EVALUATION OF A KEYSTONE/TENSAR GEOGRID RETAINING WALL SYSTEM

FINAL REPORT

Experimental Features
Project No. OR 89-01

by

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ABSTRACT

The KeyStone/Tensar Geogrid retaining wall system is an alternative to conventional reinforced concrete retaining wall structures. KeyStone concrete wall units, Tensar geogrid, and compacted soils are combined to form a reinforced soil mass that together act as a gravity wall structure to resist lateral earth pressures and surcharge loads.

The objective of this experimental features project is to evaluate the construction and performance of the KeyStone/Tensar retaining wall system. The benefits, as stated by the manufacturer, of this wall system include: design flexibility, easy installation, cost efficient, beauty, and wall face drainage properties.

The features of this wall system that were evaluated include: construction (including installation times and labor costs), quality and availability of precast elements, wall costs, aesthetics, wall stability and performance, and appropriateness of design details and parameters.

Two walls located in Portland, Oregon were evaluated as part of this research. Wall 1 is approximately 183 feet long, facing Southwest Taylors Ferry Road. The wall has multiple footing steps to accommodate the roadway grade and ranges in height from approximately 2.5 feet to 16 feet. Wall 2 is approximately 190 feet long, fronting on Southwest Bertha Boulevard. The wall has one footing step to accommodate roadway grade and ranges in height from 2.5 feet to 6.5 feet.

The KeyStone/Tensar geogrid retaining walls evaluated as a part of this project have performed well for two years. Although problems were encountered with block placement during construction of the walls, these problems can be avoided in future projects by designing footing and block placement with consideration of horizontal growth, batter due to block setback and thickness of geogrid.

Even though costs were not substantially lower than the estimate for conventional reinforced concrete retaining wall structures, the aesthetic qualities, performance, and construction time make this type of wall an acceptable alternative. Therefore, it is recommended that the KeyStone/Tensar Geogrid retaining wall system be considered as an acceptable alternative to conventional retaining walls for similar installations. Full acceptance of this retaining wall system for use on State projects will require completion of the OSHD Bridge Section's "Wall Acceptance Procedures;" these acceptance procedures are currently being developed.

ACKNOWLEDGEMENTS

The authors thank City of Portland Office of Transportation employees for providing information on construction procedures and conducting the inspections. In addition, the authors thank the following Oregon State Highway Division employees for reviewing this report and providing information regarding this project: George Machan (Region 1), Tim Dodson (Region 2 Location Crew), and Jan Six (Bridge Section). Furthermore, the authors thank Stephanie Swetland for typing this report.

DISCLAIMER

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The KeyStone/Tensar Geogrid retaining wall system is an alternative to conventional reinforced concrete retaining wall structures. KeyStone concrete wall units, Tensar geogrid, and compacted soils are combined to form a reinforced soil mass that together act as a gravity wall structure to resist lateral earth pressures and surcharge loads.

KeyStone retaining wall systems are constructed of specially shaped concrete blocks, as illustrated in Figure 1.1.

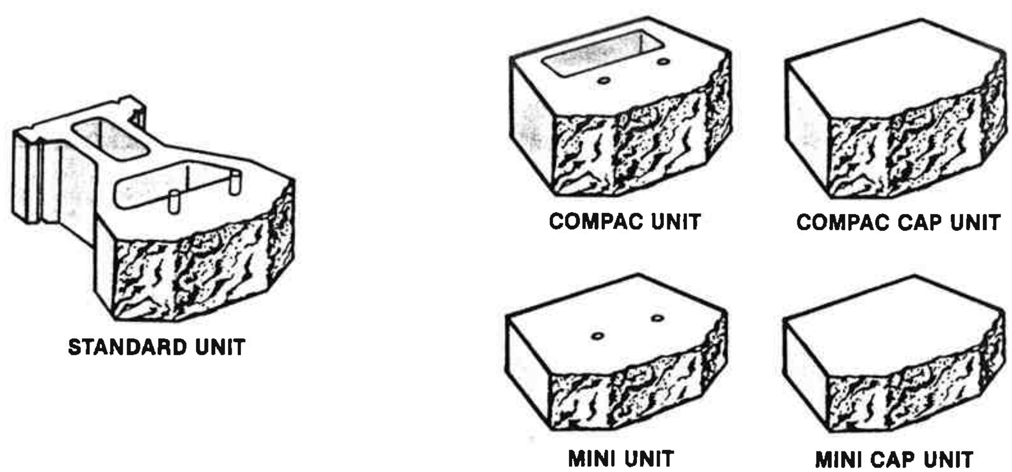


Figure 1.1: KeyStone Concrete Wall Units

Selection of the appropriate block unit is dependent on the nature of the wall being constructed. Each KeyStone unit has a pair of holes into which reinforced fiberglass pins are placed to interlock the block units. These holes may be selected with an offset for a battered wall or with no offset for a vertical wall. The shape of the blocks is such that, with proper alignment, almost any wall curvature can be constructed. If additional weight is required, the hollow nature of the blocks allows concrete to be poured into them. Normal construction practice is, however, to install the blocks as they are to reduce curing and finishing time.

Tensar geogrids are molecularily oriented polymeric grid structures specifically developed for use as tension-resistent inclusions in soils. For optimum efficiency, the geogrids are placed in the zones of largest tensile strains and in the direction of the principal tensile strains. When properly placed in a soil mass, the geogrid interlocks with the soil and reinforces it by providing tensile strength to the soil mass.

The KeyStone block units and the Tensar geogrid are combined by hooking the geogrid over the reinforced fiberglass pins connecting the block units, and extending it between the blocks into the backfill behind the wall, as illustrated in Figure 1.2.

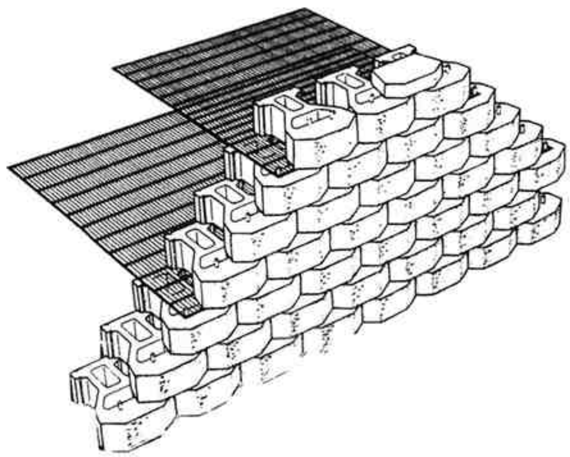


Figure 1.2: KeyStone/Geogrid Retaining Wall System

The required length of geogrid embedment into the backfill is dependent on the height of the wall, nature of the backfill material, and surcharge loading behind the wall.

The objective of the experimental features project is to evaluate the performance of the KeyStone/Tensar retaining wall system. The benefits, as stated by the manufacturer, of this wall system include:

1) Design Flexibility - Walls can be curved, straight or other complex shapes to easily adapt to the specifics of any site.

2) Easy Installation - The modular, dry stack nature of the wall facing allows for fast, labor-saving construction.

3) Cost Efficient - Construction and material costs are reduced because of the modular nature of the mass-produced wall units.

4) Beauty - The shape and texture of the blocks produces aesthetically pleasing structures.

5) Wall Face Drainage - The wall system drains without weep holes because of its morterless construction.

The features of this wall system to be evaluated include:

1) Construction; including installation times and labor costs.

2) Quality and availability of precast elements.

3) Wall costs.

4) Aesthetics.

5) Wall stability and performance.

6) Appropriateness of design details and parameters.

2.0 DESIGN

Two walls located in Portland, Oregon were evaluated as part of this research. Wall 1 is approximately 183 feet long, facing Southwest Taylors Ferry Road. The wall has multiple footing steps to accomodate the roadway grade and ranges in height from approximately 2.5 feet to 16 feet. In areas where the wall is less than 8 feet tall, the wall was designed on 6 inches of base rock material. In areas where the wall height exceeded 8 feet, the wall was designed on a 6-inch thick unreinforced concrete footing. Standard wall units were specified for base courses, compac wall units for intermediate courses and mini wall units for cap courses.

