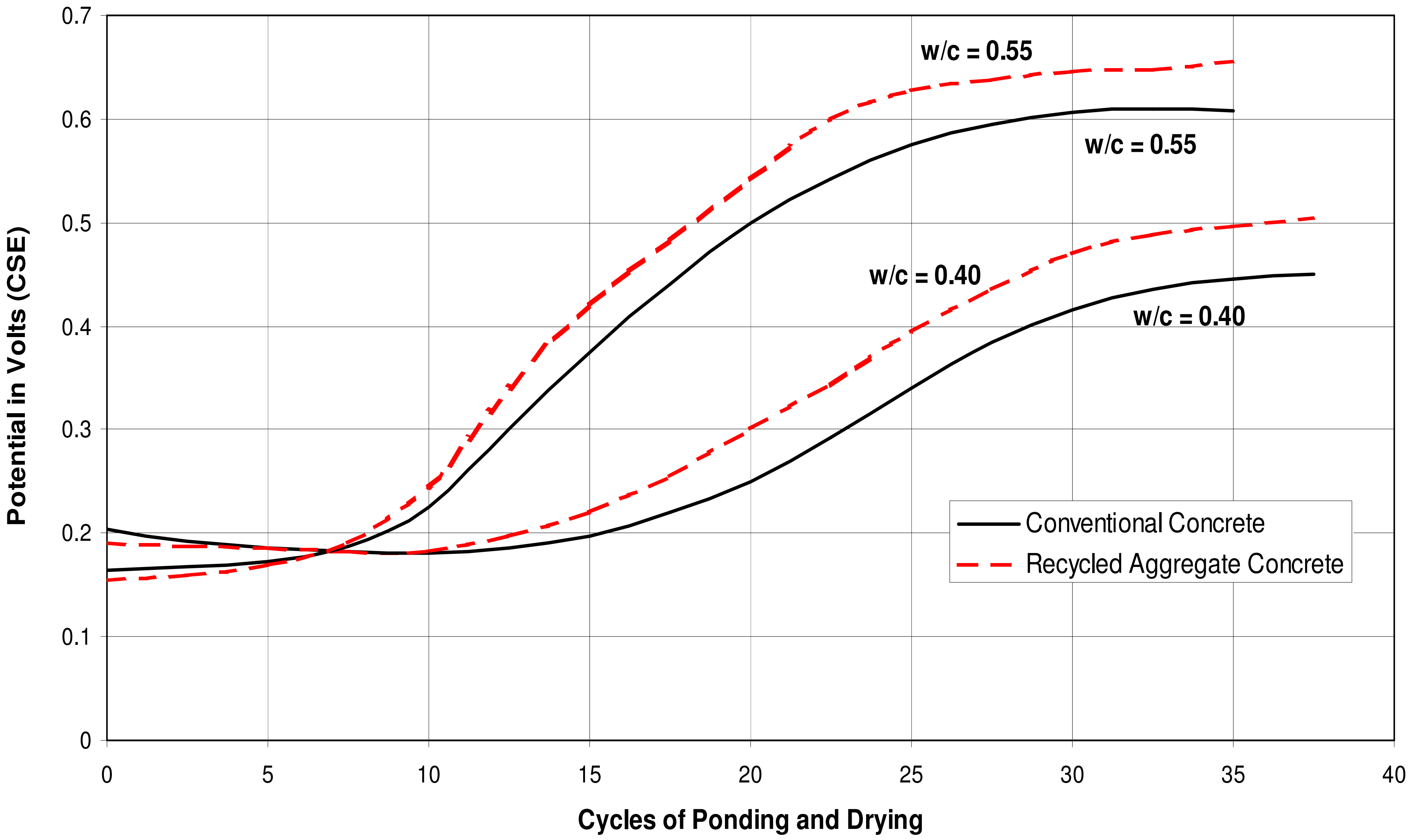
where the numbers are in $ml/m^2/sec$.

Classification of Initial Surface Absorption

ISAT Results

Grade 30/20 Control Mix						
	Specimen G			Specimen H		
	Surface A Bottom of cube	Surface B Side	Surface C Side	Surface A Bottom of cube	Surface B Side	Surface C Side
10 minutes	0.34	0.46	0.48	0.42	0.46	0.51
30 minutes	0.22	0.31	0.34	0.27	0.34	0.33
60 minutes	0.16	0.25	0.26	0.18	0.27	0.27
Permeability	Average	Average	Average	Average	Average	High

