EVALUATING FRESH AND HARDENED PROPERTIES OF SELF-CONSOLIDATING CONCRETE CONTAINING DIFFERENT SUPPLEMENTARY CEMENTITIOUS MATERIALS/FILLERS

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SESSION TITLE

Advancing Sustainability with Low Carbon Self-Consolidating Concrete

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Acknowledgments

- Iowa State University (ISU)
  - **Kejin Wang**
  - **Peter Taylor**
- Consultant
  - **Surendra P. Shah** (NWU)

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Objectives

How does supplementary cementitious material (SCM) type affect SCC properties?

- –Class C fly ash
- –Class F fly ash
- –GGBFS
- –Class F + Limestone powder

Contents

SCC Properties

- Fresh Concrete Properties
  - Rheology
  - Workability Properties
    - Filling Ability
    - Passing Ability
    - Static Stability
    - Dynamic Stability
  - Air Content
  - Workability Retention
- Early-Age Concrete Properties
  - Formwork Pressure
  - Heat of Hydration
  - Time of Setting
- Hardened Concrete Properties
  - Mechanical Properties
    - Compressive Strength
    - Modulus of Elasticity
    - Tensile Strength
    - Modulus of Rupture
    - Bond Strength
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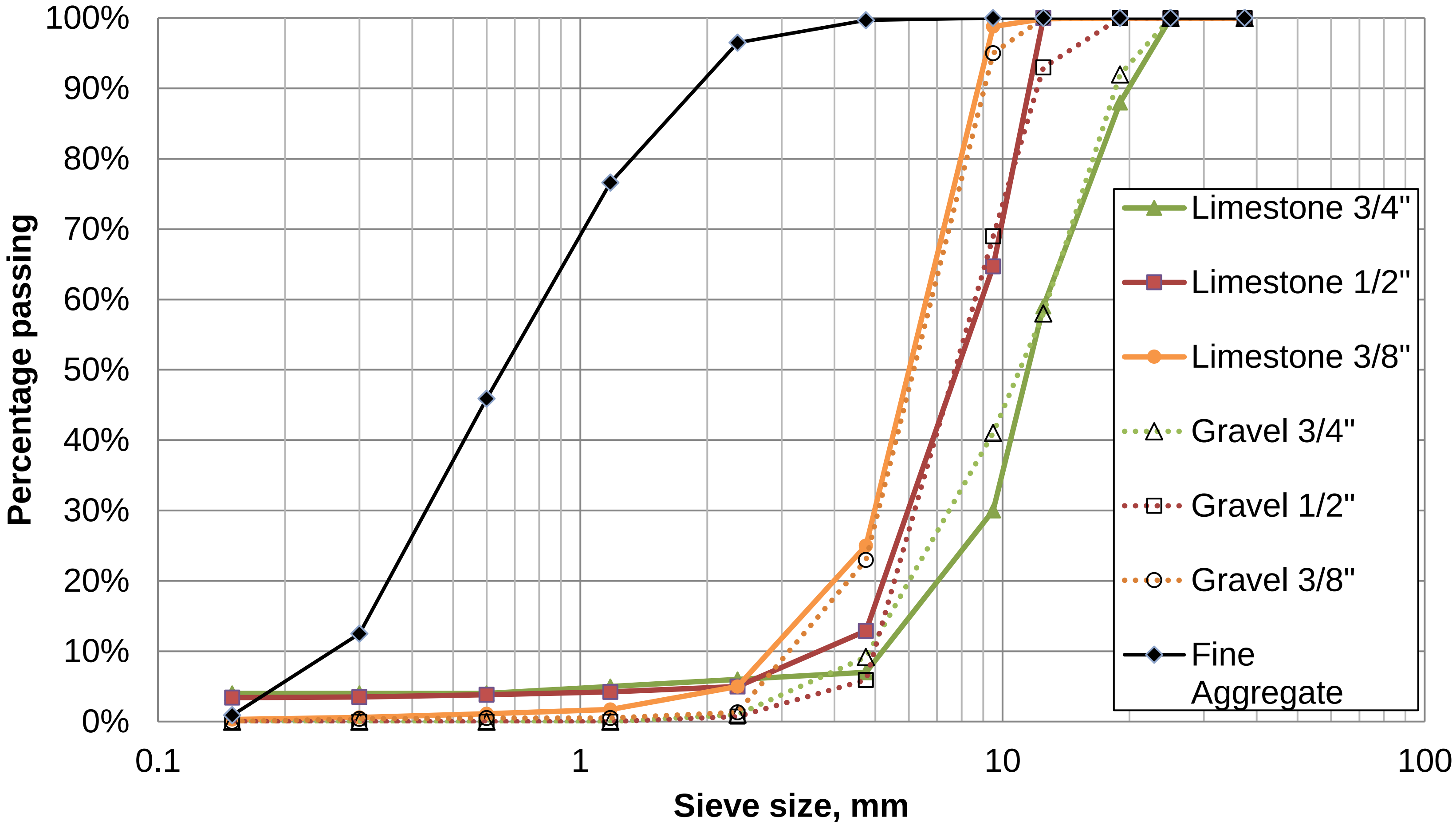
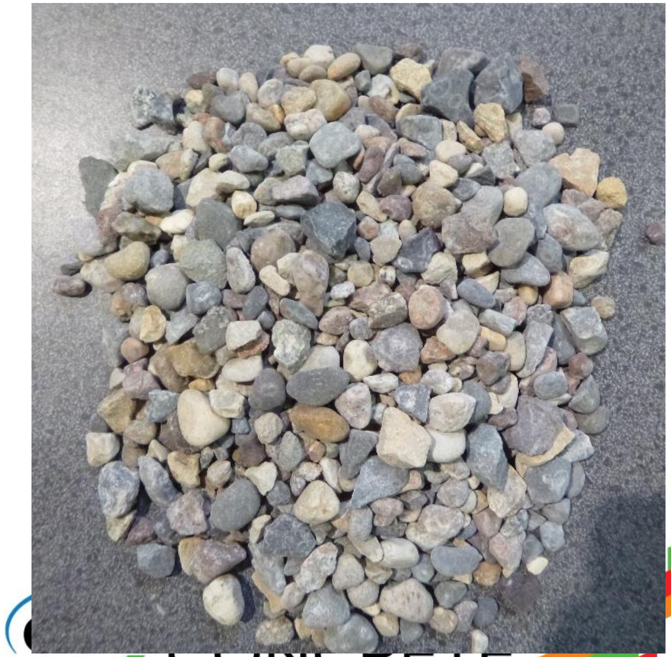
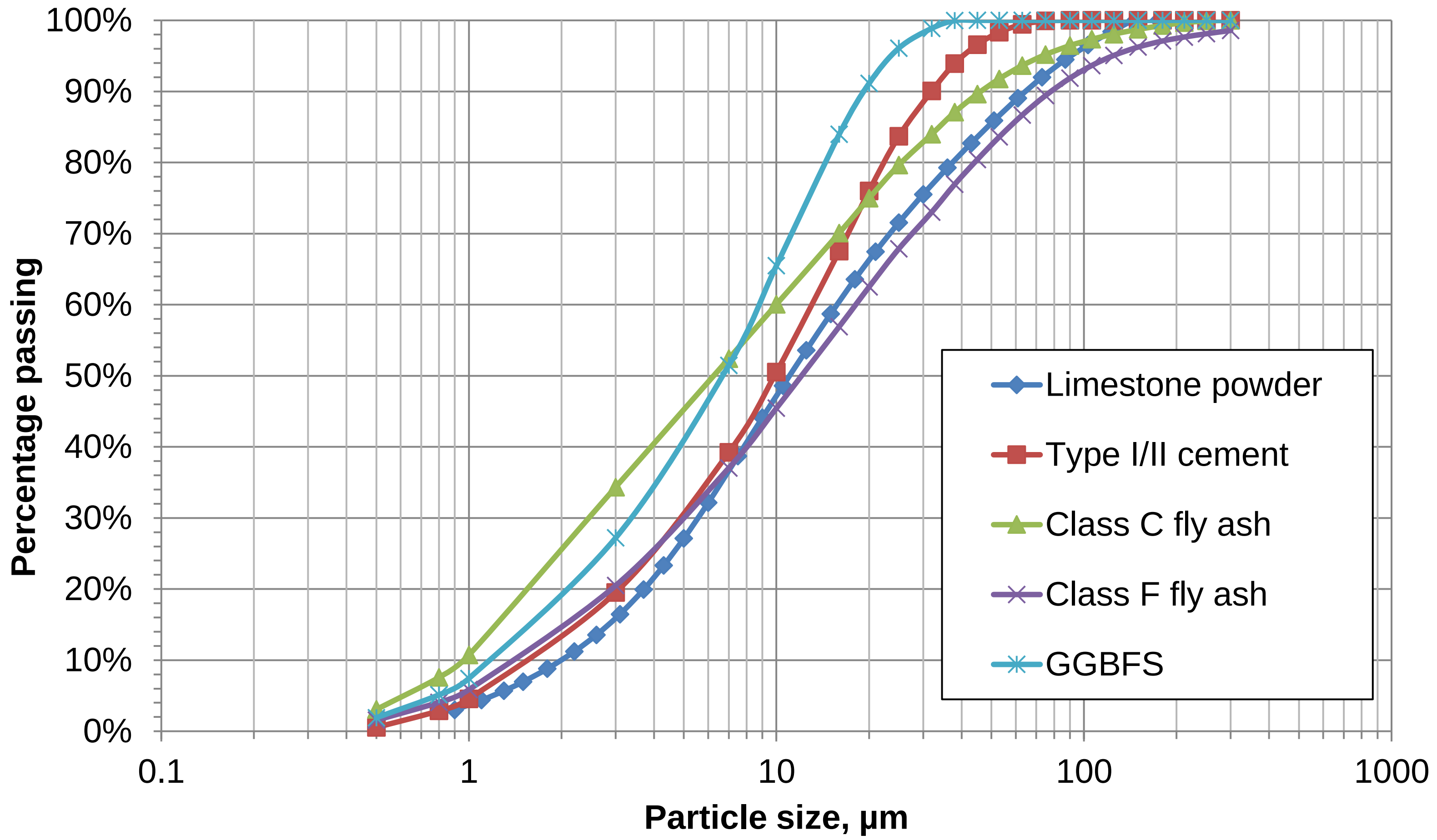
  - Visco-Elastic Properties
    - Drying Shrinkage
    - Restrained Shrinkage
    - Creep
  - Durability Properties
    - Air Void System
    - Surface Resistivity

SCC Mixtures





SCC Mixtures



SCC Mixtures (40 Mixes)

Coarse Aggregate		SCC Mixtures							
Type	NMSA (in.)	Cement Type I/II + 25% Class C Fly Ash		Cement Type I/II + 25% Class F Fly Ash		Cement Type I/II + 30% GGBFS		Cement Type I/II + 20% F Ash+15% LSP	
		Low Slump Flow	High Slump Flow	Low Slump Flow	High Slump Flow	Low Slump Flow	High Slump Flow	Low Slump Flow	High Slump Flow
Crushed Limestone (AASHTO M43)	3/4 (No. 67)	X	X	X	X	X	X	X	X
	1/2 (No. 78)	X	X	X	X	X	X	X	X
	3/8 (No. 8)		X		X		X		X
Natural Gravel (AASHTO M43)	3/4 (No. 67)	X	X	X	X	X	X	X	X
	1/2 (No. 78)	X	X	X	X	X	X	X	X
	3/8 (No. 8)		X		X		X		X
Number of Mixtures		**4**	**6**	**4**	**6**	**4**	**6**	**4**	**6**

