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THE ROLES OF FACING CONNECTION STRENGTH, TRUNCATED BASE, AND EMBEDMENT IN MECHANICALLY STABILIZED BACKFILL WALLS

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The roles of connection strength between facing elements and geosynthetic reinforcements; embedment; and truncated bases in Mechanically Stabilized Backfill (MSB) walls are reported.

Two 15 foot high MSB walls were constructed, one with concrete modular block facing elements and the other with blocks made of compressed rubber tire chips. Neither was embedded and both had truncated reinforcements at the bottom. Each was surcharged. In each, the geosysnthetic reinforcements were severed at the facing element interface following construction and surcharging.

It is concluded that; 1. Facing elements experience highest horizontal thrust during construction (compaction), where they act as forms to facilitate achieving a vertical face. Permanent loads are quite small; 2. Embedment does not improve internal stability; and 3. MSB features with truncated bases are internally stable.

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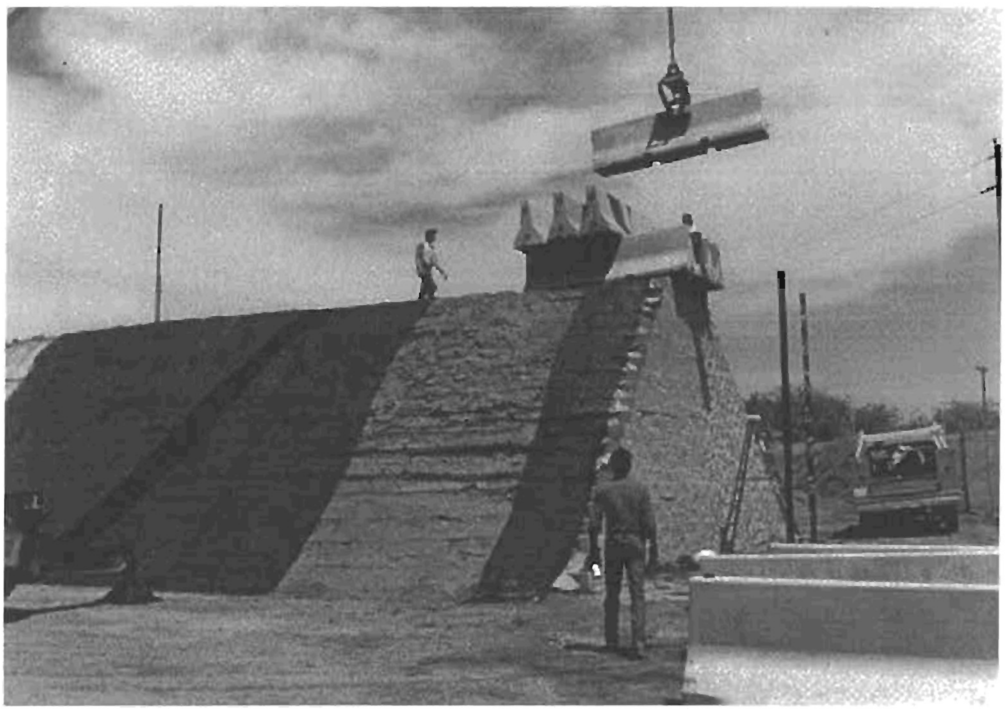
CONTENTS

INTRODUCTION

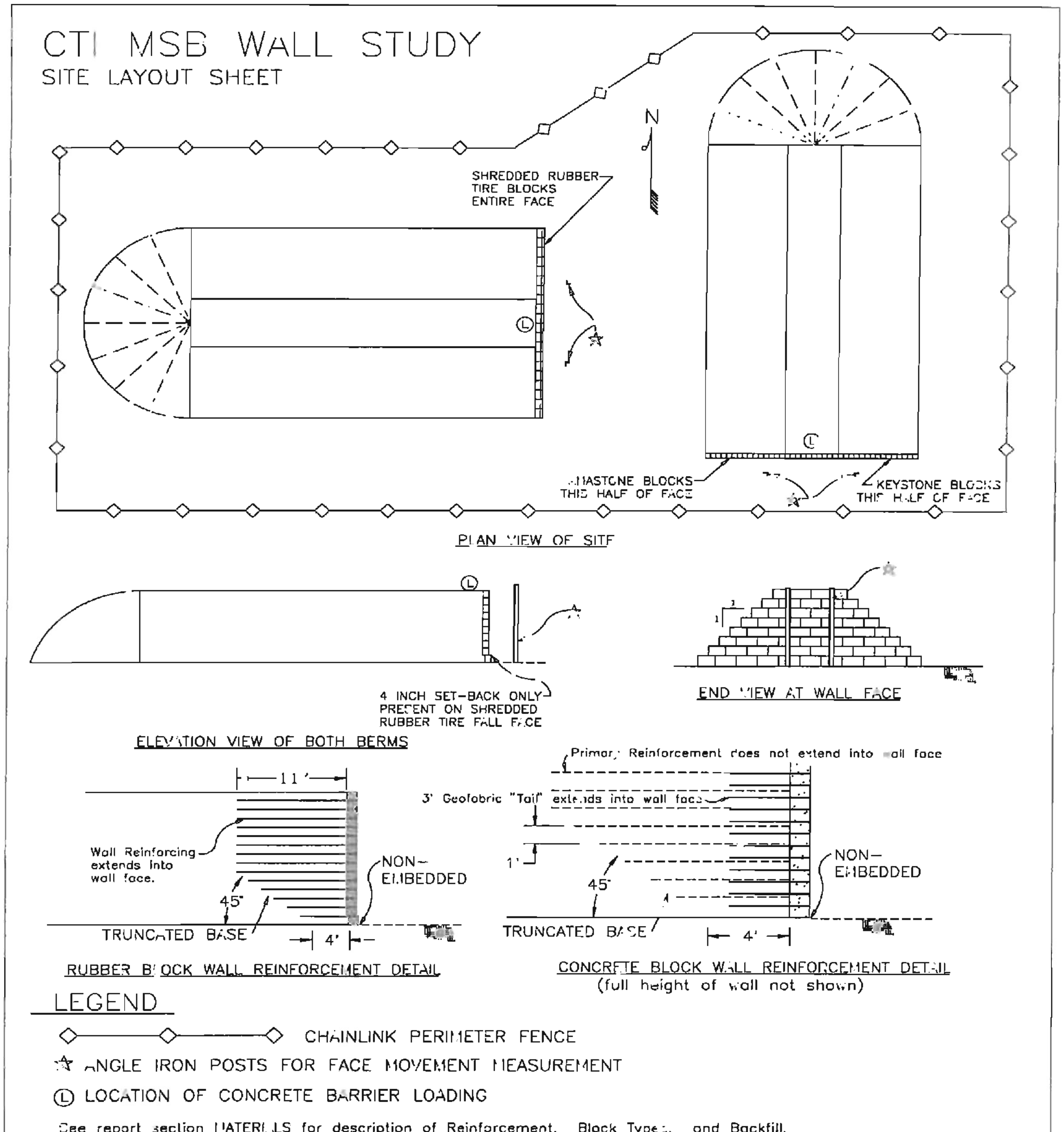
This report describes the research and results of a study of two 15 foot high mechanically stabilized backfill (MSB) walls. The purpose of the study was to gain insight into the nature of geosynthetically-reinforced, block-faced earth features. The Colorado Department of Transportation (CDOT) Research Branch and the Colorado Transportation Institute (CTI) constructed and monitored the walls.



The MSB walls were non-embedded and reinforced with a truncated section, i.e. the lower reinforcements were shortened (See **Figure A**). The reinforcement connection to the facing element was provided by friction between facing blocks and reinforcing material. After completing construction, a cantilevered surcharge load was placed on top of the wall. This load did not rest on the facing blocks. All connection between the reinforcement and the wall face was then severed. Measurements recorded lateral movement of the wall facing elements and movement between the facing elements and the backfill.

CONSTRUCTION

Two embankments were constructed at the Department of Transportation's Commerce City Maintenance Yard to study the characteristics of MSB slopes and walls. The embankments were approximately 65 feet long with a bottom width of 40 feet and a height of 15 feet. The reinforced side slopes of these berms were used as part of a concurrent study. These reinforced slopes were constructed at one-to-one slope so that the berm width was 10 feet at the top. One berm was oriented north-to-south and the other was oriented east-to-west. See **Figure A**.



FigureA

An MSB wall was built into the end of each of the two embankments. One wall was constructed with two types of concrete blocks for wall facing while the other was constructed with rubber blocks fabricated from recycled rubber tires. The MSB walls were constructed in one foot lifts with reinforcement placed at 1 foot spacings. See **Figure A**.

