J.B. SPEED SCHOOL OF ENGINEERING

Early Strength Performance of Laps Splices of Rebar in Masonry

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INTRODUCTION

Masonry walls over 8 ft must be adequately braced during construction .

Standard Practice-2012 - two periods; initial period (t< 24 hours) and the intermediate period (initial period to final lateral support).

Initial period - the restricted area evacuated when the wind exceeds 20 MPH. (8-inch-thick hollow CMU wall to 10 ft - for most Block units).

In the intermediate period, areas evacuated if wind exceeds 35 MPH, and wall and braces must be able to resist forces from a 40 MPH wind load.

Internally bracing masonry walls used instead of external bracing - based on older research and may be overly conservative. Longer laps required for full yield

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INTRODUCTION

The goals of this investigation were to:

• 1. Determine masonry assembly performance with an out-of-plane cantilevered bending strain gradients in a typical wall CMU wall configuration using contemporary units, mortars, grouts and rebar.

• 2. Determine for different grout ages, moment capacity for an 8" CMU internally braced wall configuration

• 3. Determine if high early strength cement/admixtures can be used to improve early age performance of the internally braced masonry wall.

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TEST PROGRAM

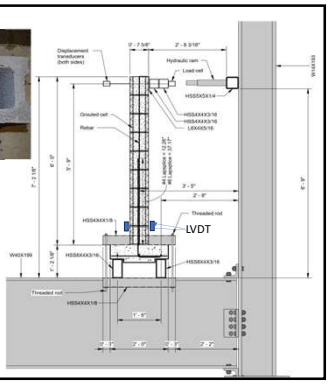
(15) #4 steel rebar

(15) #6 rebar.

Lap splice length of 12.3 in for the #4 37.2 in lap splices for the #6 rebar.

The walls were grouted and tested after allowing the grout to cure for 12 hours, 24 hours, 4 days and 28 days in lab air. 3 replicants

Grout compression specimens made for each wall



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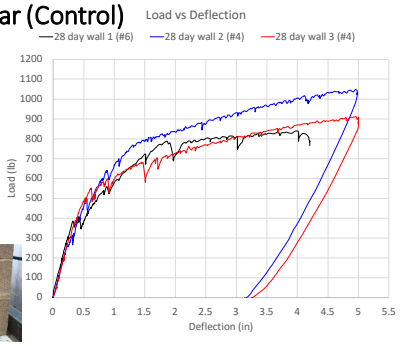
28 day Walls # 4 Rebar (Control)

Wall 1	839	lb
Wall 2	1048	lb
Wall 3	911	lb
Average	933	lb
STD	86.9	lb
COV	9.32%	

Grout 4827 – 8144 psi



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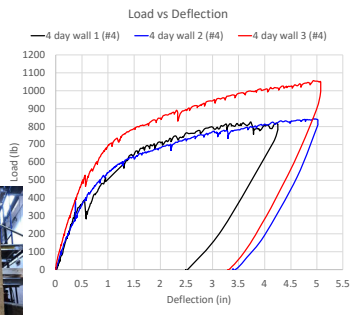
4 day walls #4 Rebar

Wall 1	825	lb
Wall 2	844	lb
Wall 3	1056	lb
Average	908	lb
STD	128	lb
COV	14%	

Grout 3527 – 5691 psi



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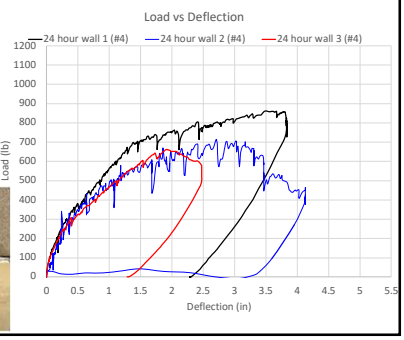
24 hour walls #4 Rebar

Wall 1	861 lb
Wall 2	714 lb
Wall 3	664 lb
Average	746 lb
STD	103 lb
COV	14%

Grout 898 – 1196 psi



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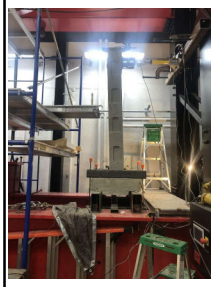

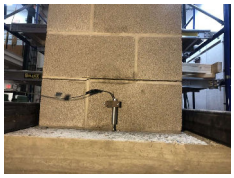

Test 1: 12 Hour

- Grout reached 593 psi.
- Maximum wall load was 323 lb.
- Maximum deflection at point load was 2.7 inches.
- Failure occurred primarily at the second mortar joint from the bottom.