The alignment of the wall includes two angle points and a 50-foot radius curve (plans are included in Appendix A). The backslope behind the wall is essentially flat and contains a paved parking lot.

Tensar UX1500 geogrid was specified for soil reinforcement. Geogrid embedment length ranged from 6 to 10 feet depending on wall height, generally placed every 2 feet (3 block levels) in the backfill. Design of the Tensar geogrid placement assumed a line load surcharge of 250 psf due to the parking lot behind the wall and was performed by Tensar Engineering.

Wall 2 is approximately 190 feet long, fronting on Southwest Bertha Boulevard. The wall has one footing step to accomodate roadway grade and ranges in height from 2.5 feet to 6.5 feet. The wall was designed on 6 inches of base rock material in all locations. Standard wall units were specified for use throughout the wall, except the cap courses.

The alignment of the wall includes a 399-foot radius cure (plans are included in Appendix A). The backslope behind the wall ranges from 1.5:1 (horizontal:vertical) to 2:1.

Tensar UX1500 geogrid was specified for soil reinforcement. Geogrid embedment length was 6.5 feet placed every 2 feet (3 block levels) in the backfill. Geogrid placement was designed by Tensar Engineering.

3.0 CONSTRUCTION

At the recommendation of KeyStone, sections of Wall 1 over 8 feet tall were placed on an 8 inch thick, non-reinforced concrete levelling pad instead of the 6 inch pad originally specified. The designer had allowed for 2 inches in horizontal growth footing step, but confusion on the plans caused the footings to be staked and poured to the theoretical width of the blocks, with no allowance for growth. When placed, the blocks crowded the footings, which was initially remedied by cutting the end block at each step to fit the space provided. Cutting the blocks in this manner caused alignment problems with the interlocking pins for subsequent block layers. The alignment problems were fixed by removing the end block entirely, and jacking the entire base course of blocks over to the "beginning" end of the course to provide a better lineup for the interlocking pins. In the opinion of one of the project's designers, the blocks would have fit if the footings had been properly staked. However, in the future it is recommended that a growth allowance of at least one half of a block width should be provided on concrete footings to ensure that blocks will fit, especially if long runs between footing steps are anticipated. Any spaces left between the block and the footing step can be either filled with a section of cut block, grouted, or filled with the pea gravel backfill used for the block cavities.

The walls were designed using modular units with interlocking pins that are set back approximately 1/2 inch per level, producing a built-in batter to the wall. This feature of the modular units created problems with the horizontal alignment of the footings at the step transitions of the base course. Because the setback was not accounted for in the design, the blocks began to move off the back of the footing as the successive courses were installed. Fortunately, this problem was detected as the first course was being placed. The field solution to this problem was to skew the placement of the blocks by approximately 1/2 inch from one end of a base course to another, within each footing step, so that the blocks were placed diagonally to the design baseline. In this manner, the upper course of blocks, which matched the baseline course at the next footing step, would be aligned with the design base line. Because the base course of blocks was always below finish grade, the skew was not visible, and the blocks easily fit on the footings. In the future, designers should take the block setback into account when laying out walls with multiple stepped footings by stepping the footing baseline back by the appropriate amount.

The built in setback feature of the KeyStone unit also caused problems at the angle points and in the curved portion of Wall 1. As the blocks were placed higher up the wall face, they began to crowd the adjacent blocks because the tangent lengths between the angle points got shorter and the radius of the curve became smaller. KeyStone is aware of this problem and now manufactures the units with two pin locations so that the built in setback can be utilized or the blocks can be set with no setback for transition areas such as these. The crowding of the blocks, at the angle points and curved area of Wall 1, was fixed by the contractor by setting the blocks with a slight gap between them at the base course, allowing successive courses to have room to crowd together, and by slightly angling the units across their width within a course. As a result, some areas of the wall had gaps large enough for gravel backfill to spill out. These areas were corrected by grouting the gaps closed.

A problem also arose in the vertical alignment of the wall resulting from the multiple layers of geogrid used in the wall. The Tensar geogrid has a thickness of approximately 1/8 inch and was placed at various elevations in each wall section, creating small, but cumulative, grade differences at each geogrid layer. The designer had questioned both KeyStone and Tensar representatives about this matter during the design process and was told that the geogrid thickness had never caused problems with vertical alignment in prior designs. This problem was solved in the field by using short lengths of geogrid material as shims, where required, to obtain a consistent grade from one course to the next. As a future design consideration, allowance should be made to all footing and/or course elevations to account for the geogrid thickness where multiple courses of geogrid are anticipated with abrupt breaks in elevation.

A few other problems arose during the construction of the walls which were caused by poor construction practices. Although the contractor was repeatedly warned not to place more than one course at a time before backfilling, per KeyStone and Tensar specifications, up to three courses were placed without backfill before being detected by the Engineer. These areas were disassembled and rebuilt according to specifications. The contractor also did not always stake the Tensar geogrid back so that it was tight before attempting to backfill. The contractor's preferred method appeared to be to mound backfill on the geogrid to hold it in place, which was not always successful. This was corrected whenever it was detected. It was also noted that because the geogrid was provided on a roll that it tended to want to "remember" that configuration as it was laid out, and would try to roll up if placed concave upward. To defeat this problem, the layers were placed concave downward, which tended to pull the KeyStone block units into the backfill as the roll flattened out with placement. As long as the blocks were not pulled too far backward, the geogrid could be tightened by pulling the blocks forward. The Tensar representative, who was onsite for a portion of the wall construction, saw no problem with tensioning the grid in this manner. In some instances, the spacing of the slots in the geogrid did not allow easy passage of the interlocking pins of the KeyStone block units, so, with the approval of the Tensar representative, a strand of the geogrid was cut where needed for the pins to engage. Despite the problems listed above, both walls were constructed very rapidly. Wall 1 was completed in about three weeks (exclusive of excavation), and Wall 2 was completed in eight days. Both walls are very attractive and were well received by the neighborhoods. In addition, the rough texture has so far discouraged any graffiti or any other vandalism. Thus far, no maintenance costs have been incurred, and the survey monitoring of the wall has not detected any significant movements. Photographs of the walls under and after construction are included in Appendix C.

4.0 MATERIAL COSTS

A separate breakdown of the materials and installation costs for the construction of the KeyStone/Tensar geogrid walls cannot be made directly because the walls were bid as lump sum items for both projects. The cost of the walls on a unit basis, i.e. cost per square foot, can be determined by dividing the actual bid price by the Engineer's estimated quantities. This provides a convenient method for quickly estimating wall cost, since the basic layout of the wall is generally known. KeyStone provided a figure of $17 per square foot as a high end estimate for walls greater than 10 feet in height, utilizing geogrid reinforcement and native backfill materials. (Note that these figures were used for initial cost estimates only and do not reflect the use of special wall backfill.) This value was used to make initial estimates of the cost of Wall 1 at $30,000, and Wall 2 at $18,000. These costs were contrasted to preliminary estimates for an equivalent reinforced concrete cantilever wall at Terwilliger/Taylors Ferry Road (Wall 1) of $44,000 and $28,000 for a gravity type concrete wall at Bertha Boulevard (Wall 2).

A more refined Engineer's estimate was prepared after the wall designs were completed and final wall quantities were known. This estimate used more detailed information provided by KeyStone for the actual delivered cost of the materials, i.e. both full size and compact modular units, fiberglass pins, and Tensar geogrid, as well as an average cost for installing the units. This information was utilized in conjunction with current cost figures provided by the OSHD Bridge Section for structural excavation, special wall backfill and other related work, to result in a total estimated cost for Wall 1 of $32,000 ($18.42 per square foot) and $24,000 ($22.49 per square foot) for Wall 2.