A Case W14 front end loader was used to place the backfill and to compact the edges of the embankments. A seven ton double drum roller was used for wall compaction. Wall backfill within 3 feet of the wall face was compacted with an 8 horsepower vibrating plate compactor.

Wall construction was completed May 1, 1994.

MATERIALS

The embankment material used to construct the berms was a silty, gravelly sand with an AASHTO classification of A-2-4(40). The backfill for the MSB walls consisted of aggregate material meeting Colorado Department of Transportation specifications for Class 6 Aggregate Base Course, known locally as road base. The backfill material had an internal friction angle of 34 degrees.

The concrete block faced wall was reinforced with Tensar geogrid ux1400 on one foot spacings. The ux1400 has a Minimum Average Roll Value (MARV) of 3,700 lbs./ft.. The Tensar ux1400 was not attached to the block facing. The concrete blocks were attached to the embankment by means of a "tail" of Trevira 1125 extended from between each block three feet into the embankment. The rubber block faced wall was reinforced with Amoco 2044 (MARV of 4,800 lbs./ft.) on one foot lifts. The connection between the blocks and the embankment was by friction between the blocks and the reinforcement or tail at each lift of the block facing. Wire was taped securely to the fabric connecting the wall blocks to backfill immediately behind the blocks in both walls prior to placement of backfill material. This wire was heated to cut the fabric and sever all connection between the wall facing blocks and the backfill. Several blocks were removed to view the geosynthetics and confirm that they were indeed severed.

The concrete blocks were provided by Amastone and Keystone companies. Amastone block is an 8 inch by 16 inch face by 10 inch deep split-face concrete block with two inch wall thickness. The Amastone blocks were not filled during construction. Keystone block is an 8 inch by 16 inch face by 12 inch deep, solid split-face concrete block. Amastone was used on the west half and Keystone was used on the east half of the wall. The Rubber blocks used are composed of automobile tire shreds of about 3/8 inch nominal size cemented and compressed into one foot by two foot face by one foot deep blocks. The rubber block weighs about 60 pounds per cubic foot.

INSTRUMENTATION

The walls were instrumented with linear potentiometers and measurement hook points. The potentiometers were attached to the reinforcing fabric two feet behind the wall facing blocks. Three potentiometers were installed in the rubber block wall and four in the concrete block wall. Each potentiometer was enclosed in a 1 inch diameter PVC pipe with the stylus extended and attached to the facing block to measure the movement of the facing relative to the reinforcement. CTI calibrated the potentiometers to allow a conversion from potentiometer output to inches of movement. Two 3 inch by 3 inch by 1/4 inch angle iron posts were set permanently in front of each wall to provide a fixed location from which to measure total horizontal movement of the wall at the hook point locations on the wall face.

MSB WALL FACE MOVEMENT MONITORING

CTI monitored both walls to detect wall face movement by measuring distance from a fixed angle iron post and potentiometer output.

Two steel angle iron posts were permanently set in front of both walls with one to the left and one to the right of wall face center. Seven measuring hooks were set into the wall face from bottom to top in line with each angle iron post. The angle irons were marked at the levels corresponding to the wall face hooks. The right angle iron was used to measure the wall face hook points numbered one to seven and the left to measure points eight to fourteen. **Tables 1a and 1b** show the location of each hook point.

RUBBER Block Wall Hook Point Location

Hook Point Number	Left/Right Of Center	Inches Above Wall Base
1	Rt.	16
2	Rt.	42
3	Rt.	65
4	Rt.	90
5	Rt.	114
6	Rt.	141
7	Rt.	166
8	Lt.	5

TABLE 1a

RUBBER Block Wall Hook Point Location Hook Point Number	Left/Right Of Center	Inches Above Wall Base
9	Lt.	30
10	Lt.	54
11	Lt.	79
12	Lt.	103
13	Lt.	127
14	Lt.	151

TABLE 1a

CONCRETE Block Wall Hook Point Location Hook Point Number	Left/Right Of Center	Inches Above Wall Base
1	Rt.	23
2	Rt.	47
3	Rt.	72
4	Rt.	95
5	Rt.	120
6	Rt.	143
7	Rt.	168
8	Lt.	12
9	Lt.	35
10	Lt.	59
11	Lt.	84
12	Lt.	108
13	Lt.	132
14	Lt.	156

TABLE 1b

CTI monitored wall movement by recording tape measured distances from each of the wall face hook points to the corresponding mark on the angle iron post.

MSB structure such that any movement in wall facing relative to reinforcement at a potentiometer location would cause potentiometer output to change. The rubber block wall contained three potentiometers located near the wall center running from wall bottom to top roughly dividing the wall height between the number of sensors. The concrete block wall contained four potentiometers placed in the same manner. Potentiometer number one is the bottom potentiometer in both walls.

Both walls were surcharged with 40,000 pounds on May 11, 1994. Wall movement readings were taken during the loading at 16, 28 and 40 thousand pound load increments. The 40,000 pound surcharges (+/-625psf) were left in place until May 18, 1994 when 8,000 pounds was transferred from the rubber block wall to the concrete block wall. The loads were maintained from that time forward with the rubber block wall having 32,000 pounds (+/-500psf) and the concrete block wall having 48,000 pounds (+/-750psf) of surcharge.

The connection between the reinforced backfill and the facing blocks was cut on June 2, 1994 by heating preset wires in the fabric that ran the length of the wall face. A welding generator was used to accomplish this and the cut was confirmed by removing facing blocks and inspecting the geosynthetics.

Wall deflection measurements were taken three to four times per week for the first three weeks beginning April 29, 1994. These were the week before, the week during, and the week after the application of concrete barrier surcharging to the top of the MSB walls. Measurements were taken one to two times per week thereafter. Floating-five-point-average of wall deflection versus time for each hook point is shown in the plots in **Appendix A**. Also included in **Appendix A** are the plots of measured movement from the potentiometers versus time and plots for each wall of total deflection. Differential settlement between the MSB composite and the facing blocks probably occurred. This movement would be additive to the potentiometer reading.

The hook point data plots show that little deflection occurred near the bottom of the walls. The amount of deflection outward becomes more pronounced in those points higher on the wall faces. In both walls a jump is evident in the wall deflection at the point where surcharging is introduced. Both walls show similar rates of deflection after the surcharging. No change or jump in deflection rates occurred at the time when the connection between wall facing blocks and reinforcement was cut, indicating that existing lateral earth pressures exerted on the facing blocks were minimal. It follows that long term loads or thrust on facing elements is limited to the horizontal force component from the unreinforced soil between reinforcement layers.

The plots of potentiometer movement show that the bottom of the rubber block wall (potentiometer #1) moves away from the embankment at the point of loading and continues to move further out compared to the wall top. The plots of final wall deflection for the hook points and potentiometers show that the bottom of the rubber block wall experienced greater deflection than the bottom of the concrete block wall.

CONCLUSION

Wall movement as measured using the hook points and tape measure is a measure of total wall deflection from original location. The potentiometers were intended to measure the wall facing block separation from the reinforced embankment; however, this measurement would include a portion of the differential settlement between the MSB composite and the less compressible facing blocks. Much of the movement shown by the potentiometers is thought to be a result of this differential movement since the rate of deflection did not change when the connection was severed.

The plots of wall deflection in **Appendix A** show that the top of both walls moved the most. Based on the logarithm of time plots we assume that the walls will deflect less than two inches in their lifetime. This is not a significant amount of movement.

In these two walls, the majority of wall deflection is related to compression of the MSB composite. The fact that the facing blocks did not topple when cut free supports this conclusion. When MSB walls are constructed as in this study, wall facing is mainly an aesthetic and erosion protection element. It is not necessary or cost effective to construct facing elements that can withstand unreinforced soil pressures when reinforced backfills are used. Not including earthquake loads, the highest forces experienced by the facing elements in MSB features built with similar specifications will result from construction compaction loads. Wall facing connection to the MSB composite is not critical to the lifelong internal stability of MSB walls.