Grade 30/20 60% replacement 25% PFA						
	Specimen G			Specimen H		
	Surface A Bottom of cube	Surface B Side	Surface C Side	Surface A Bottom of cube	Surface B Side	Surface C Side
10 minutes	0.39	0.44	0.45	0.41	0.37	0.43
30 minutes	0.23	0.25	0.25	0.25	0.23	0.22
60 minutes	0.17	0.18	0.18	0.17	0.17	0.17
Permeability	Average	Average	Average	Average	Average	Average



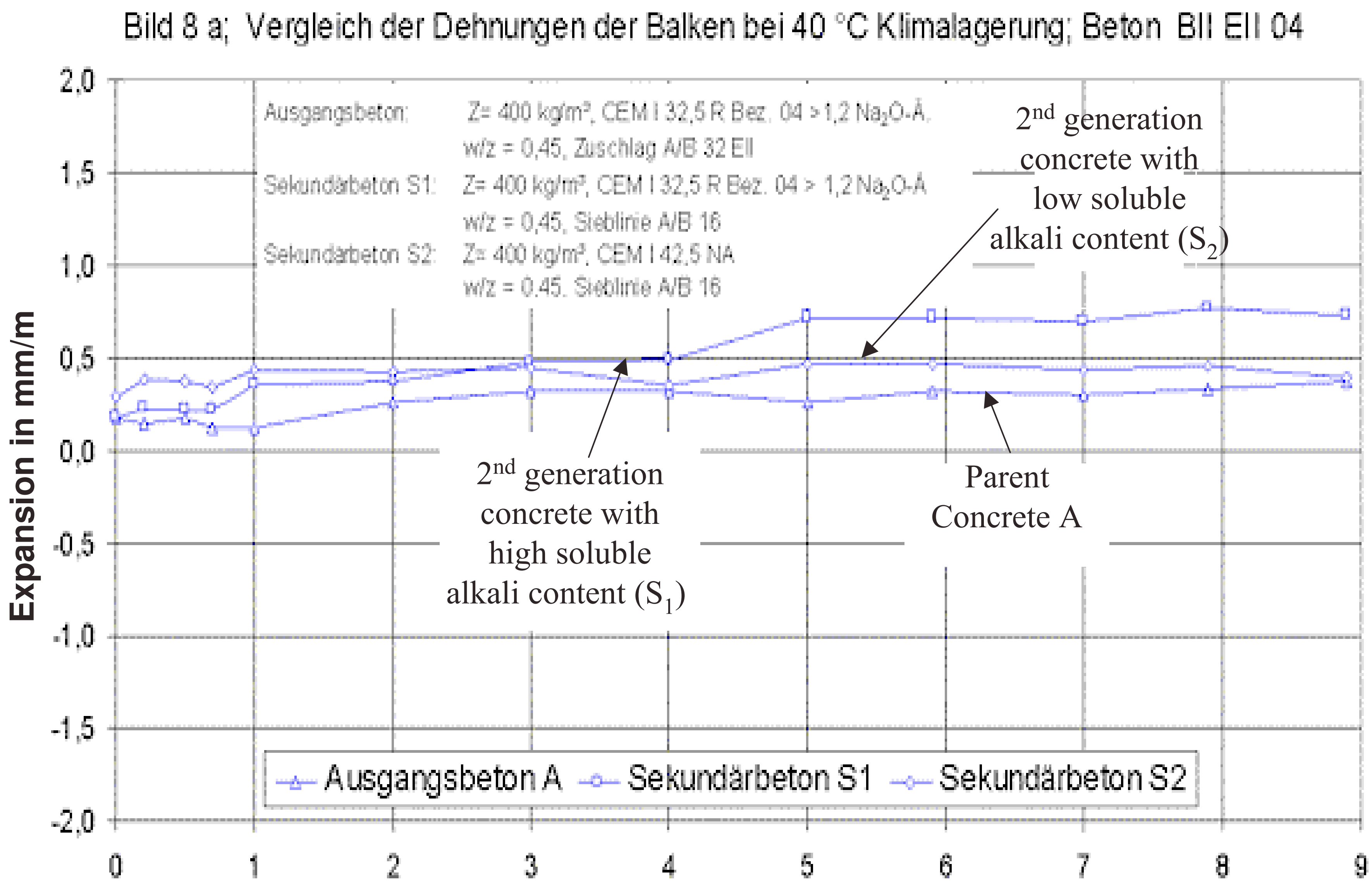
Half-cell potentials of steel bars embedded in specimens made from recycled and conventional aggregate

(ACI Manual, 2003)