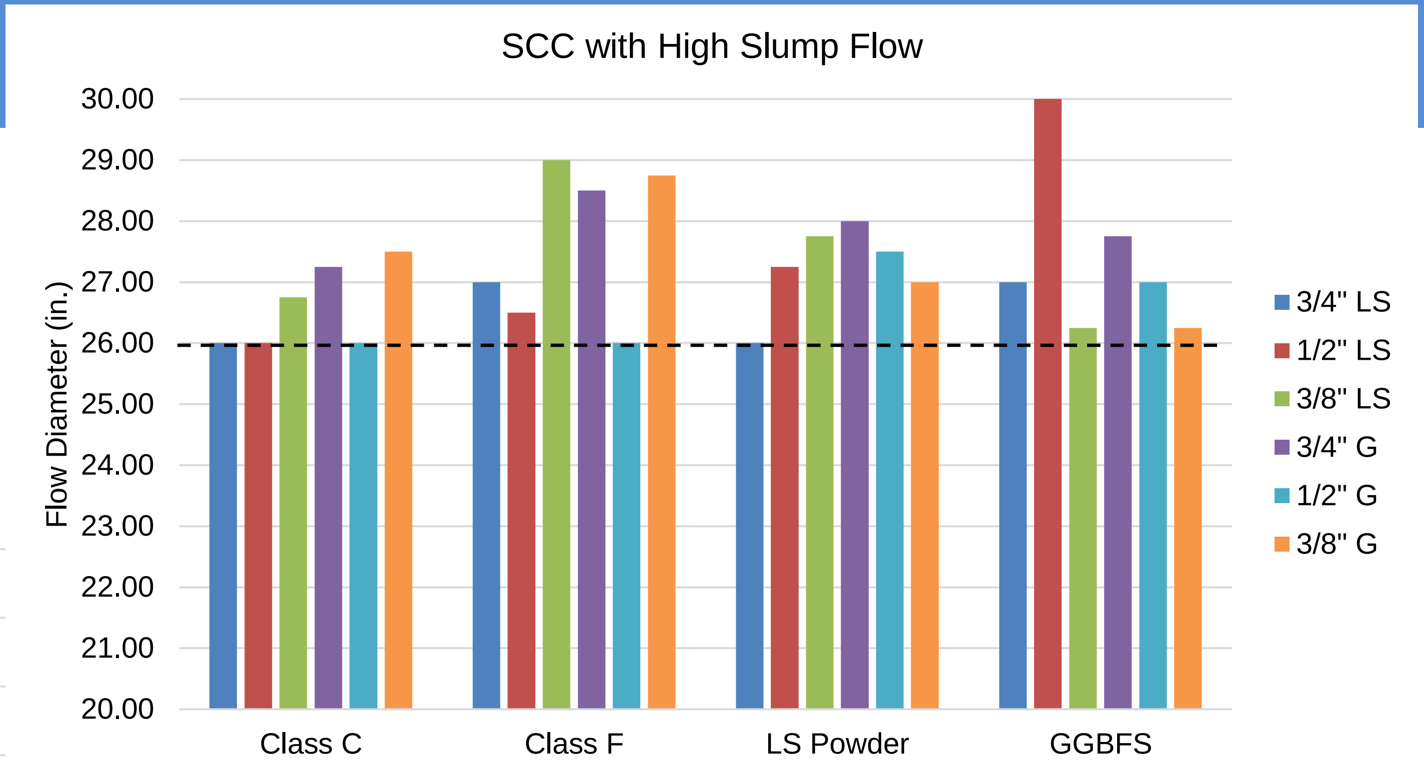
Low-Slump Flow 22”-26”

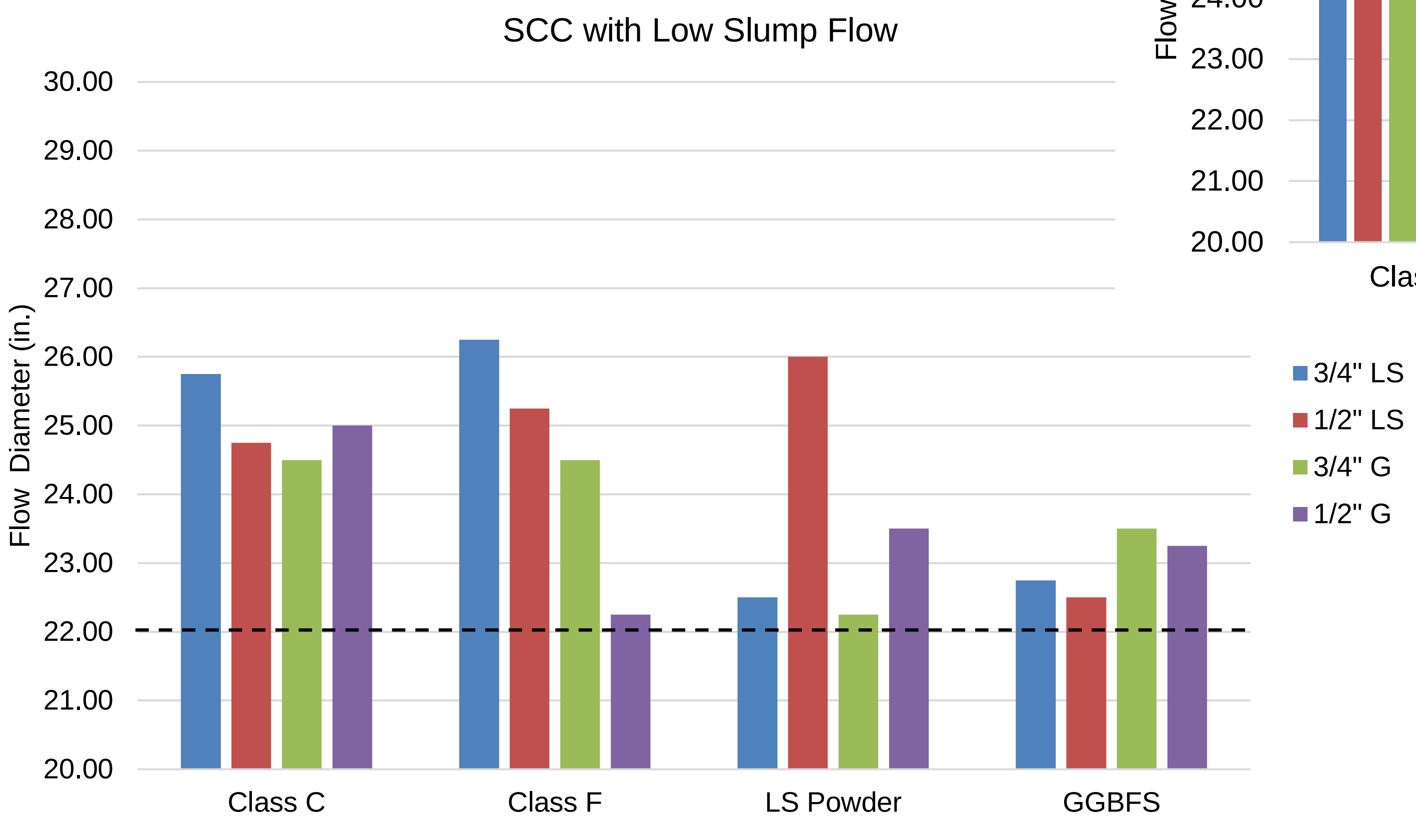
High-Slump Flow 26”-30”

SCC Mixtures (with limestone aggregate)

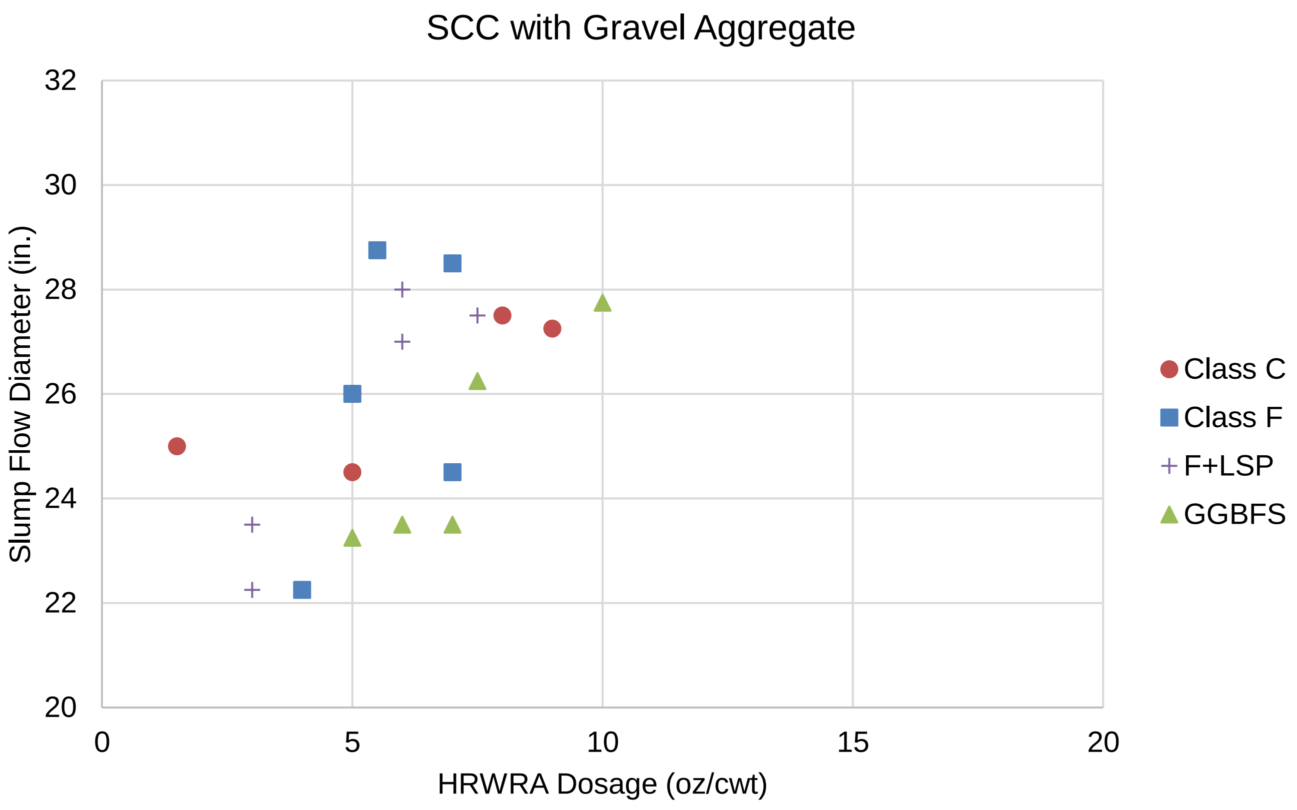
Mixture Type	SCC Mixtures																			
SCMs/Fillers	25% Class C Fly Ash					25% Class F Fly Ash					30% GGBFS					20% Class F Fly Ash + 15% LSP				
Flowability	Low slump flow		High slump flow			Low slump flow		High slump flow			Low slump flow		High slump flow			Low slump flow		High slump flow		
NMSA, in.	3/4	1/2	3/4	1/2	3/8	3/4	1/2	3/4	1/2	3/8	3/4	1/2	3/4	1/2	3/8	3/4	1/2	3/4	1/2	3/8
Mixture ID	111	121	211	221	222	111	121	211	221	222	111	121	211	221	222	111	121	211	221	222
Cement Type I/II, lb/cy	531	535	568	572	587	531	535	568	572	587	521	525	539	543	558	456	460	488	491	504
SCM, lb/cy	177	178	189	191	196	177	178	189	191	196	223	225	231	233	239	140	141	150	151	155
Filler, lb/cy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	105	106	113	113	116
Coarse Agg., lb/cy	1,542	1,462	1,518	1,439	1,334	1,542	1,462	1,518	1,439	1,334	1,542	1,462	1,530	1,450	1,345	1,542	1,462	1,518	1,439	1,334
Natural Sand, lb/cy	1,262	1,297	1,242	1,276	1,334	1,262	1,297	1,242	1,276	1,334	1,262	1,297	1,252	1,286	1,345	1,262	1,297	1,242	1,276	1,334
Water, lb/cy	280	295	280	295	305	280	295	280	295	305	280	295	280	295	305	280	295	280	295	305
HRWRA, oz/cwt	12.0	14.0	12.0	16.0	13.0	6.0	4.0	8.0	8.0	13.0	12.0	10.0	18.0	16.0	15.0	11.0	9.0	12.0	12.0	15.0
VMA, oz/cwt	0.0	0.0	6.0	0.0	0.0	3.0	0.0	3.0	6.0	0.0	0.0	0.0	3.0	3.0	0.0	0.0	0.0	3.0	6.0	0.0
AEA, oz/cwt	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Total Weight, lb/cy	3,792	3,767	3,797	3,772	3,756	3,792	3,767	3,797	3,772	3,756	3,828	3,803	3,832	3,807	3,792	3,786	3,761	3,790	3,765	3,749
Total Aggregate, lb/cy	2,804	2,759	2,760	2,714	2,669	2,804	2,759	2,760	2,714	2,669	2,804	2,759	2,782	2,737	2,691	2,804	2,759	2,760	2,714	2,669
Total Powder, lb/cy	708	713	757	763	783	708	713	757	763	783	744	750	770	776	797	702	707	751	756	776
W/P Ratio	0.40	0.41	0.37	0.39	0.39	0.40	0.41	0.37	0.39	0.39	0.38	0.39	0.36	0.38	0.38	0.40	0.42	0.37	0.39	0.39
S/A Ratio	0.45	0.47	0.45	0.47	0.50	0.45	0.47	0.45	0.47	0.50	0.45	0.47	0.45	0.47	0.50	0.45	0.47	0.45	0.47	0.50
Paste Volume %	37.0%	38.0%	38.0%	39.0%	40.0%	37.0%	38.0%	38.0%	39.0%	40.0%	37.0%	38.0%	37.5%	38.5%	39.5%	37.0%	38.0%	38.0%	39.0%	40.0%
Coarse Agg. Vol. %	34.4%	32.6%	33.9%	32.1%	29.8%	34.4%	32.6%	33.9%	32.1%	29.8%	34.4%	32.6%	34.1%	32.4%	30.0%	34.4%	32.6%	33.9%	32.1%	29.8%

