CREEP IN BALE WALLS

Abstract:

The tests are aimed at determining the vertical creep or settlement of various bale walls loaded vertically for 12 months. In the base group are two stacks of 6 unplastered rice 3-string bales which are tested with uniform low (100plf) and high (400plf) loads. A comparative group includes wheat 3-string, rice 2-string, and rice 3-string on-edge, all at high loading. A third group tests the effect of intermittent load, to simulate the effect of a later seismic event, at low and high load. Last, two plastered wall stacks, a cement and an earth plastered, are tested.

Dan Smith
June 30, 2003

Description of Tests (see drawing of test assembly, Fig. 1)

The test format consists of 9 stacks of 6 bales each, with measured weight at the top, with one stack per test. Bales are contained horizontally within a open 2x4 frame, primarily measuring vertical displacement. The weight is sand in a ply bin atop the stack. Settlement is measured initially, and then approximately at days 1,2, 7, 14, and at months 1,2,6, and 12 months.

Test stacks:

Base Group: This is the control group, of California 3-string rice bales, typically 23" wide, 47" long and 15" high, with various continuous loads.

Test A: Low Load: 400 lbs total, (102 plf, 53 psf, 0.37 psi)
Test B: High Load 1600 lbs, (404 plf, 210 psf, 1.46 psi)

Comparative Group: Individuals in this group are designed to test specific variables. C tests a change in straw grain, wheat vs. rice, (with some minor changes in bale dimension, 44"long, 16" high). Test D tests a change in bale thickness, to 18" wide, 46" long 2-string rice bales. Test E turns the 3-string bale on edge, changing the direction of the grain and effectively switching the width and height, with a 4 bale stack in this case.

Test C: Wheat 3-String 1600 lbs, (436 plf, 227 psf, 1.58 psi)
Test D: 2-String Rice 1600 lbs, (418 plf, 279 psf, 1.9 psi)
Test E: 3-String Rice on Edge 1024 lbs, (267 plf, 213 psf, 1.48 psi)

Intermittent Load Group: This group has the same initial conditions as the base group, however 2x2 14ga welded wire mesh is wrapped up and over the bale stack to hold the compression. The load is applied, the bale stack takes its initial compression, the mesh is stretched tight and stapled to the plates to keep the bales from expanding upwards, and

then the load is removed. The load gets reapplied after 44 weeks. Photo #1 shows Test F in the mid ground with the mesh applied and load removed, and Test G in the background with the load still in place.

Test F: Low Load Intermittent 400 lbs, (102 plf, 53 psf, 0.37 psi)
Test G: High Load Intermittent 1600 lbs, (408 plf, 213 psf, 1.48 psi)

Plastered Group: This group is designed to test the effects of plaster on creep. The walls are plastered after the full weight has been applied for 1.5 weeks. The walls are plastered on the two 48" faces, with 14 ga 2x2 mesh, with the plaster allowed to bear on the base.

Test H: Earth Plaster, 400 lbs, (100 plf, 52 psf, 0.36 psi)
Test I: Cement Lime Plaster, 1600 lbs, (408 plf, 213 psf, 1.48 psi)

The cement-lime plaster was a Quickcrete mix of approximately 4 parts Portland cement, 1 lime, and 20 sand

Record of each specimen test (see attached graphs)

Figure 1: These diagrams illustrate the entire assembly.
Figure 2: Overall Test Graph: shows the overall results of the 9 tests over the full range of time, and shows the initial compression as well as the creep. Measurements were typically taken at the front right corner of the stack only. This may explain why some readings would appear to indicate negative creep; minor tilting and twisting of the bale stack is likely to account for this.
Figure 3-6: These graphs have the starting point set after the point of initial compression. (see summary)
Figure 7: This chart shows the relative weights, length and density of the bales.

Test Protocol

This test is very roughly based on the Standard Test Method for Creep of Concrete in Compression, ASTM-C512-87, which is the closest comparable published standard. The procedures have to be modified a significant amount to pertain to straw bales. The testing sample is a stack of six single bales as opposed to a stack of 6"d x 12" concrete cylinders.

