Strength Testing of Reinforced Autoclaved Aerated Concrete (AAC) Lintels

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WHAT IS AAC ? (1)

AAC is lightweight cellular concrete made of cement , sand , lime , water , expansive agents , and possibly other materials such as fly ash.

WHAT IS AAC ? (2)

This innovative material was introduced into the US market and 1900 as a response to the WWI energy crisis.

It is used for it's reliability and other advantageous properties, including:

-fire resistance

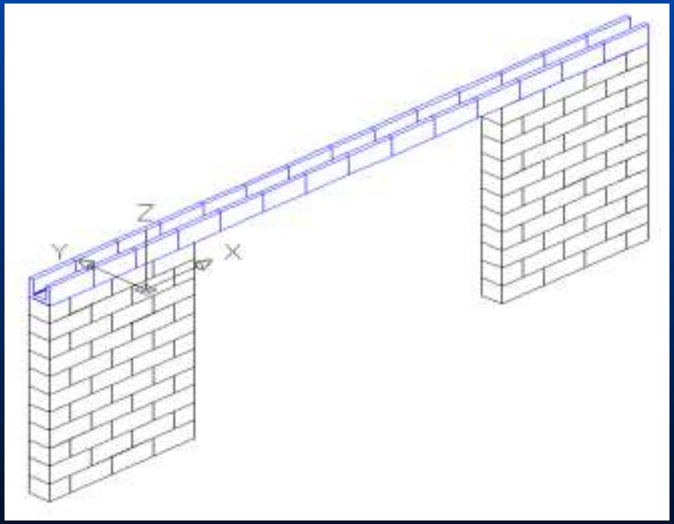
-low density (lightweight)

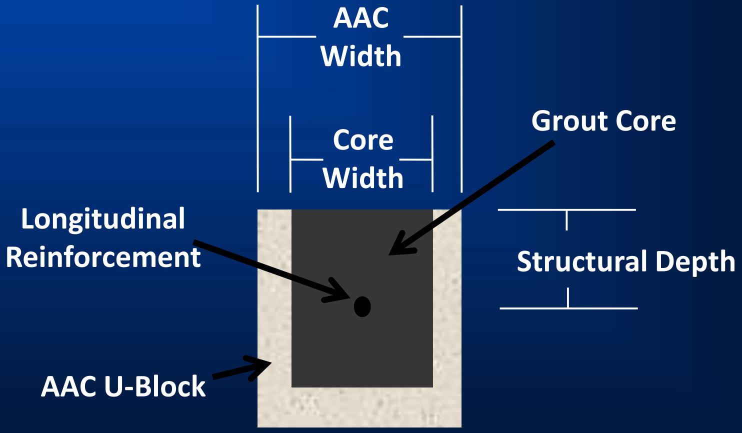
-high thermal efficiency

-acoustic damping

MASONRY LINTELS

Lintels are beams that horizontally span openings to accommodate doors and windows, and carry loads from walls above the opening. Standard U-block construction with grouted, longitudinal steel is shown.





RESEARCH PURPOSE

Current masonry design provisions include AAC design but do not reference any experimental testing of grouted reinforced AAC lintels using.