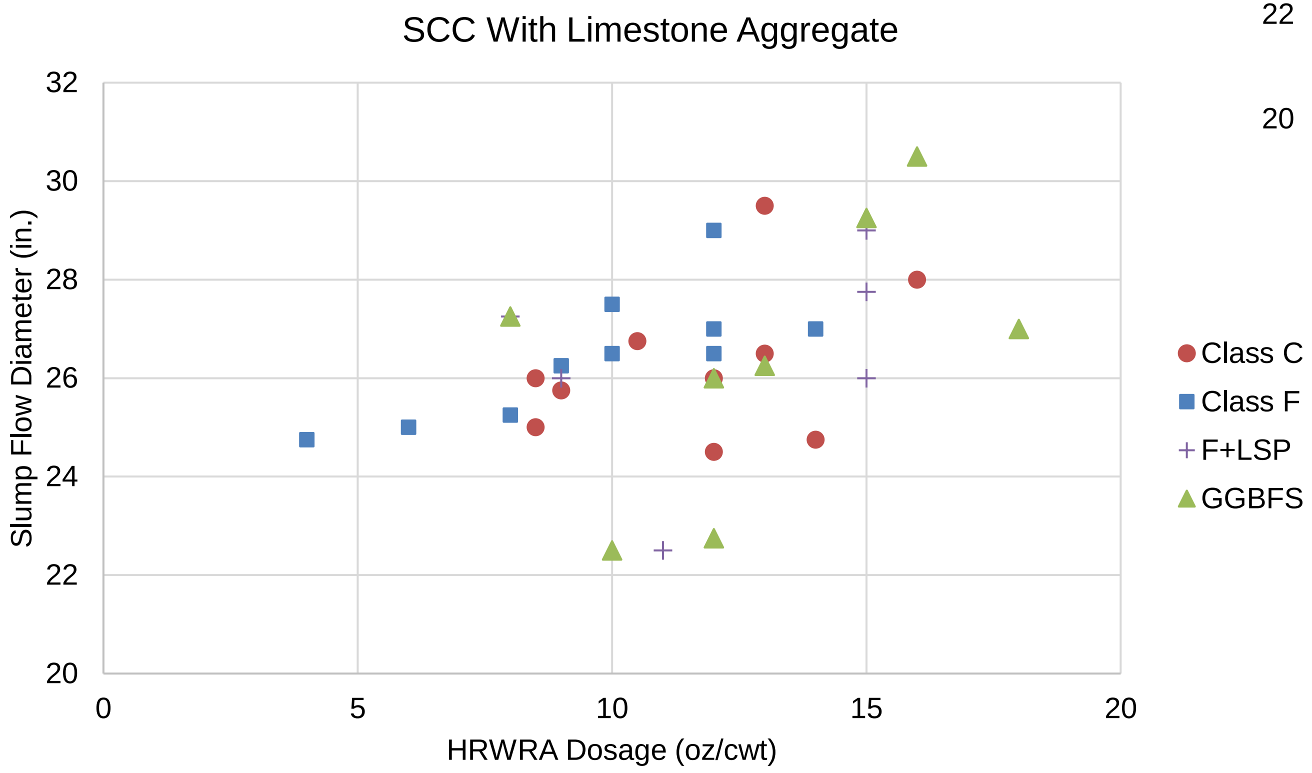
Filling Ability ***(AASHTO T347) (ASTM C1611)***

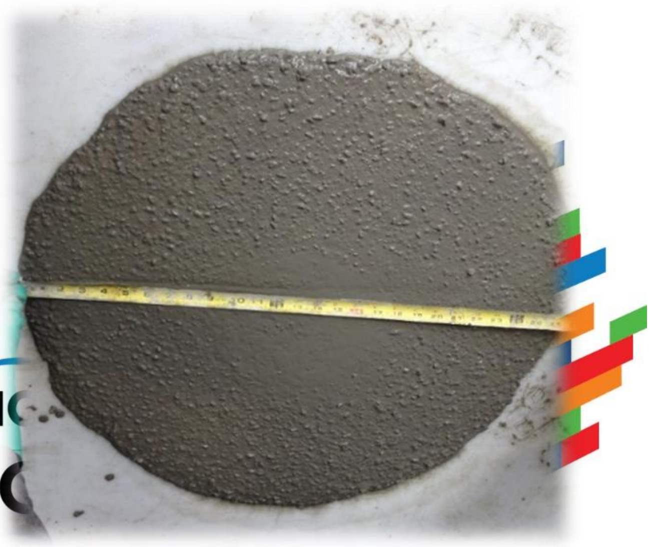




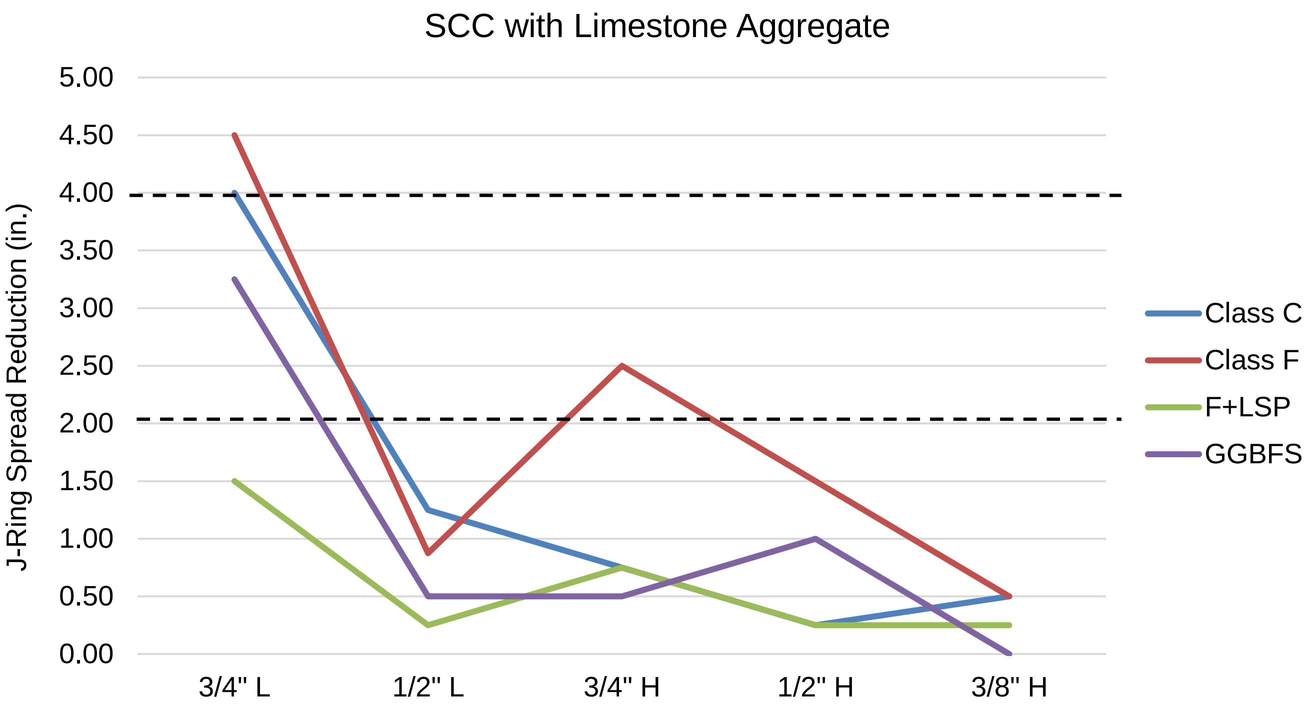
Filling Ability ***(AASHTO T347) (ASTM C1611)***

