The Effects of $MgCl_2$ and $CaCl_2$ on Plain and Fly Ash Pavement Concretes

Phase 1

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Objectives

- Investigate the effects of de-icing/anti-icing chemicals on durability of concrete
- Evaluate the chemical interactions of de-icing chemicals with concrete matrix and aggregates
- Compare the effects of de-icing chemicals on plain (Type I) and fly ash (FA20) concretes

Wetting & Drying (W/D) – Previous studies

Previous studies utilized wide ranges of concentrations of deicers, temperature and length of exposure cycles; some combinations resulting in unrealistic conditions

Researchers	Wetting		Drying		Deicing Solutions		
	Temp ^{o}C	time in hours	Temp ^{o}C	time in hours	NaCl	$CaCl_2$	$MgCl_2$
Wang et al. [1]	4	15	23	9	26.50%	37.90%	-
Darwin et al. [2]	23	96	38	72	6.04 and 1.06 molal	6.04 and 1.06 molal	6.04 and 1.06 molal
Lee et al. [3]	58	132	58	24	0.75 M	0.75 M	0.75 M
Cody et al. [4]	60	132	60 or 90	24	3/ 0.75 M	3/ 0.75 M	3/ 0.75 M
Current study	4	16±1	23	8±1	23.3 %	28%	25 %

No prior investigations as to how accelerated testing affects the wetting and drying (or freezing and thawing) processes and thus the interaction of de-icer solution with concrete

Freezing & Thawing (F/T) – Previous studies

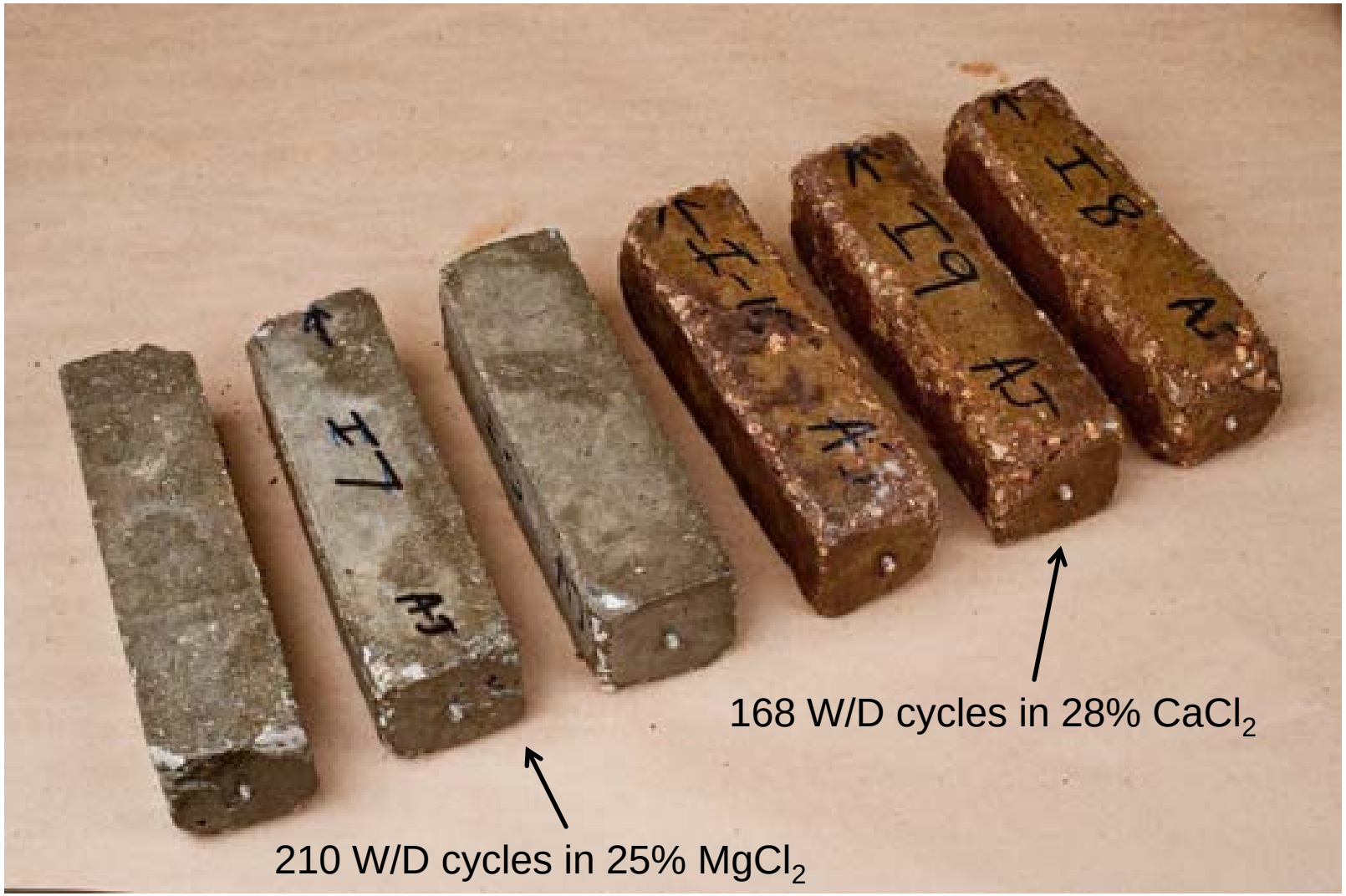
	Freezing		Thawing		Deicing Solutions		
Researchers	**Temp °C**	**Time hours**	**Temp °C**	**Time hours**	**NaCl**	**$CaCl_2$**	**$MgCl_2$**
Wang et al. [1]	-20	15	Warm water	9	13.3	9.5	
Kozikowski et al. [5]	-18	16-18	23	6-8	4 & 30 %	----	30%
Lee et al. [3]	-4	24	58	132	0.75 M	0.75 M	0.75 M
Cody et al. [4]	0 or -70		25		3M/0.75 M	3M / 0.75 M	3M / 0.75 M
Current study	-20	12	20	12	14%	17%	15%

Similarly large variations in F/T parameters

Experimental program

- The durability of the two concretes exposed to
  - Wetting and drying (W/D) cycles
  - Freeze-thaw (F/T) cycles
- Periodic monitoring of mass loss/ length changes and resonance frequencies of specimens exposed to W/D and F/T cycles
- Determination of compressive strength of companion specimens