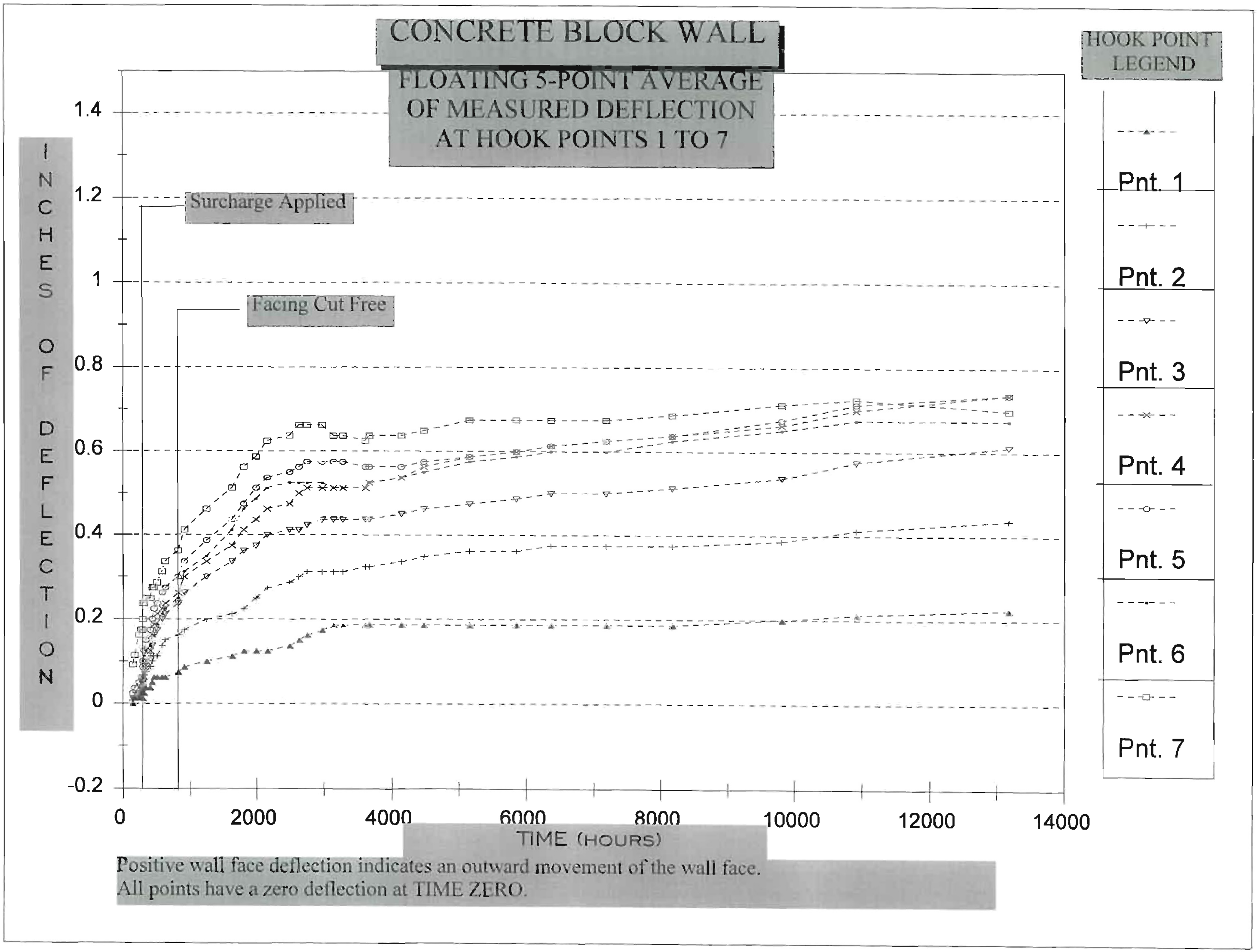
Embedment was not found to be a significant factor in the stability of these two demonstration walls. These non-embedded walls performed well and embedment of the wall base would not result in a more stable wall because embedment is not related to internal stability. Embedment will only result in higher feature cost.

When foundation conditions are questionable, subexcavation to stable foundation material or improvement of the at-grade foundation will be necessary. The MSB technology is best utilized in this situation by improving the foundation and constructing a non-embedded MSB feature on top of this improved foundation. This configuration is generally more economical than subexcavating and constructing an embedded feature.

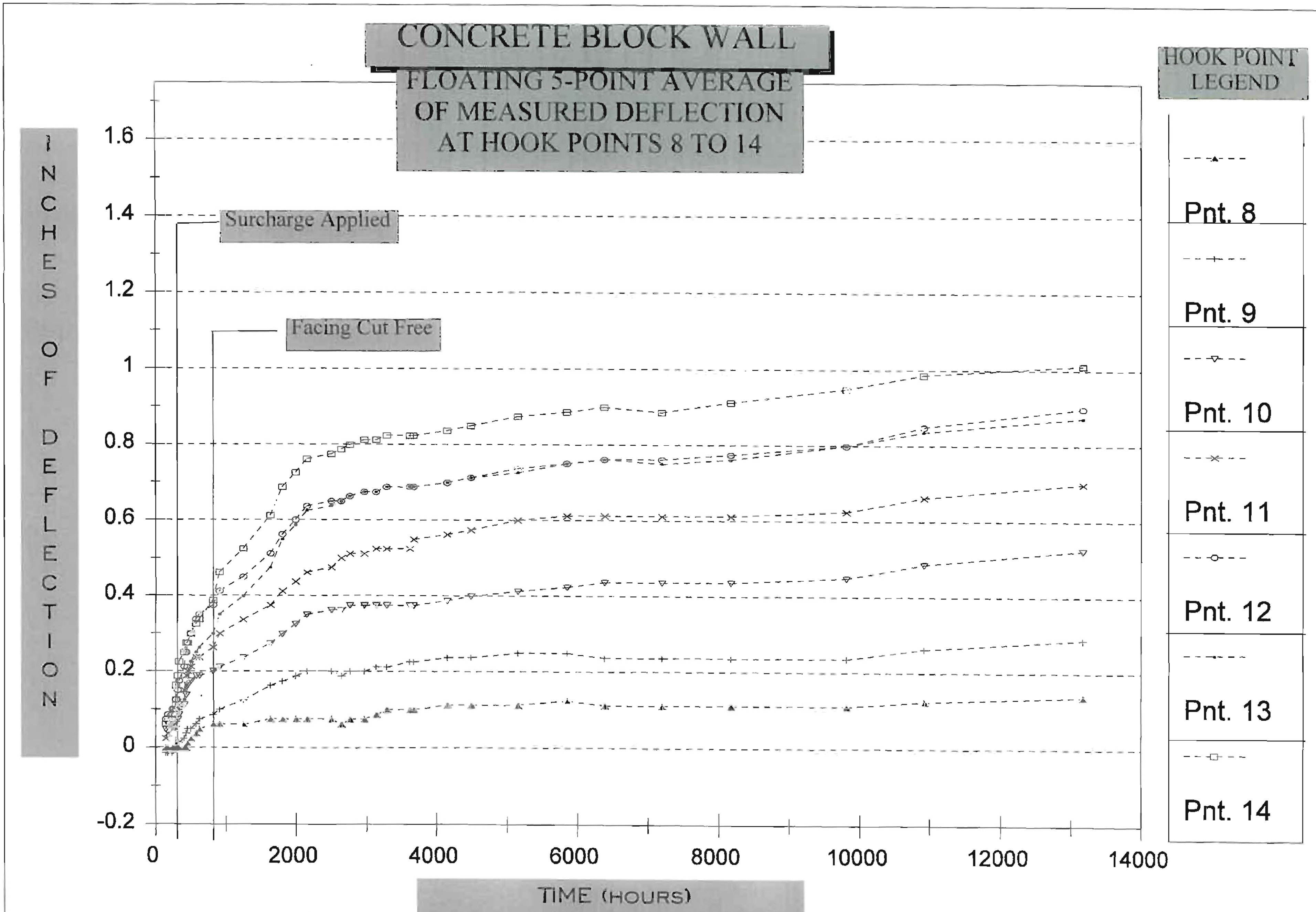
Load distributions in major MSB analytical models suggest that shortened reinforcement lengths in the lower third of the MSB composite do not significantly reduce internal stability. These walls were constructed with truncated bases and were very stable. We conclude that external stability will control selection of this design.