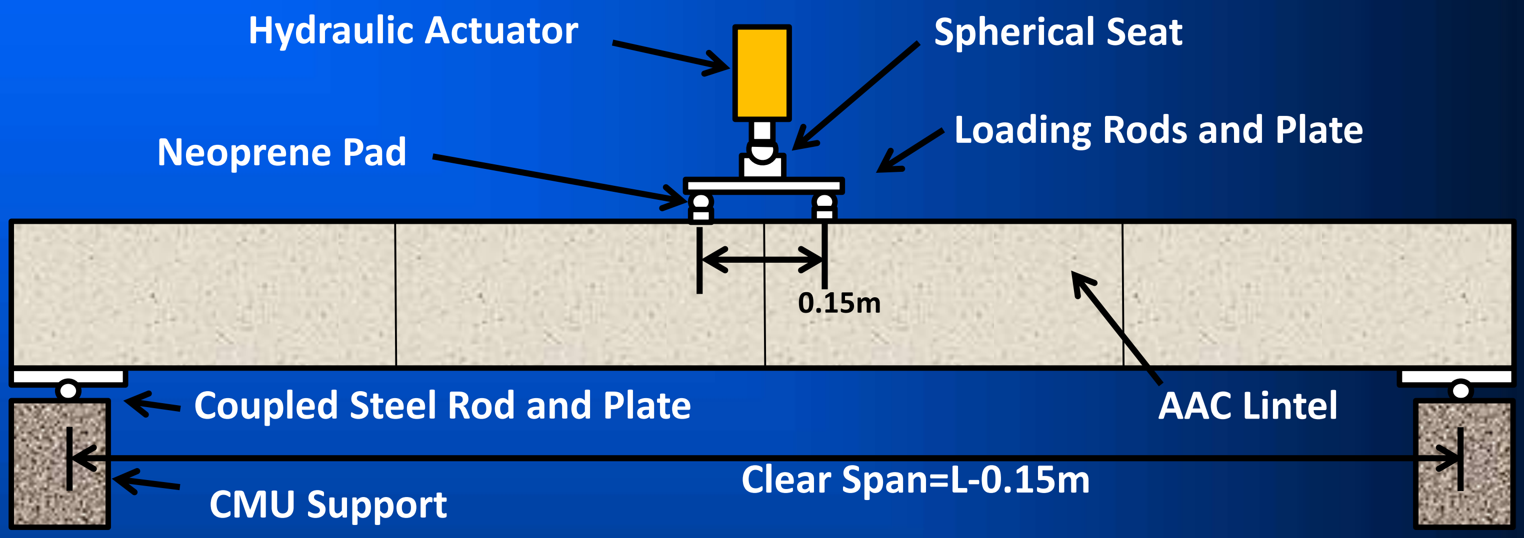
The hypothesis is that lightly reinforced and grouted AAC lintels, designed according to current masonry design provisions for typical lintel construction (MSJC), will be conservative.

SPECIMEN CONSTRUCTION

A suite of beams were constructed with varying length and reinforcement. The core of each beam was then grouted and then given 7-41 days to cure to full strength.

Specimen Name	Length m	Width of AAC		Width of Core		Structural Depth		Failure mode	Steel
		m	in.	m	in.	m.	in.		
P8-6 G1	2	0.20	8	0.10	4	0.10	3.75	Flexure	2 No.3
P10-6 G1	2	0.25	10	0.13	5	0.09	3.5	Flexure	1 No.3
SP10-4 G2	1.2	0.25	10	0.13	5	0.09	3.5	Flexure	1 No.3
P10-4 G2	1.2	0.25	10	0.13	5	0.09	3.5	Flexure	1 No.3
P8-8 G3	2.4	0.20	8	0.10	4	0.10	3.75	Flexure	2 No.3
P10-8 G4	2.4	0.25	10	0.13	5	0.09	3.5	Flexure	1 No.3
P8-10 G4	3	0.20	8	0.10	4	0.10	3.75	Flexure	2 No.3
P10-10 G4	3	0.25	10	0.13	5	0.09	3.5	Flexure	2 No.3
P12-4.5 G5	1.4	0.30	12	0.15	6	0.32	12.5	Shear	2 No.4
P12-8 G5	2.4	0.30	12	0.15	6	0.11	4.5	Flexure	2 No.4
P12-8 G6	2.4	0.30	12	0.15	6	0.11	4.5	Flexure	2 No.3
P8-8 G6	3	0.2	8	0.10	4	0.32	12.5	Shear	2 No. 4

LINTEL TESTING SETUP



The lintels were subjected to four-point loading at the center-span. A gap was included at the load to reduce shear forces at the location of maximum moment.

FRAME SETUP

A steel frame was used to test the specimens in flexure. CMU supports were placed under the beams. A series of steel rods, steel plates, and thin neoprene pads were placed at the center of the beam for distribution of the load.

DATA COLLECTION

For each beam tested, the applied load and corresponding displacement was recorded at various intervals.

A single-acting, hydraulic actuator was used to apply the loads. These loads were applied manually using a hand pump, and a pressure transducer was used to monitor the load.

