

Report No. CDOT/CTI-96-3

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

COLORADO TRANSPORTATION INSTITUTE

**William R. Schiebel
Design Engineer
Colorado Department of Transportation**

**Albert C. Ruckman
Consultant in MSB Design and Construction
Denver, Colorado**

**Robert K. Barrett
Manager of Geotechnical Research
Colorado Transportation Institute**

**J.T.H. Wu
Professor of Civil Engineering
University of Colorado/Denver**

MARCH, 1996

The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views of the Colorado Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

REPORT DOCUMENTATION PAGE			FORM APPROVED OMB NO. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave Blank)		2. REPORT DATE March, 1996		3. REPORT TYPE AND DATES COVERED Final Report, 2 years
4. TITLE AND SUBTITLE The Roles of Facing Connection Strength, Truncated Base, and Embedment in Mechanically Stabilized Backfill Walls				5. FUNDING NUMBERS
6. AUTHORS(S) William R. Schiebel, Albert C. Ruckman, Robert K. Barrett, J.T.H. Wu				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(S) Colorado Department of Transportation 4201 E. Arkansas Ave. Denver, Colorado 80222				8. PERFORMING ORGANIZATION REPORT NUMBER CDOT/CTI-96-3
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(S) Colorado Department of Transportation 4201 E. Arkansas Ave. Denver, Colorado 80222				10. SPONSORING/MONITORING AGENCY REPORT NUMBER CDOT/CTI-96-3
11. SUPPLEMENTARY NOTES Prepared in Cooperation with the U.S. Department of Transportation, Federal Highway Administration				
12a. DISTRIBUTION/AVAILABILITY STATEMENT No Restrictions: This report is available to the public through the National Technical Information Service. Springfield, VA 22161				12b. DISTRIBUTION CODE
13. ABSTRACT (Maximum 200 words) 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 geosynthetic 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.				
14. SUBJECT TERMS Connection Strength Truncated Base Reinforced Earth Embedment Modular Blocks Geosynthetic Reinforcement				15. NUMBER OF PAGES
				16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified		18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified		19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified
20. LIMITATION OF ABSTRACT				

ACKNOWLEDGMENTS

Ralph Trapani, CTI President, and Rich Griffin, CDOT Research Coordination Engineer, provided oversight and funding that enabled us to complete this milestone MSB research project.

CDOT Maintenance personnel, under the direction of Al Kline, provided the site, equipment, materials and manpower. This support was critical to the success of this project. We are greatly indebted to them.

Steve Foster and Steve Hieber, CDOT Region 3, were construction supervisors.

Tensar Earth Technologies and Jeff Rodencal contributed funding, materials and technical expertise to the steepened slope research, without which we could not have completed this MSB wall study.

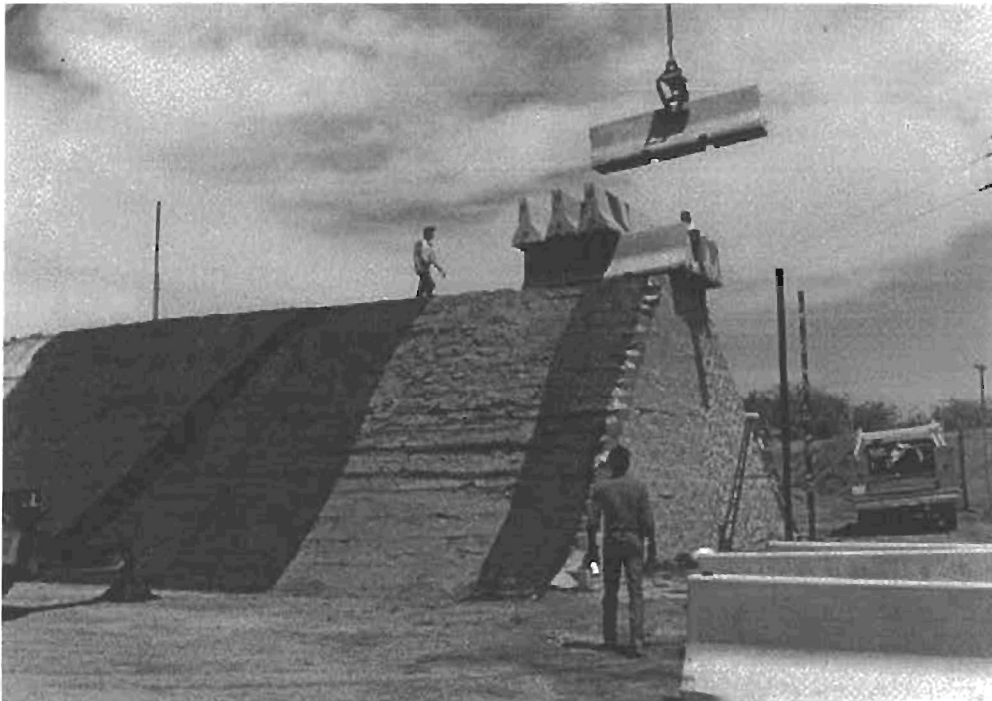
Michael McMullen, Bridge Design Engineer - CDOT, and Shan-Tai Yeh, Geotechnical Engineer - CDOT, for their review of and comments on this report.

CONTENTS

Introduction.....	p.1
Construction.....	p.2
Materials.....	p.3
Instrumentation.....	p.4
MSB Wall Face Movement Monitoring.....	p.4
Conclusion.....	p.7
Appendix - Wall Face Deflection Plots.....	p.9