The actual bid prices for the walls exhibited no predictable pattern, ranging from a low bid of $24,992 ($23.42 per square foot) for Wall 2, to a high bid of $166,000 ($95.57 per square foot) for Wall 1. The contracts for both projects were awarded to Gelco Construction, and their wall subcontractor RKO Enterprises, Inc., which also provided the lowest bids for the walls. Gelco's bid for Wall 2 was $24,992 ($23.42 per square foot), very close to the Engineers estimate of $24,000, and their bid for Wall 1 was $42,500 ($24.47 per square foot), approximately a third higher than the Engineer's estimate.

Examination of the low bids (Table 4.1) reveals a very slight economy in specifying the KeyStone/Tensar Geogrid retaining wall system over conventional construction methods for these projects. The wide range in the bids seems to indicate that unfamiliarity with the product was a contributing factor in the higher prices, especially when compared to the cost history provided by KeyStone for walls constructed in more established markets. It is known that the subcontractor had contacted the superintendent on a much larger private contract utilizing KeyStone that was under construction in the Portland area at the time these projects were bid, and his bid could have been influenced by the (reportedly unfavorable) experiences encountered on that job. In addition, since the project schedules placed the wall construction early on the critical path, it is possible that the bid prices were inflated to take advantage of an early capital recovery from the first progress payment. In any case, as the use of these products becomes more widespread in this region, it is expected that the costs will go down.

Table 4.1: Wall Cost Summary

	Wall 1	Wall 2
Preliminary Estimates: Keystone/Geogrid Conventional Wall	 $30,000[1] ($17.00/sq.ft.) $44,000[2]	 $18,000[1] ($17.00/sq.ft.) $28,000[3]
Engineer's Estimate Keystone/Geogrid	$32,000 ($18.42/sq.ft.)	$24,000 ($22.49/sq.ft.)
Low Bid Prices	$42,500 ($24.47/sq.ft.)	$24,992 ($23.42/sq.ft.)

[1]Estimate utilizing native backfill.
[2]Reinforced concrete cantilever wall.
[3]Gravity type concrete wall.

5.0 EVALUATION

1. Construction; including installation times and labor costs.

Problems that were encountered during the construction of the wall were caused by a combination of confusing, inadequate design drawings and poor construction practices. Fitting together of blocks require close placement tolerances. This should be accounted for by designers, who should provide allowances for horizontal and vertical growth in the wall. The problems associated with installation and construction practices on these walls can be eliminated on future projects by learning from the experiences of these projects.

Despite the problems encountered during construction, both walls were completed rapidly. Wall 1 was completed in 21 days, excluding excavation, and Wall 2 was completed in 8 days.

No labor costs were available because the walls were bid on a lump sum basis.

2. Quality and availability of precast elements.

No problems were encountered with the quality and the availability of materials. No strength testing was completed on the block units.

3. Aesthetics

The consensus is that the walls are attractive and they have been well received by the neighborhoods. The texture of blocks gives the appearance of a quarried stone wall and has, to date, discouraged any graffiti or other vandalism. Photos of the completed wall are included in Appendix C.

4. Wall Stability

Wall movements were monitored at 14 points on Wall 1 and at 7 points on Wall 2. Measurements were made at 6, 20, and 94 weeks. The average movement in millimeters at 94 weeks were:

	Wall 1	Wall 2
Settlement	Max -2	Max -3
(+:upward)	Min -1	Min -1
	Ave -1	Ave -2
Horizontal	Max -5	Max -3
(+:into backfill)	Min 0	Min 0
	Ave -2	Ave -1
Lateral	Max -13	Max -8
(+:to left of observer)	Min -2	Min -2
	Ave -5	Ave -5

Complete records of the measured wall movements and the locations of the points monitored are contained in Appendix B.

The movement of the walls downward (settlement) and away from the backfills (horizontal) was insignificant (an average of 1 to 2 millimeters). The movement of the walls to the right was small (an average of 5 millimeters), however, the data does not appear to be random. Therefore, the movement of the walls will continue to be monitored.

5. Appropriateness of original design details and parameters.

Many of the problems encountered during the installation of these walls were related to the lack of attention to detail in the design and specification of footing and block unit placement. Allowances must be made for horizontal growth between blocks, the built in setback feature of the block units, and for the thickness of the geogrid layers in the design of the placement of footings and block units.

There is no indication of problems in the design related to the structural adequacy of either wall.

6. Other observations related to long-term wall performance.

Longitudinal cracks have been noted in the sidewalks in front of both walls approximately three feet from, and parallel to the face. These cracks died out 3-4 feet from the ends of the walls, and are not evident in other sections of the sidewalks. No differential settlement has been observed across these cracks.

Stains were observed on Wall 1 and Wall 2. On Wall 1, the stains were observed during construction. Additional stains may have been reduced by grouting the gaps closed. However, grouting of gaps may have an adverse effect on aesthetics and drainage.

On Wall 2, the stains may have been caused by water flowing from the backfill through the joints of the individual wall elements, and from the sloping backfill behind the wall. The majority of the staining on the wall appears to be located where runoff from a parking lot above the wall is draining on the backslope. Riprap has been placed on the slope to prevent further erosion. Some of the pea gravel wall backfill has spilled through the joints, apparently because the wall blocks weren't placed close enough together during construction.

On both walls, the staining occurred in various locations. The backfills were free-draining and there were subdrain systems. The water flowing near the walls should have been captured in the subdrain systems and not been able to get to the wall faces. Therefore, another possible explanation is that the stains were related to the construction of the walls.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The KeyStone/Tensar Geogrid retaining walls evaluated as a part of this project have performed well for two years. Although problems were encountered with block placement during construction of the walls, these problems can be avoided in future projects by designing footing and block placement with consideration of horizontal growth, batter due to block setback and thickness of geogrid.

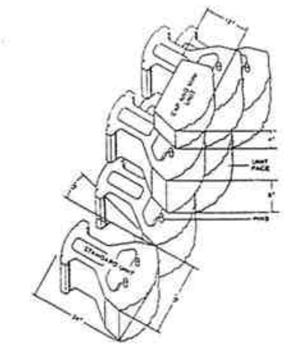
6.2 Recommendations

Even though costs were not substantially lower than the estimate for conventional reinforced concrete retaining wall structures, the aesthetic qualities, performance and construction time make this type of wall an acceptable alternative. Therefore, it is recommended that the KeyStone/Tensar Geogrid retaining wall system be considered as an acceptable alternative to conventional retaining walls for similar installations. Full acceptance of this retaining wall system for use on State projects will require completion of the OSHD Bridge Section's "Wall Acceptance Procedures;" these acceptance procedures are currently being developed.

APPENDIX A

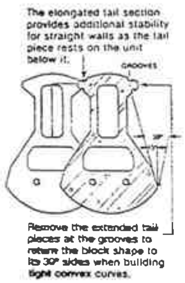
PLANS

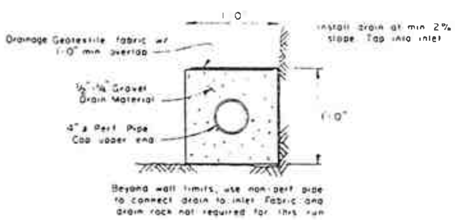
SW VERMONT ST. - SW BARBUR BLVD. (PORTLAND) SEC. S.W. BERTHA BLVD. MULTNOMAH COUNTY				SHEET No. 2D
FED. ROAD DIV. No.	STATE	PROJECT NUMBER	FISCAL YEAR	TOTAL SHEETS
10	OREGON	9420( )	1989	See Index