APPENDIX

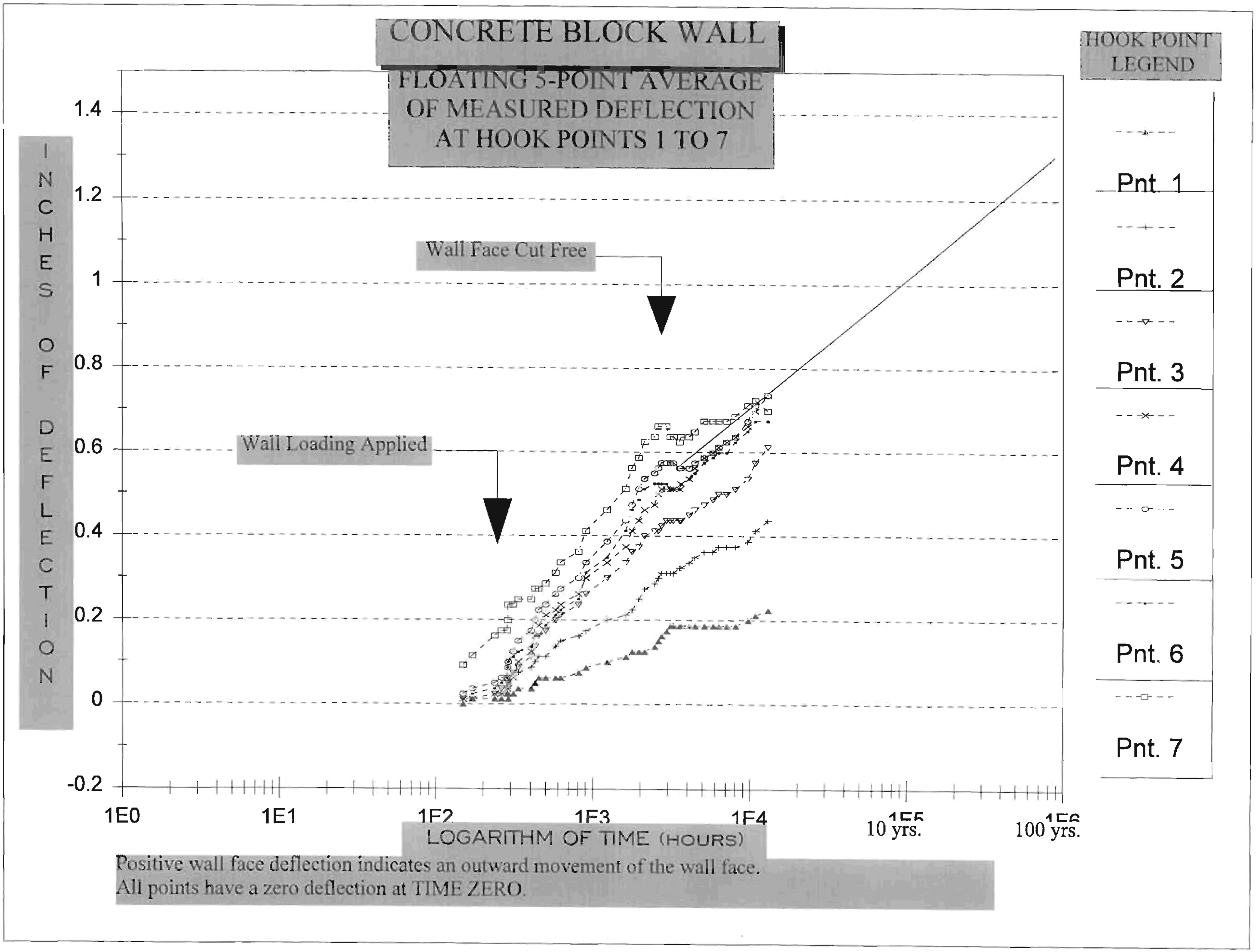
WALL FACE DEFLECTION PLOTS

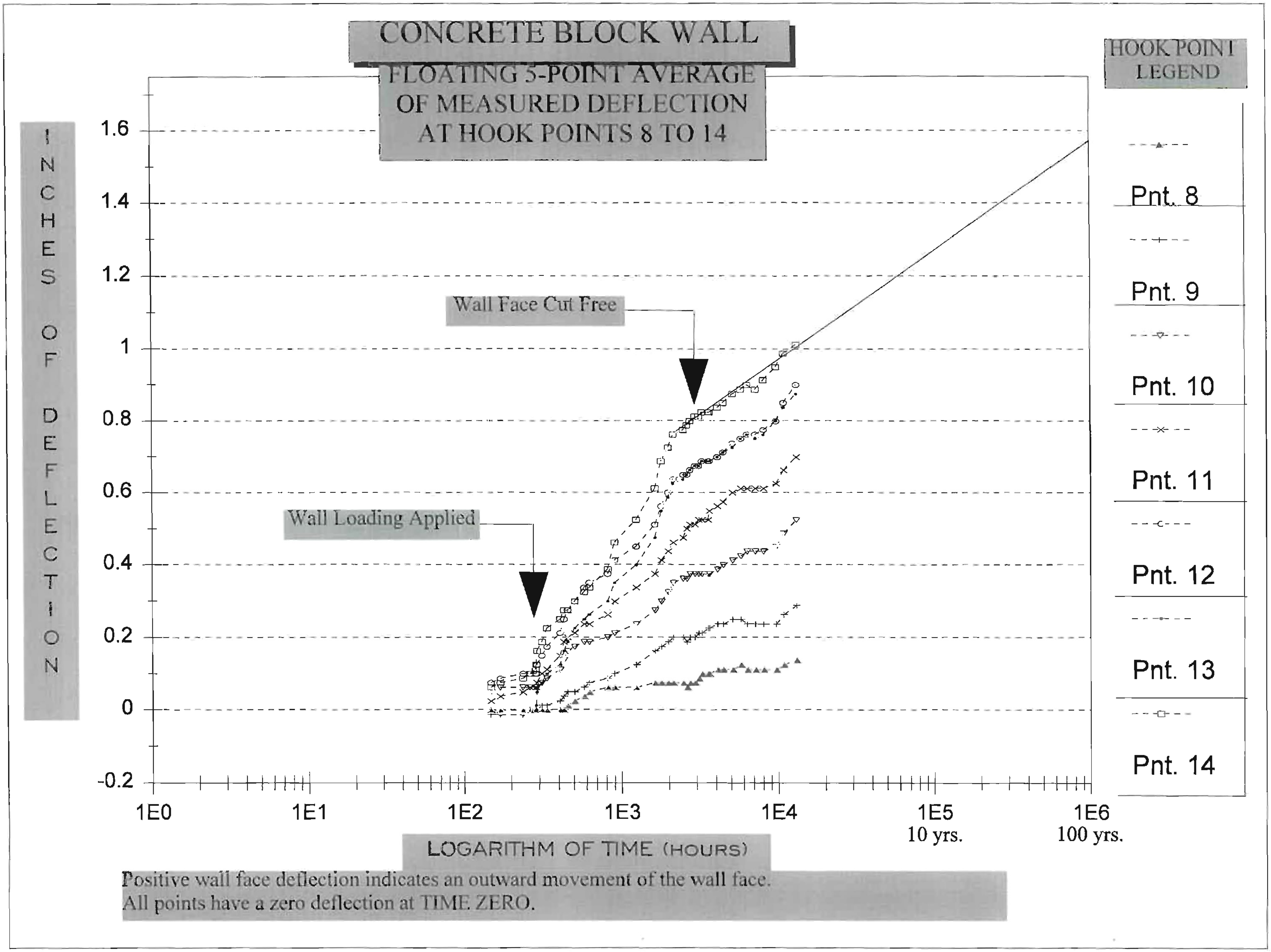


CONCRETE BLOCK WALL
FLOATING 5-POINT AVERAGE OF MEASURED DEFLECTION AT HOOK POINTS 1 TO 7
HOOK POINT LEGEND
Pnt. 1
Pnt. 2
Pnt. 3
Pnt. 4
Pnt. 5
Pnt. 6
Pnt. 7
Surcharge Applied
Facing Cut Free
INCHES OF DEFLECTION
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
2000
4000
6000
8000
10000
12000
14000
TIME (HOURS)
Positive wall face deflection indicates an outward movement of the wall face.
All points have a zero deflection at TIME ZERO.