INTRODUCTION

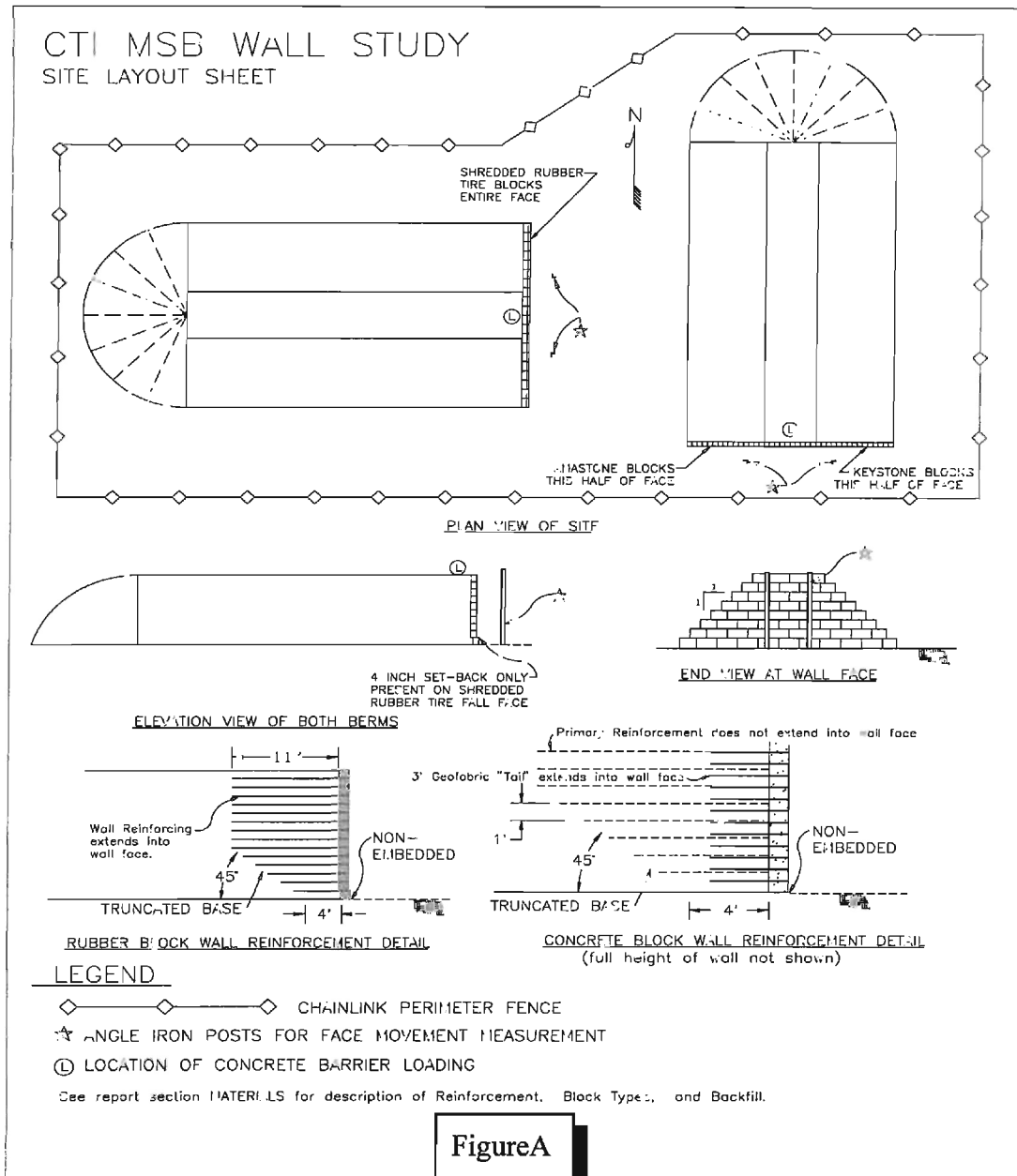
This report describes the research and results of a study of two 15 foot high mechanically stabilized backfill (MSB) walls. The purpose of the study was to gain insight into the nature of geosynthetically-reinforced, block-faced earth features. The Colorado Department of Transportation (CDOT) Research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



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 (± 625 psf) 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 (± 500 psf) and the concrete block wall having 48,000 pounds (± 750 psf) 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