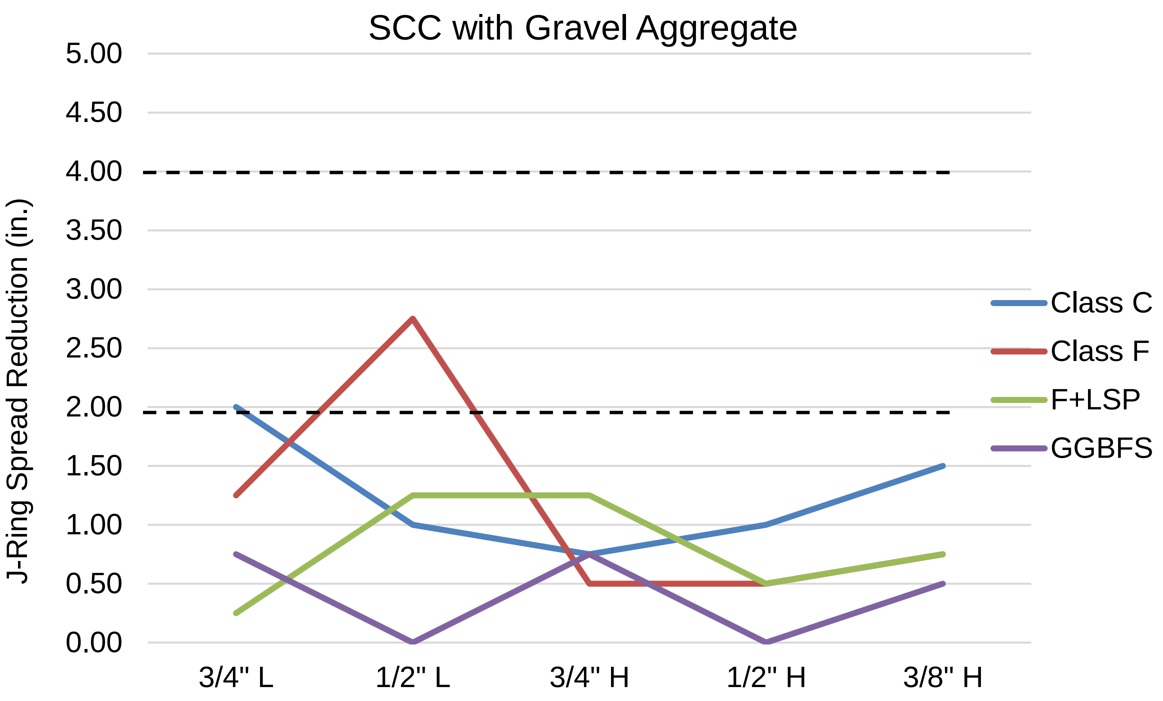




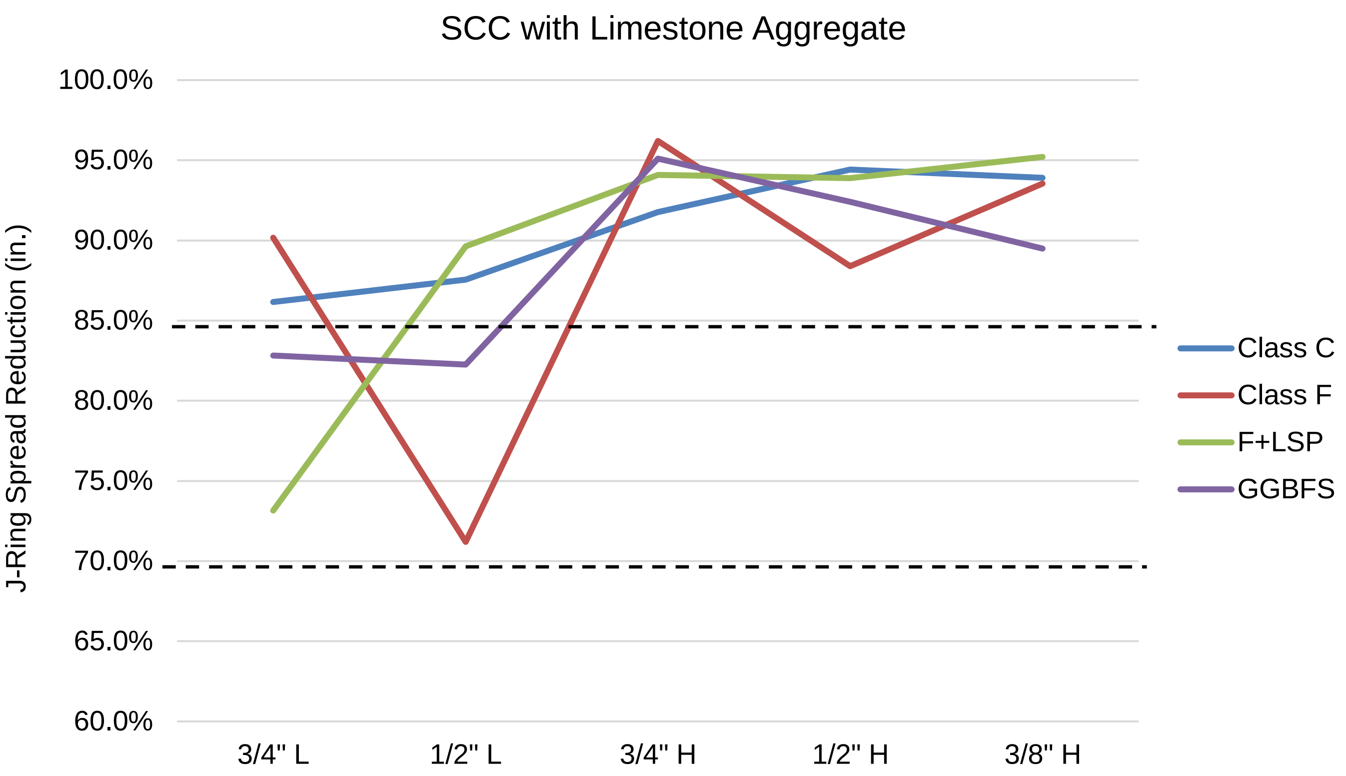


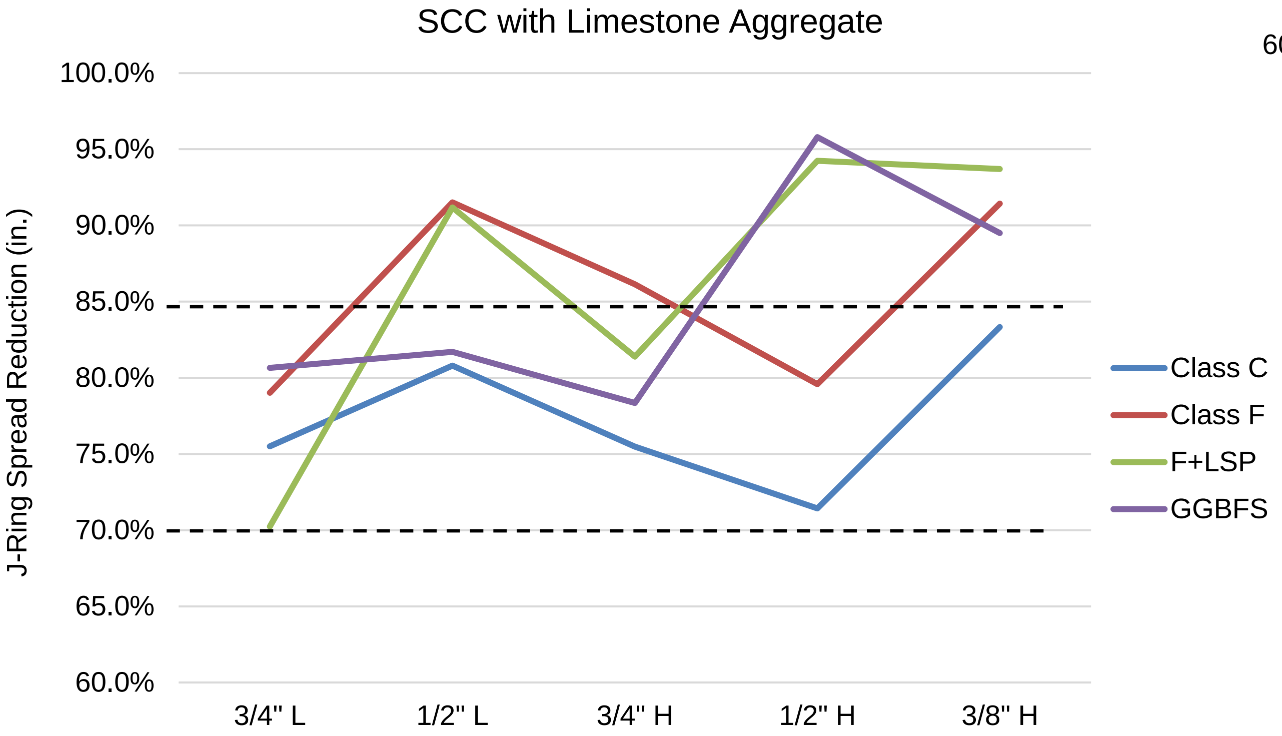
Passing Ability *(AASHTO T345)* *(ASTM C1621)*