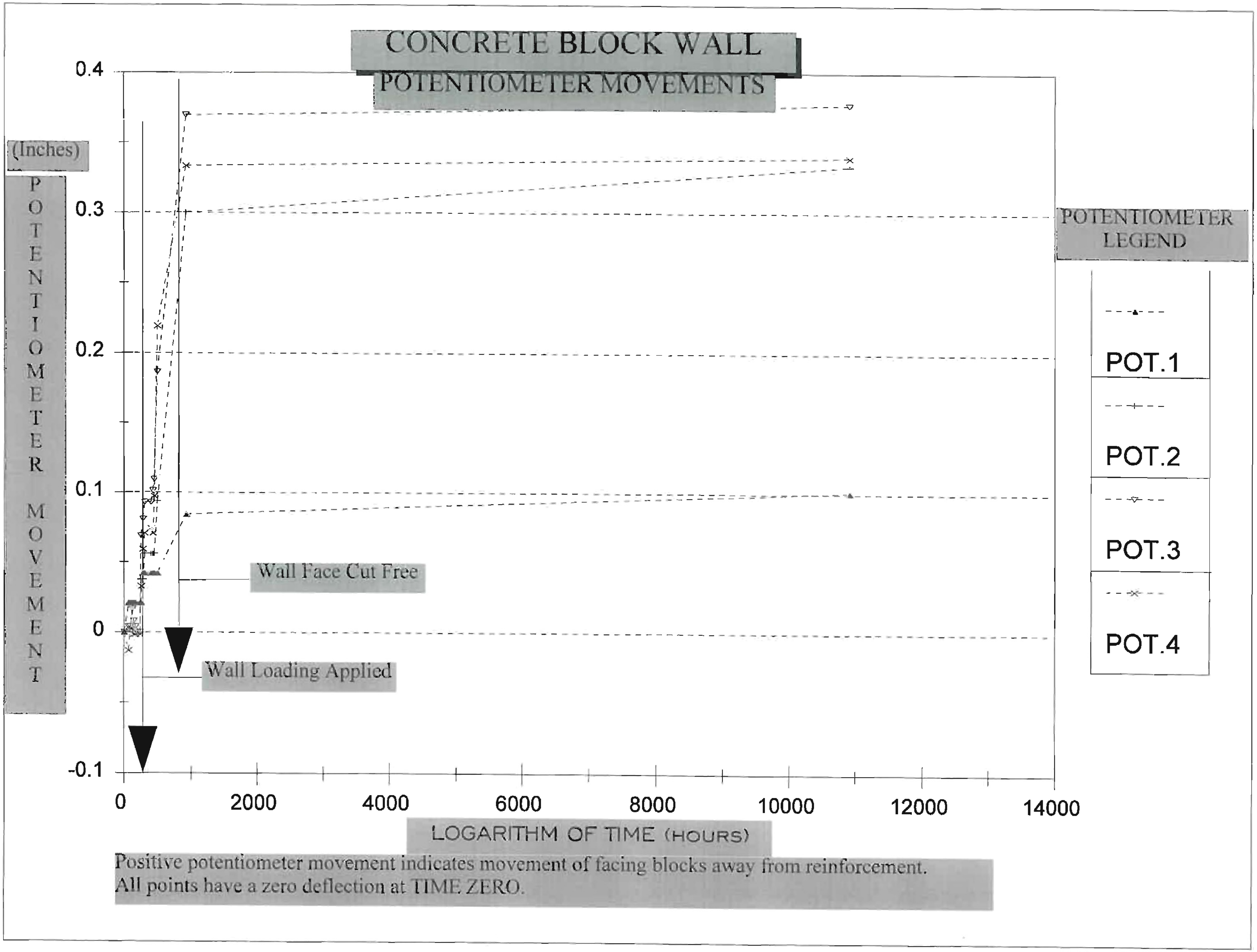


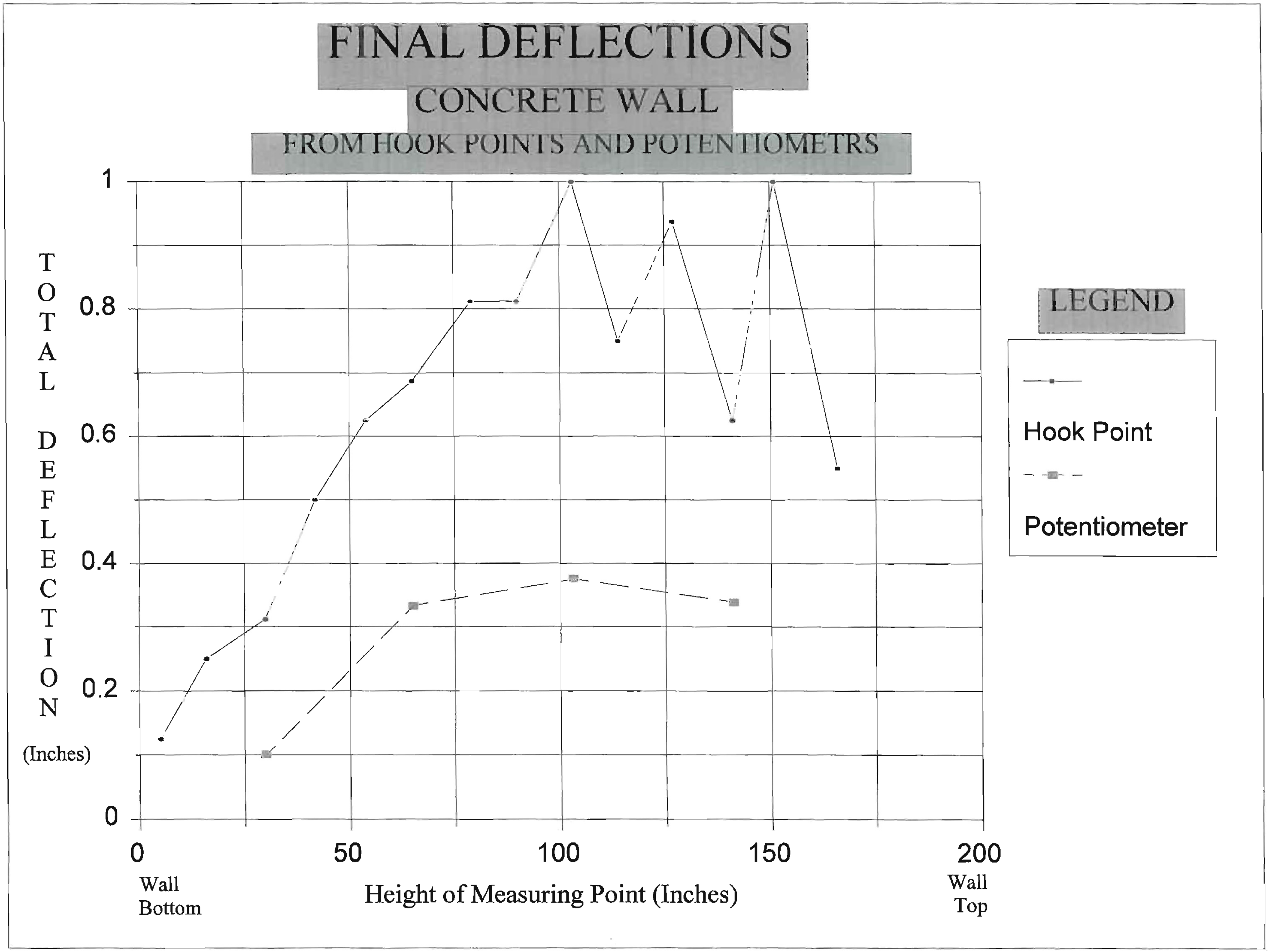
Positive wall face deflection indicates an outward movement of the wall face.
All points have a zero deflection at TIME ZERO.