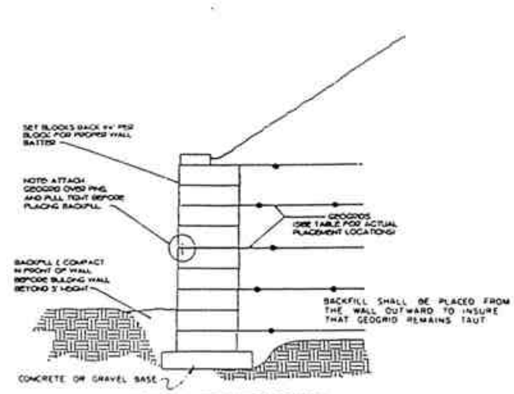

CONVEX CURVES


CONCAVE CURVES

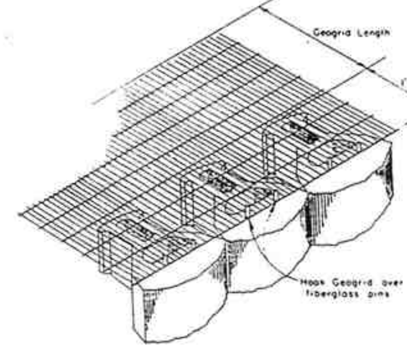




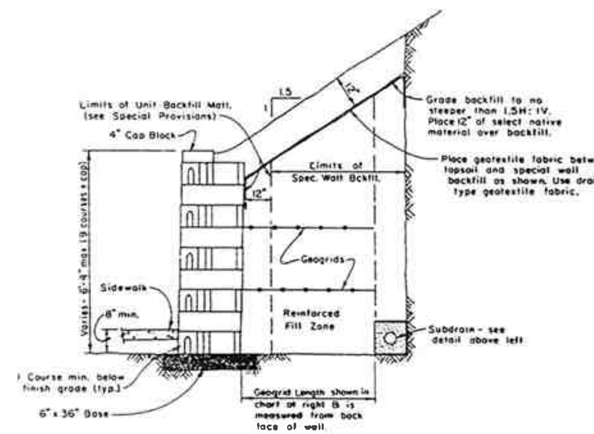
DRAINAGE DETAIL



GEOGRID ATTACHMENT DETAIL



GEOGRID LAYER ATTACHMENT DETAIL



TYPICAL SECTION

GENERAL NOTES

All materials and workmanship shall conform to the requirements of the Special Provisions and 1984 Standard Specifications for Highway Construction of the Oregon State Highway Division.

The Contractor shall carefully examine the plans and specifications to determine the extent of any shoring required to protect the public, workers, jobsite and private property during construction of the wall.

Base material shall be placed on undisturbed soil. Granular base material shall be 3/4"-0 compacted to 95% relative max density. Concrete base material, where required, shall conform to the provisions of Section 554, "Commercial Concrete" (f'_c = 3300 psi)

Unit fill shall be pea gravel extending a minimum of one foot behind the back face of the Keystone units.

Special Wall Backfill conforming to Sec 251.13 shall be used. Backfill shall be placed in 8 inch lifts and compacted to 95% of rel max density per ASTM D698-78. Do not use mechanical compactors directly on Keystone units.

Keystone units shall be placed to the lines and grades shown. Units shall be interlocked to adjoining units using high strength fiberglass pins. Cap blocks shall be bonded to the course below with a cement base waterproof anchoring cement.

Wall steps greater than 8 inches at the top of wall shall be wrapped into the embankment with convex end returns. A minimum of 3 units shall be wrapped at the ends. Returns are not required for elevation changes of 8 inches or less.

Tensar Geogrid shall be placed at the locations and elevations shown in the table for the wall sections specified. Geogrid length is as measured from the back face of the Keystone unit.

No changes to the Geogrid layout, including but not limited to length, Geogrid type, or elevation, shall be made without explicit written permission from the Engineer.

WALL SECTION DESIGNATION	GEOGRID TYPE	NUMBER OF GEOGRID LAYERS	LENGTHS (FT)	MAXIMUM DESIGN BRG. PRESSURE-PSF	GEOGRID LEVEL - DIST. ABOVE BOTTOM OF PANEL (FT) 1	2	3	4	5	6	7	8	9	10
A	UX 1500	1	6.5	2500	1.33									
B		2	6.5		1.33	3.33								
C		2	6.5		2.00	4.00								
D	↓	1	6.5	↓	2.00									

No.	DATE	DESCRIPTION	APPD
		REVISION	

CONSTRUCTED BY
PROJECT COMPLETED
MAP CORRECTED BY
DATA ENTERED ON 1/4 SEC MAP BY ______ CHECKED BY ______
DATA ENTERED ON DIST MAP BY ______ CHECKED BY ______
FINAL MAP DATA

DESIGNED BY	DATE APPROVED
S. ___	
DRAWN BY	CH. ENGINEER
P. ___	RMM
CHECKED BY	RESOLUTION No.
SLB	
FILE No.	UNDERGROUND

APPROVALS
PRINCIPAL ENGR. REG. PROF. ENGR.
CITY ENGINEER REG. PROF. ENGR.

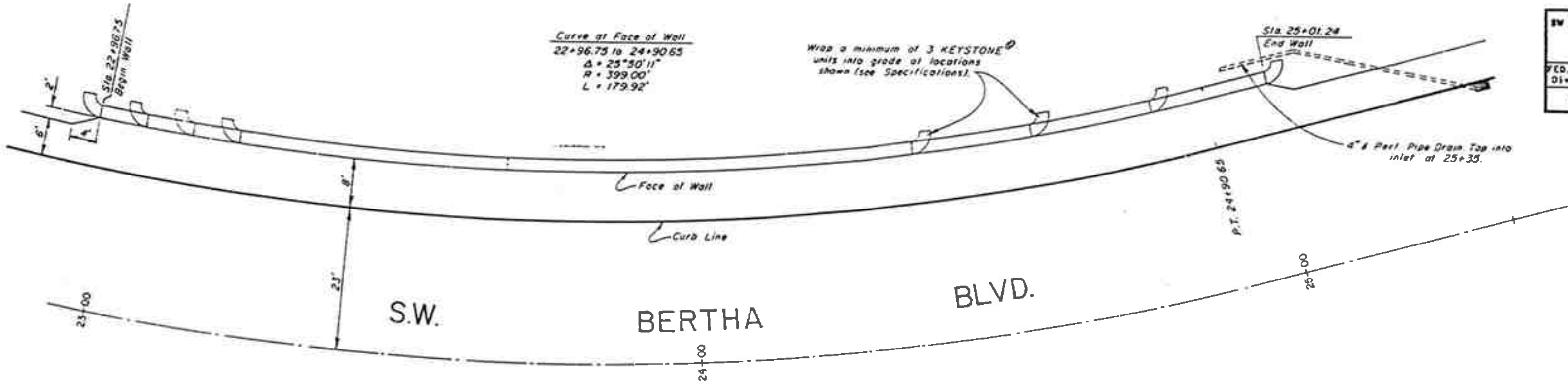
CITY OF PORTLAND, OREGON
PORTLAND
OFFICE OF TRANSPORTATION
EARL BLUMENAUER — COMMISSIONER
RICHARD O. SCHMIDT, P.E. — CITY ENGINEER

IN ORDER TO PROTECT UNDERGROUND FACILITIES, EXCAVATORS PERFORMING WORK SHOWN ON THESE PLANS MUST COMPLY WITH THE PROVISIONS OF ORS 757.541 TO 757.571.