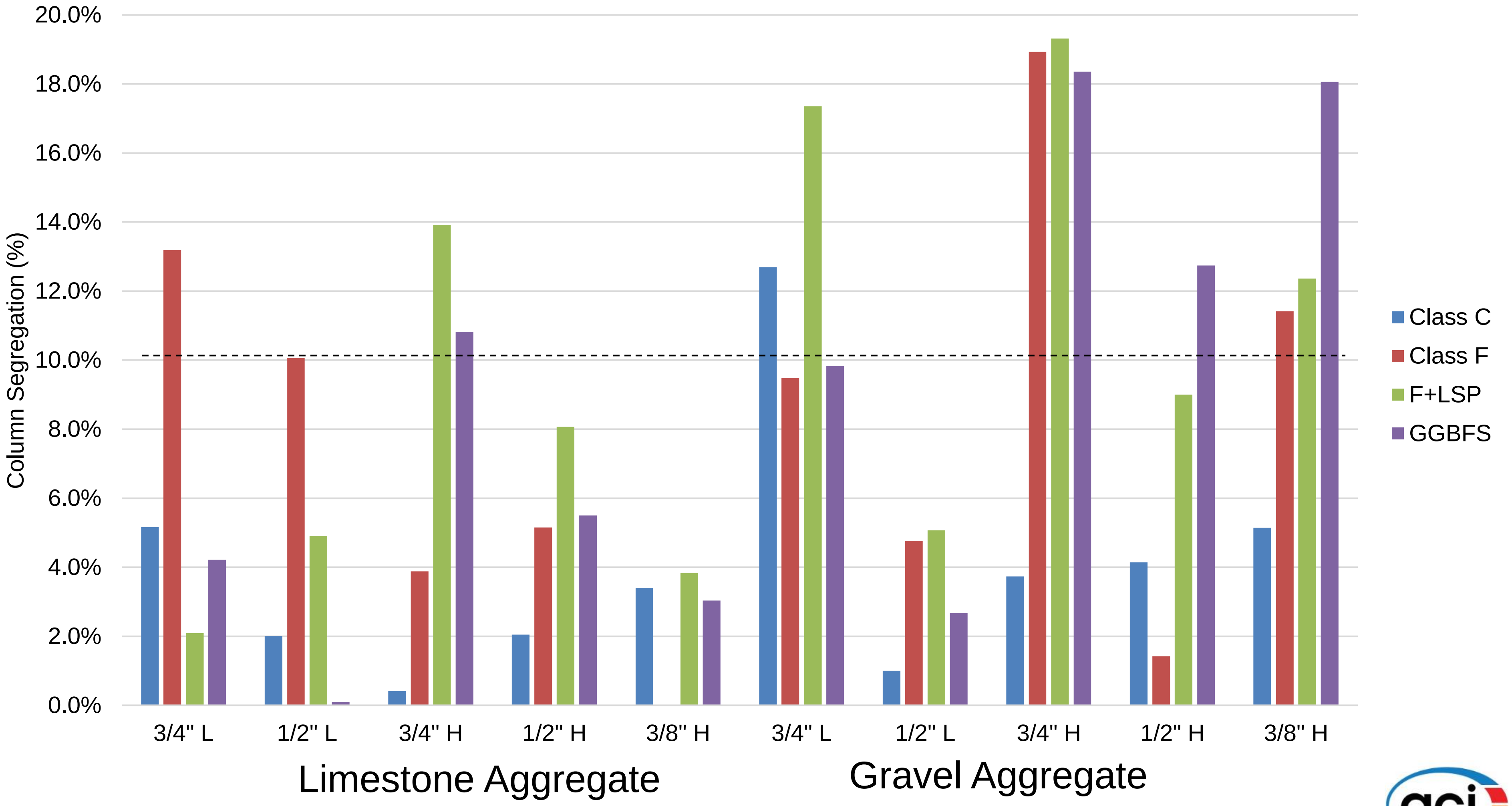
Filling Capacity *(AASHTO T349)*



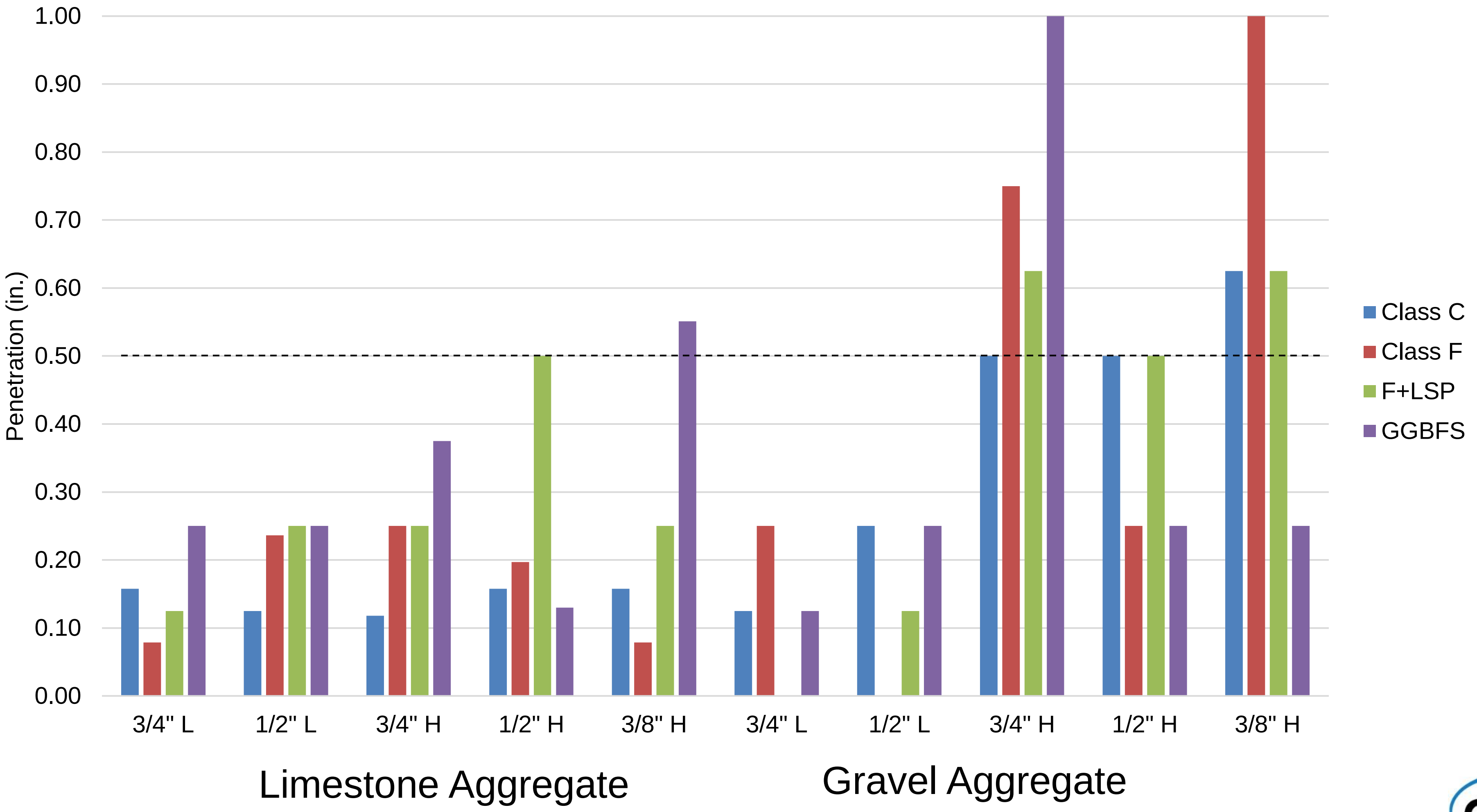


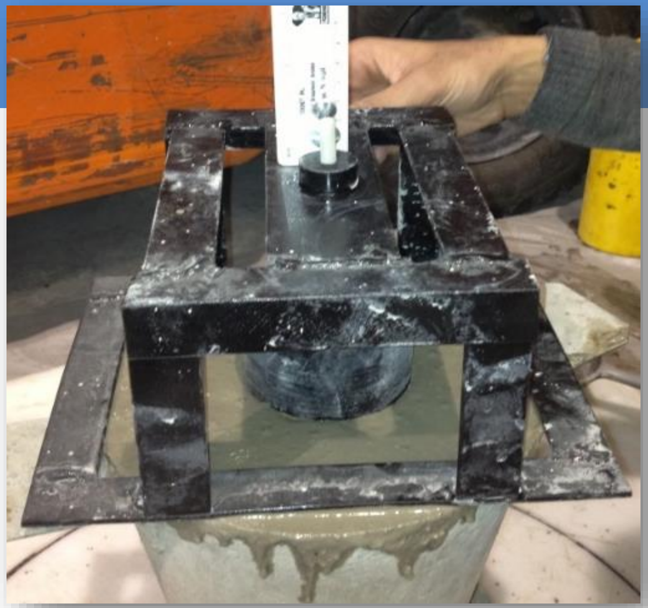
CONCRETE

Static Stability *(ASTM C1610)*



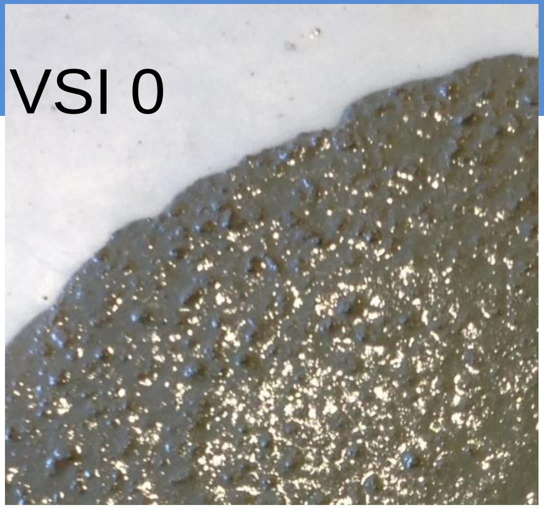
Static Stability ***(ASTM C1712)***

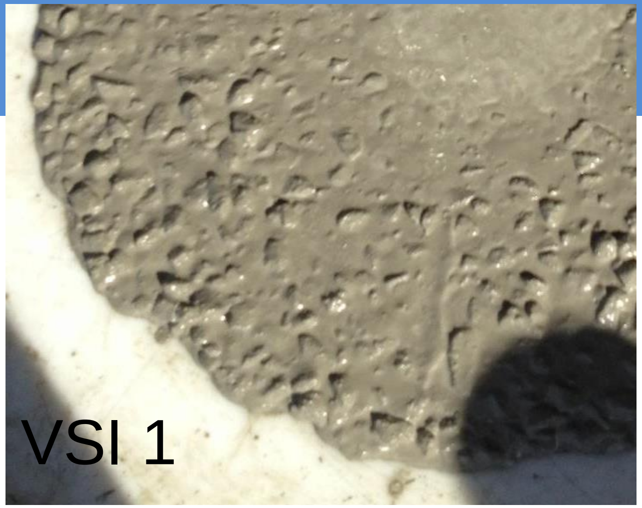


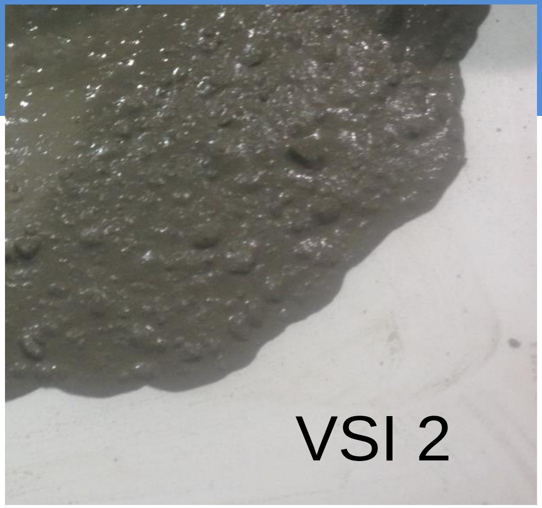


Visual Stability Index (VSI) ***(AASHTO T351) (ASTM C1611)***

SCM	VSI		HVSI	
	0	1	0	1
Class C	7	3	4	6
Class F	4	6	5	5
F + LSP	5	5	5	5
GGBFS	7	3	5	5







Hardened Visual Stability Index (HVSI) ***(AASHTO PP 58)***

HVSI 0

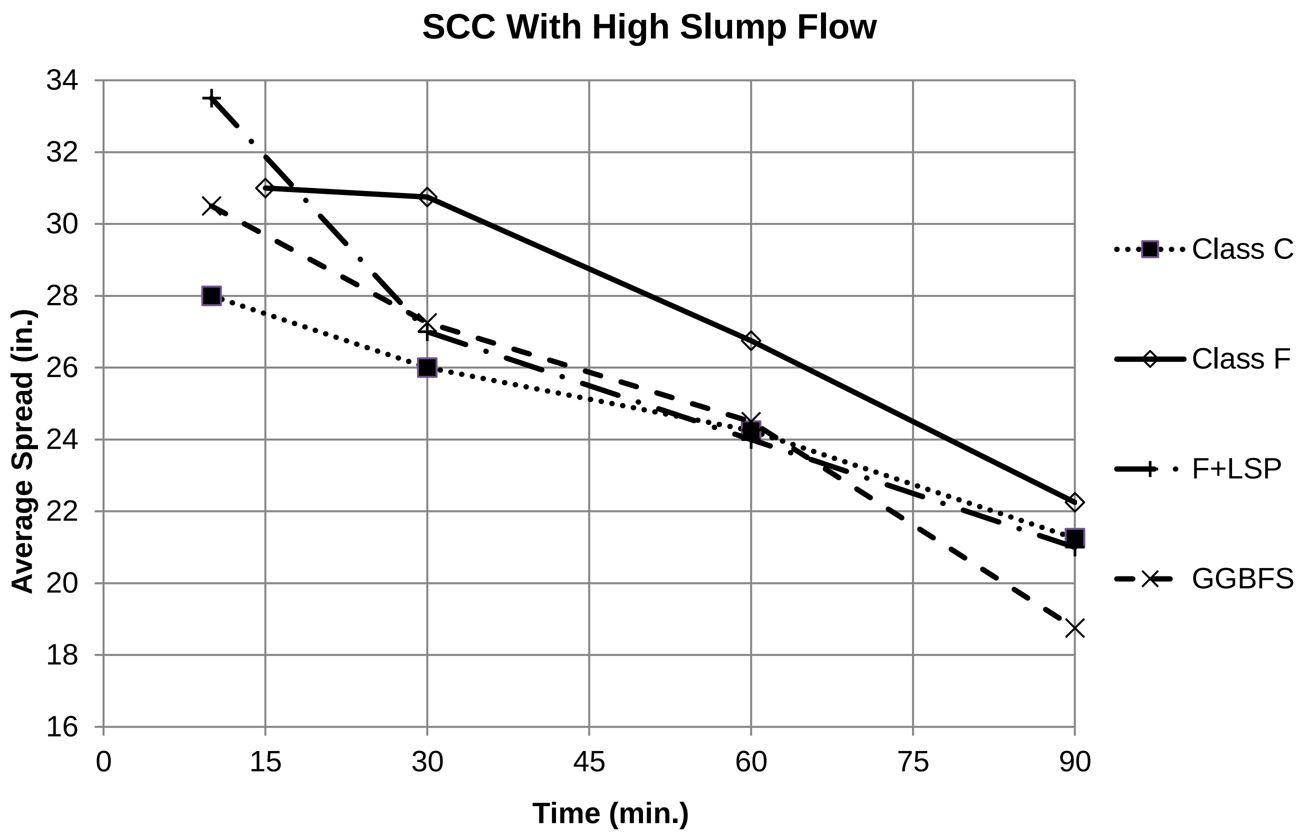
HVSI 1

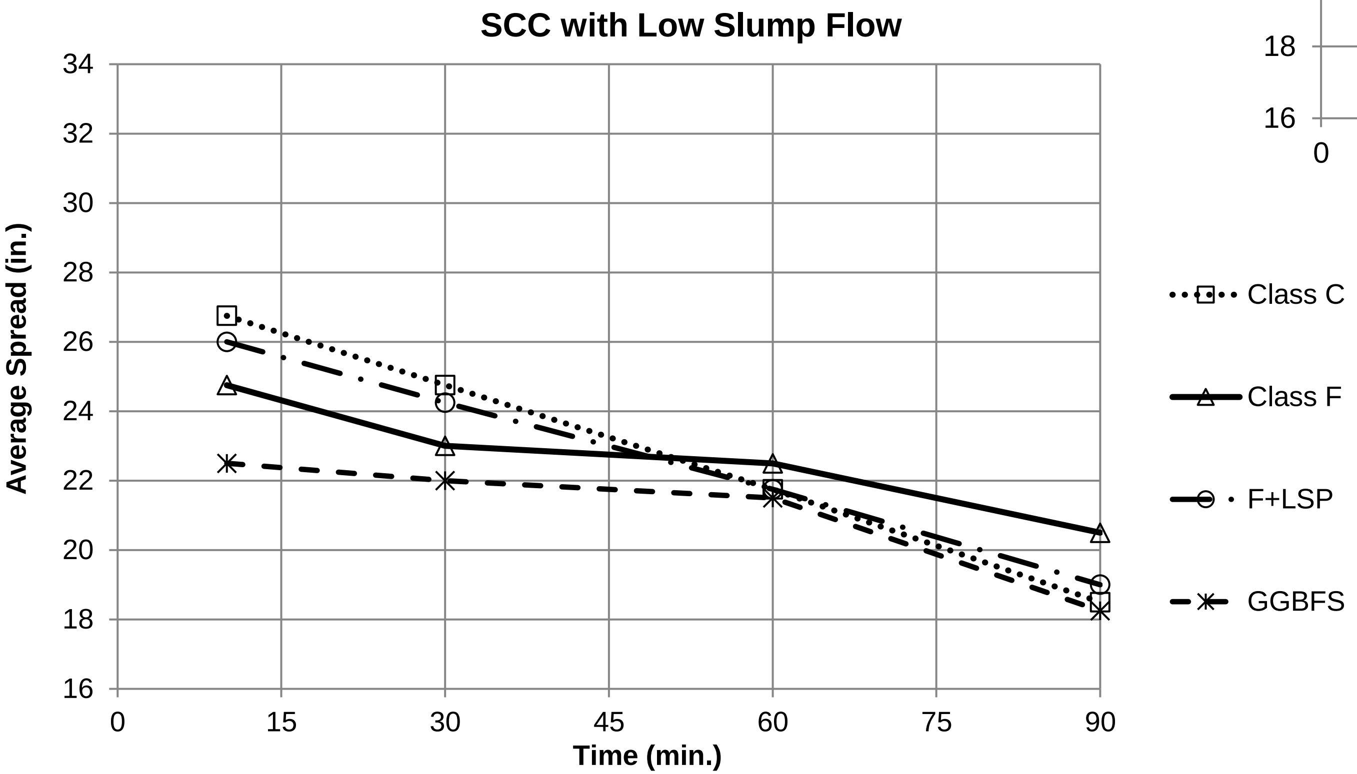
HVSI 2

Workability Retention

(AASHTO T347)

(ASTM C1611)