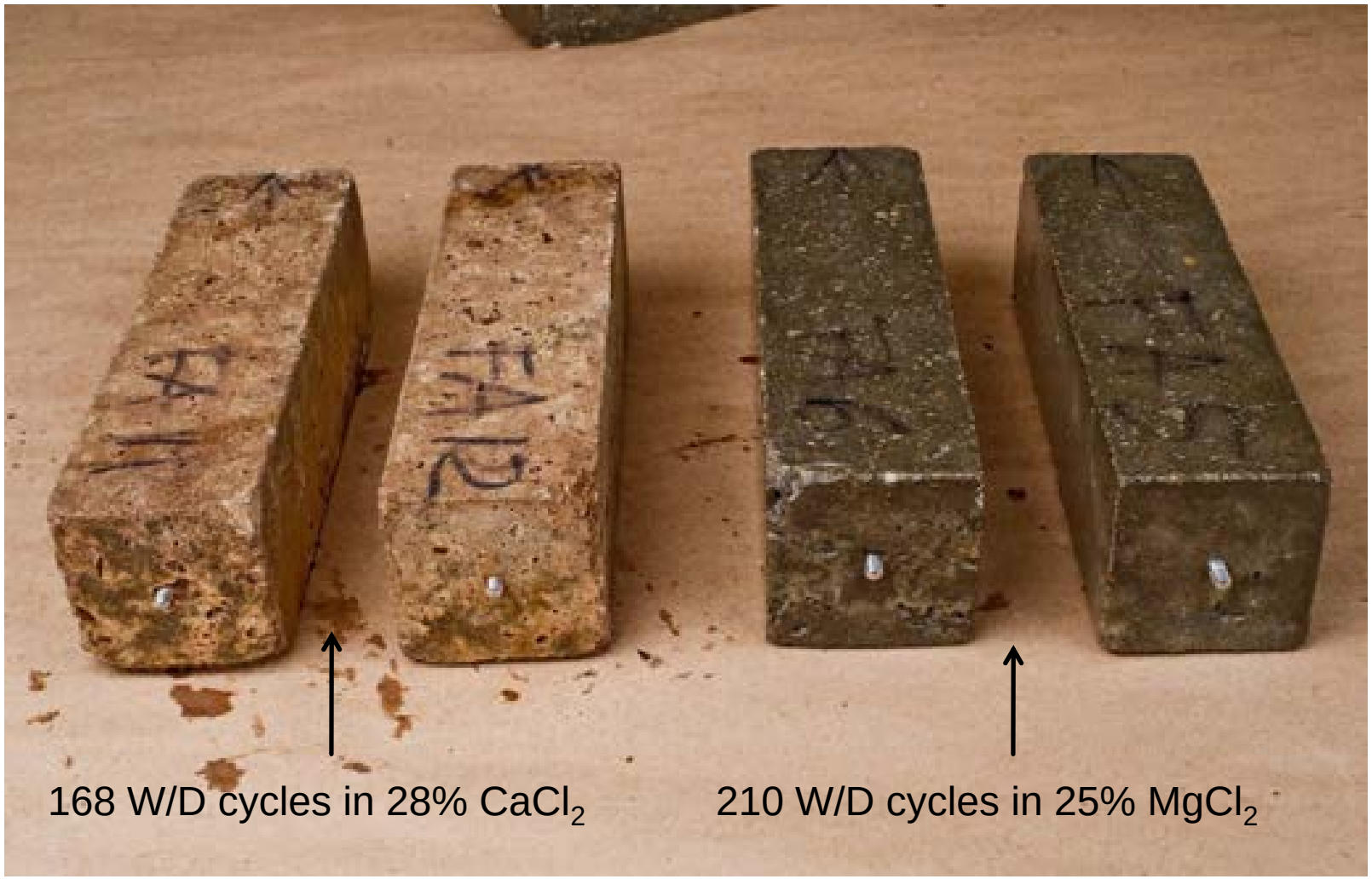
Type I specimens after W/D cycles in 25% $MgCl_2$ & 28% $CaCl_2$ solutions



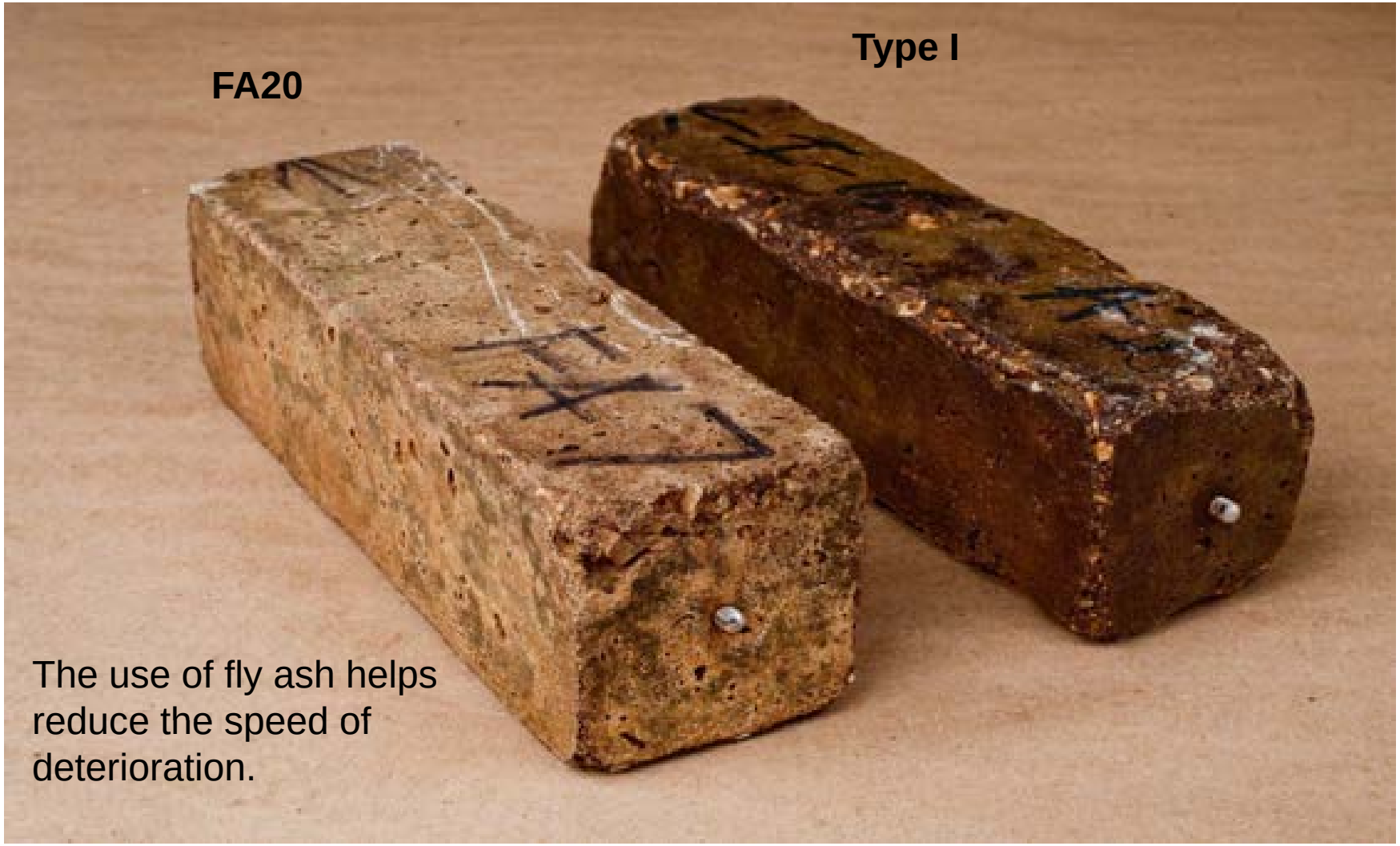
Type I specimens after 168 W/D cycles in 28% $CaCl_2$ solution

Testing ceased after 168 W/D cycles due to extensive visible deterioration.