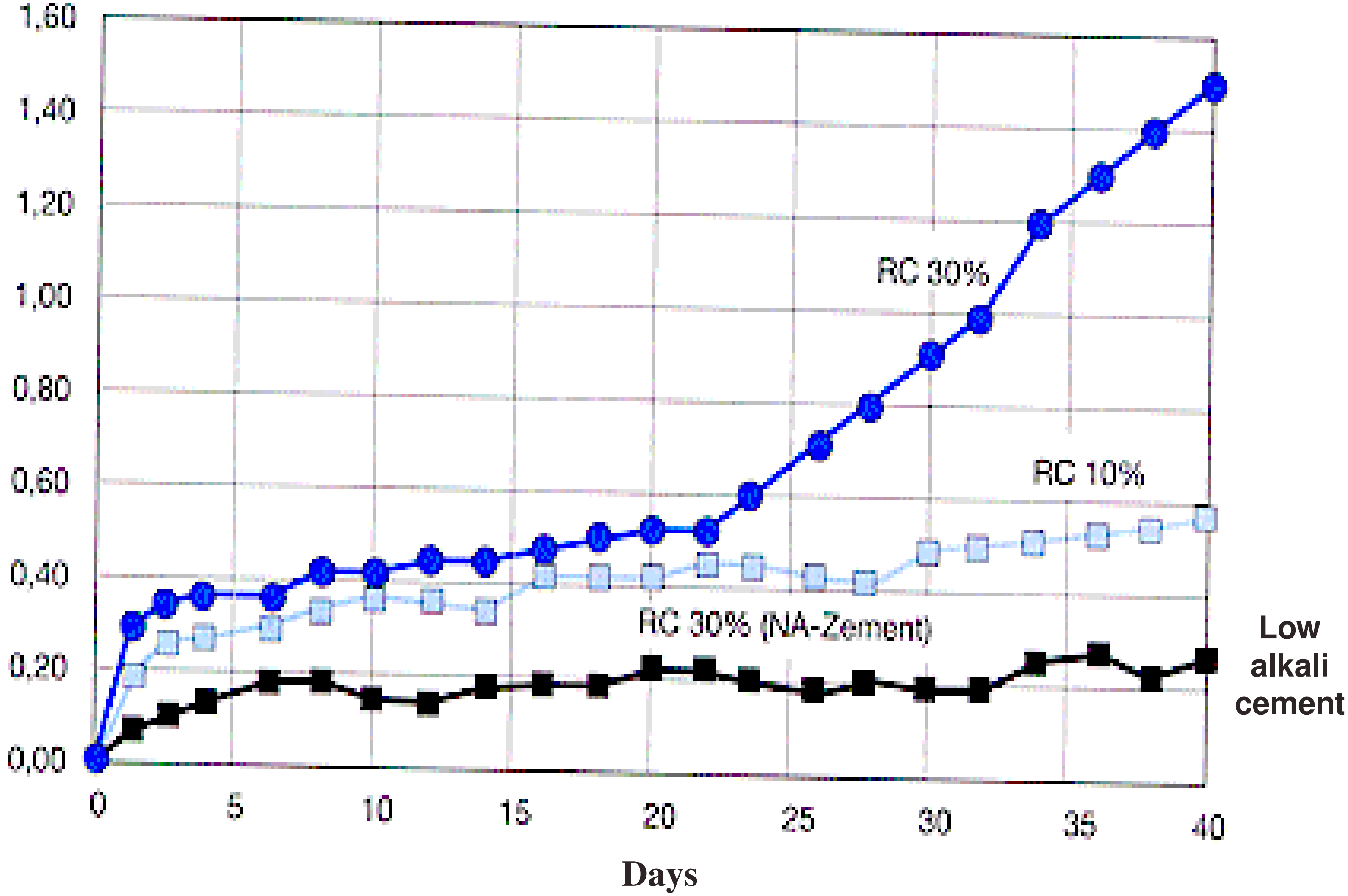
Recycled coarse Aggregate (%)	Recycled fine aggregate (%)	Moisture content in concrete (%)	Explosive fracture	Residual compressive strength (%)
0	0	4.7	No	14.5
0	30	5.7	No	12.8
30	0	5.2	No	12.2
30	30	6.2	No	13.0
0	50	6.0	No	13.5
0	100	7.1	No	13.1

Residual Compressive Strength of Concretes after Fire

(Teranishi et al 1998)



Comparison of expansion of 3 concrete prisms at 40°C and 100% RH



Expansion of concrete prisms containing different percentage of recycled aggregates

(Haase and Dahms, 1998)

Durability Indicators

- *Carbonation*
- *Resistance to Chloride Penetration*
- *Permeability*
- *Resistance to Corrosion*
- *Fire Resistance*
- *Alkali Aggregate Reaction*

Conclusion

- *From all tests which serve as indicators of durability, it is evident that:*
- *Recycled Concrete is just as durable as Ordinary Concrete*

Thank You