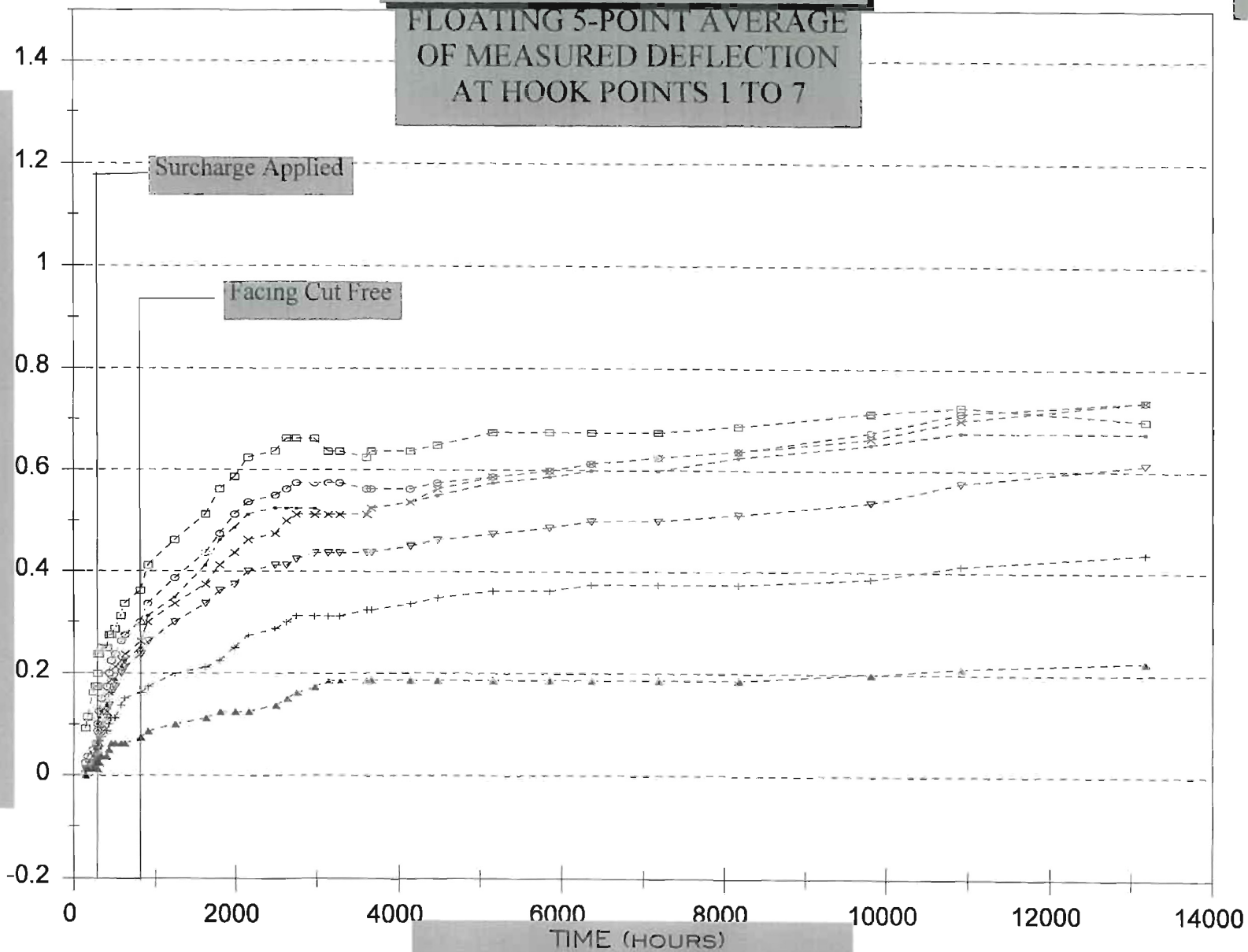
Pnt. 4

Pnt. 5

Pnt. 6

Pnt. 7

INCHES
OF
DEFLECTION

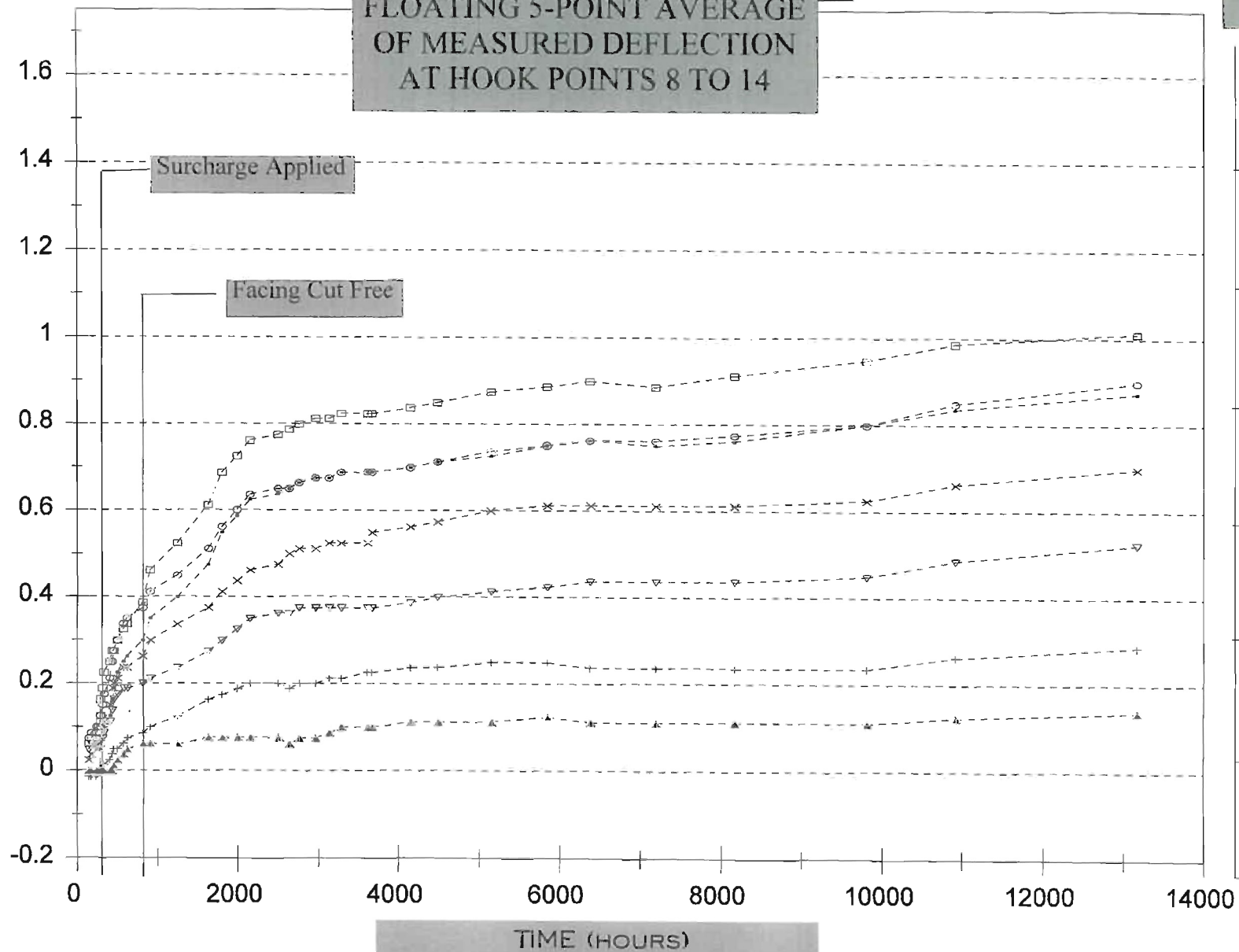


Positive wall face deflection indicates an outward movement of the wall face.
All points have a zero deflection at TIME ZERO.