Fly Ash specimens after W/D cycles in 25% $MgCl_2$ & 28% $CaCl_2$ solution

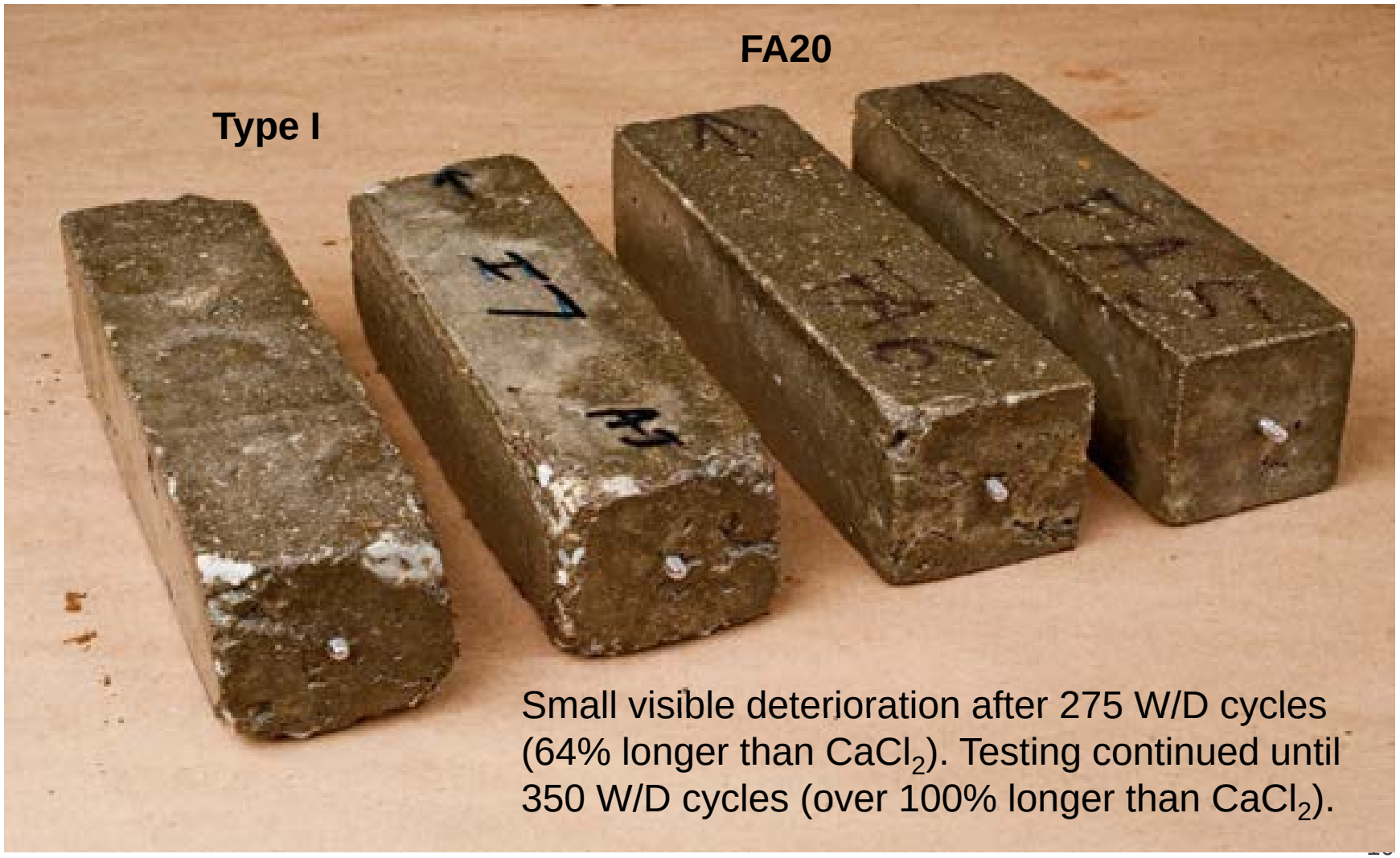


Type I & Fly Ash specimens after 168 W/D cycles in 28% $CaCl_2$ solution



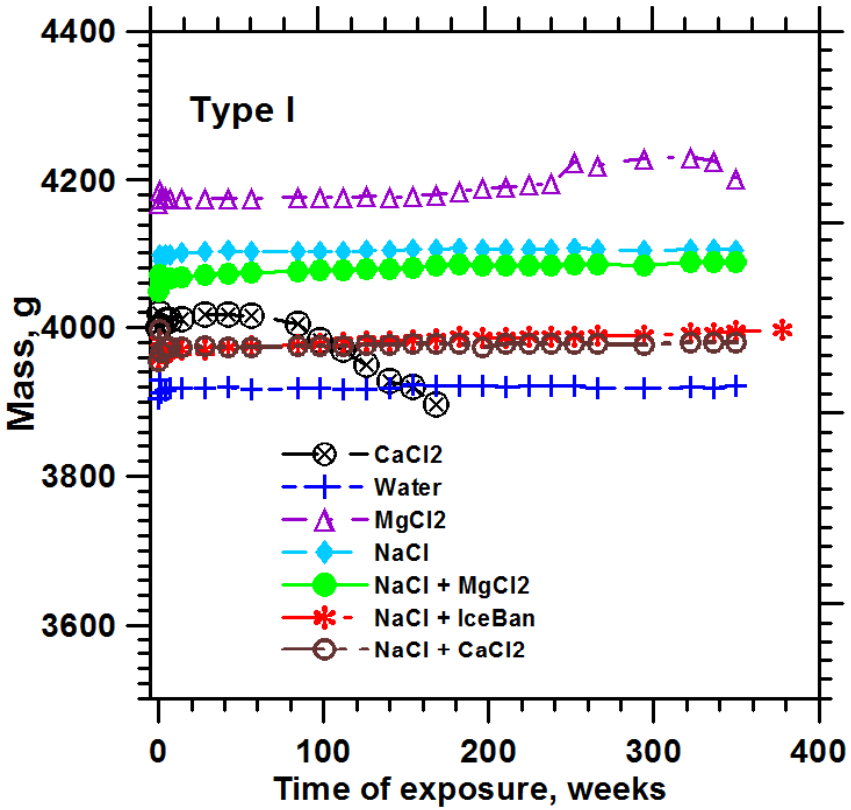
The use of fly ash helps reduce the speed of deterioration.

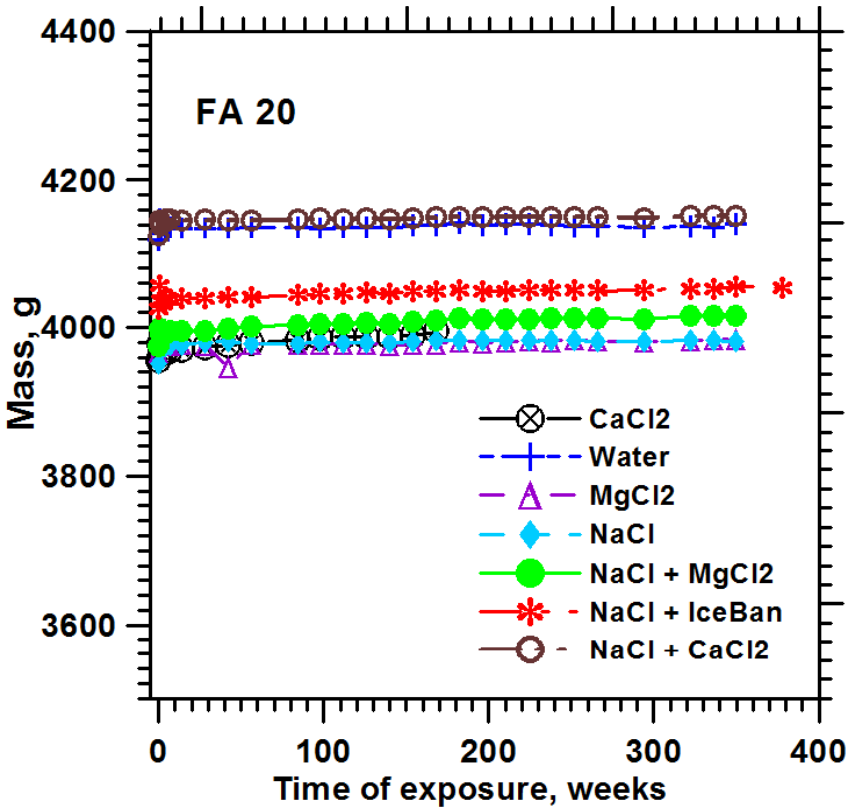
Type I & Fly Ash specimens after 275 W/D cycles in 25% $MgCl_2$ solution