Summary and Conclusions:

General Notes:

Initial Compression (measured right after loading): This varied in unpredictable ways, and since this was not the central focus, we have made the comparative creep graphs (Fig. 3-6) start after the initial compression. The walls were not carefully or uniformly "stomped" into place or otherwise precompressed, as is often done in actual bale wall construction. Generally we interpret this phase as the period when the bale inconsistencies, especially the bale surface, are compressed and the bale shapes conform to one another. Creep is considered the period when the individual straw fibers deform over time. Both effects happen simultaneously to a certain extent, therefore is it

somewhat difficult to separate these two phenomena. Initial Compression averaged 1" for the 400# load, or 1.1%, and 2.25" for the 1600# load, or 2.5%. Note that the 2-string wall compressed about 4.5%.

Early Creep: There seems to be relatively fast creep over the first 1-2 weeks, at least on the higher loads.

Slowing Creep: After the initial period, most walls settled more minimally for another 5-8 weeks or so.

Stabilization: After 10 weeks, most walls were seemed stable, with no measurable additional creep. Overall the creep in the rice 3-string was about .8" for the low load (.9%), and 1.1" for the high (1.2%). The creep to compression ratio was 73% (0.8 to 1.1) for the low load, and 49% (1.1 to 2.25) for the high.

Unlike the other specimens, the most heavily loaded wall, the 2-string rice bales, at 1.9 psi, continued to settle throughout the period. And the rice on-edge stack had a much longer creep period (43 weeks) before a minimal stabilization, although the amount of creep was similar at 1.4%.

The Intermittantly Loaded Walls:

This test showed that the walls retained 75-80% of their previous compression after 8 months. In other words, the walls only deformed another 20-25% as compared to the initial compression, after the load got reapplied. For example, the initial compression on wall G is 2.75", and 50 weeks later when the load is reapplied, it settles 0.75". This seems to support the value of precompressing bale walls before plastering when the walls might be subjected to severe loading such as seismic or high snow loads.

The Plastered Walls:

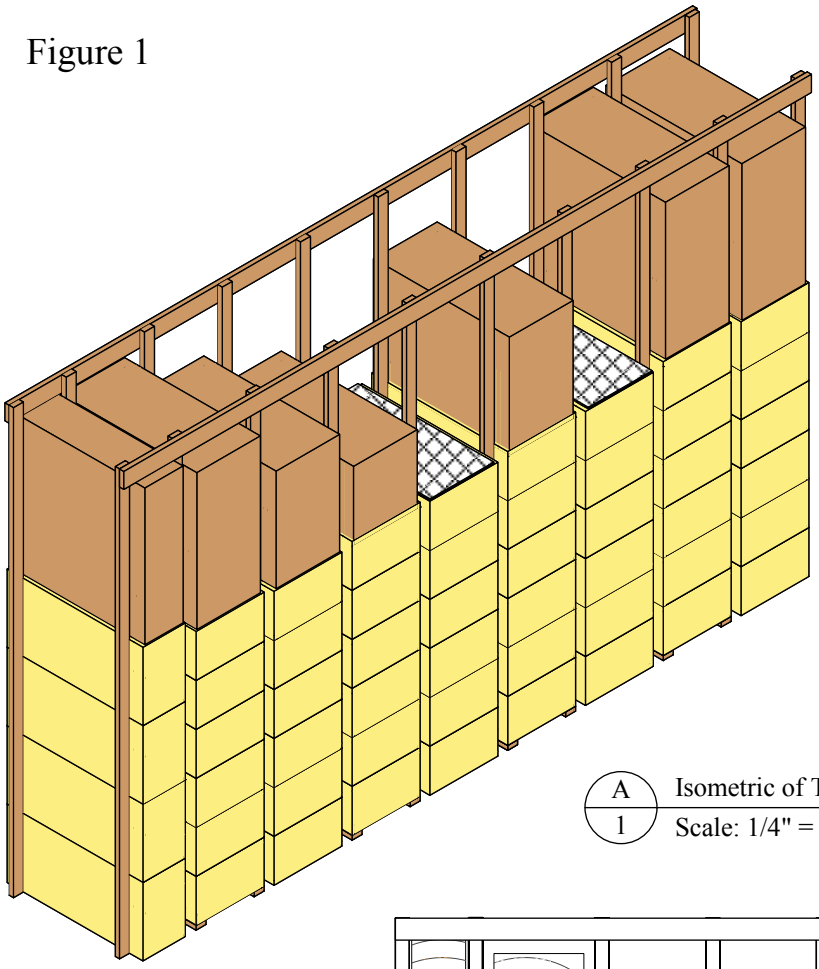
The cement lime plastered wall, at 400plf, showed no noticeable settlement at all. This was to be expected, since these are service loads and not near enough to ultimate to show settlement.