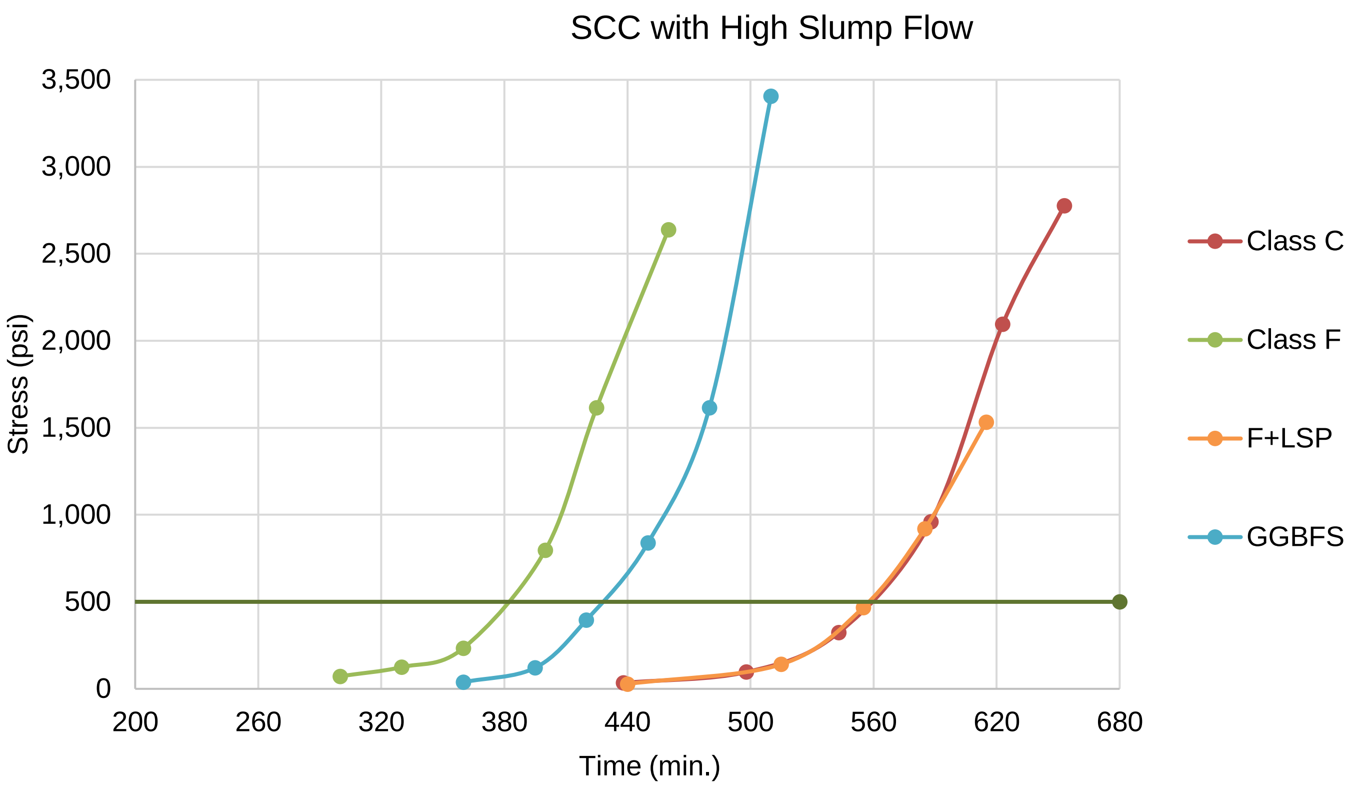


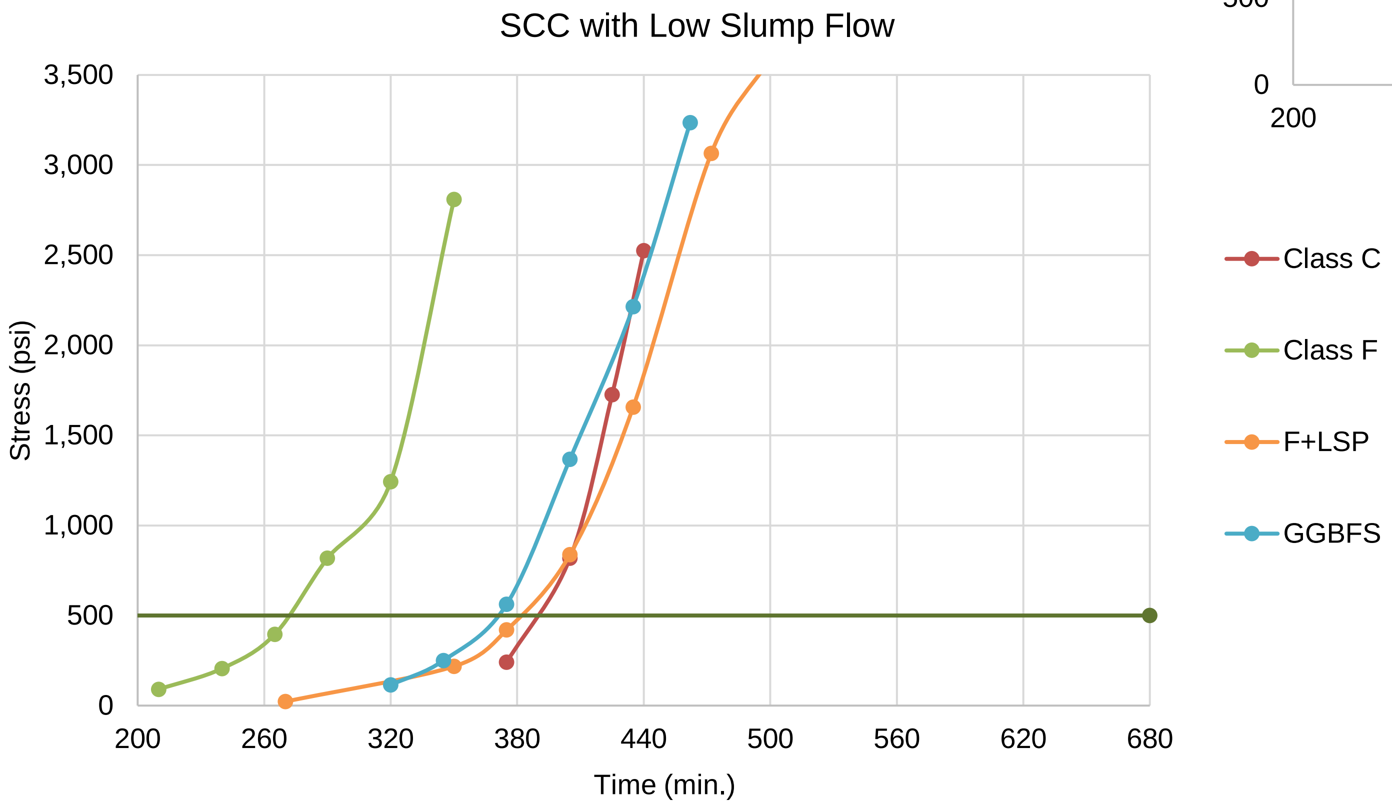


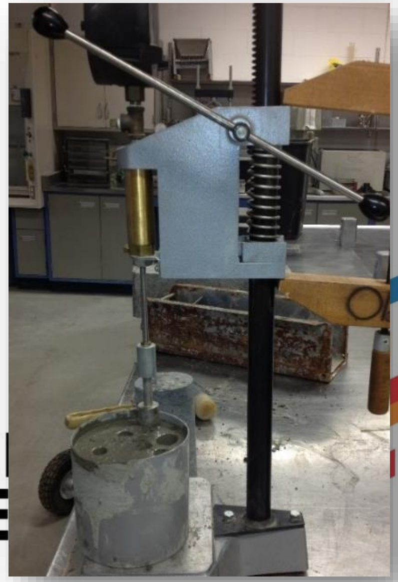
NCRETE

Time of Setting

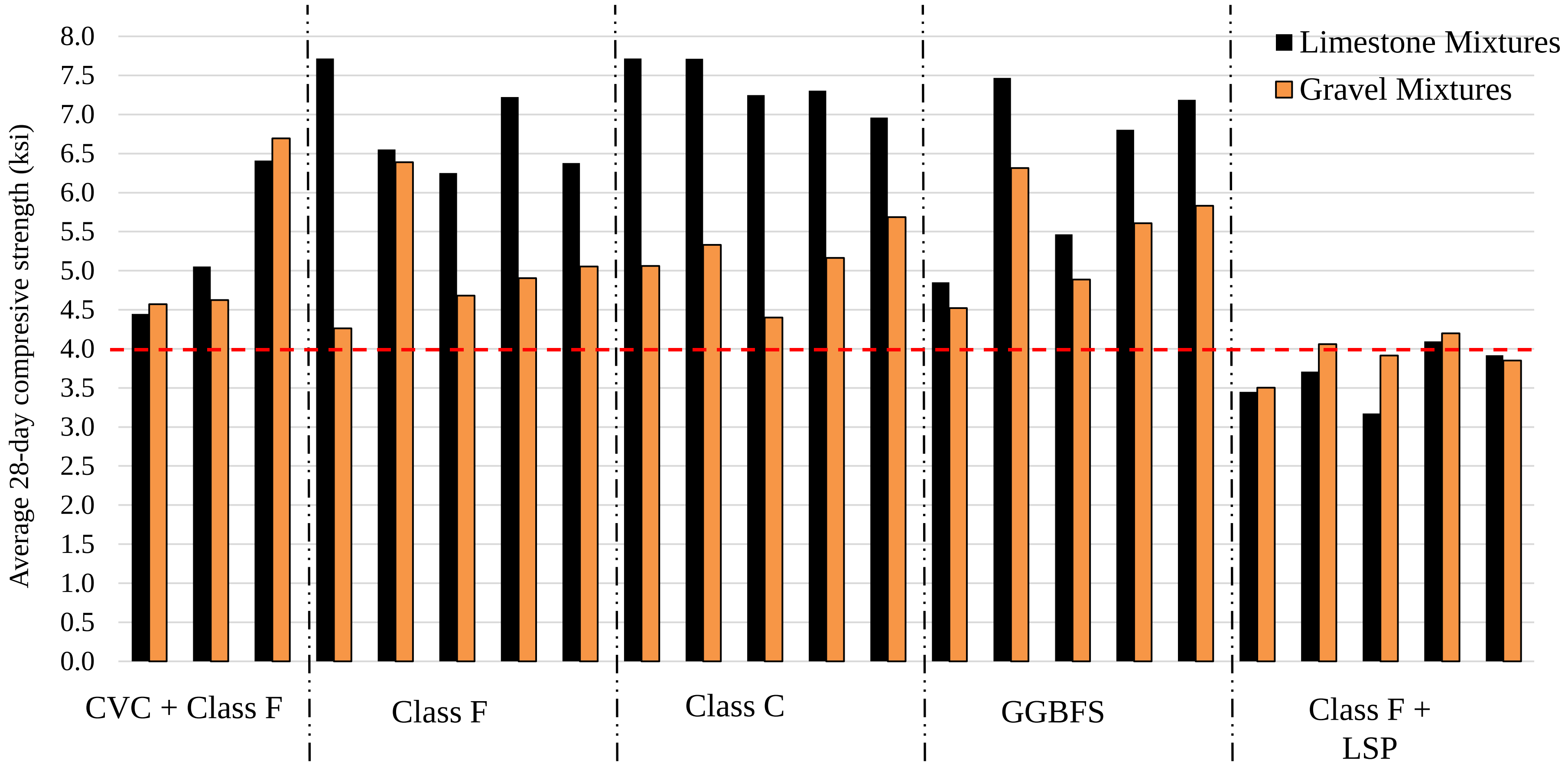
(AASHTO T197)







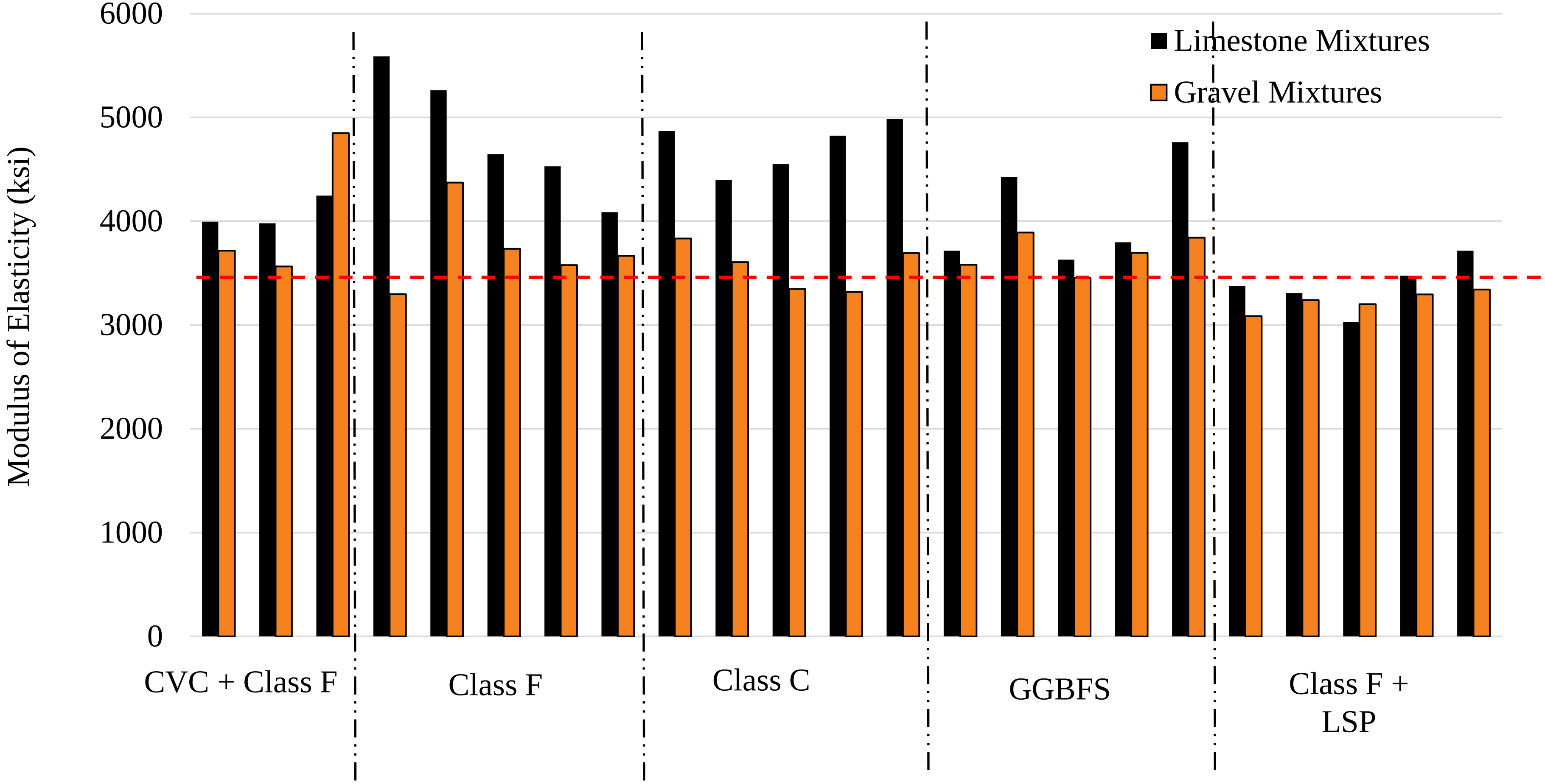
Compressive Strength (AASHTO T22) (ASTM C39)