CONCRETE BLOCK WALL

FLOATING 5-POINT AVERAGE
OF MEASURED DEFLECTION
AT HOOK POINTS 8 TO 14

HOOK POINT LEGEND



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

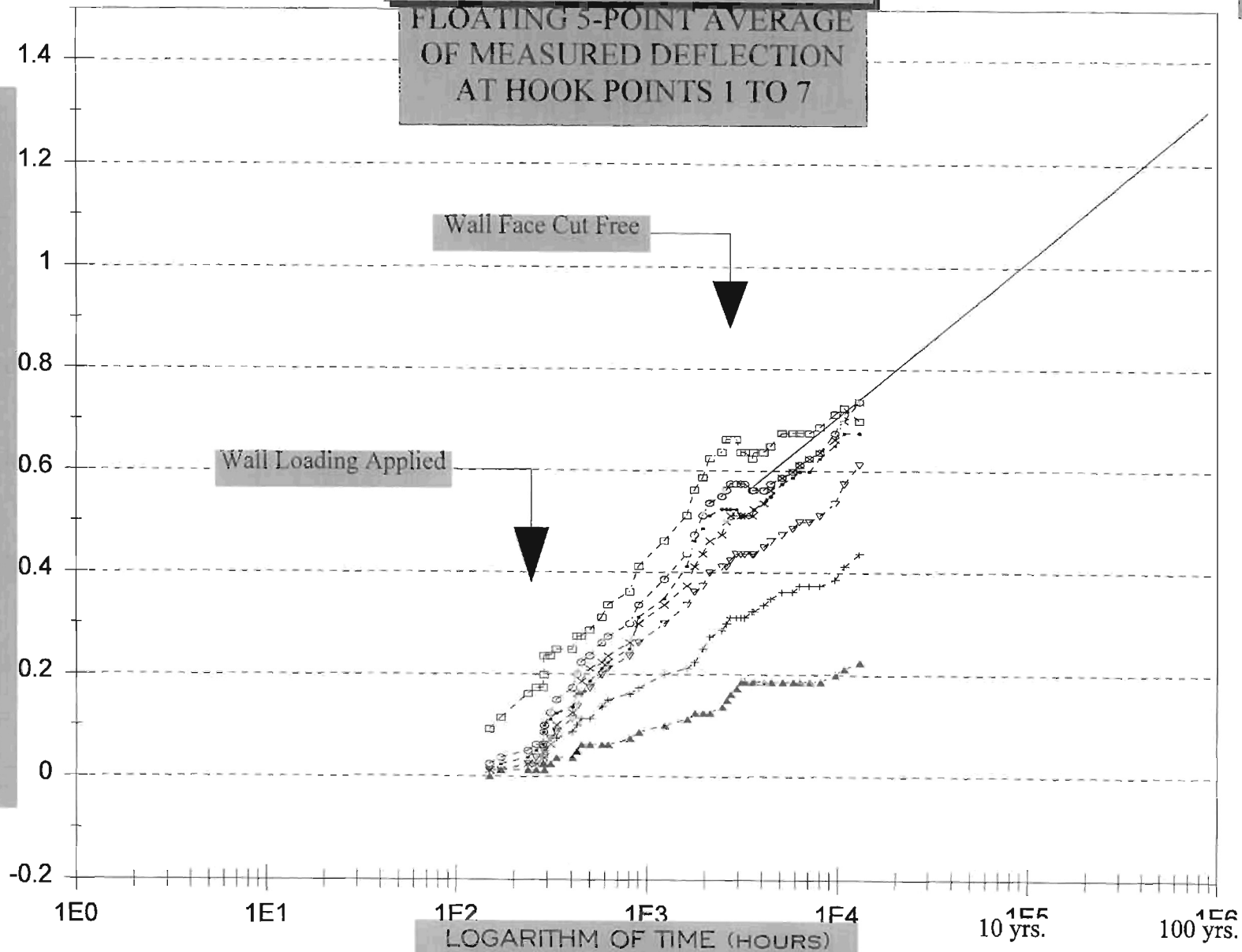
Pnt. 6

Pnt. 7

Wall Face Cut Free

Wall Loading Applied

INCHES
OF
DEFLECTION



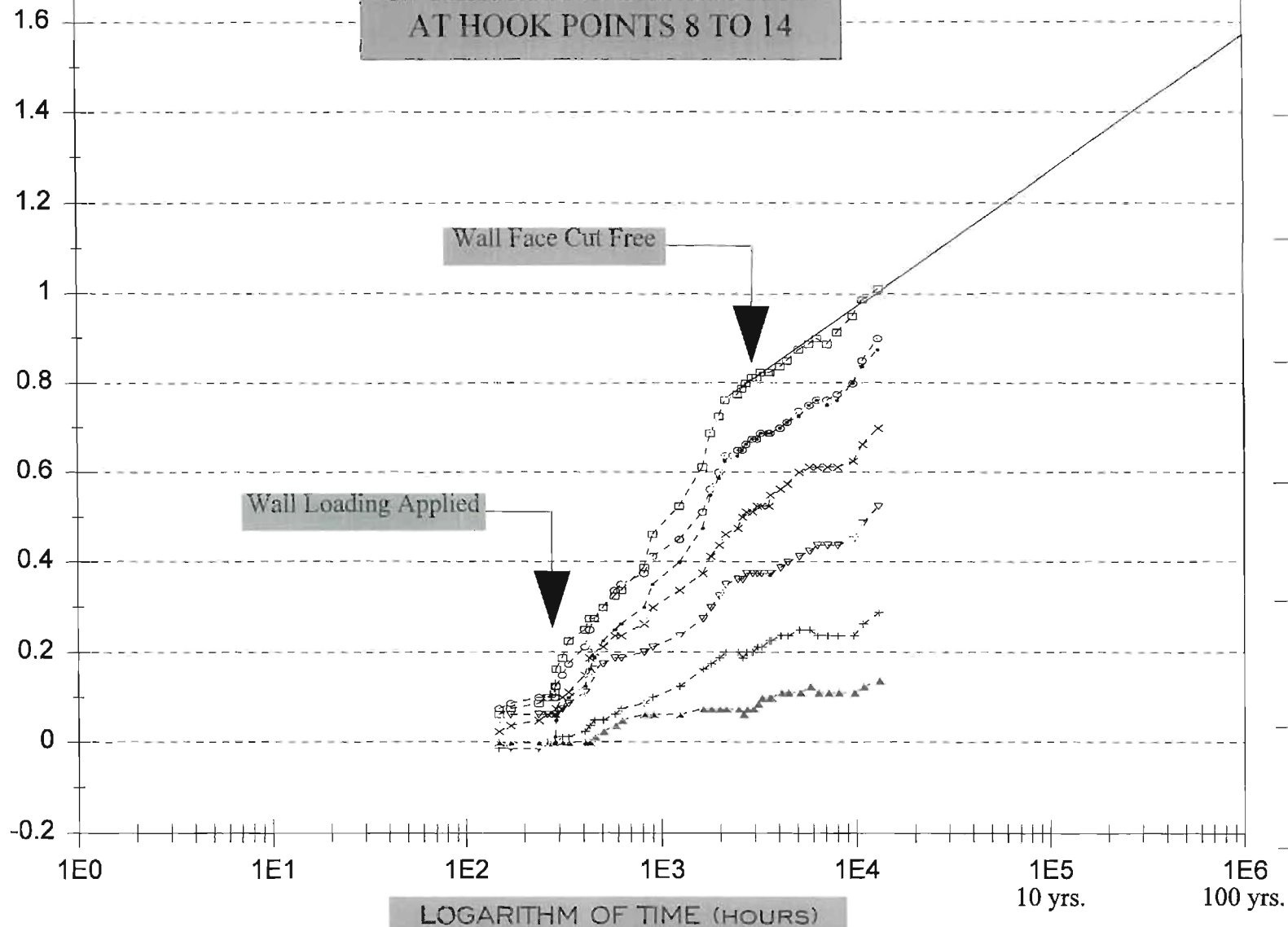
Positive wall face deflection indicates an outward movement of the wall face.
All points have a zero deflection at TIME ZERO.