The earth plastered wall, at 100plf, however did show some settling, 1 ½" in the initial weeks as the first coat of plaster was still curing. We had provided some precompression, with the load applied for 1.5 weeks before plastering.

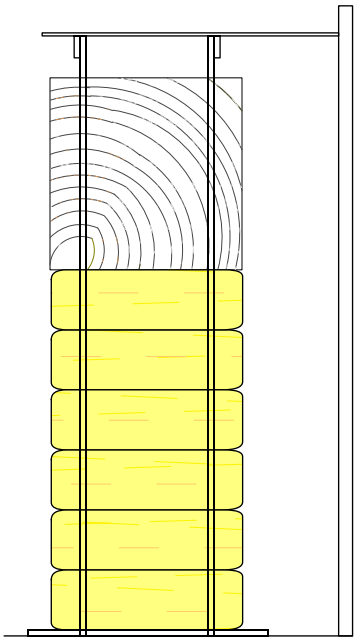
Test Author and Contact Information
Dan Smith, DSA Architects
With Graphic Analysis by Carla Hyman
DSA Architects, 1107 Virginia Street
Berkeley, CA 94704
(510) 526-1935
fax 526-1961
www.dsaarch.com
dan@dsaarch.com
Test Construction and Recording by Bill Camp of Vital Systems

Photo #1: Creep test stack assembly, showing Stacks 8, 5, and 3.

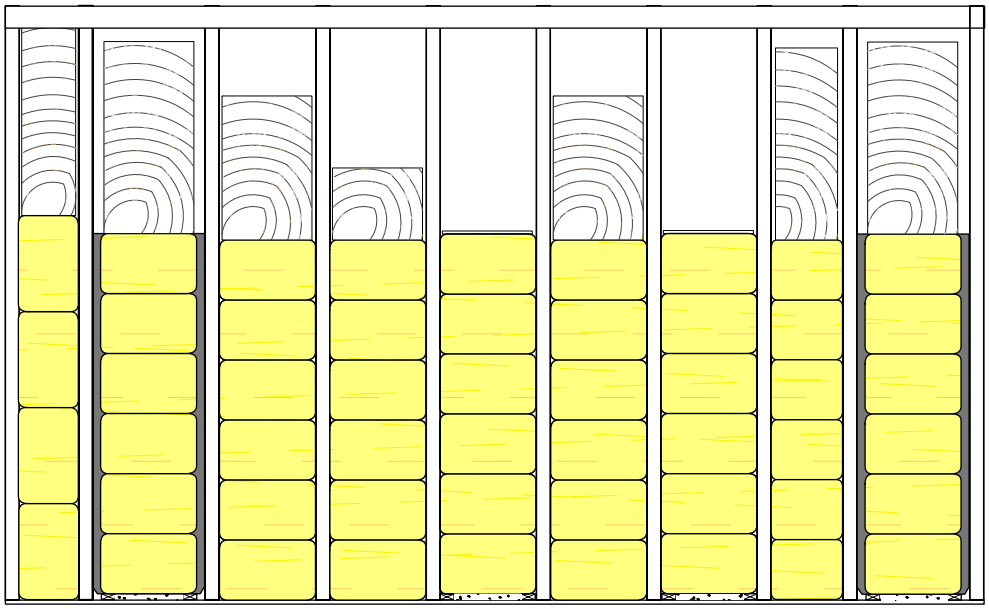
Figure 1



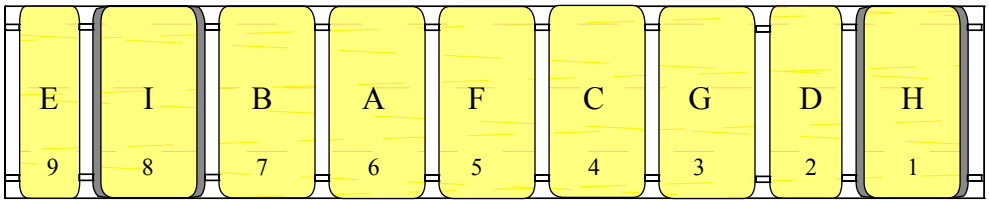
A / 1 Isometric of Test Assembly
Scale: 1/4" = 1'-0"