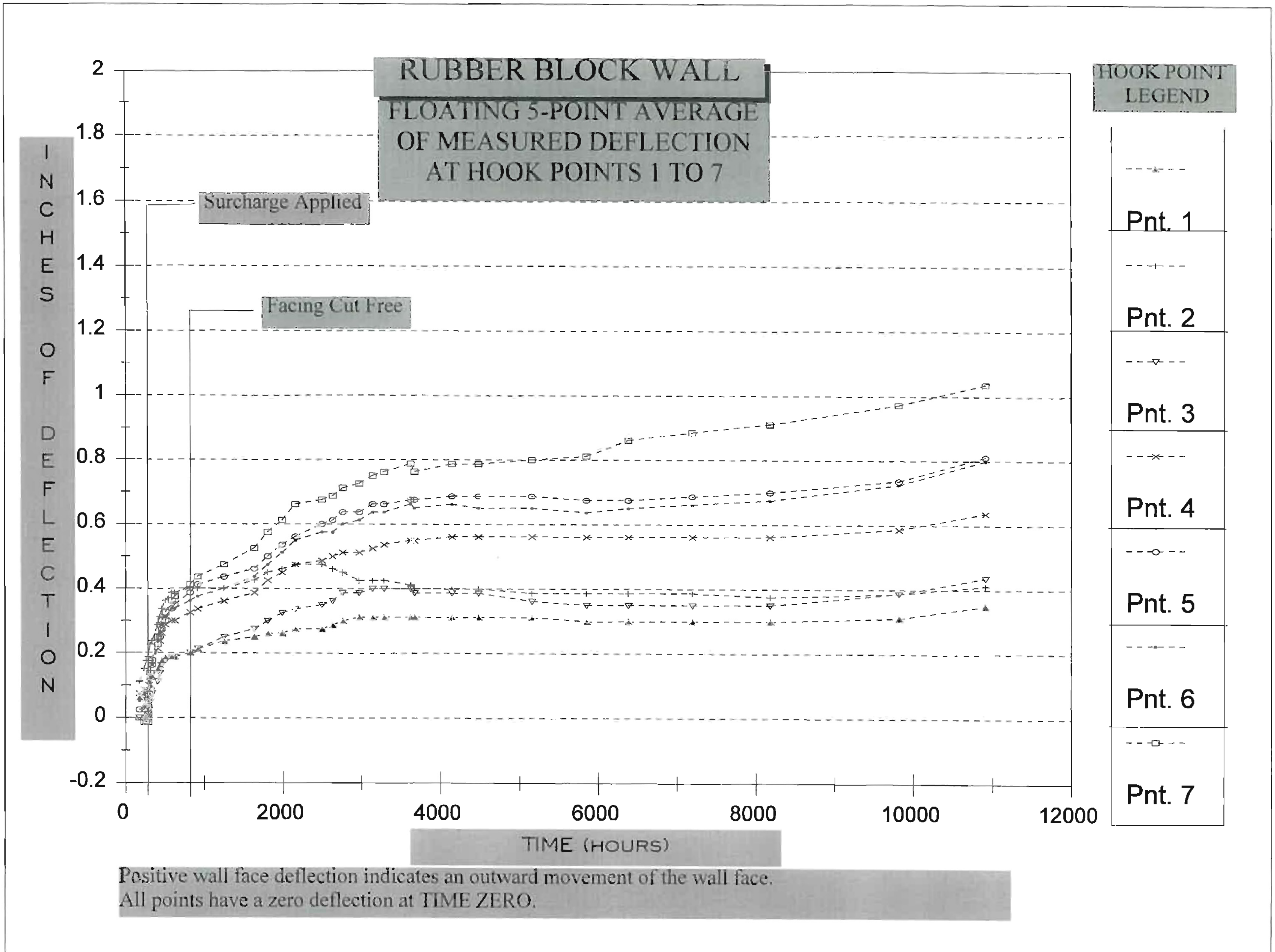

CONCRETE BLOCK WALL
FLOATING 5-POINT AVERAGE OF MEASURED DEFLECTION AT HOOK POINTS 1 TO 7
HOOK POINT LEGEND
Pnt. 1
Pnt. 2
Pnt. 3
Pnt. 4
Pnt. 5
Pnt. 6
Pnt. 7
Wall Face Cut Free
Wall Loading Applied
INCHES OF DEFLECTION
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
1E0
1E1
1E2
1E3
1E4
1E5
1E6
10 yrs.
100 yrs.
LOGARITHM OF TIME (HOURS)
Positive wall face deflection indicates an outward movement of the wall face.
All points have a zero deflection at TIME ZERO.