CONCRETE BLOCK WALL

FLOATING 5-POINT AVERAGE
OF MEASURED DEFLECTION
AT HOOK POINTS 8 TO 14

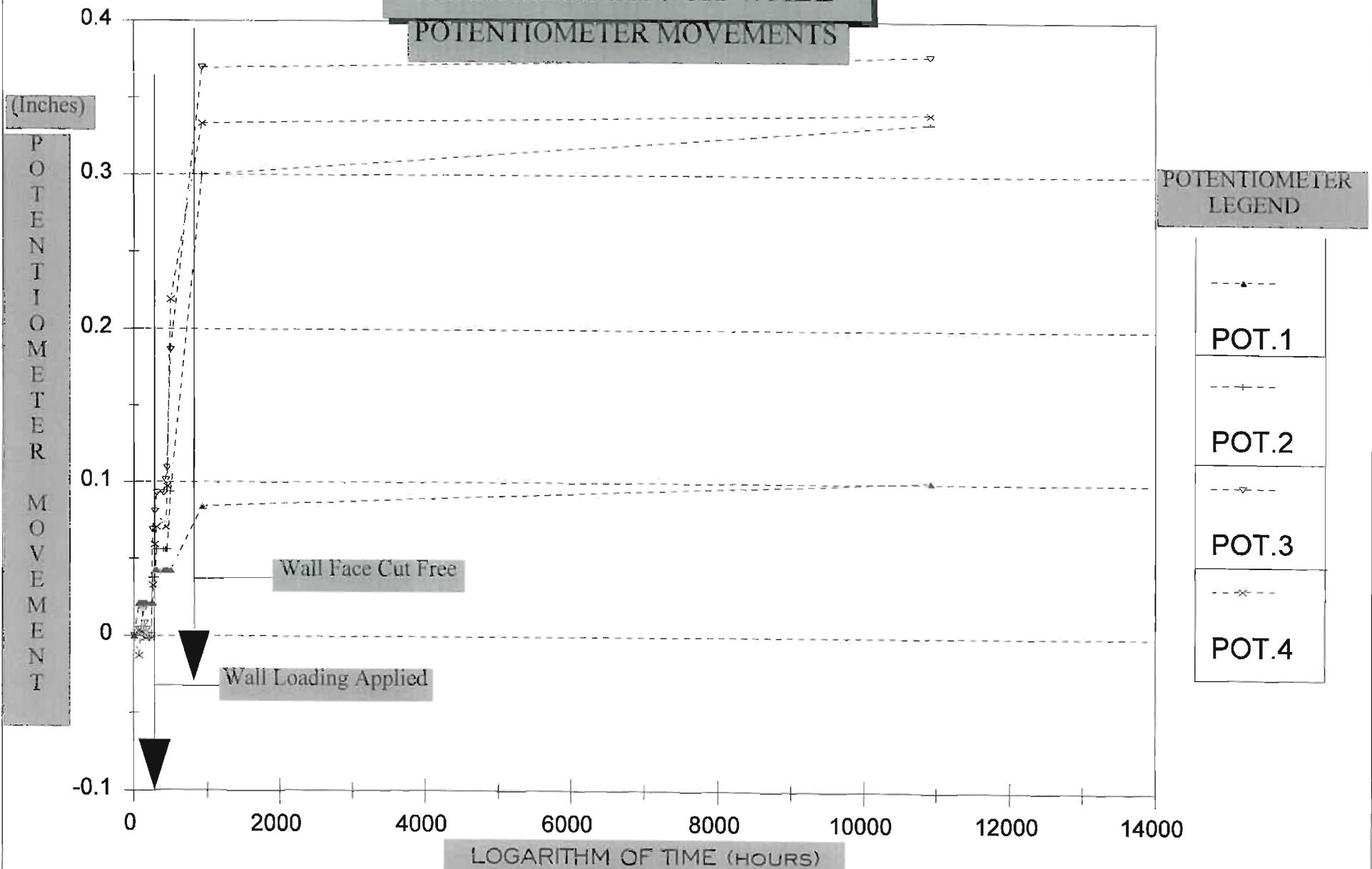
HOOK POINT LEGEND

- ▲--- Pnt. 8
- +--- Pnt. 9
- ◇--- Pnt. 10
- x--- Pnt. 11
- c--- 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.