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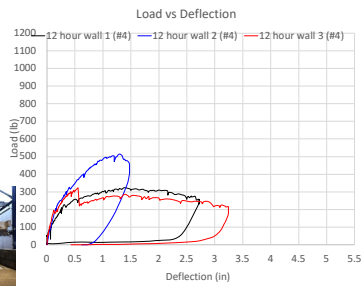
12 hour #4 Rebar

Wall 1	323 lb
Wall 2	513 lb
Wall 3	322 lb
Ave	386 lb
STD	110 lb
COV	28%

Grout 434 - 629 psi



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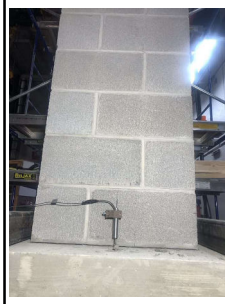

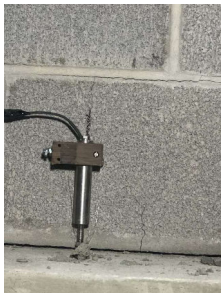

Test 1: 12 Hour High-Early Grout #4 rebar

- Grout reached 1093 psi.
- Maximum wall load was 801 lb.
- Maximum deflection at point load was 2.2 inches.
- Failure occurred primarily at the base.
- Vertical cracking mid height

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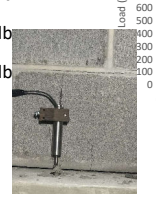
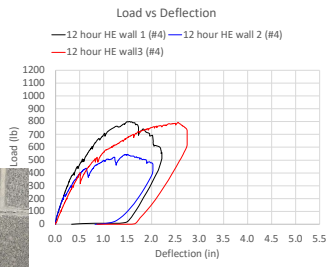
12 hour High-Early # 4 rebar

Wall 1 High-Early	801	lb
Wall 2 High-Early	545	lb
W 3 High-Early	795	lb
Average	713	lb
STD	119.	lb
COV	17%	

Grout 768 - 1093 psi





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- Cleanouts were cut into all (15) # 6
- Cut section was mortared back into place on the compression side of the wall.
- Some blowouts occurred during grouting and were repaired, loads seemed to be unaffected.

#6 REBAR Clean outs

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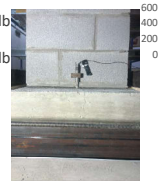
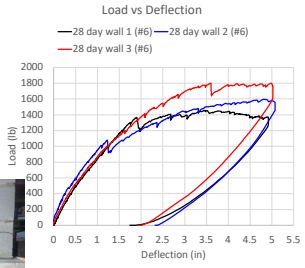
28 day #6 Rebar

Wall 1	1455	lb
Wall 2	1592	lb
Wall 3	1800	lb
Average	1616	lb
STDV	141.7	lb
COV	8.77%	

Grout 3275 - 3728 psi





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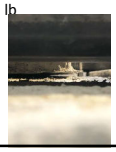
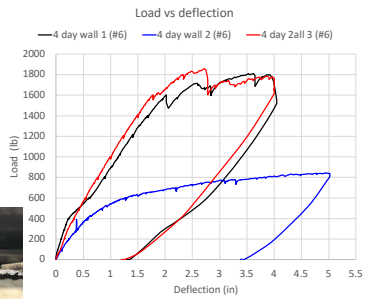
4 day # 6 Rebar

Wall 1	1810	lb
Wall 2	844	lb
Wall 3	1856	lb
Average	1503	lb
STDV	467	lb
COV	31.0%	

Grout 934 - 2438 psi





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24 hour # 6 Rebar

Wall 1	12201	lb
Wall 2	1447	lb
Wall 3	1656	lb
Average	1080	lb
STDV	177	lb
COV	16.4%	