MODULAR RETAINING WALL
STA. 22+96.75 to 25+01.24

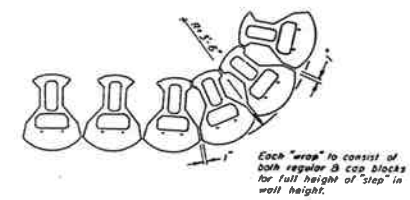
1/4 SECTION 3727
JOB No.
SHEET No. 2D

SW VERMONT ST.–SW BARBUR BLVD. (PORTLAND) SEC. S.W. BERTHA BLVD. MULTNOMAH COUNTY				SHEET No.
				2D-2
FED. ROAD DIV. No.	STATE	PROJECT NUMBER	FISCAL YEAR	TOTAL SHEETS
10	OREGON	9420( )	1989	See Index



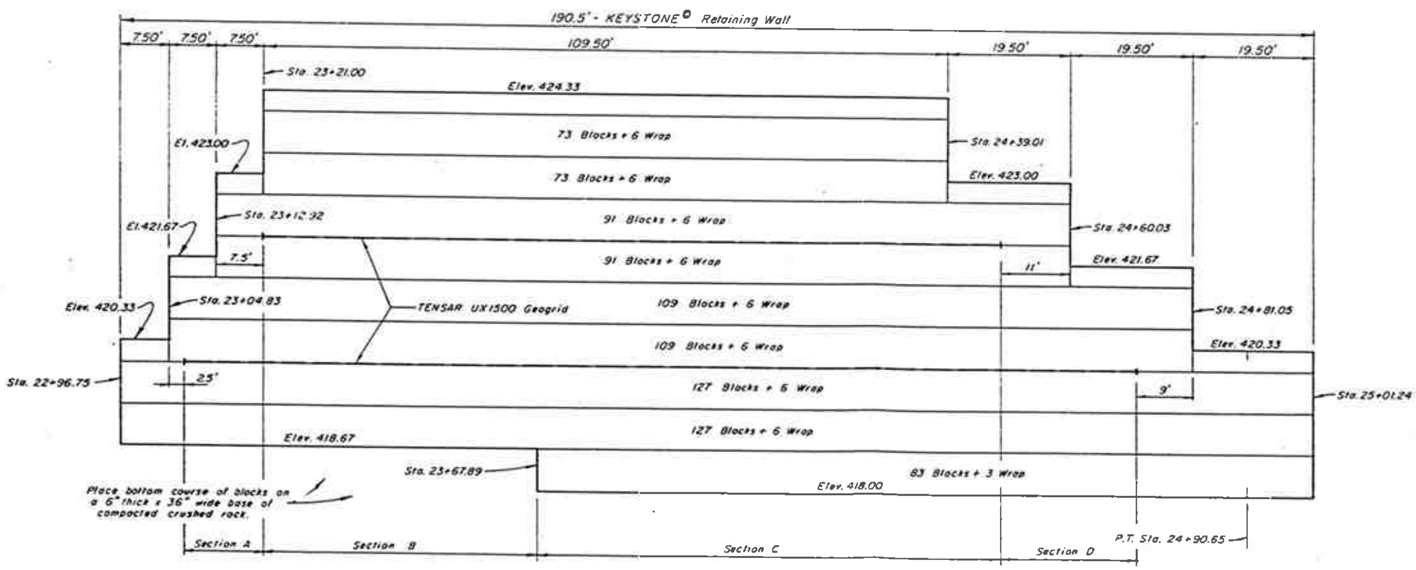
PLAN VIEW

SCALE: 1" = 10'-0"



WRAP DETAIL

NOT TO SCALE



DEVELOPED ELEVATION

SCALE: 1" = 10'-0" Horizontal, 1" = 1'-0" Vertical

No.	DATE	DESCRIPTION	APPD
		REVISION	

FINAL MAP DATA

CONSTRUCTED BY
PROJECT COMPLETED
MAP CORRECTED BY
DATA ENTERED ON 1/4 SEC. MAP BY ____ CHECKED BY ____
DATA ENTERED ON DIST. MAP BY ____ CHECKED BY ____

DESIGNED BY S. Yates
DRAWN BY P. Gorniak
CHECKED BY SLB
FILE No.
DATE APPROVED
DIV. ENGINEER RMM
RESOLUTION No.
UNDERGROUND

APPROVALS:
PRINCIPAL ENGR. REG. PROF. ENGR.
Richard O. Schmidt
CITY ENGINEER REG. PROF. ENGR.

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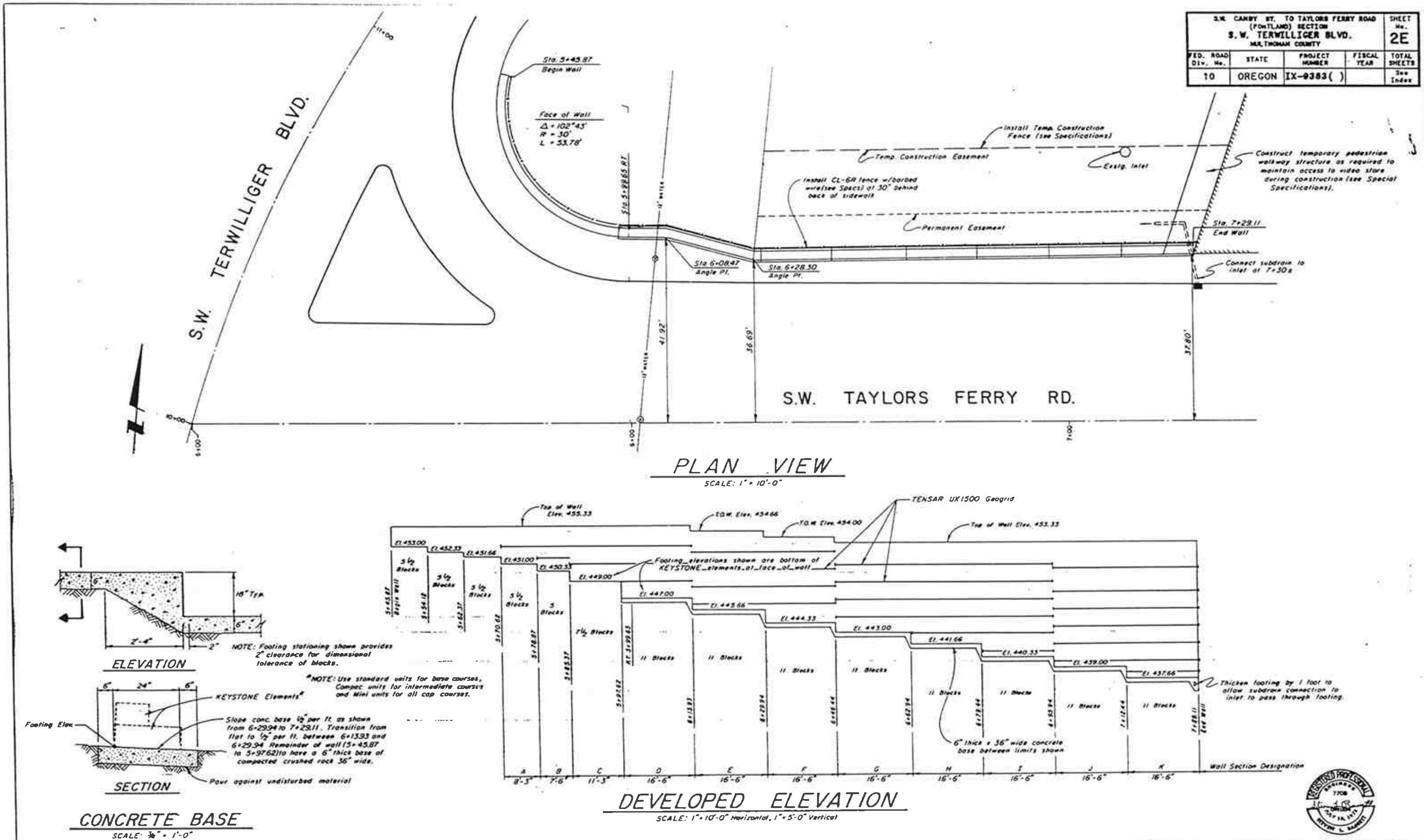
JOB No.
SHEET No. 2D-2



#	DATE	DESCRIPTION	APPD
		REVISION	

FINAL MAP DATA: CONSTRUCTED BY / PROJECT COMPLETED / MAP CORRECTED BY / DATA ENTERED ON 1/4 SEC. MAP BY ___ CHECKED BY ___ / DATA ENTERED ON DIST. MAP BY ___ CHECKED BY ___

DESIGNED BY: S. Yates — DRAWN BY: P. Gornick — CHECKED BY — FILE NO. — CITY ENGINEER: TLB — DATE APPROVED — RESOLUTION NO. — UNDERGROUND

APPROVALS: DIVISION MANAGER, REG. PROF. ENGR. — CITY ENGINEER, REG. PROF. ENGR.