Modulus of Elasticity (ASTM C469)

$$E = 33{,}000\,K_1\,w_c^{1.5}\sqrt{f_c}$$

AASHTO LRFD 5.4.2.4-1

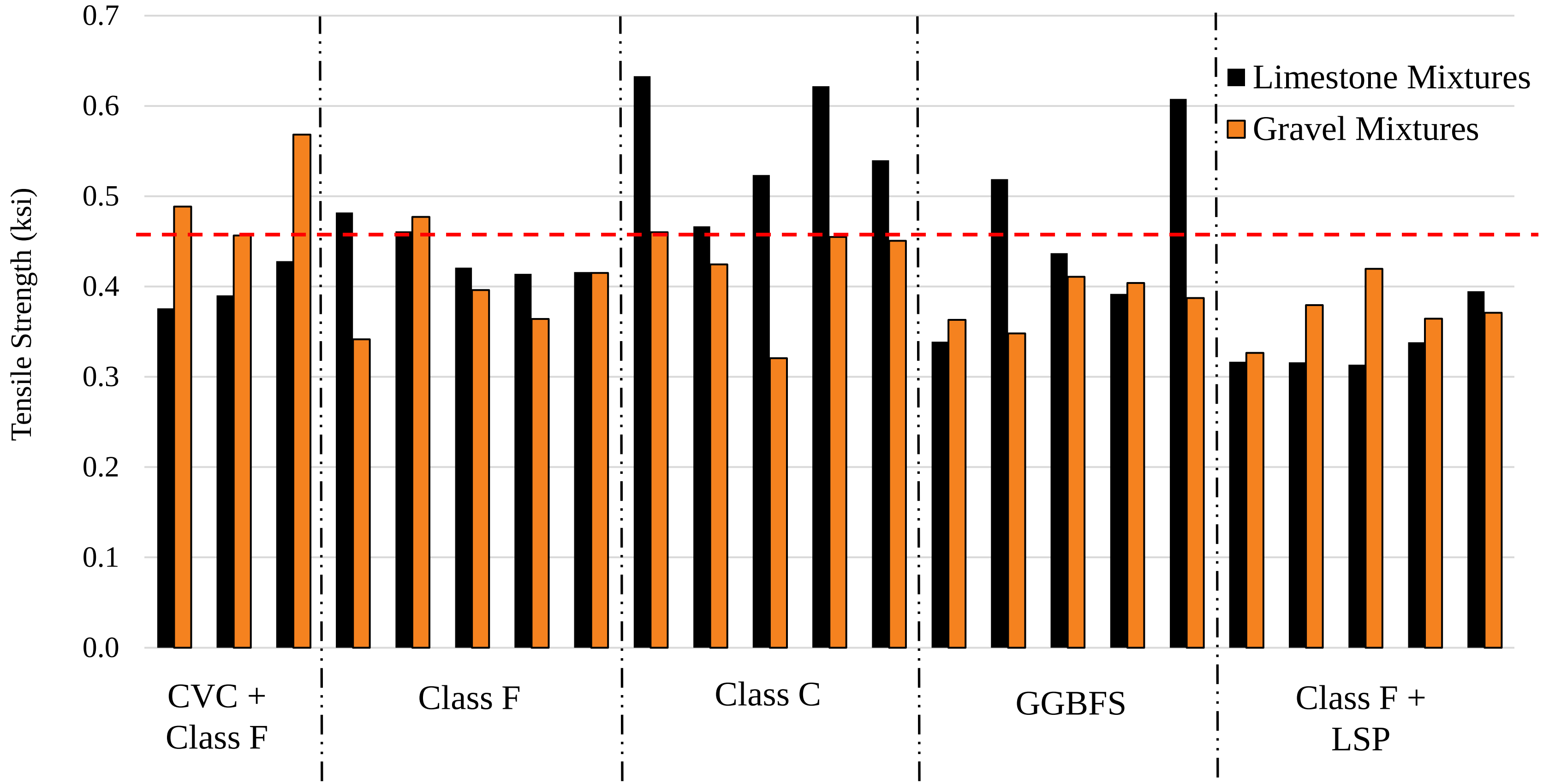


Splitting Tensile Strength

(AASHTO T198)
(ASTM C496)

$f_t = 0.23\sqrt{f_c}$

AASHTO LRFD C5.4.2.7

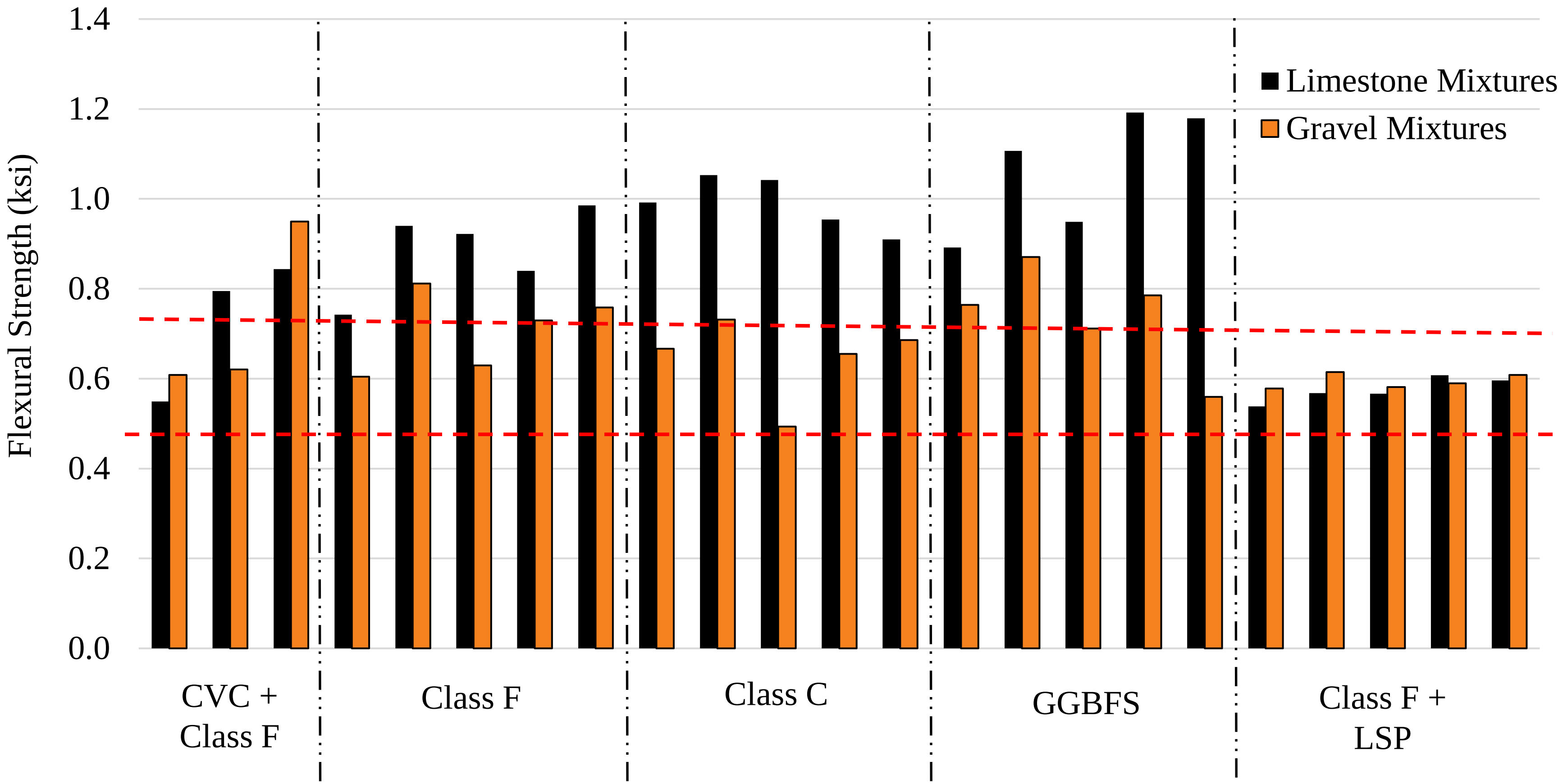


Flexural Strength

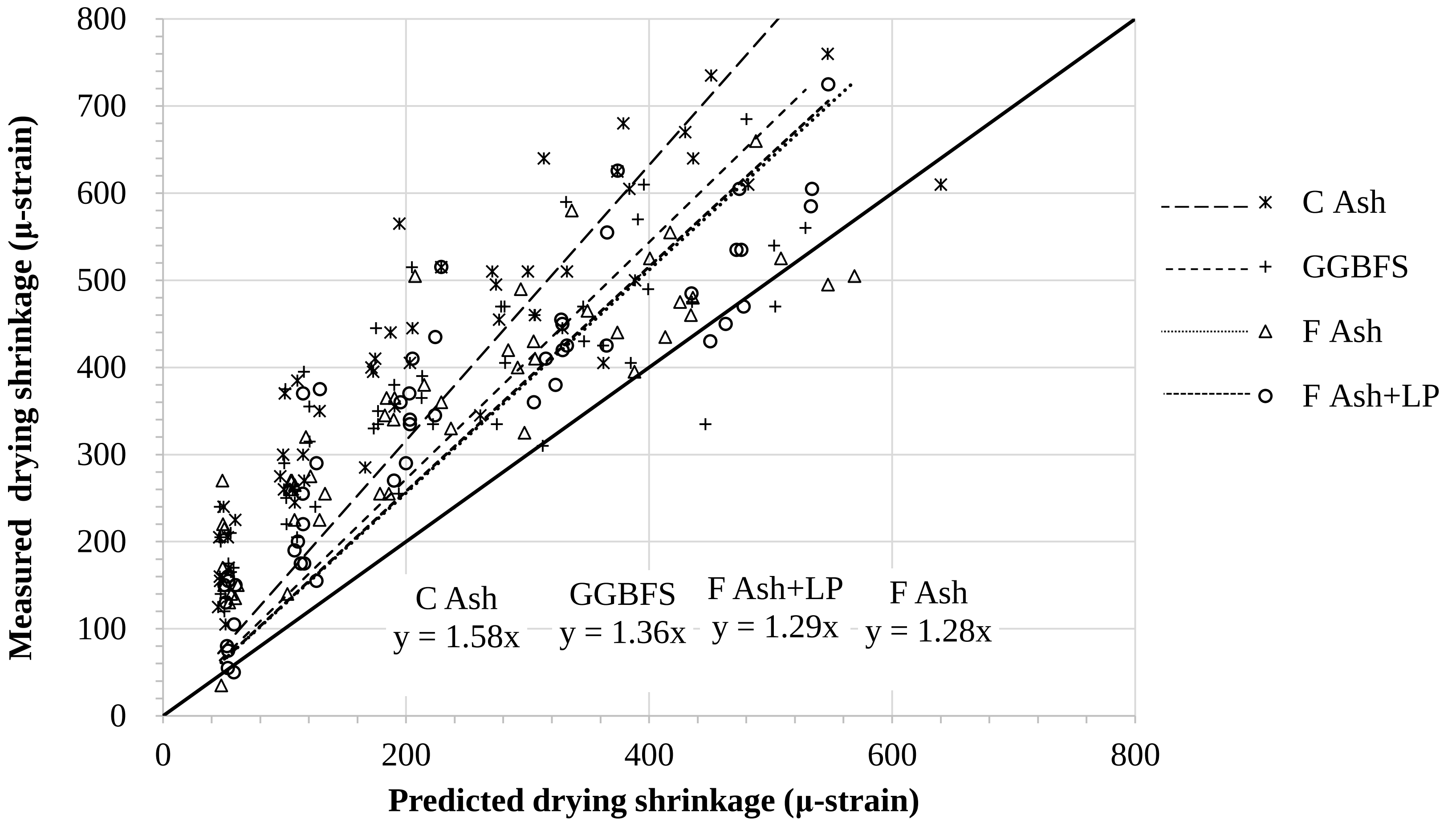
(AASHTO T97)
(ASTM C78)