CONCRETE BLOCK WALL POTENTIOMETER MOVEMENTS

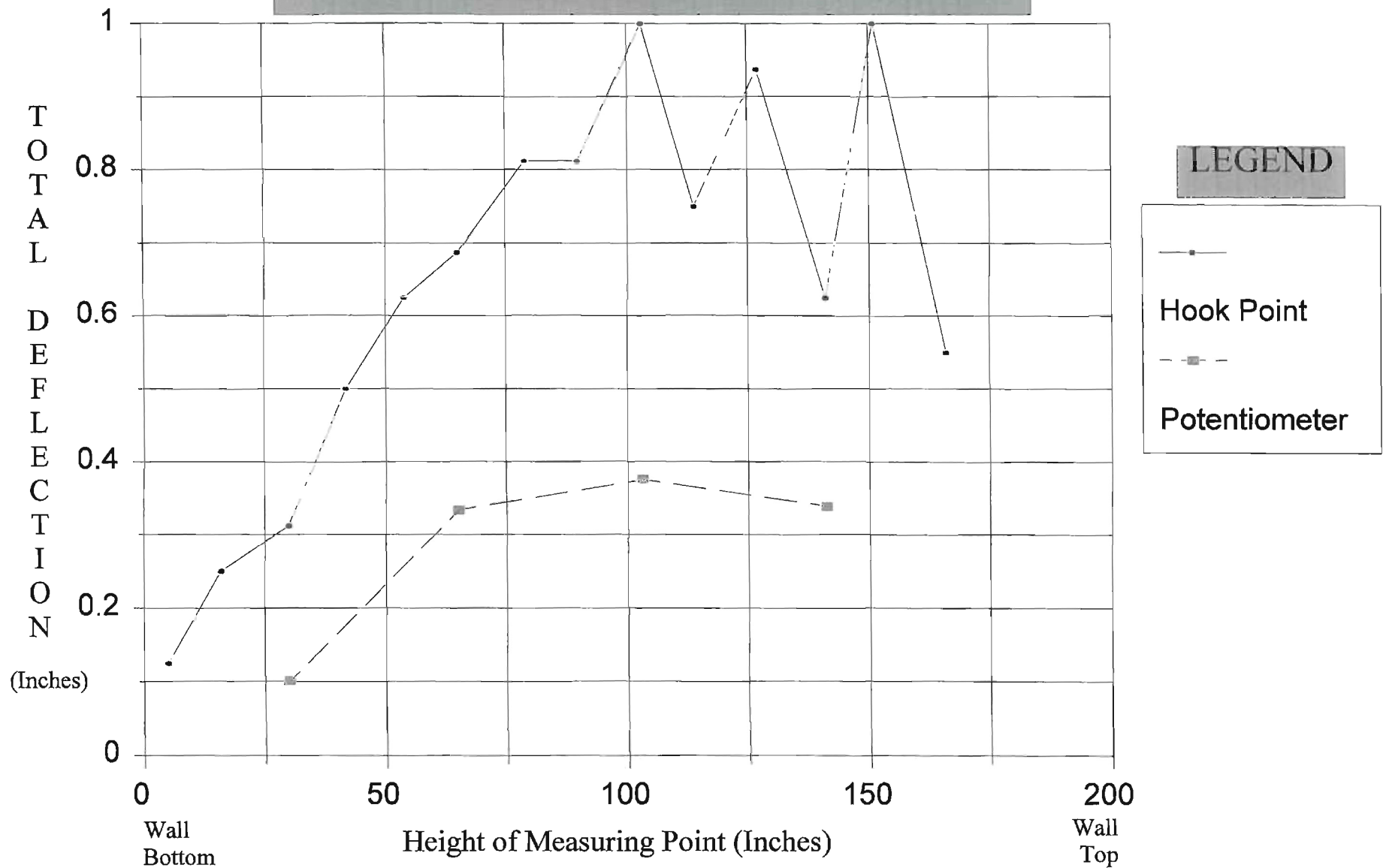


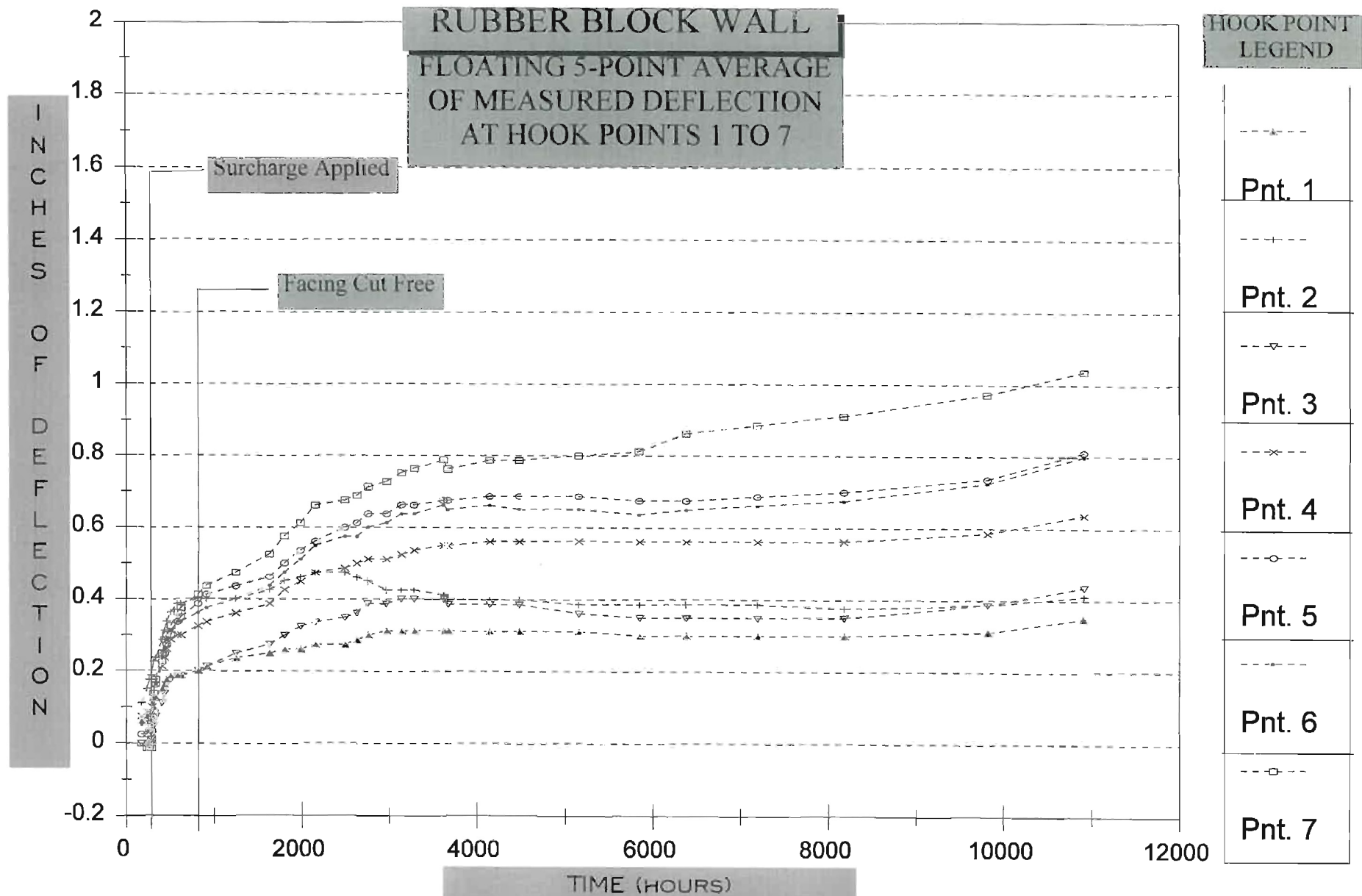
Positive potentiometer movement indicates movement of facing blocks away from reinforcement.
All points have a zero deflection at TIME ZERO.