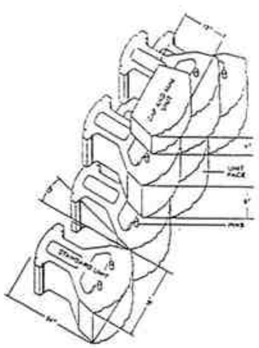
CITY OF PORTLAND, OREGON
PORTLAND OFFICE OF TRANSPORTATION
EARL BLUMENAUER — COMMISSIONER
RICHARD O. SCHMIDT, P.E. — CITY ENGINEER

IN ORDER TO PROTECT UNDERGROUND FACILITIES, EXCAVATORS PERFORMING WORK SHOWN ON THESE PLANS MUST COMPLY WITH THE PROVISIONS OF ORS 757.541 TO 757.571.

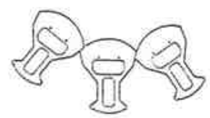
RETAINING WALL

SHEET NO. 2E

S.W. CANBY ST. TO TAYLORS FERRY ROAD (PORTLAND) SECTION S. W. TERWILLIGER BLVD. MULTNOMAH COUNTY					SHEET No. 2E-2
FED. ROAD DIV. No.	STATE	PROJECT NUMBER	FISCAL YEAR		TOTAL SHEETS
10	OREGON	IX-9383( )			See Index

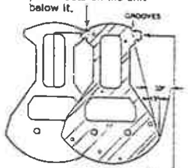


CONVEX CURVES

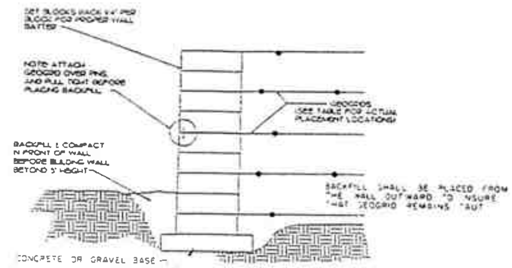


CONCAVE CURVES

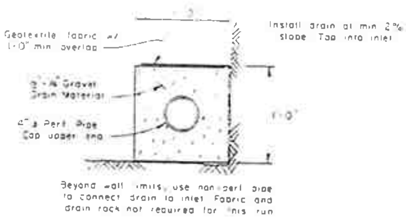
The elongated tail section provides additional stability for straight walls as the tail piece rests on the unit below it.



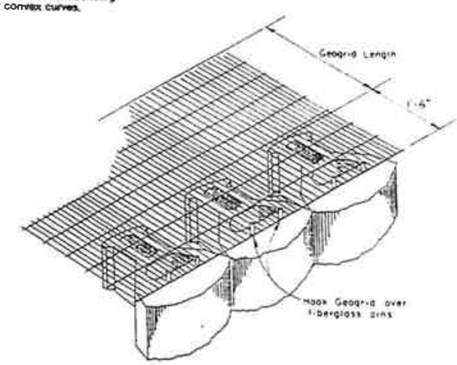
Remove the extended tail pieces at the grooves to return the block shape to its 30° sides when building tight convex curves.



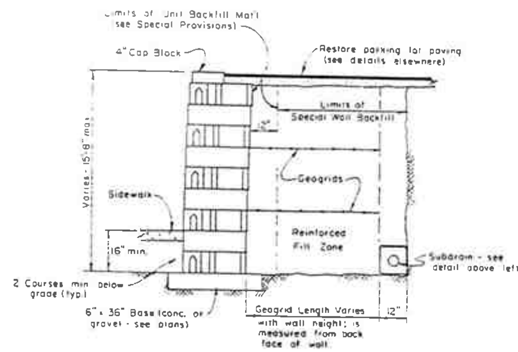
GEOGRID ATTACHMENT DETAIL



DRAINAGE DETAIL



GEOGRID LAYER ATTACHMENT DETAIL



TYPICAL SECTION

GENERAL NOTES

All materials and workmanship shall conform to the requirements of the Special Provisions and 1984 Standard Specifications for Highway Construction of the Oregon State Highway Division.

The Contractor shall carefully examine the plans and specifications to determine the extent of any sharing required to protect the public, workers, jobsite and private property during construction of the wall.

Base material shall be placed on undisturbed soil. Granular base material shall be 3/4"-0 compacted to 95% relative max density. Concrete base material, where required, shall conform to the provisions of Section 554, "Commercial Concrete" (f'_c = 3300 psi).

Unit fill shall be pea gravel extending a minimum of one foot behind the back face of the Keystone units.

Special Wall Backfill conforming to Sec. 251.13 shall be used. Backfill shall be placed in 8 inch lifts and compacted to 95% of rel maximum density per ASTM D698-78. Do not use mechanical compactors directly on Keystone units.

Keystone units shall be placed to the lines and grades shown. Units shall be interlocked to adjoining units using high strength fiberglass pins. Cap blocks shall be bonded to the course below with a cement base waterproof anchoring cement.

Wall steps greater than 8 inches at the top of wall shall be wrapped into the embankment with convex end returns. A minimum of 3 units shall be wrapped at the ends. Returns are not required for elevation changes of 8 inches or less.

Tensar Geogrid shall be placed at the locations and elevations shown in the table for the wall sections specified. Geogrid length is as measured from the back face of the Keystone unit.

No changes to the Geogrid layout, including but not limited to length, Geogrid type, or elevation, shall be made without explicit written permission from the Engineer.

* WALL SECTION DESIGNATION	GEOGRID TYPE	NUMBER OF GEOGRID LAYERS	LENGTHS (FT)	MAXIMUM DESIGN BRG. PRESSURE-PSF	GEOGRID LEVEL - DIST. ABOVE BOTTOM OF PANEL (FT)									
					1	2	3	4	5	6	7	8	9	10
A	UX 1500	1	6.0	3200	2.00									
B		2	6.0		1.33	2.67								
C		2	6.0		2.00	4.00								
D		3	6.0		2.00	4.00	6.00							
E		4	6.0		0.67	2.67	4.67	6.67						
F		4	6.0		2.00	4.00	6.00	8.00						
G		4	7.0		2.00	4.00	6.00	8.00						
H		5	7.0		1.33	3.33	5.33	7.33	9.33					
I		6	7.0		0.67	2.67	4.67	6.67	8.67	10.67				
J		6	8.5		0.67	2.67	4.67	6.67	8.67	11.33				
K		7	10.0		0.67	2.00	4.00	6.00	8.00	10.00	12.67			

* SEE SHEET 2E

No.	DATE	DESCRIPTION	APPD
REVISION			

CONSTRUCTED BY
PROJECT COMPLETED
MAP CORRECTED BY
DATA ENTERED ON 1/4 SEC MAP BY ______ CHECKED BY
DATA ENTERED ON DIST MAP BY ______ CHECKED BY
FINAL MAP DATA

DESIGNED BY S. Tazen
DRAWN BY P. Garcia
CHECKED BY
FILE No.
DATE APPROVED
CITY ENGINEER TLB
RESOLUTION No.
UNDERGROUND

APPROVALS

PORTLAND
OFFICE OF TRANSPORTATION
EARL BLUMENAUER COMMISSIONER
RICHARD O. SCHMIDT, P.E. CITY ENGINEER

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RETAINING WALL

1/4 SECTION
JOB No.
SHEET No. 2E-2

APPENDIX B

SURVEY MEASUREMENTS

Table B.1: Survey Measurements for Wall Movements at SW Terwilliger Boulevard/SW Taylors Ferry Road Wall