MOR = 0.24 √f_c – 0. 37 √f_c

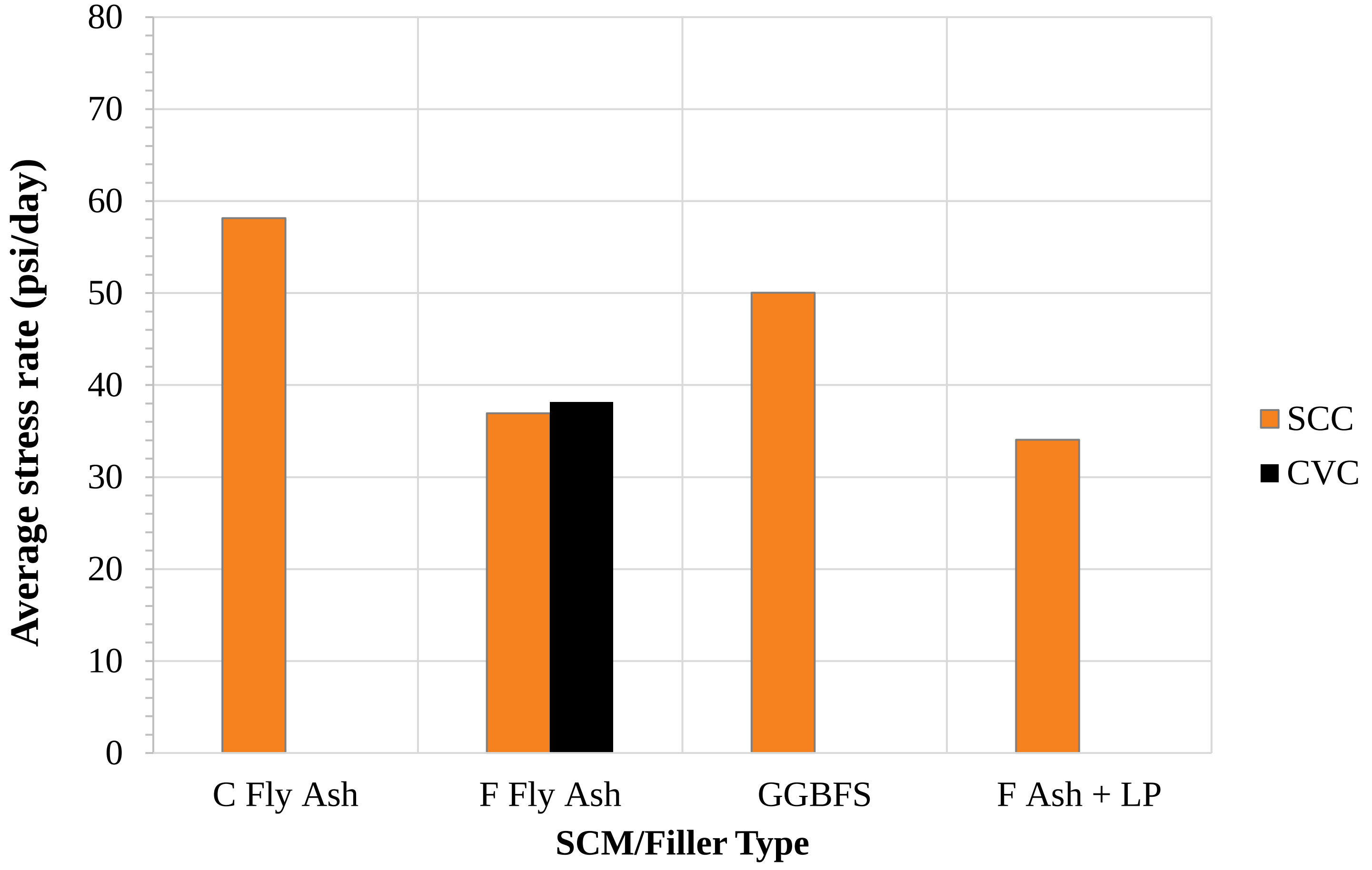
AASHTO LRFD C5.4.2.6



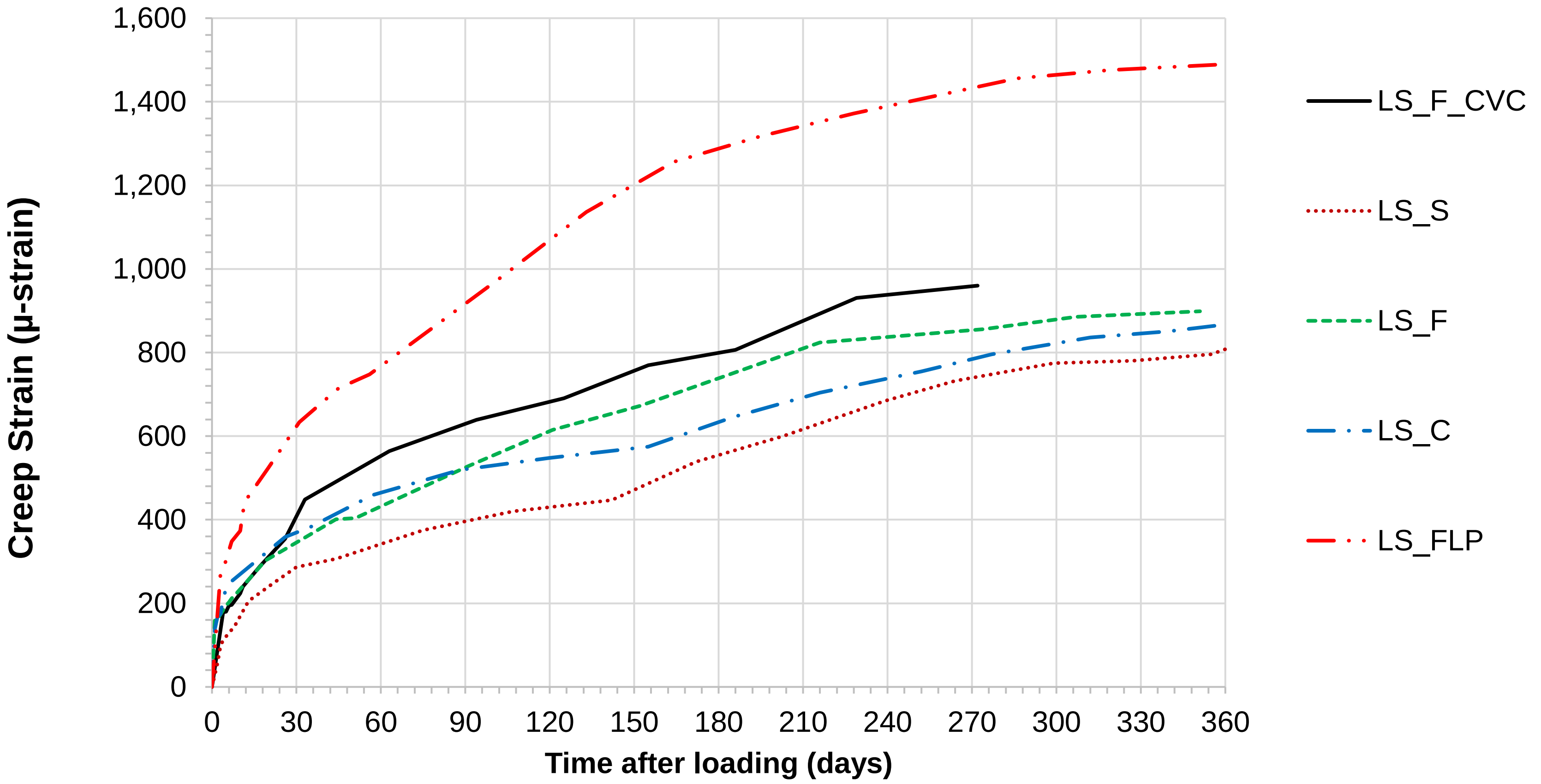
Drying (Free) Shrinkage **(AASHTO T160) (ASTM C157)**



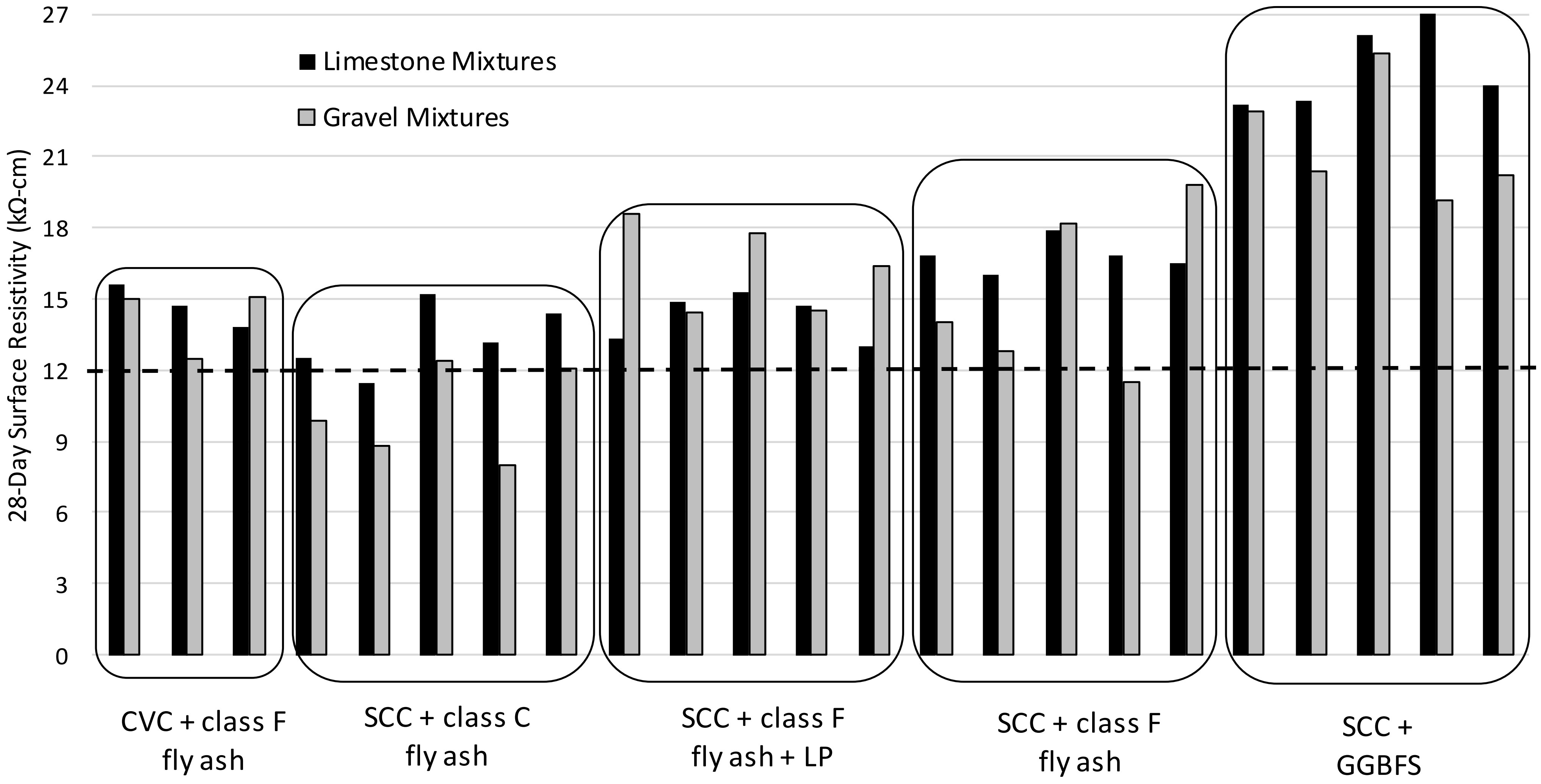
Restrained Shrinkage (ASTM C1581)



Creep (ASTM C512)



Surface Resistivity **(AASHTO TP 95)**



Conclusions

1. Changing the type of SCM/filler did not show consistent effect on the workability properties of SCC. The type of aggregate, its size, and dosage of HRWRA have more effect on workability.

2. SCC mixtures containing Class F fly ash had the shortest time of setting compared to those with other SCMs/filler.

3. SCC mixtures with LSP yield the lowest mechanical properties compared to those with other SCMs as it had the highest cement replacement percentage (35%).

4. SCC mixtures containing LSP yielded higher creep strains than those with SCMs.

5. SCC mixtures with class C fly ash yielded higher drying shrinkage than those with other SCMs/filler.

6. SCC mixtures with GGBFS have the highest surface resistivity compared to those with other SCMs/filler

Thank you

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