Grout 212 - 2268 psi

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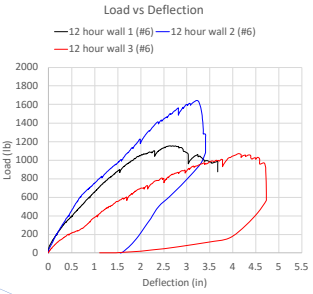
12 hour # 6 rebar

Wall 1	1155 lb
Wall 2	1642 lb
Wall 3	1070 lb
Average	1289 lb
STDV	252 lb
COV	19.6%

Grout 317 to 489 psi



Vertical Crack

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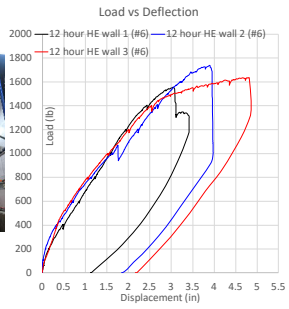
12 hour High-Early #6 Rebar

Wall 1 High-Early	1554 lb
Wall 2 High-Early	1739 lb
Wall 3 High-Early	1635 lb
Average	1643 lb
STDV	75.6 lb
COV	4.60%

Grout 520 to 933 psi



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Reinforced Wall Test Maximum Wall Load Results for # 4 Rebar & 28-dayPred (full yield).

Wall Specimen	Pmax (lb.)	Pmax/Ppred.28d	Average Load (lb.) (Ratio)	Coefficient of Variation
28-day grout #1	839	1.321	933 (1.74)	9.3%
28-day grout #2	1048	1.651		
28-day grout #3	911	1.435		
4-day grout #1	825	1.299	908 (1.43)	11.5%
4-day grout #2	844	1.329		
4-day grout #3	1056	1.663		
24-hour grout #1	861	1.357	746 (1.18)	11.3%
24-hour grout #2	714	1.125		
24-hour grout #3	663	1.044		
12-hour grout #1	323	0.509	386 (0.61)	23.2%
12-hour grout #2	513	0.808		
12-hour grout #3	322	0.507		
12-hour grout HE #1	801	1.262	703 (1.11)	19.1%
12-hour grout HE #2	513	0.808		
12-hour grout HE #3	795	1.252		

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Reinforced Wall Test Maximum Wall Load Results for # 6 Rebar & 28-dayPred (full yield).

Wall	Pmax (lb.)	Pmax/Ppred.28d	Average Load (lb.) (Ratio)	Coefficient of Variation
28-day grout #1	1455	1.098	1616 (1.22)	8.77%
28-day grout #2	1592	1.202		
28-day grout #3	1800	1.358		
4-day grout #1	1810	1.366	1833 (1.83)	
4-day grout #2	844	0.637		
4-day grout #3	1856	1.401		
24-hour grout #1	1221	0.921	1440 (1.09)	12.27%
24-hour grout #2	1446	1.092		
24-hour grout #3	1654	1.248		
12-hour grout #1	1155	0.872	1289 (0.97)	19.56%
12-hour grout #2	1642	1.240		
12-hour grout #3	1070	0.808		
12-hour grout HE #1	1554	1.173	1643 (1.24)	4.60%
12-hour grout HE #2	1739	1.313		
12-hour grout HE #3	1635	1.234		

Wall Specimen #2 with 4-day old grout had a low load test result.
Demolition to expose the grouted core in the lap splice region found voids over the lap splice.

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Conclusions

1) Current practice for lap splices in 24-hour grout are conservative. All tests significantly exceeded the reduced calculated capacities. In all but one test, these walls exceeded the unreduced calculated capacity of the wall.
2) Grout strength appears to have a variable impact on wall capacity depending on the diameter of the reinforcing steel. Shift in mode makes it unclear.
3) The procedures described in the Bracing Practice appeared to be quite conservative for the walls reinforced with #6 rebar but slightly unconservative for the walls reinforced #4 rebars, although this low result is likely due to the unexpected low lap splice lengths due to mortar droppings in the cell.
4) The 12 Hour high-early strength grout wall tests indicated that standard lap splices without a reduction can be used when high-early grout is used.

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