FINAL DEFLECTIONS

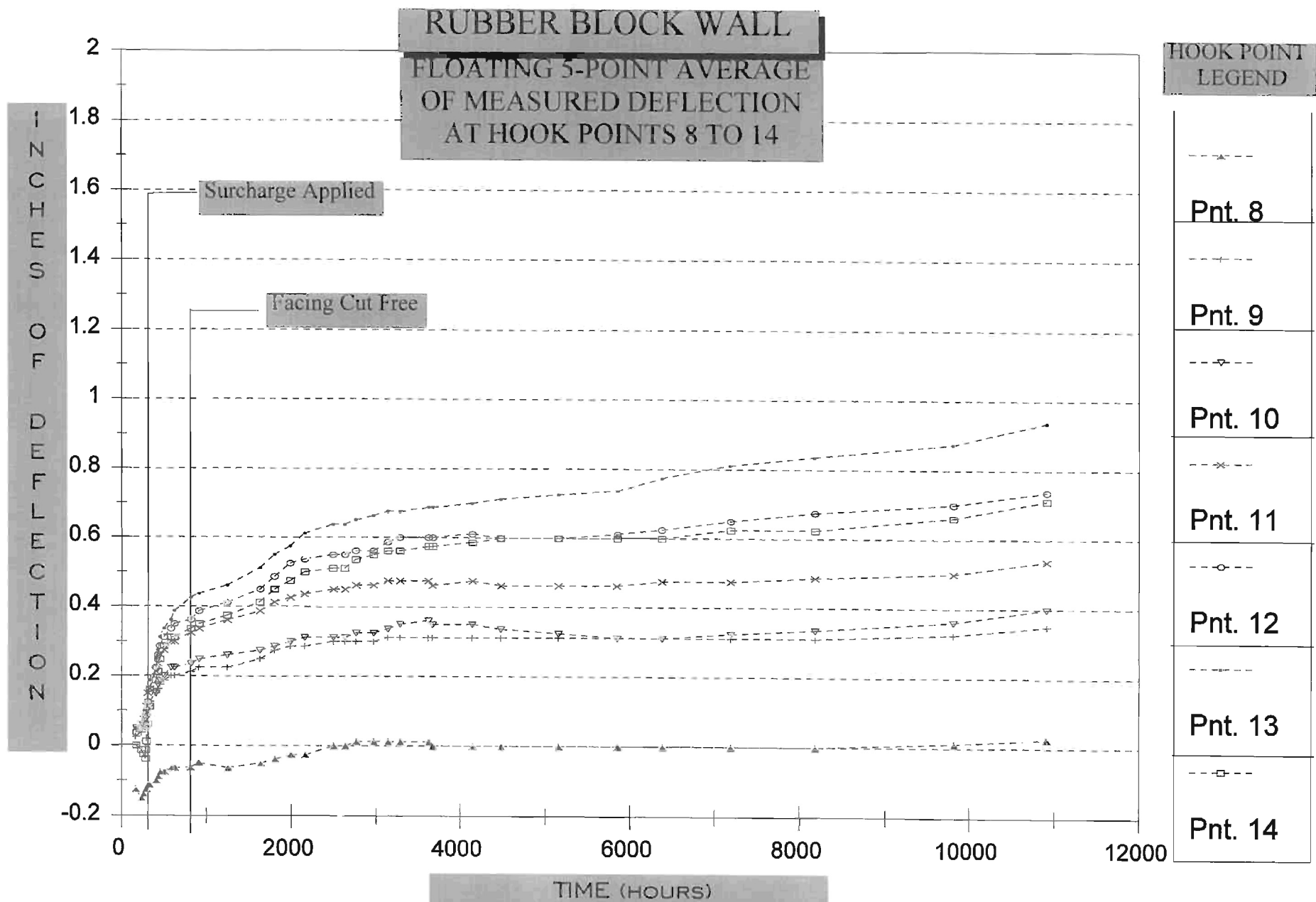
CONCRETE WALL

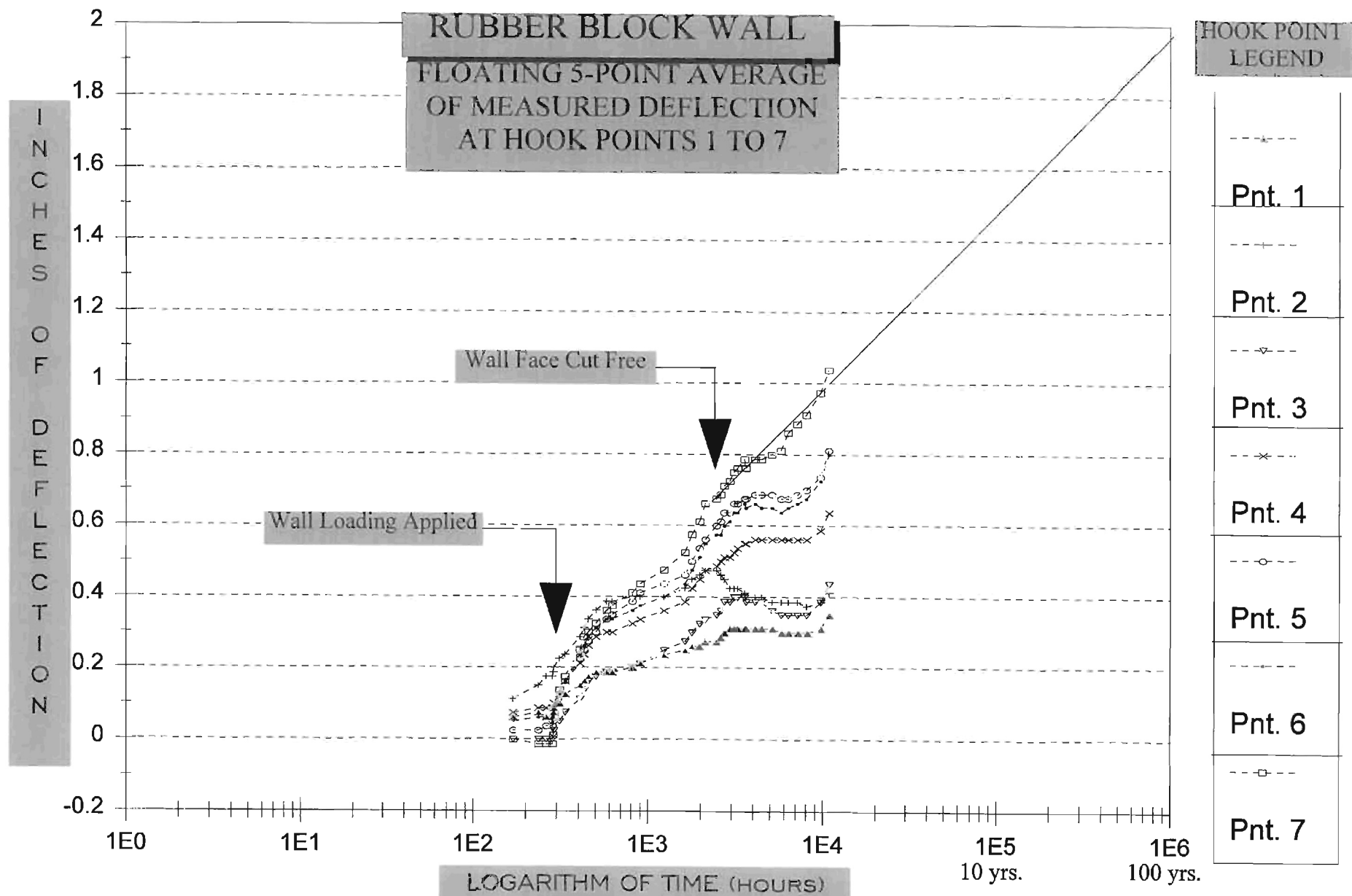
FROM HOOK POINTS AND POTENTIOMETERS



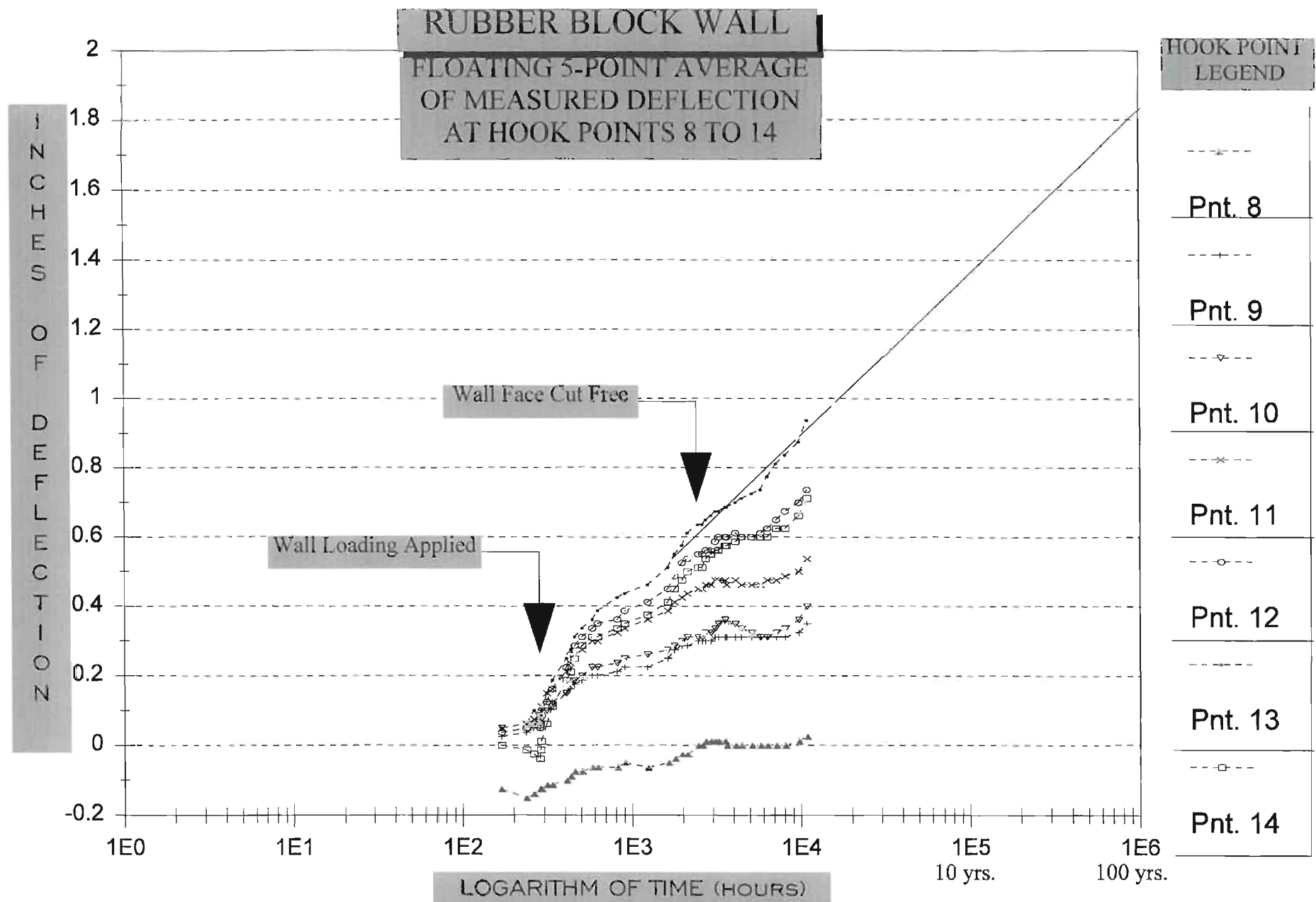


Positive wall face deflection indicates an outward movement of the wall face.
All points have a zero deflection at TIME ZERO.