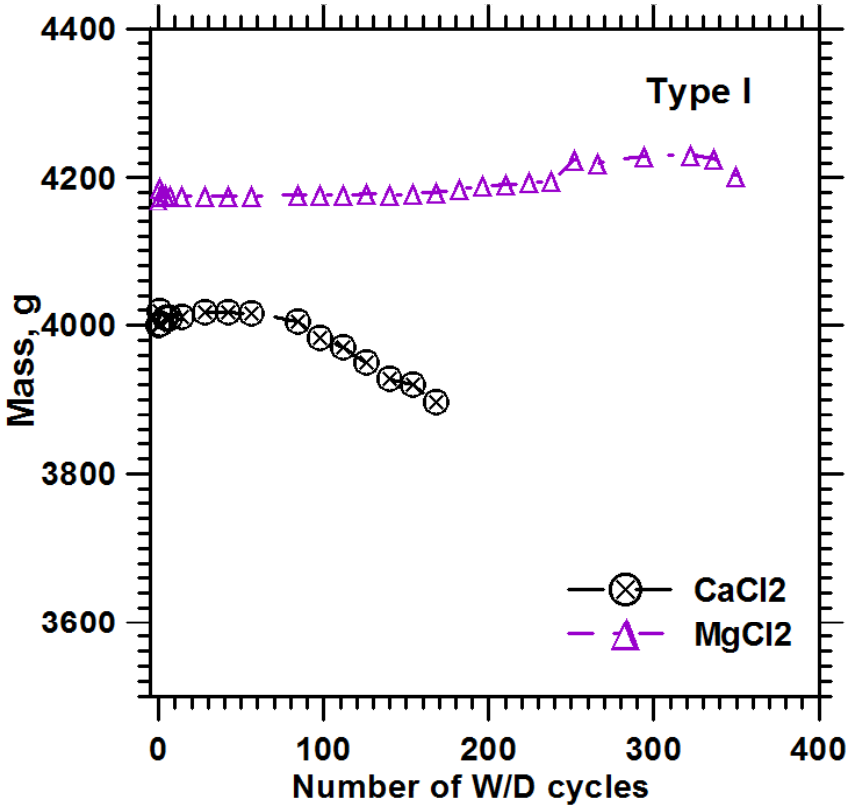
Small visible deterioration after 275 W/D cycles (64% longer than $CaCl_2$). Testing continued until 350 W/D cycles (over 100% longer than $CaCl_2$).

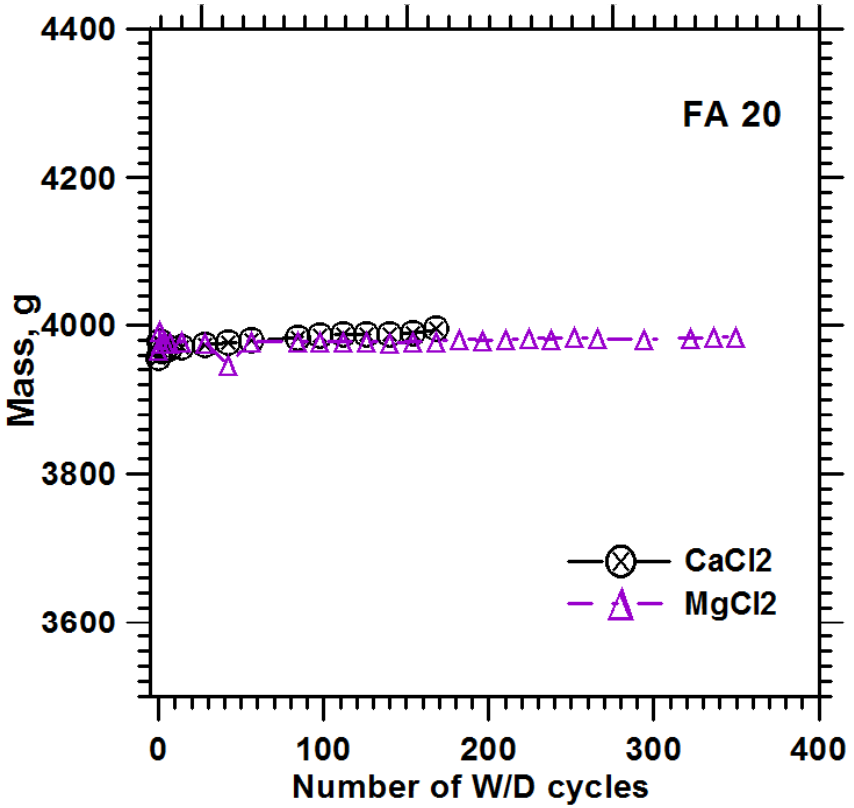
Mass Changes for W/D exposure (all solutions)



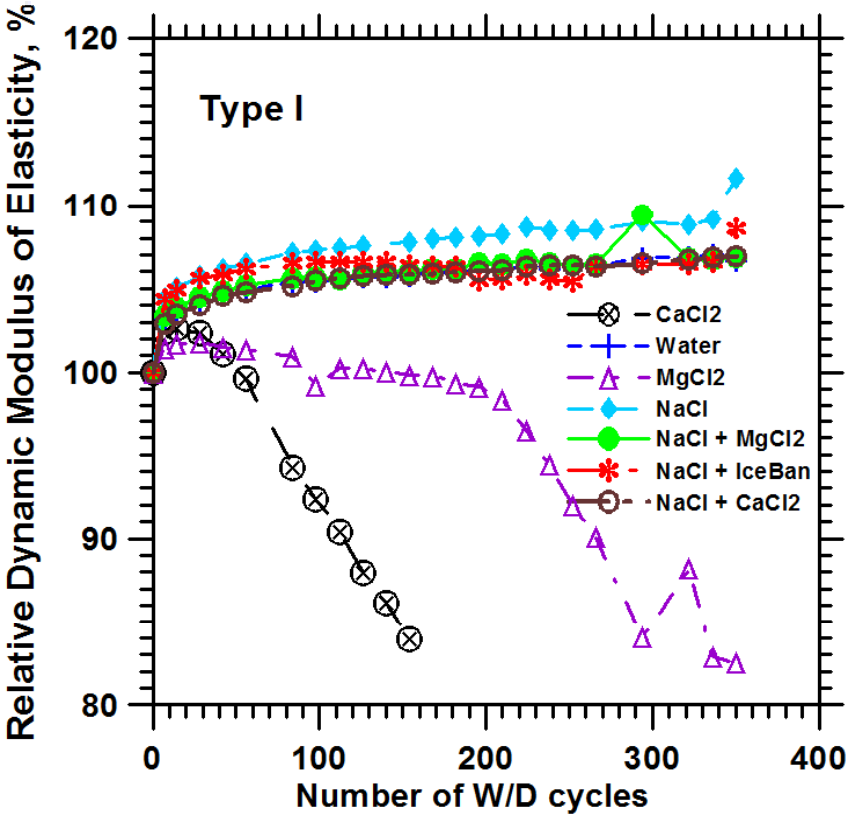


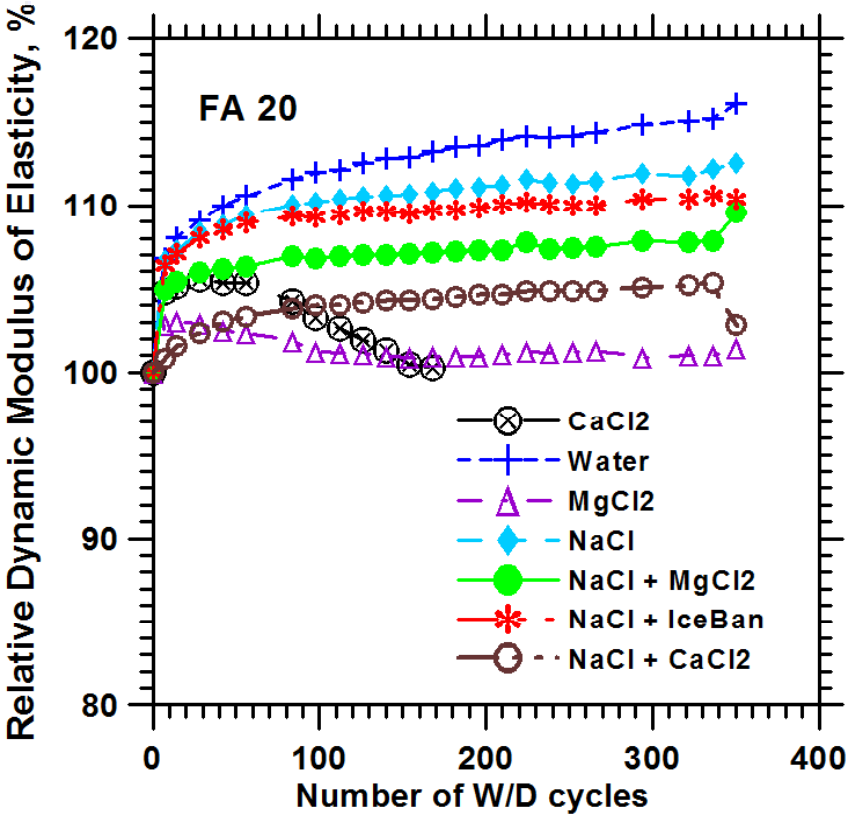
Mass Changes W/D exposure regime ($MgCl_2$ and $CaCl_2$ solutions)