A linear potentiometer, placed at the beam center-span, measured the displacement of the beam during testing.

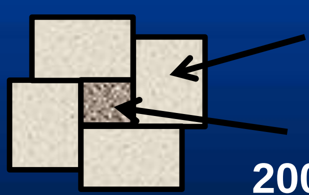
MATERIAL PROPERTIES (AAC)

Typical AAC properties are shown below. To confirm our AAC conformed with these values, select samples of AAC were taken and cut into 0.1 m x 0.1 m x 0.2 m (4 in. x 4 in. x 8 in.) specimens for compressive strength evaluation. The compressive strength averaged about 2.4 MPa (355 psi).

compressive strength	*290 - 870 psi*
dry density	*25 - 44 pcf*
modulus of elasticity	*222 - 432 ksi*

MATERIAL PROPERTIES (Grout)

During each of the grouting sessions, grout specimens were created for compression testing. Grout prism molds were used to replicate the AAC absorption and standard cylinders were also created for comparison.



Grouting Session	Average Grout Prism Compressive Strength		Age at test date (days)	AAC Prism	Average AAC Prism Compressive Strength	
	MPa	psi			MPa	psi
1*	9.7	1408	7	P8-6 G1	2.9	417
2	14.2	2066	27	P10-6 G1	1.9	281
3	14.8	2147	20	P10-4 G2	2.4	354
4	9.8	1418	41	P8-8 G3	2.5	367
5	11.0	1593	28	-	-	-
6**	8.7	1266	28	-	-	-
Average	**12.5**	**1806**		**Average**	**2.4**	**355**
St. Deviation	2.45	356		**St. Deviation**	0.39	56

MATERIAL PROPERTIES
(Mortar and Reinforcing Bars)

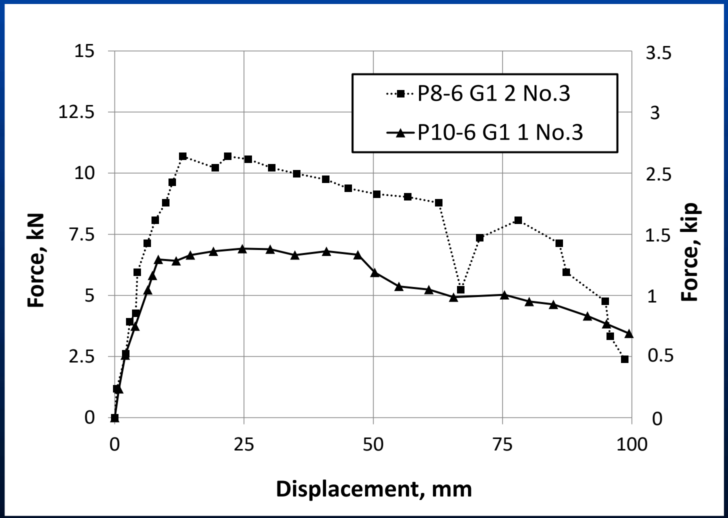
The mortar that was used to bond the AAC block segments into full length beams was a thin-set mortar made by Versabond. It is a polymer-modified, high-grade, fortified, thin-set mortar meant for application of stone, tile, walls or countertops and works well with AAC.

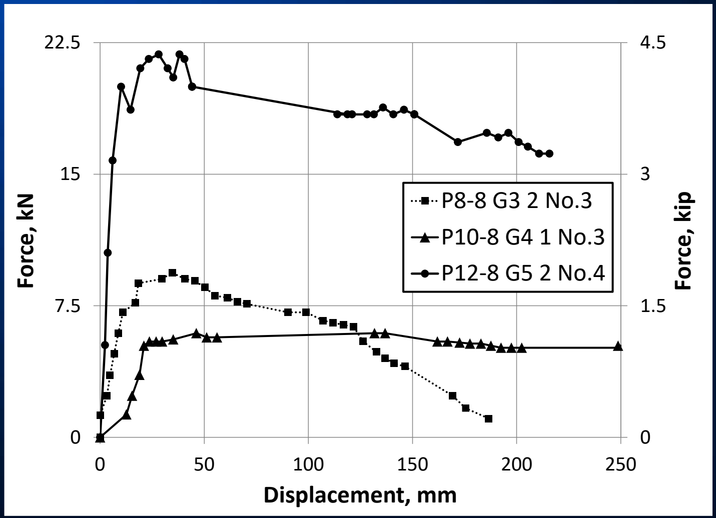
The steel reinforcing bars used were either grade 50 (No.3 bars) or grade 60 (No.4 bars). Tested No.3 bars yielded at 345-380 MPa, with an ultimate strength of 450 MPa.