B / 1 Section
Scale: 1/4" = 1'-0"



C / 1 Elevation
Scale: 1/4" = 1'-0"

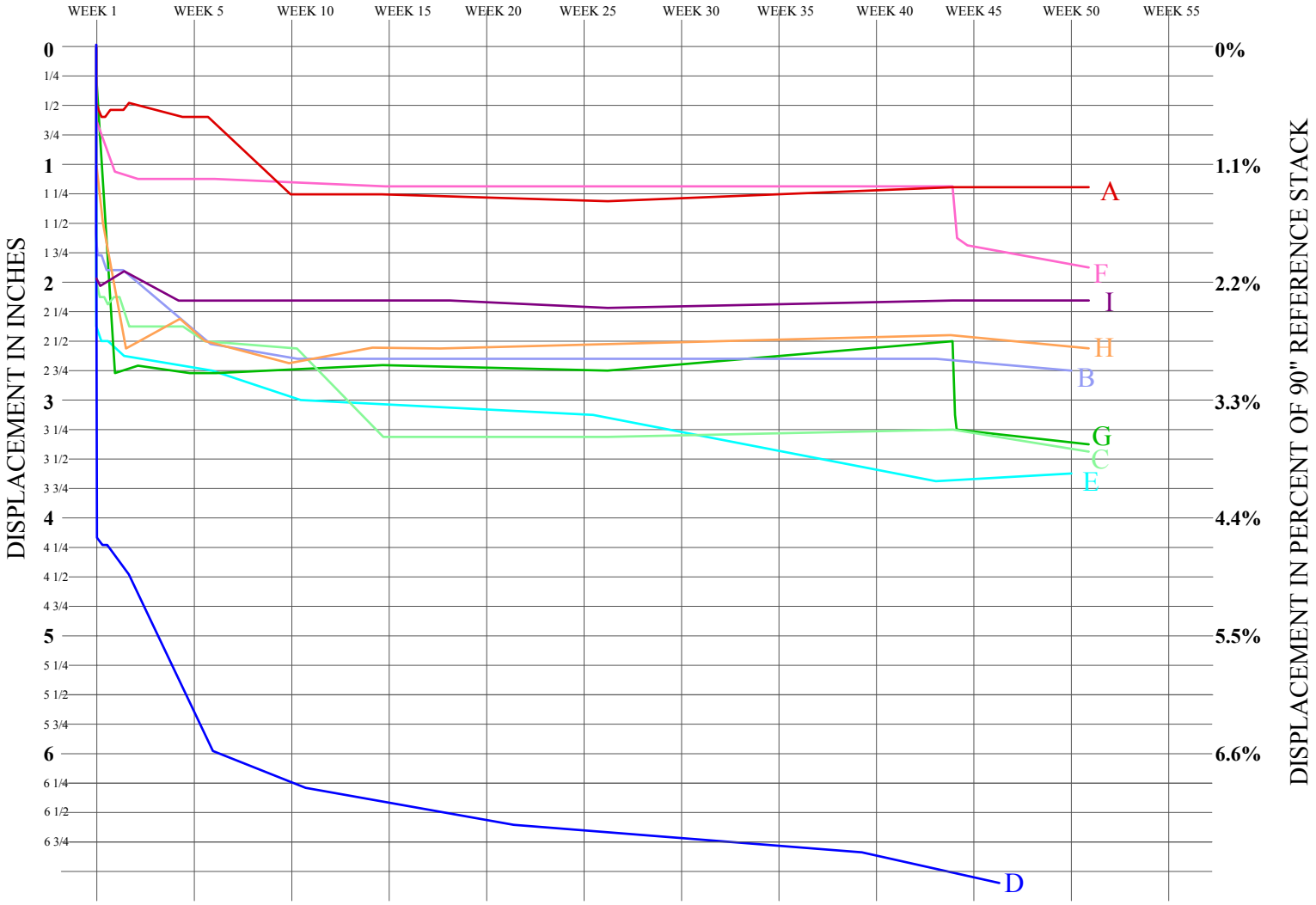


on edge 1024# | lime-cement plaster 1600# | rice high load 1600# | rice low load 400 # | low intermit-tant 400 # | wheat 3-string 1600 # | high intermit-tant 1600# | rice 2-string 1600 # | earth plaster 400 #

D / 1 Plan
Scale: 1/4" = 1'-0"

FIGURE 2: OVERALL CREEP TEST DATA

TIME OVER 55 WEEKS



KEY:

STACK A 3-STRING LOW

STACK B 3-STRING HIGH

STACK C WHEAT 3-STRING 1600lb.