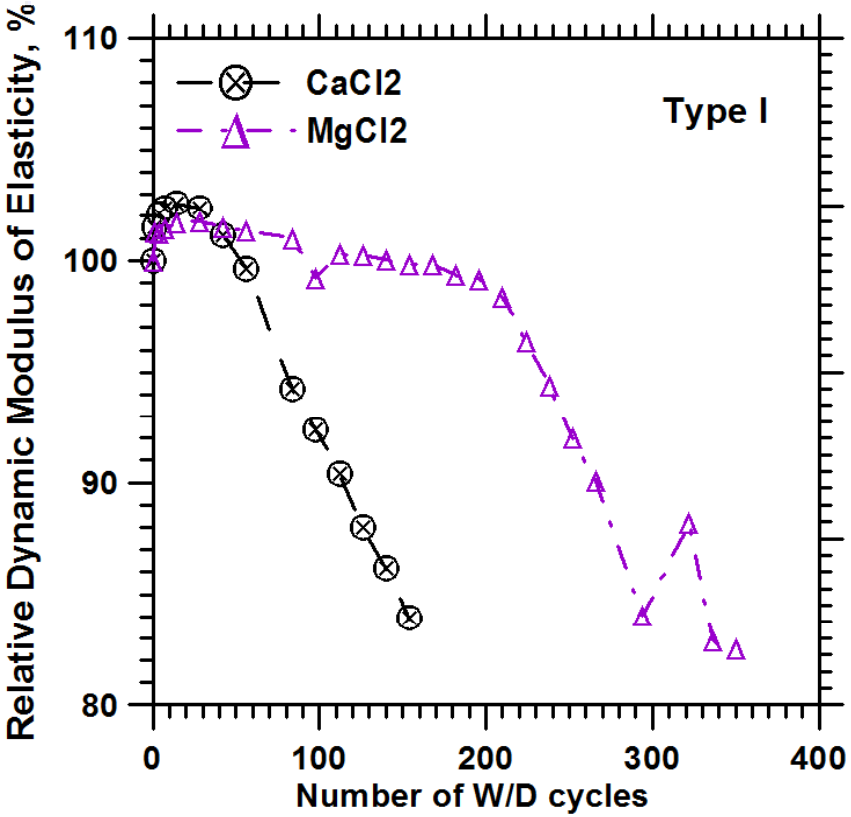


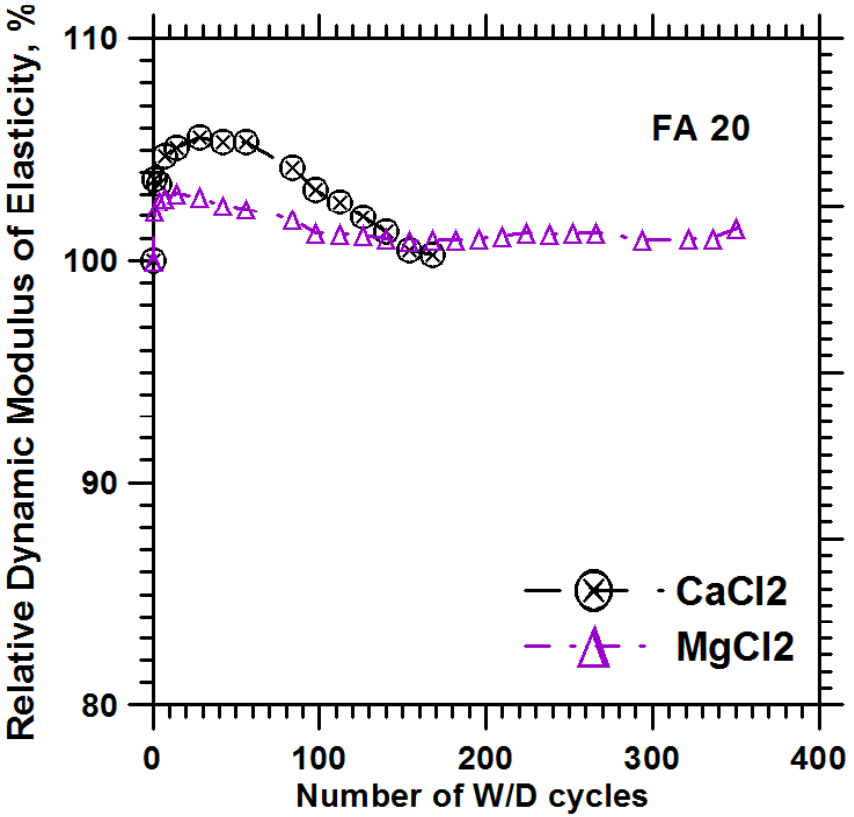
Relative Dynamic Modulus of Elasticity (RDME) for W/D exposure





Relative Dynamic Modulus of Elasticity (RDME) for W/D exposure





F/T exposure - Type I Specimens

166 F/T cycles in 15% $MgCl_2$ solution

166 F/T cycles in 17% $CaCl_2$ solution

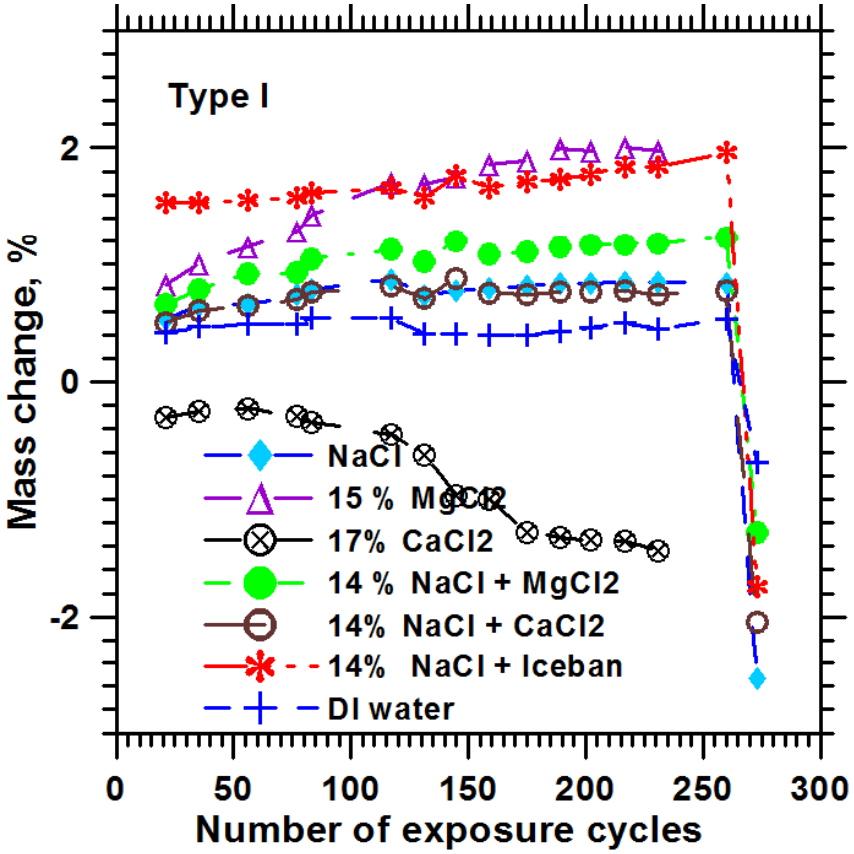
Similar to the W/D cycles extensive visible deterioration occurred