ACE

TEST RESULTS (1)

The data from the flexural tests were used to plot force-displacement curves of each beam. Different maximum loads were reached due to the variability in beam length and reinforcement. This was normalized using a flexural steel ratio.

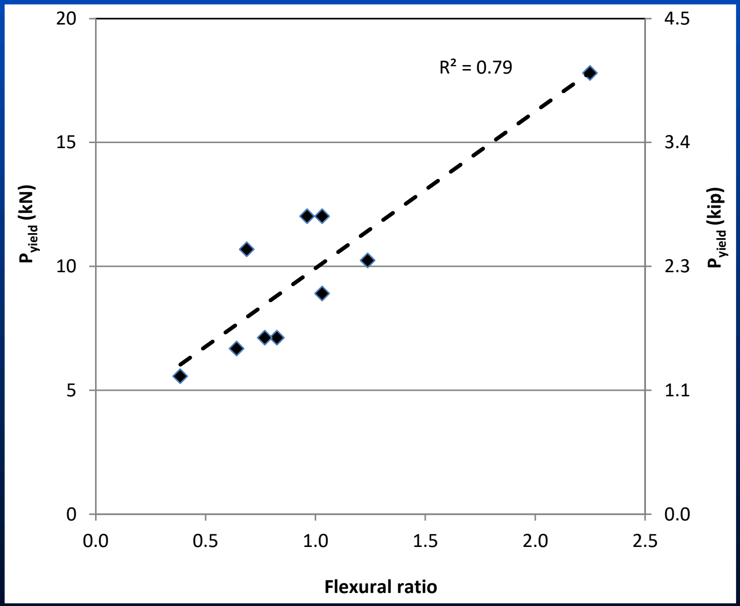




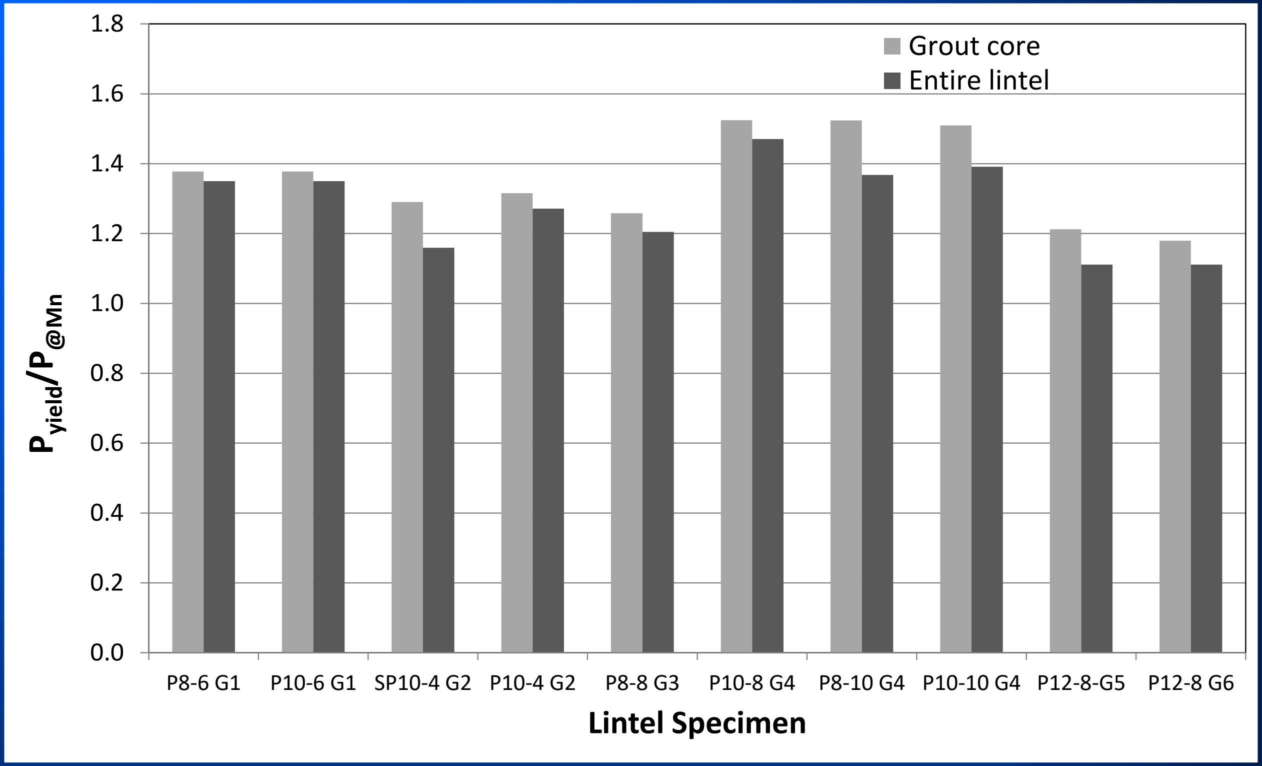
TEST RESULTS (2)