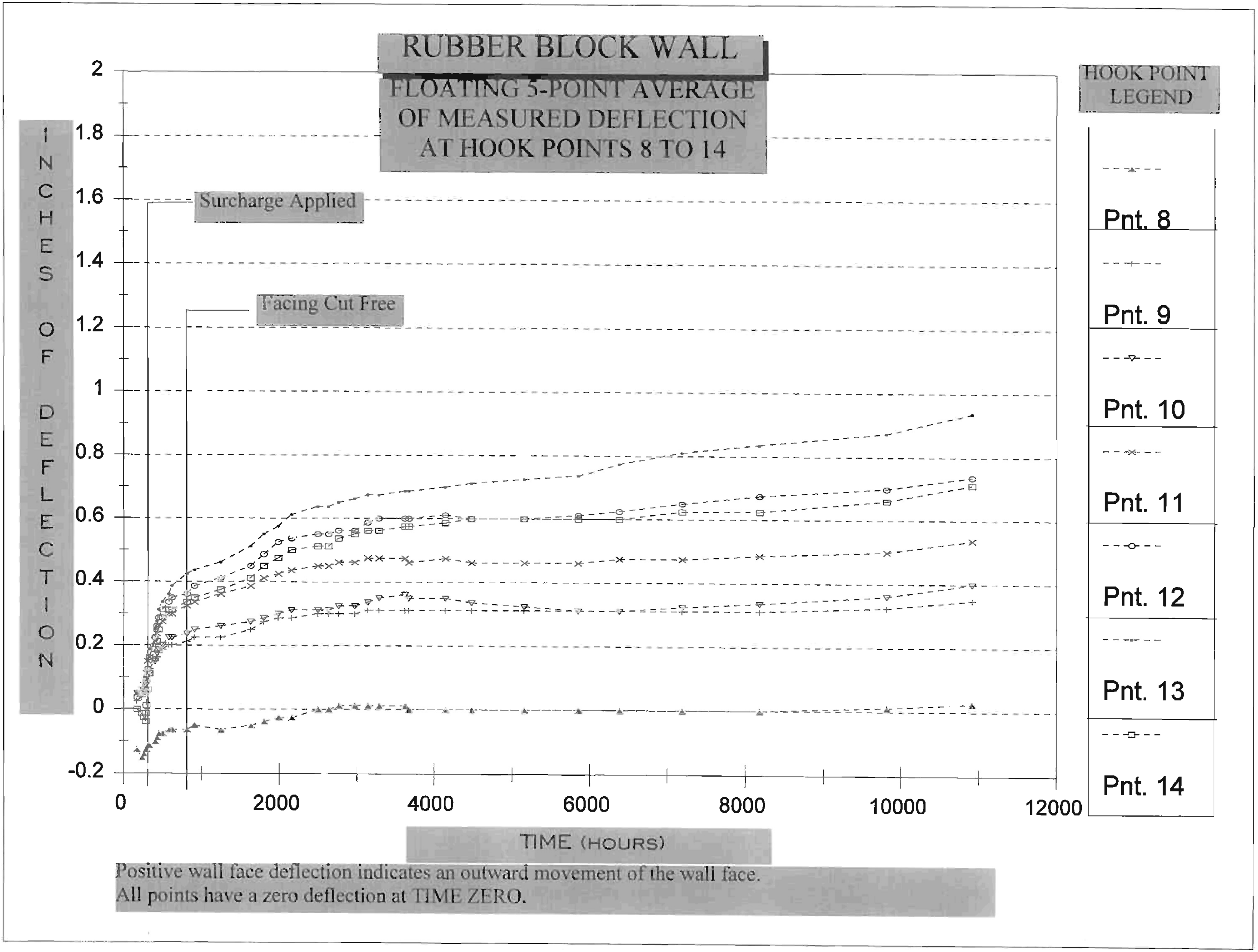


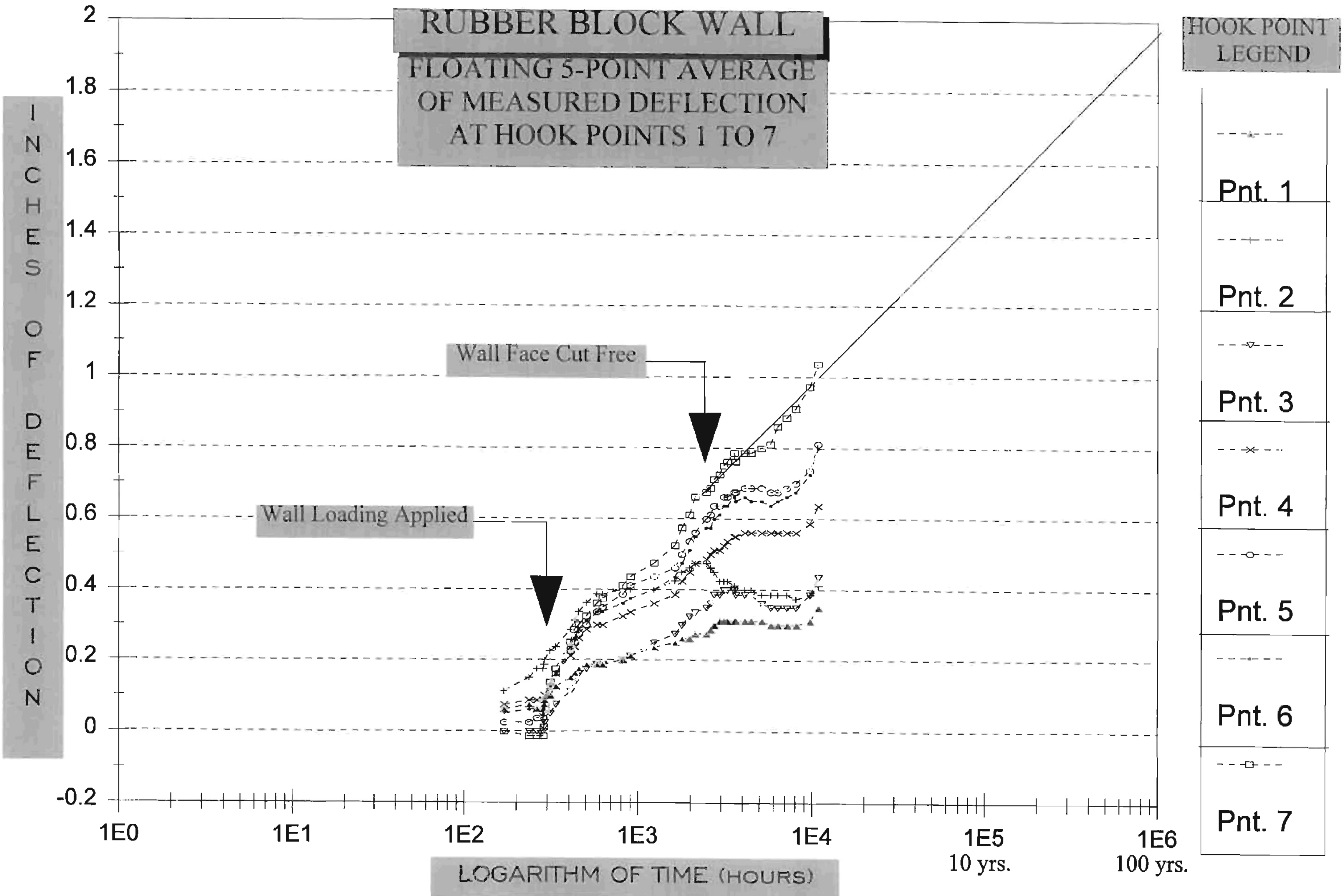
CONCRETE BLOCK WALL
FLOATING 5-POINT AVERAGE OF MEASURED DEFLECTION AT HOOK POINTS 8 TO 14
HOOK POINT LEGEND
Pnt. 8
Pnt. 9
Pnt. 10
Pnt. 11
Pnt. 12
Pnt. 13
Pnt. 14
INCHES OF DEFLECTION
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
Wall Face Cut Free
Wall Loading Applied
1E0
1E1
1E2
1E3
1E4
1E5
10 yrs.
1E6
100 yrs.
LOGARITHM OF TIME (HOURS)
Positive wall face deflection indicates an outward movement of the wall face.
All points have a zero deflection at TIME ZERO.


CONCRETE BLOCK WALL
POTENTIOMETER MOVEMENTS
(Inches)
POTENTIOMETER MOVEMENT
0.4
0.3
0.2
0.1
0
-0.1
0
2000
4000
6000
8000
10000
12000
14000
LOGARITHM OF TIME (HOURS)
Wall Face Cut Free
Wall Loading Applied
POTENTIOMETER LEGEND
POT.1
POT.2
POT.3
POT.4
Positive potentiometer movement indicates movement of facing blocks away from reinforcement.
All points have a zero deflection at TIME ZERO.

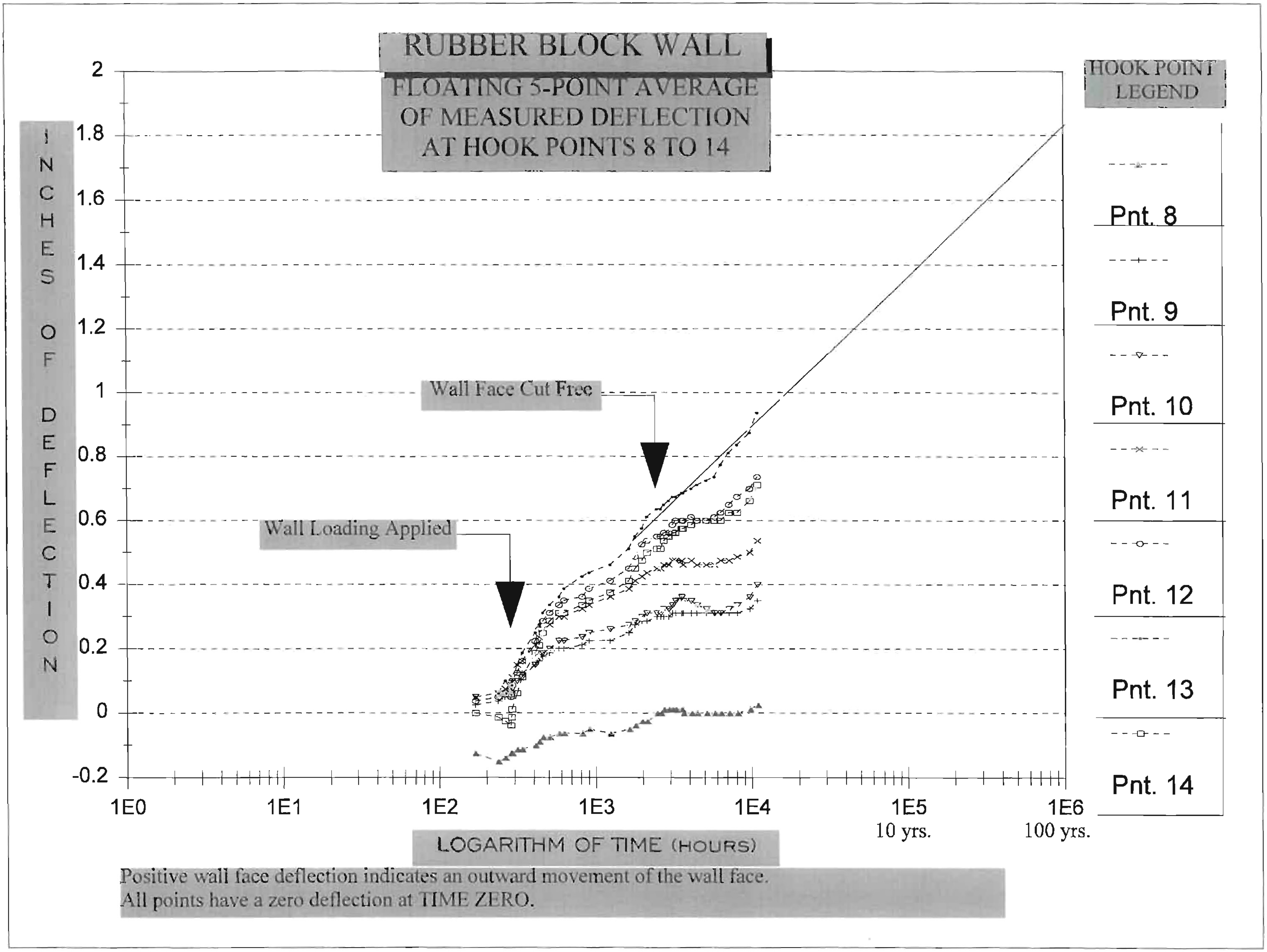

FINAL DEFLECTIONS
CONCRETE WALL
FROM HOOK POINTS AND POTENTIOMETRS
TOTAL DEFLECTION
(Inches)
0
0.2
0.4
0.6
0.8
1
0
50
100
150
200
Wall Bottom
Height of Measuring Point (Inches)
Wall Top
LEGEND
Hook Point
Potentiometer