STACK D 2-STRING RICE 1600 lb.

STACK E 3-STRING ON EDGE 1024lb.

STACK F INTERMITTANT LOW 400lb.

STACK G INTERMITTANT HIGH 1600lb.

STACK H EARTH PLASTER LOW 400lb.

STACK I CEMENT LIME PLASTER

FIGURE 3: BASE GROUP

TIME OVER 18 WEEKS

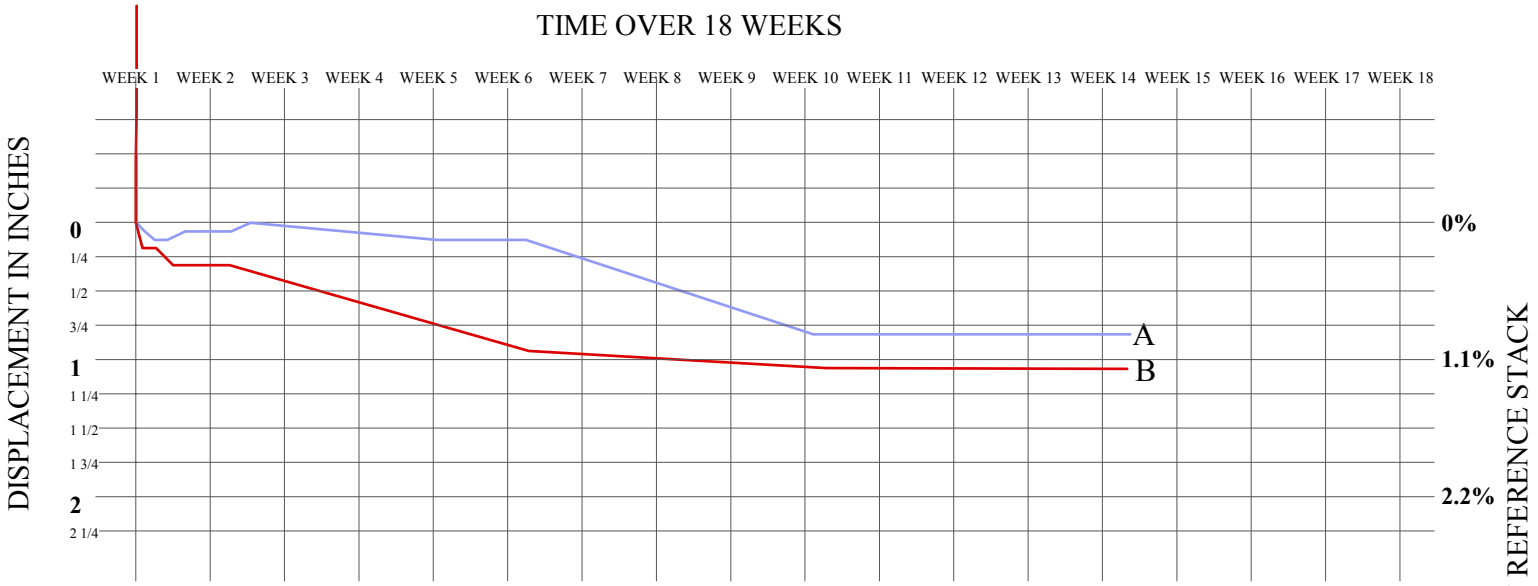
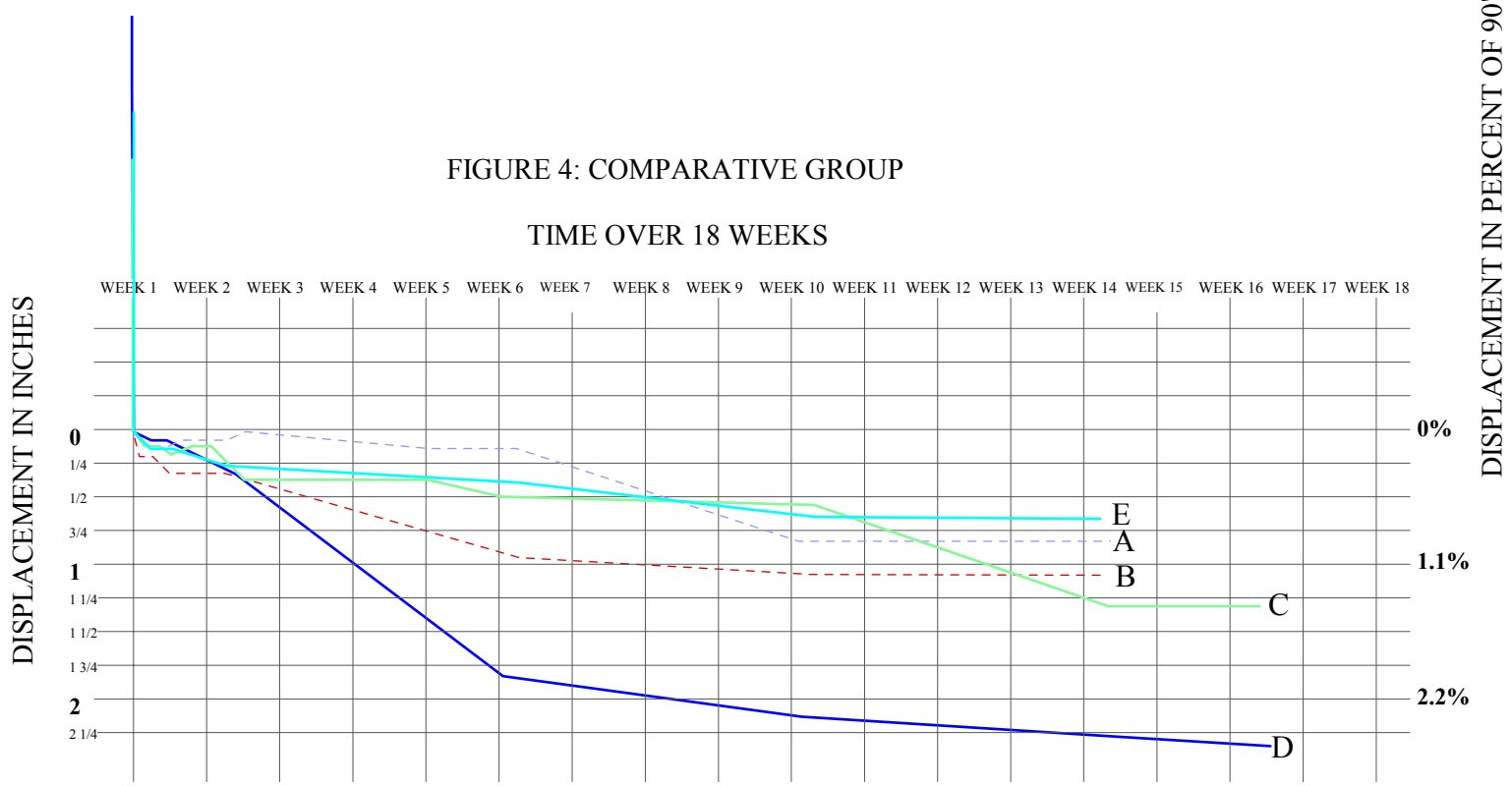