The normalized flexural results show a linear trend between the yield load and the flexural ratio.

Distributed flexural cracking was also observed, but were irrelevant as the yield load was controlled by the reinforcing bars.



TEST RESULTS (3)



Theoretical beam behavior was evaluated based on nominal flexural capacity and ultimate strength.

TEST RESULTS (4)

All lintel beams have reserve capacity when designed based on the masonry code provisions (MSJC)

In an attempt to evaluate over-reinforced specimens, P8-6-G1, P8-10-G4 and P12-8-G5 have calculated strains less than yield.

These specimens would need to be designed with less steel or additional courses to comply with the masonry code (TMS 402).

TEST RESULTS (5)

As expected, the force-displacement behavior was linear until cracking, when the load dropped abruptly.

Ratios of the flexural specimens ranged from 0.7 to 1.65 with an average of 1.1 and a COV of 31%. While not perfect, these calculations generally agree.

Lintel Name	Theroetical Stiffness kN/mm	Experimental Stiffness kN/mm	Theroetical Stiffness kip/in.	Experimental Stiffness kip/in.	Ratio
P8-6 G1	1.16	1.20	6.6	6.9	1.04
P10-6 G1	0.72	1.02	4.1	5.8	1.42
SP10-4 G2	2.42	1.89	13.8	10.8	0.78
P10-4 G2	2.42	1.68	13.8	9.6	0.70
P8-8 G3	0.49	0.53	2.8	3.1	1.09
P10-8 G4	0.26	0.37	1.5	2.1	1.43
P8-10 G4	0.19	0.32	1.1	1.8	1.65
P10-10 G4	0.21	0.27	1.2	1.6	1.29
P12-4.5 G5	49	18	280	100	0.36*
P12-8 G5	3.10	2.34	17.7	13.4	0.76
P12-8 G6	1.14	0.92	6.5	5.3	0.81
P8-8 G6	10.9	3.9	62	22.4	0.36*
*Excluded from average.				**Average**	**1.10**
				St. Deviation	**0.34**
				COV	**31%**

CONCLUSIONS (1)

Flexural specimens behaved in a ductile manner based on cracking patterns and measured data.

In a quantitative manner, force-displacement plots clearly indicate yielding of the longitudinal reinforcement.

In addition, a linear elastic portion and yield plateau are observed. Ratios of observed to theoretical specimen behavior range from 1 to 1.5.

CONCLUSIONS (2)

The average AAC lintel performance exceeds the design capacity by a ratio of 1.28, or 28% better than theoretically determined.

On average, the grouted core performs 36% better than the design capacity.

The ratios of maximum tested strength to ultimate capacity (f_s=f_u) range from 1 to 1.3.

Designs based on the masonry code are conservative.

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