SW TERWILLIGER BLVD./SW TAYLORS FERRY RD. WALL (WALL 1)									
	SETTLEMENT in millimeters after WEEKS			HORIZONTAL in millimeters after WEEKS			LATERAL in millimeters after WEEKS		
Point	6	20	94	6	20	94	6	20	94
1	-1	-2	-2	0	-1	0	+2	+2	-4
2	-1	-1	-1	+1	-2	0	-1	0	-4
3	+1	0	-1	+1	-1	0	+1	0	-6
4	0	-1	-1	0	+2	0	-1	0	-4
5	0	+1	-1	-1	+1	-1	-1	-1	-6
6	+1	0	-2	0	+2	-4	0	-1	-6
7	0	-1	-1	-1	0	-1	+1	+2	-2
8	0	-1	-1	0	+1	-1	+2	+1	-3
9	0	0	-1	+1	0	-5	+2	0	-4
10	0	0	-2	0	0	-5	0	0	-5
11	0	0	-1	-2	0	-2	0	0	-6
12	0	0	-1	-1	0	-4	0	-2	-7
13	+2	+1	-1	0	+2	-2	+1	+1	-6
14	+1	+1	-2	-1	+1	-4	-2	-2	-13

See notes on following page.

Table B.2: Survey Measurements for Wall Movements at SW Bertha Boulevard Wall

SW BERTHA BLVD. WALL (WALL 2)									
Point	SETTLEMENT in Millimeters after WEEKS			HORIZONTAL in Millimeters after WEEKS			LATERAL in Millimeters after WEEKS		
	6	20	94	6	20	94	6	20	94
1	+3	+1	-1	-2	+1	-3	-1	-1	-6
2	+2	0	-1	-1	0	-1	-1	-1	-2
3	+1	0	-2	-1	+1	+2	-1	-2	-6
4	+2	0	-2	0	+3	+2	-1	-1	-4
5	+1	-1	-4	0	+1	-1	-1	-3	-6
6	+2	-1	-3	+1	0	0	-2	-6	-8
7	+2	-1	-3	+2	0	-1	0	0	-6

NOTES:

1) Wall movements are referenced to the initial survey readings made on 12/14/89.

2) Horizontal movements are movements perpendicular to the long axis of the wall. Positive values indicate wall movement into the backfill.

3) Lateral movements are movements parallel to the long axis of the wall. Positive values indicate movement to the left of the observer.

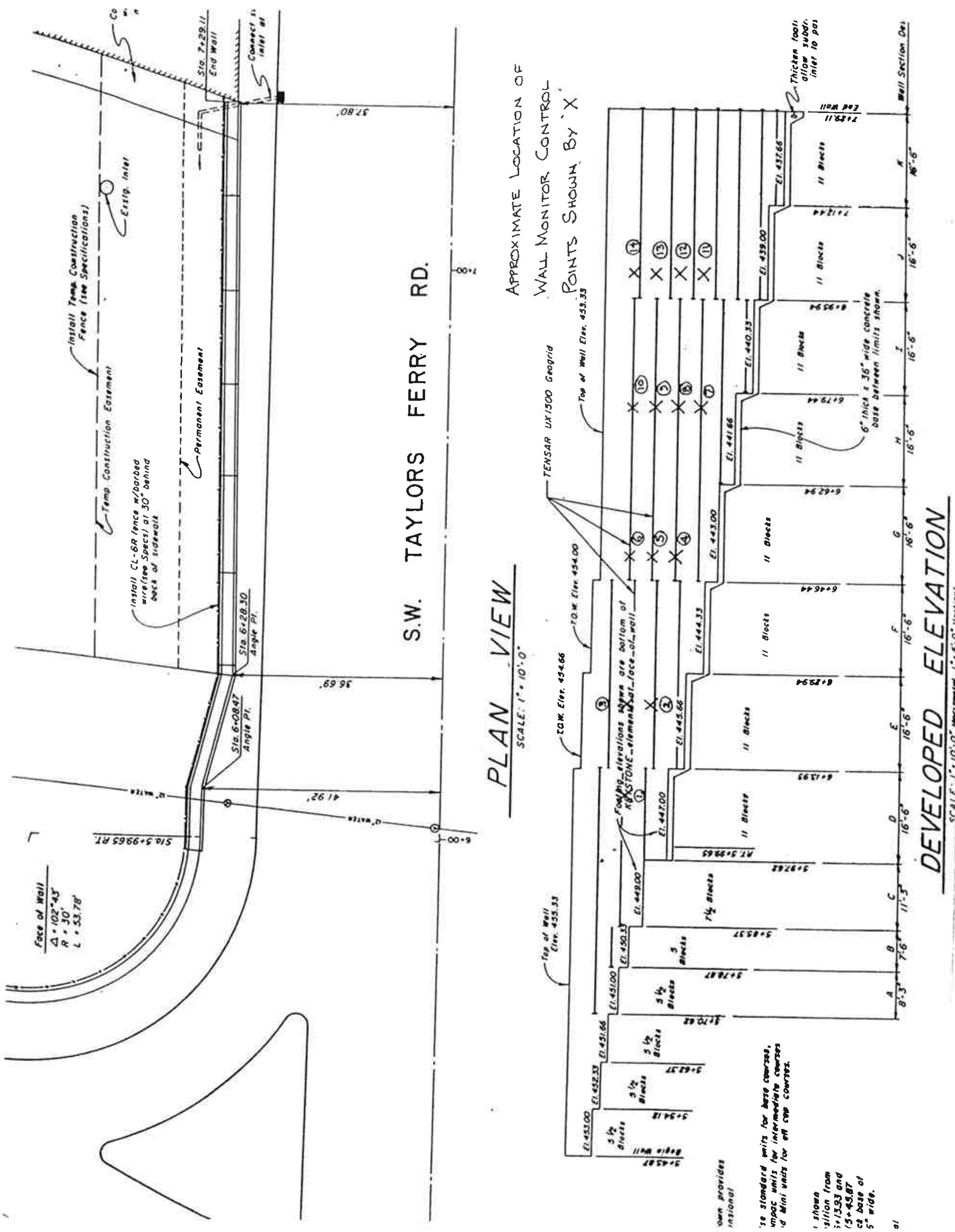


Figure B.1: Location of Wall Monitor Control Points on the SW Terwilliger Boulevard/Taylors Ferry Road Wall