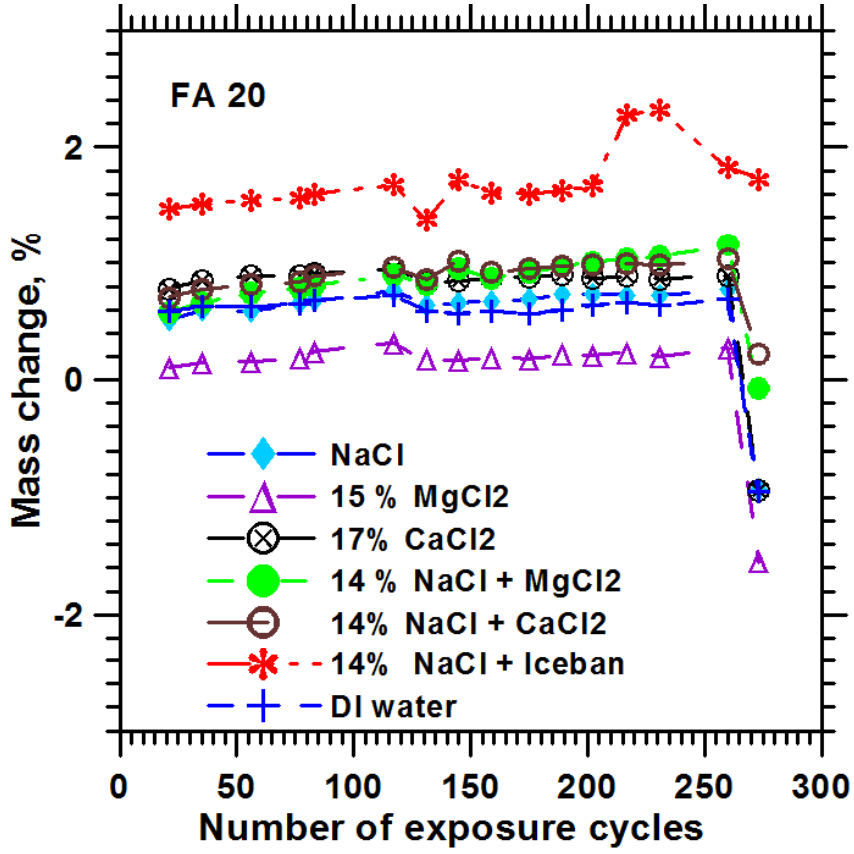
F/T Exposure - Type I & Fly Ash Specimens

Type I & Fly Ash specimens after 166 F/T cycles in 15% $MgCl_2$ solution

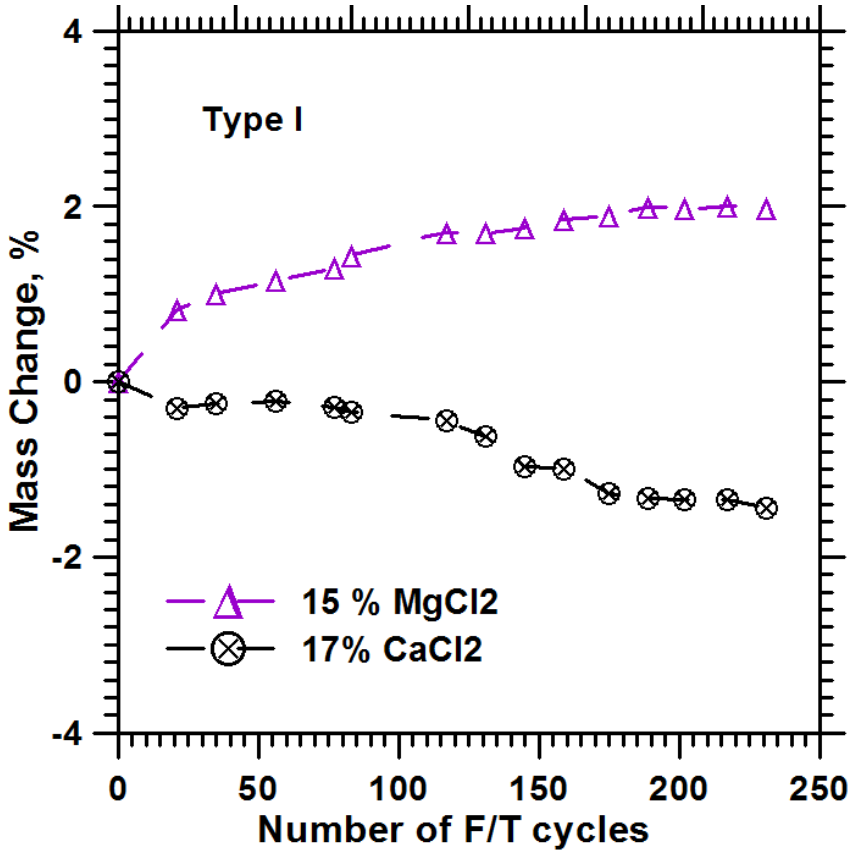
Type I & Fly Ash specimens after 166 F/T cycles in 17% $CaCl_2$ solution