FIGURE 4: COMPARATIVE GROUP

TIME OVER 18 WEEKS



KEY:

STACK A	3-STRING LOW	STACK F	INTERMITTANT LOW 400lb.
STACK B	3-STRING HIGH	STACK G	INTERMITTANT HIGH 1600lb.
STACK C	WHEAT 3-STRING 1600lb.	STACK H	EARTH PLASTER LOW 400lb.
STACK D	2-STRING RICE 1600 lb.	STACK I	CEMENT LIME PLASTER
STACK E	3-STRING ON EDGE 1024lb.		

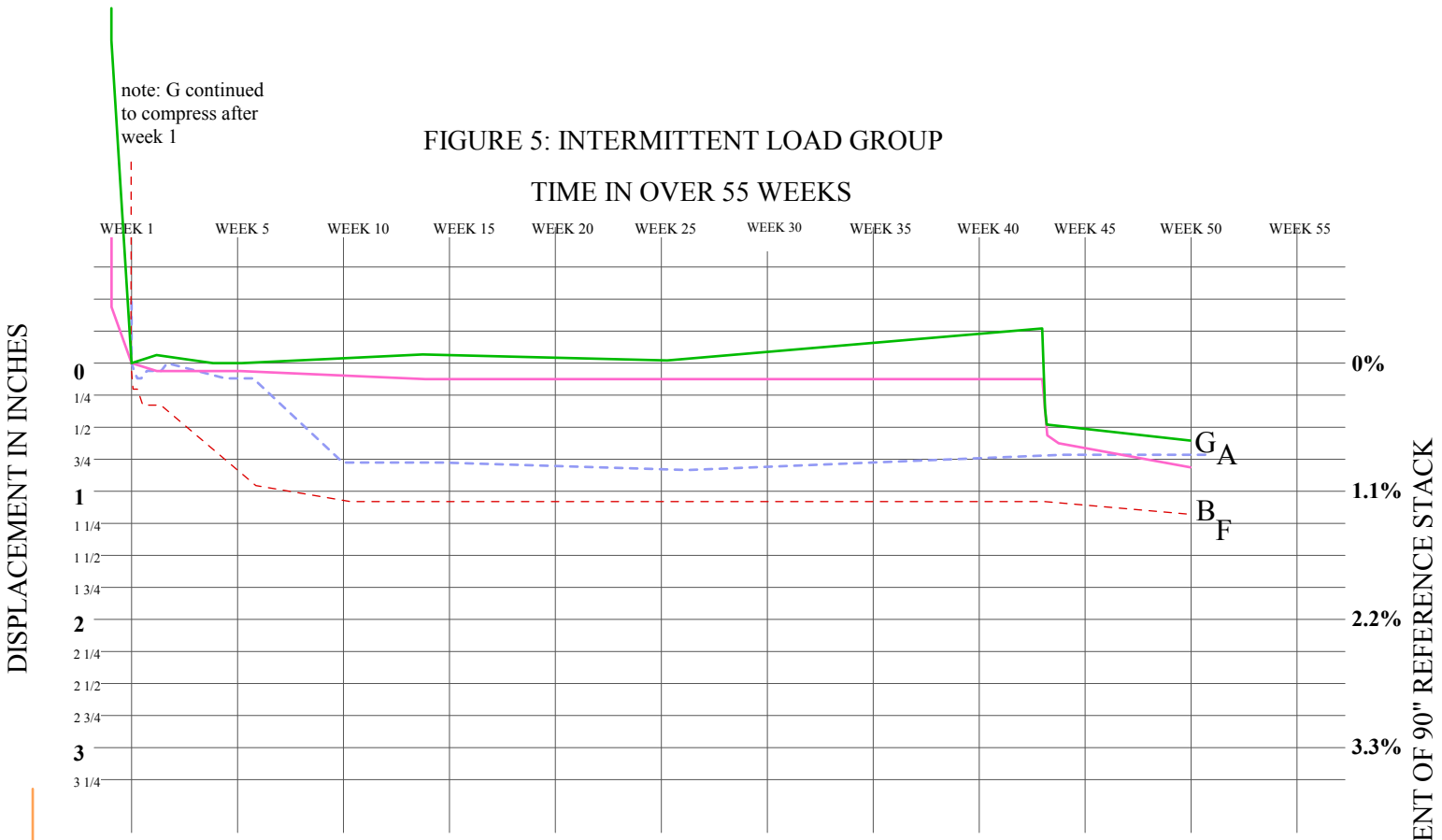


FIGURE 5: INTERMITTENT LOAD GROUP

TIME IN OVER 55 WEEKS

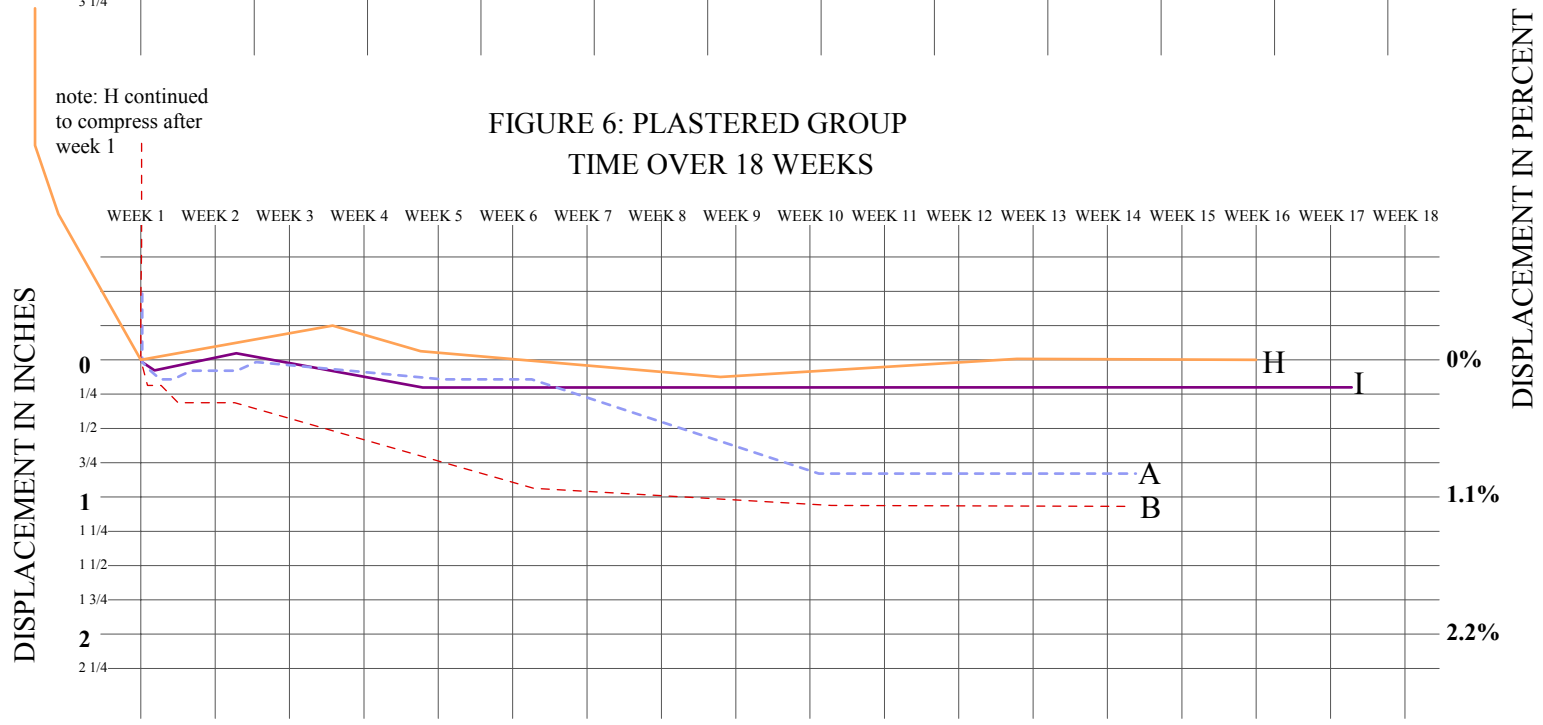


FIGURE 6: PLASTERED GROUP

TIME OVER 18 WEEKS

KEY:

STACK A	3-STRING LOW	STACK F	INTERMITTANT LOW 400lb.
STACK B	3-STRING HIGH	STACK G	INTERMITTANT HIGH 1600lb.
STACK C	WHEAT 3-STRING 1600lb.	STACK H	EARTH PLASTER LOW 400lb.
STACK D	2-STRING RICE 1600 lb.	STACK I	CEMENT LIME PLASTER
STACK E	3-STRING ON EDGE 1024lb.		

Figure 7: Weight, Length and Density of Stack

	A-6 low reg	B-7 high reg	C-4 wheat	D-2 two-string	E-9 on edge	F-5 low inter	G-3 high inter	H-1 earth plaster	I-8 cement-lime
weight (lbs)	78	75	59	55	71	85	80	79	80
	92	85	60	62	71	77	77	91	81
	69	82	65	56	70	80	75	78	78
	66	89	62	59	75	78	79	77	79
	68	74	73	54		81	88	80	79
	68	76	62	56		76	80	76	75
total	441	481	381	342	287	477	479	481	472
length (in)	46	47	44	45	48	48	47	47	46
	51	49	44	48	45	47	45	48	48
	46	48	45	45	47	47	46	46	47
	47	47	44	47	45	45	49	50	47
	46	47	43	44		47	49	49	45
	47	47	44	45		47	48	48	47
average	47.17	47.5	44	45.67	46.25	46.83	47.33	48	46.67
density (lbs/cu ft)	7.805	8.453	7.2285	7.489	7.285	8.502	8.448	8.365	8.443