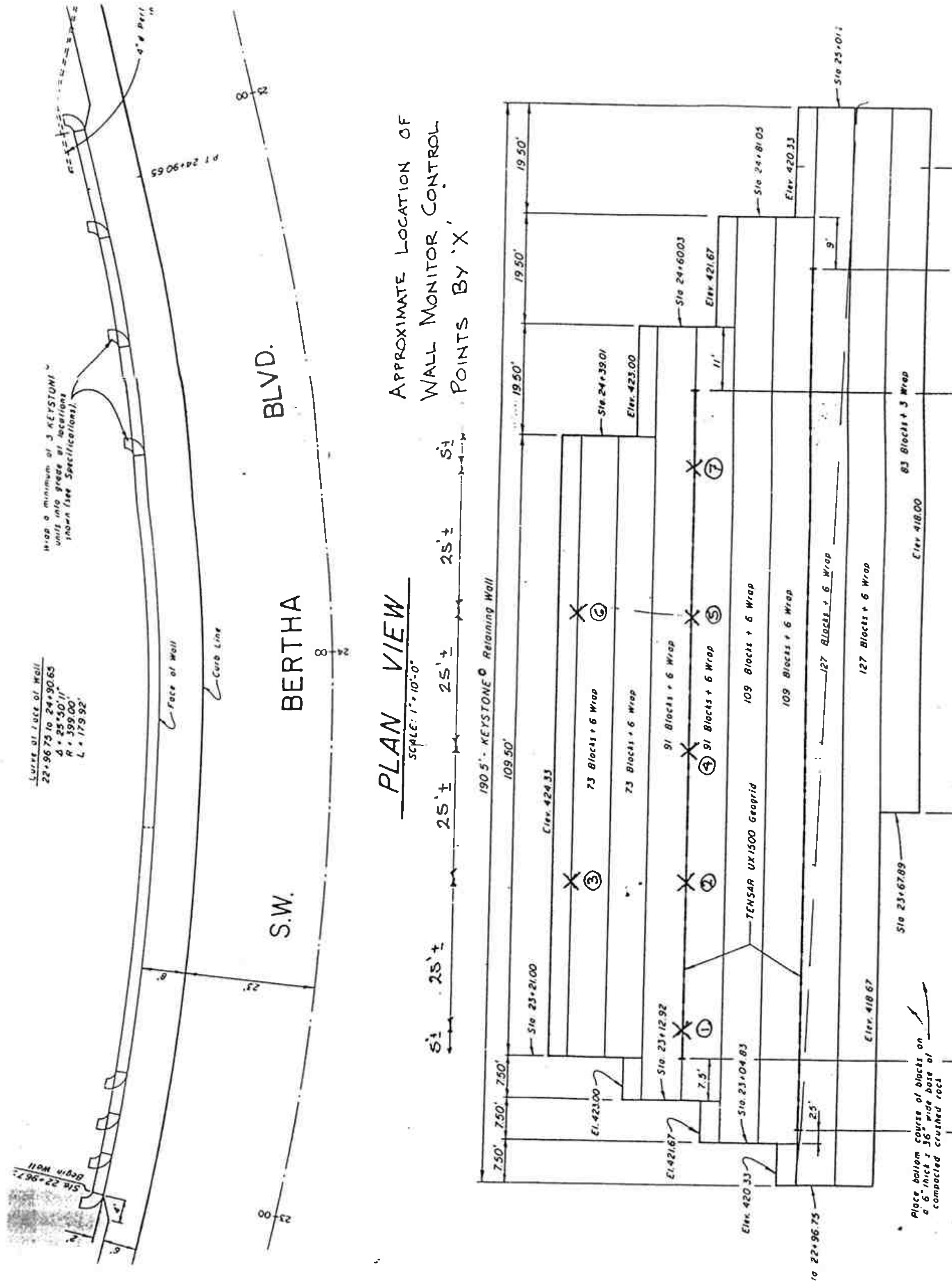
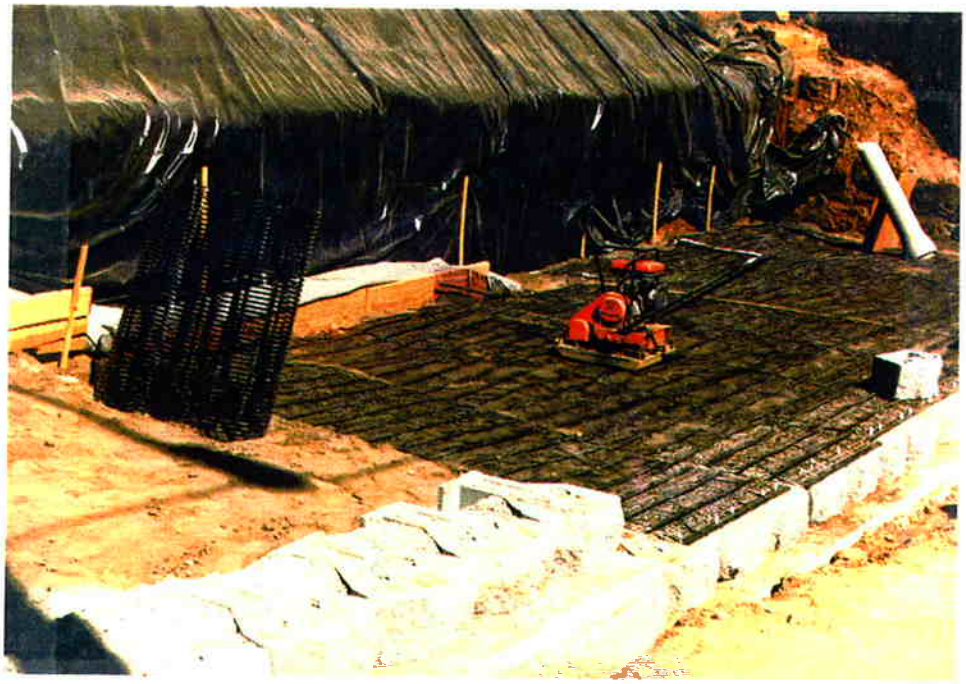


Figure B.2: Location of Wall Monitor Control Points on the SW Bertha Boulevard Wall

APPENDIX C

PHOTOGRAPHS



A: Placement of geogrid and wall.

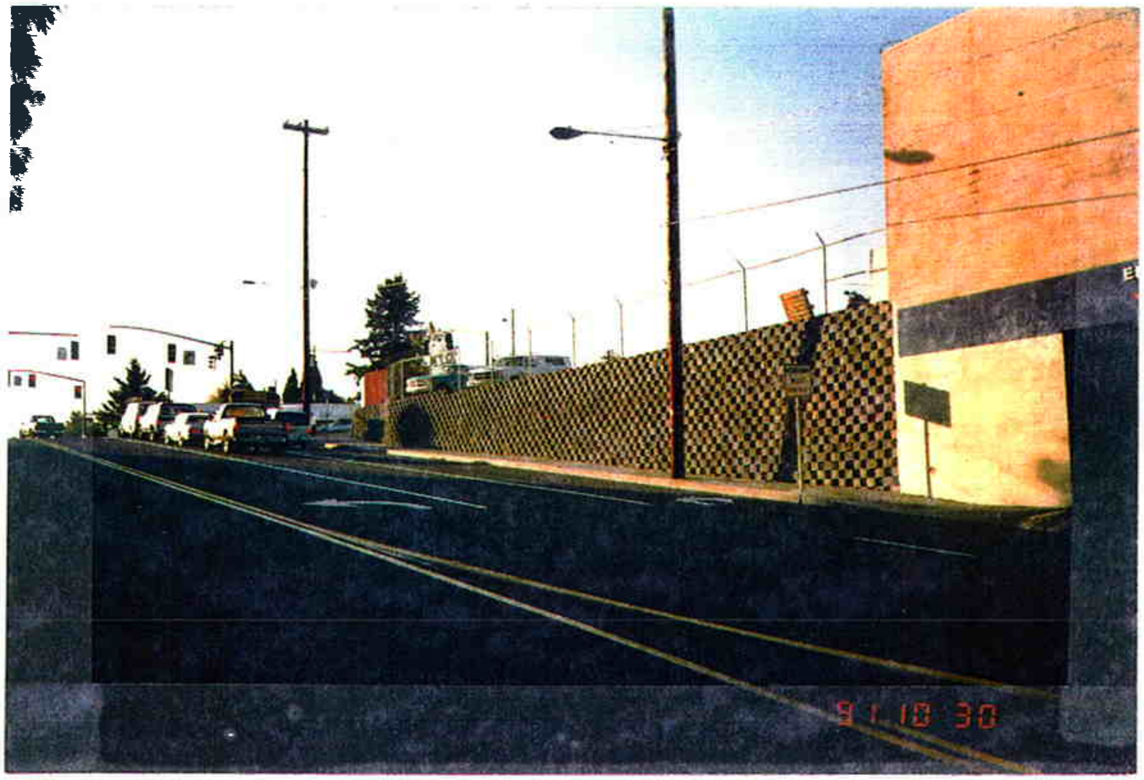
B: Placement of backfill.

Figure C.1: Construction of wall at SW Terwilliger/Taylors Ferry Road.

A: Curved wall section.

B: Placement of backfill.

Figure C.2: Construction of wall at SW Bertha Boulevard.



A: SW Terwilliger/Taylors Ferry Road.

B: SW Bertha Boulevard.

Figure C.3: Completed walls.