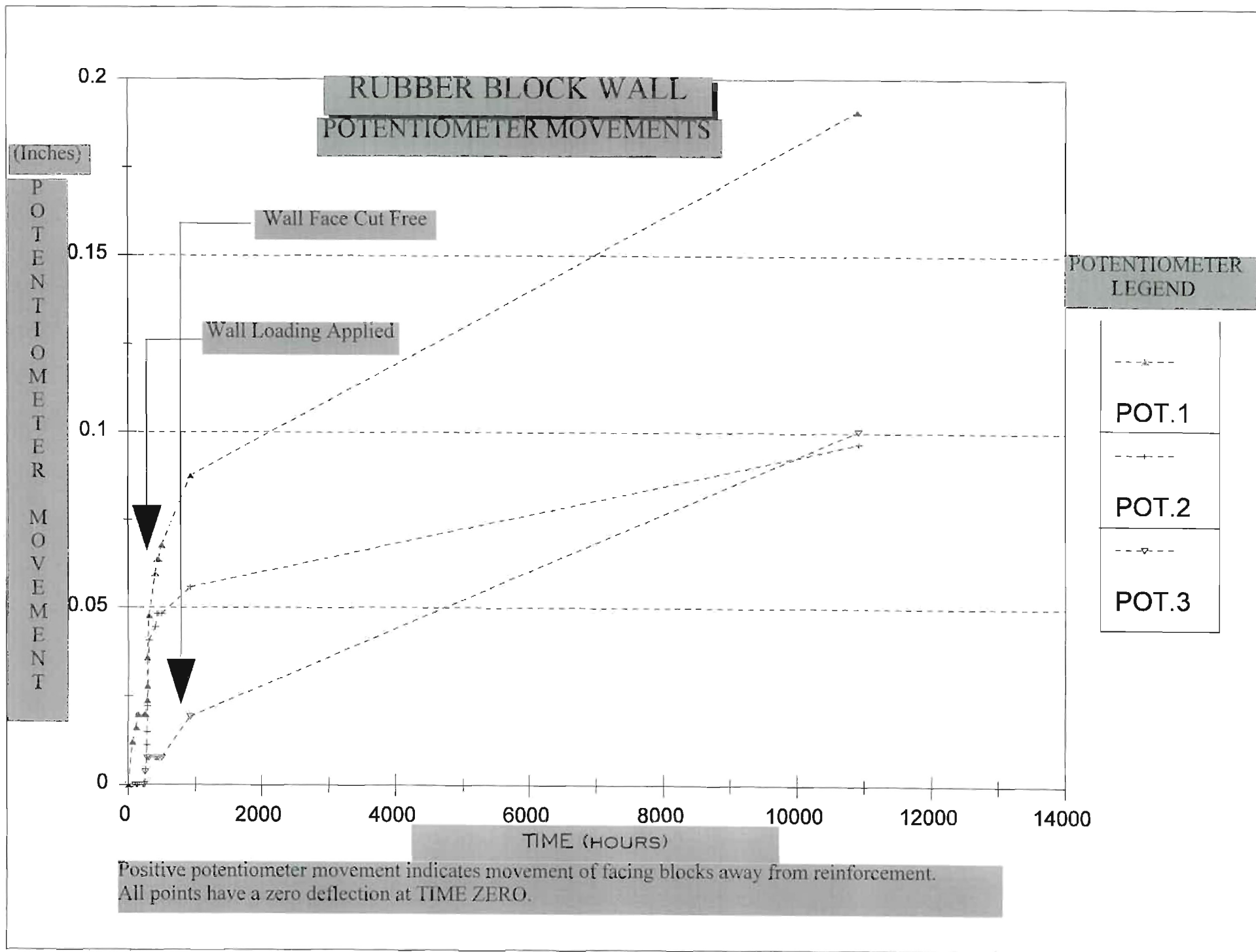




Positive wall face deflection indicates an outward movement of the wall face.
All points have a zero deflection at TIME ZERO.



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



FINAL DEFLECTIONS

RUBBER WALL

FROM HOOK POINTS AND POTENTIOMETERS