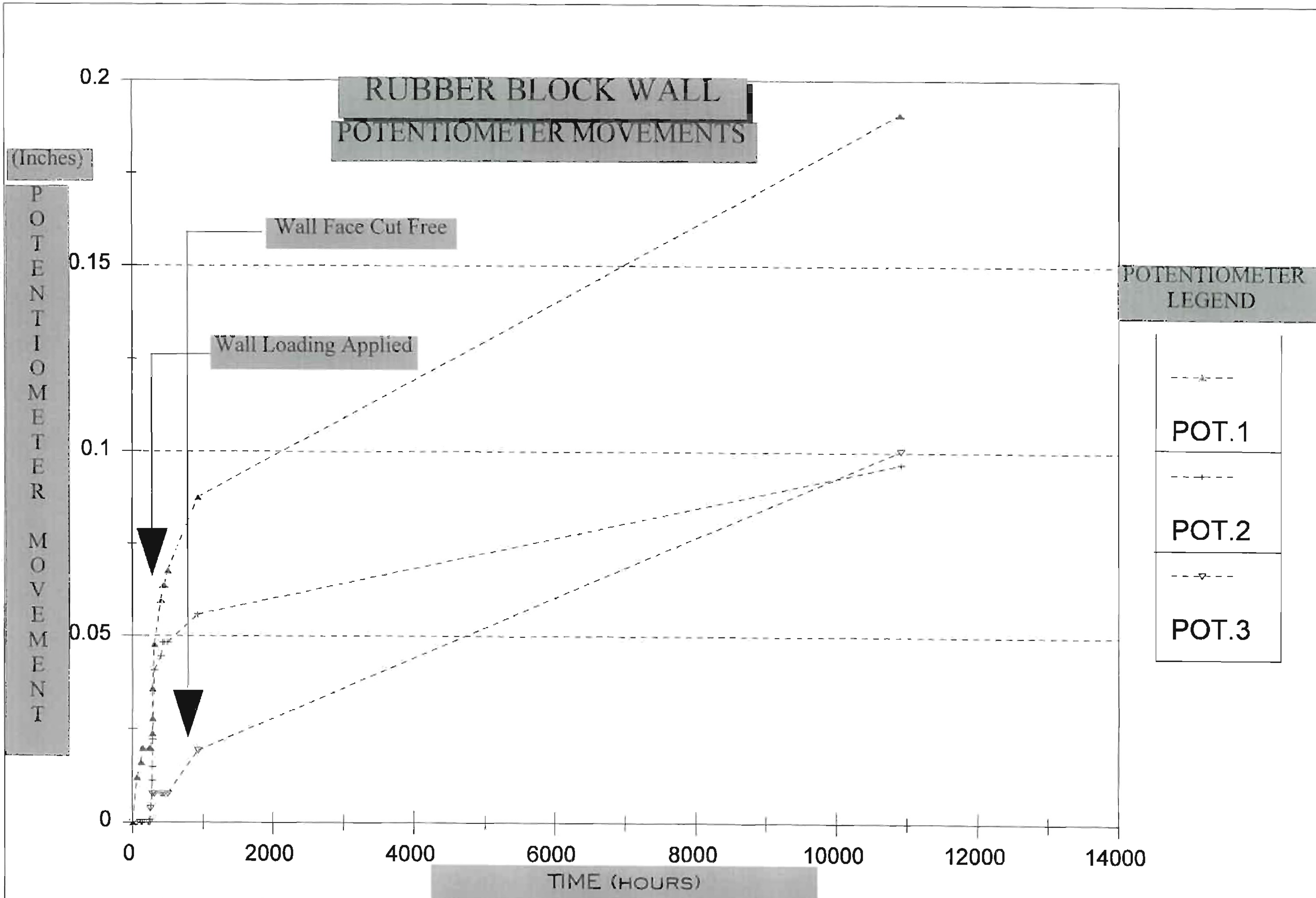

RUBBER BLOCK WALL
FLOATING 5-POINT AVERAGE OF MEASURED DEFLECTION AT HOOK POINTS 1 TO 7
HOOK POINT LEGEND
Pnt. 1
Pnt. 2
Pnt. 3
Pnt. 4
Pnt. 5
Pnt. 6
Pnt. 7
Surcharge Applied
Facing Cut Free
INCHES OF DEFLECTION
TIME (HOURS)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
2000
4000
6000
8000
10000
12000
Positive wall face deflection indicates an outward movement of the wall face.
All points have a zero deflection at TIME ZERO.


RUBBER BLOCK WALL
FLOATING 5-POINT AVERAGE OF MEASURED DEFLECTION AT HOOK POINTS 8 TO 14
INCHES OF DEFLECTION
TIME (HOURS)
Surcharge Applied
Facing Cut Free
HOOK POINT LEGEND
Pnt. 8
Pnt. 9
Pnt. 10
Pnt. 11
Pnt. 12
Pnt. 13
Pnt. 14
Positive wall face deflection indicates an outward movement of the wall face.
All points have a zero deflection at TIME ZERO.

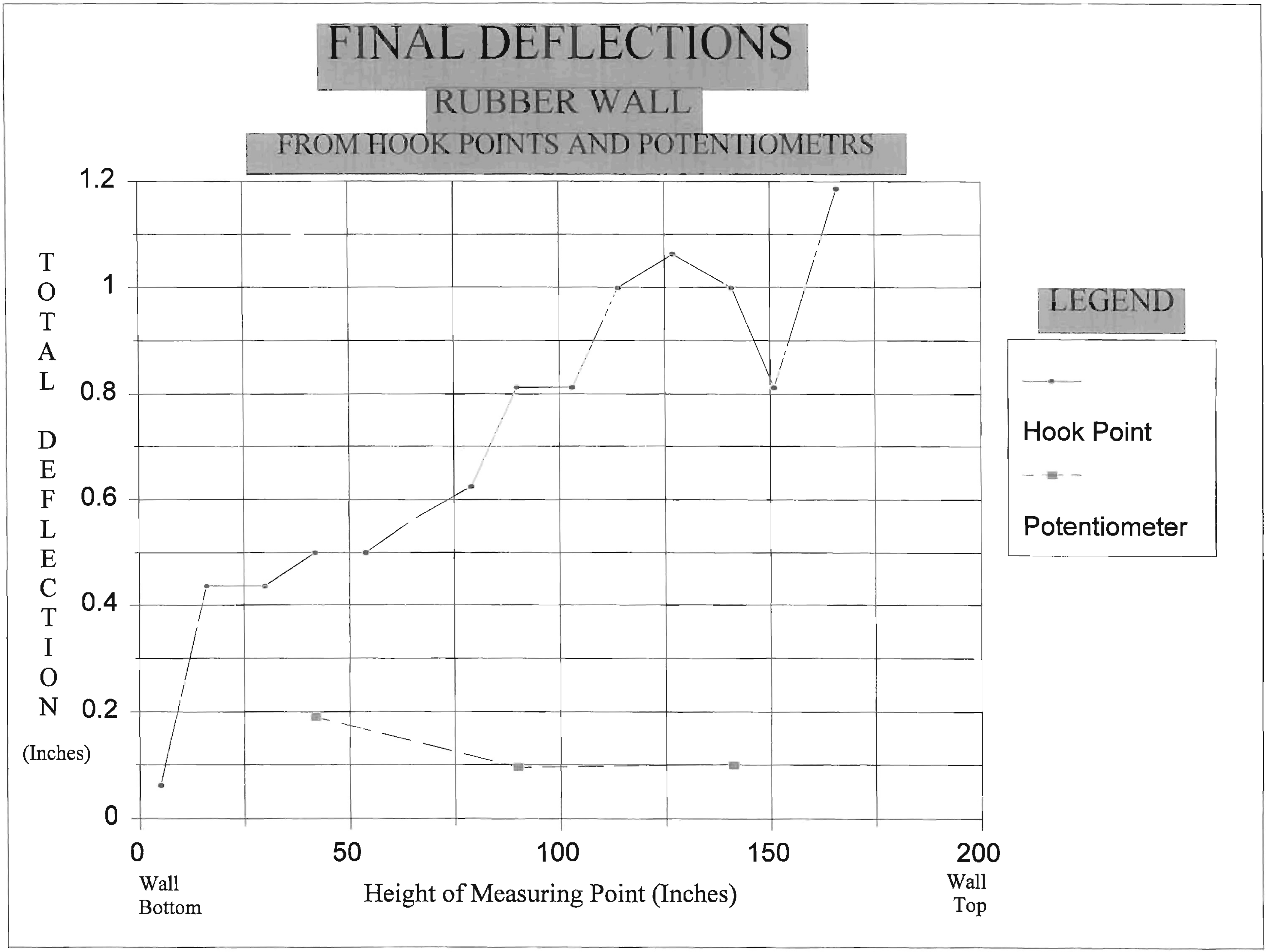


Positive wall face deflection indicates an outward movement of the wall face.
All points have a zero deflection at TIME ZERO.


RUBBER BLOCK WALL
FLOATING 5-POINT AVERAGE
OF MEASURED DEFLECTION
AT HOOK POINTS 8 TO 14
INCHES OF DEFLECTION
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
Wall Face Cut Free
Wall Loading Applied
1E0
1E1
1E2
1E3
1E4
1E5
10 yrs.
1E6
100 yrs.
LOGARITHM OF TIME (HOURS)
HOOK POINT LEGEND
Pnt. 8
Pnt. 9
Pnt. 10
Pnt. 11
Pnt. 12
Pnt. 13
Pnt. 14
Positive wall face deflection indicates an outward movement of the wall face.
All points have a zero deflection at TIME ZERO.



Positive potentiometer movement indicates movement of facing blocks away from reinforcement.
All points have a zero deflection at TIME ZERO.


FINAL DEFLECTIONS
RUBBER WALL
FROM HOOK POINTS AND POTENTIOMETRS
TOTAL DEFLECTION
(Inches)
1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
Wall Bottom
Height of Measuring Point (Inches)
Wall Top
LEGEND
Hook Point
Potentiometer