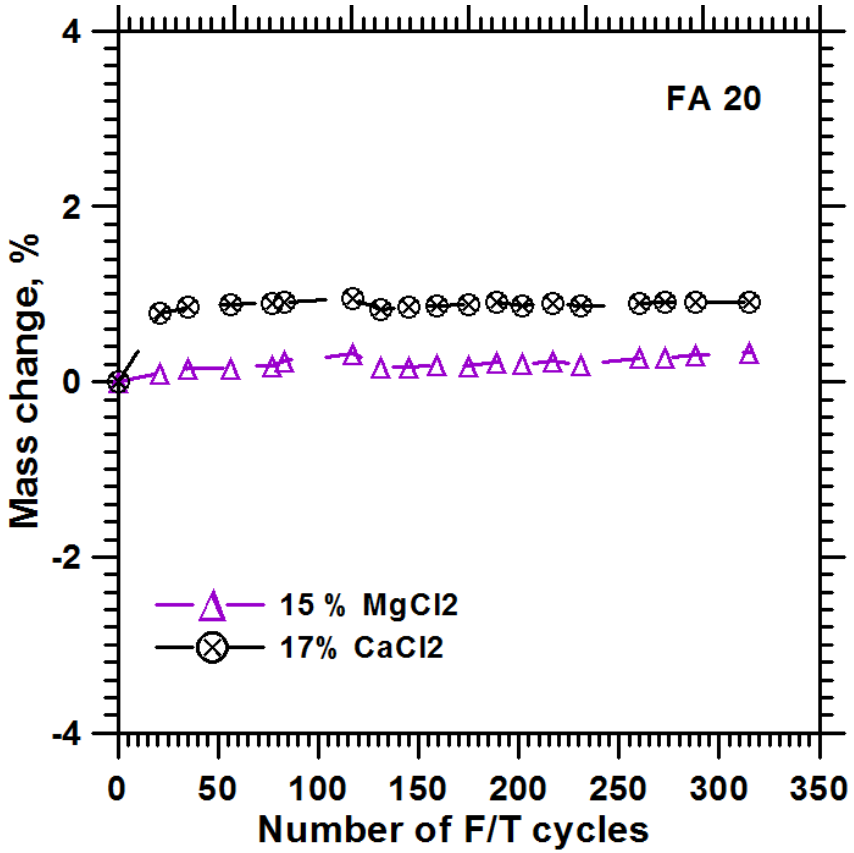
Mass Changes for F/T exposure



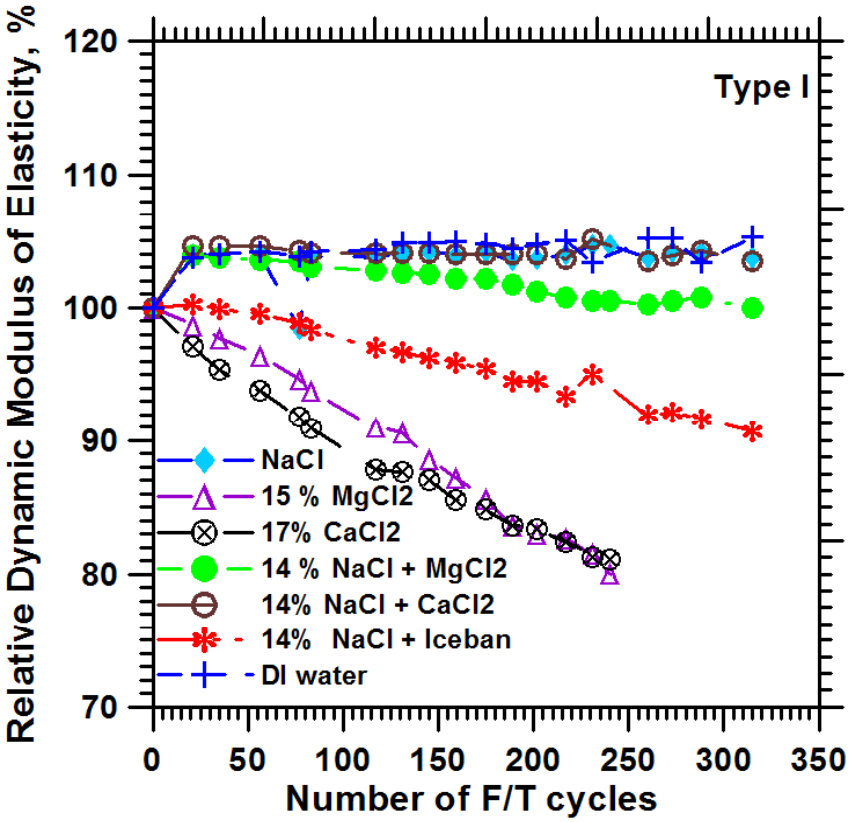


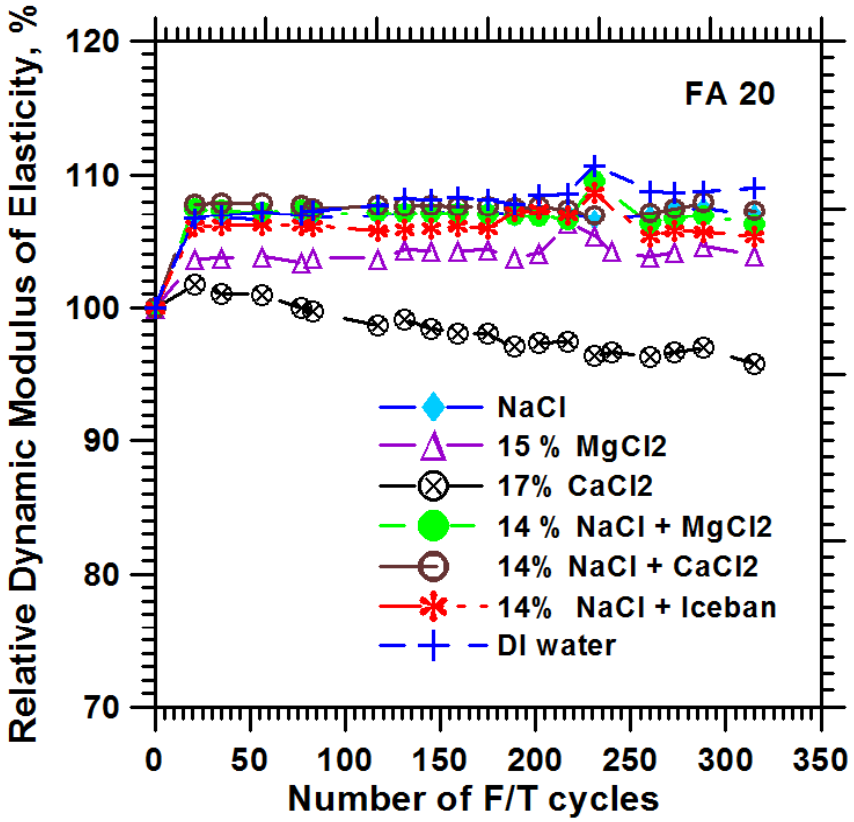
Mass Changes for F/T exposure



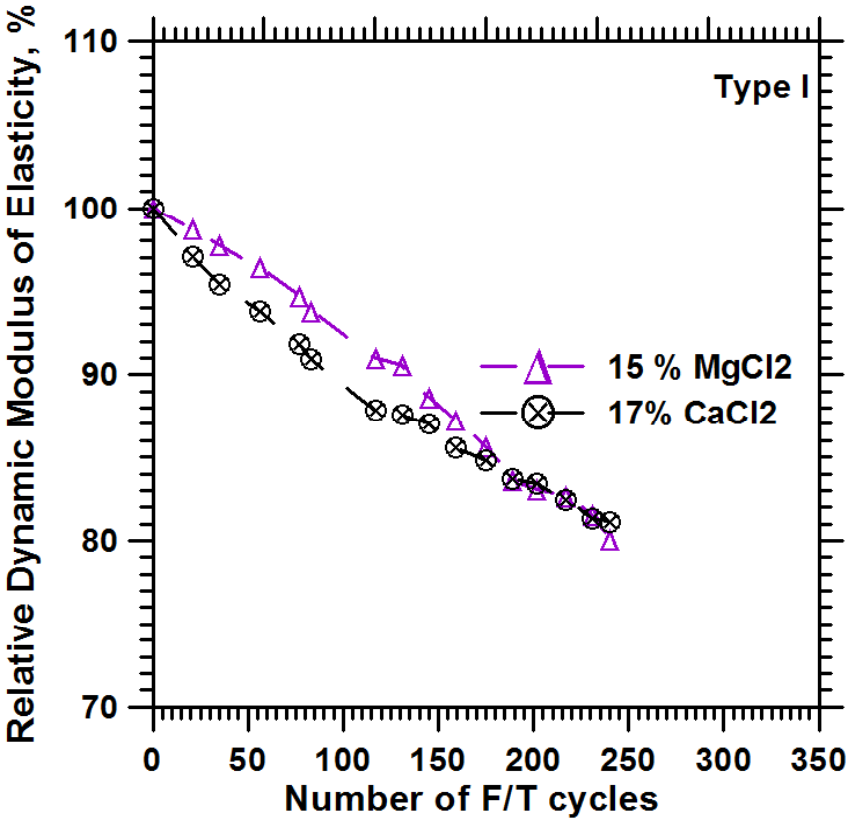


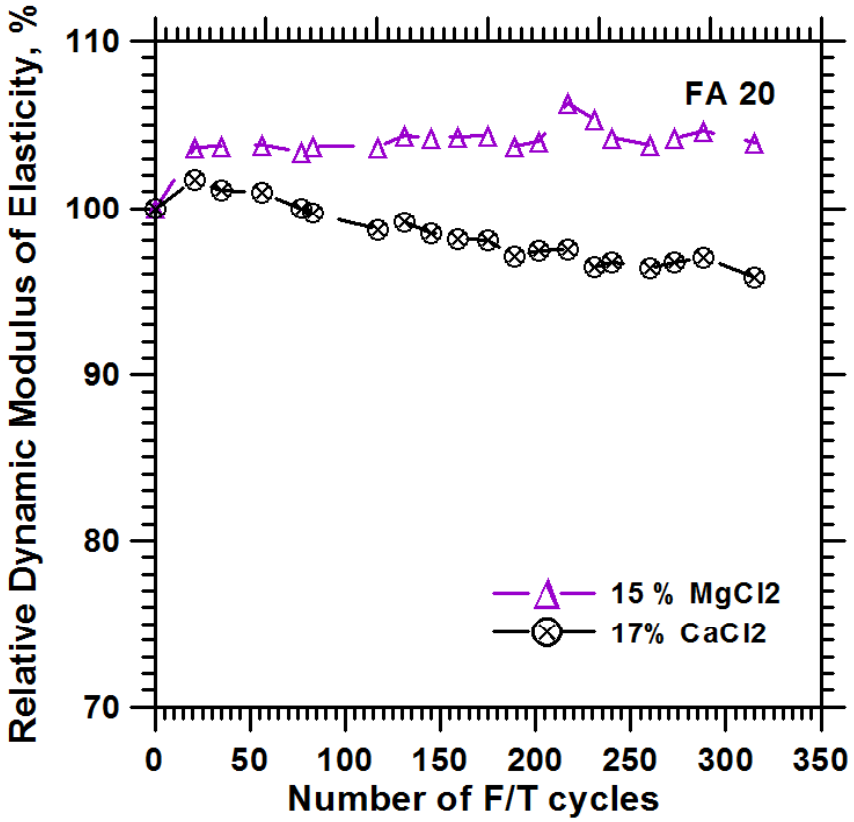
Relative Dynamic Modulus of Elasticity (RDME) for F/T exposure



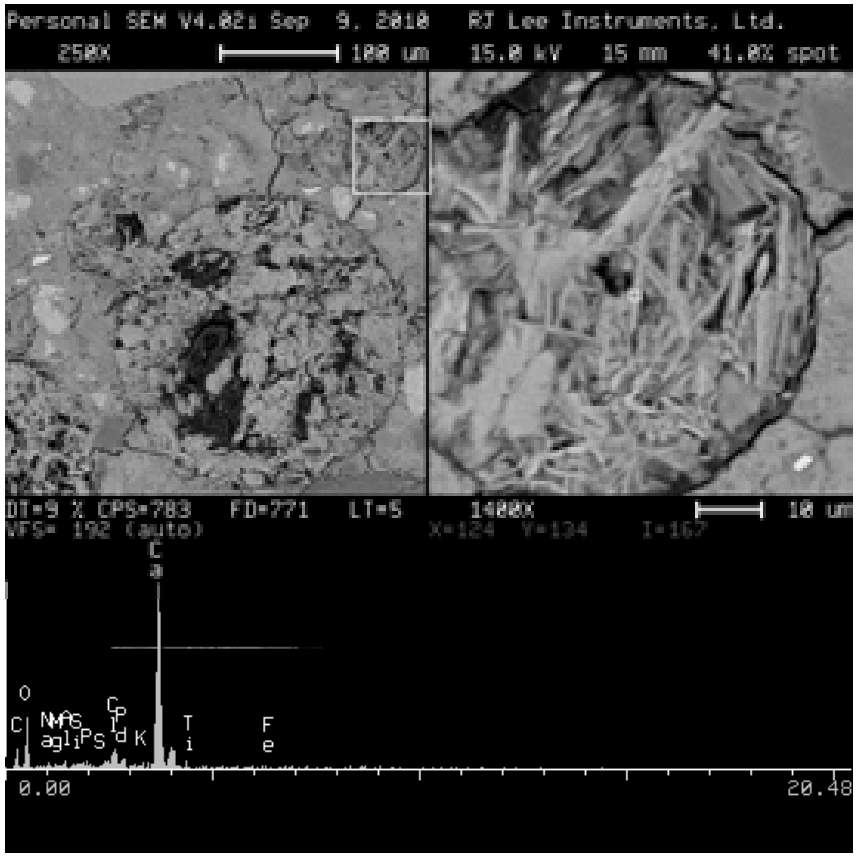


Relative Dynamic Modulus of Elasticity (RDME) for F/T exposure

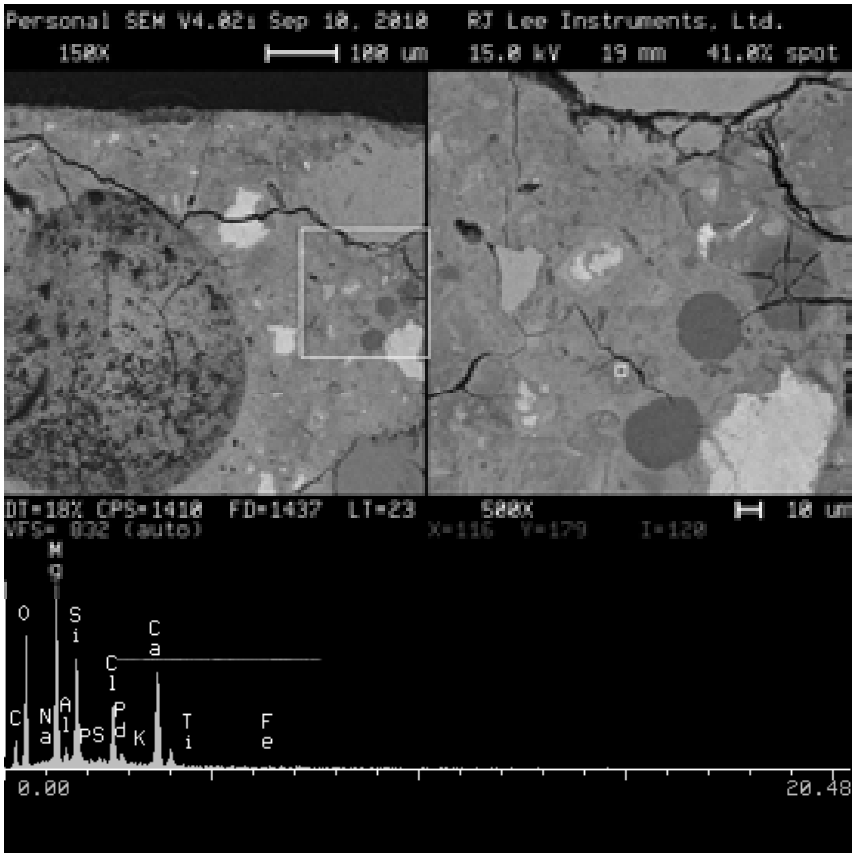




Microstructure-W/D Cycles



In $CaCl_2$ solution



In $MgCl_2$ solution

Conclusions

- External signs of deterioration were more extensive in Type I specimens exposed to 168 W/D cycles in $CaCl_2$ solution than those observed in specimens exposed to 210 W/D cycles in $MgCl_2$ solution (despite 25% longer exposure).
- Initial signs of distress were observed in the $MgCl_2$ exposed specimens after 275 W/D cycles but the overall damage was still much less than that observed in the $CaCl_2$ specimens after 168 W/D cycles (despite 60% longer exposure).
- Surface deterioration of Type I specimens in the $MgCl_2$ solution for 350 W/D cycles was observed to be comparable to the surface deterioration of the equivalent specimens in the $CaCl_2$ for 168 W/D cycles. This indicates the specimens in the $CaCl_2$ were deteriorating at the rate at least twice as fast as the specimens in the $MgCl_2$ solution.

Conclusions

- The RDME values of the specimens exposed to $MgCl_2$ stayed at the 100% level for almost 200 W/D cycles as opposed to about 30 cycles for specimens exposed to the $CaCl_2$. This indicates that the $CaCl_2$ solutions accelerate the deterioration rate to approximately 3 times that of the $MgCl_2$ solutions.
- The fly ash concrete demonstrates better performance compared with the Type I specimens.