Investigation of the April 5, 2011 Flow Equalization Basin Wall Collapse at Wastewater Treatment Plant in Gatlinburg, TN

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Occupational Safety and Health Administration
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TABLE OF CONTENTS

1. THE INCIDENT 3
2. DESCRIPTION OF THE FLOW EQUALIZATION BASIN 6
3. STRUCTURAL FAILURE INVESTIGATION 8
4. CONCLUSIONS 15
5. REFERENCES 17
6. FIGURES 19
7. APPENDIX A A-1 to A-12
8. APPENDIX B B-1 to B-7
9. APPENDIX C C-1 to C-7

Office of Engineering Services
Directorate of Construction

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1. The Incident

On September 6, 2011, the Division of Occupational Safety and Health (TOSH) in the Department of Labor & Workforce Development of the State of Tennessee asked the U.S. Occupational Safety and Health Administration, in Washington, DC to provide technical assistance in the investigation of the April 5, 2011 incident at Gatlinburg, TN where two workers were killed. The incident involved the structural failure of a concrete wall at the Gatlinburg wastewater treatment plant.

A structural engineer from the Directorate of Construction (DOC), U.S. Occupational Safety and Health Administration, Washington, DC visited the incident site of the Wastewater Treatment Plant at Gatlinburg, TN on September 14, 2011. He inspected the fallen concrete wall, the failed connections of the intersecting walls, the splicing couplers, and the equalization basin structure.

TOSH provided original engineering drawings of the sewage plant to DOC. They also provided nine couplers recovered by the City of Gatlinburg from the site for our examination. The City of Gatlinburg also took core samples of the concrete.

In 1992, the City of Gatlinburg (City) retained Flynt Engineering Company (Flynt) of 2125 University Avenue, Knoxville, TN to prepare engineering plans for “Modifications to Wastewater Treatment Plant”. The treatment plant is located at 1025 Banner Road, Gatlinburg, TN. The plans were dated 1992 but the construction did not start until 1994, and was completed in 1996. Crowder Construction company of North Carolina was to be the general contractor. The plans included the construction of a new equalization basin, a 124 ft. long by 64 ft. wide, and 30 ft. high cast in place open concrete structure. A few feet east of the basin was a Flow Control Room, a small one-story structure to regulate the flow from the basin. During the construction, the City retained Flynt to supervise construction to ensure compliance with drawings and specifications. Flynt and Crowder are both now out of business.

The flow chart of the treatment plant is shown in Fig.1. The equalization basin (basin) is the first recipient of the sewage waste and storm drain water in the treatment plant. Though the plant is essentially meant to treat sewage, an undetermined amount of storm water is inevitably present. The volume of wastewater differs depending upon the weather. In dry weather, the volume could be as low as 2-3 million gallons per day, and in wet weather, it could rise to up to 9 million gallons per day. The plant was designed to treat up to 9 million gallons of wastewater per day. The depth of wastewater in the basin could vary from between 3 to 26 feet. During normal operations, the water is approximately 10 ft. high in the basin. The maximum depth of the water could be 30 ft. before it overflows. There are no confirmed reports that the water level ever reached 30 ft. in the past.

On the morning of April 5, 2011, the 18" thick, 30 ft. high concrete east wall of the basin suddenly separated from the rest of the basin structure, and fell to the ground in an eastward direction. During the collapse, the control valve room situated a few feet from the east wall was crushed, killing two employees inside the control room. It is estimated that the water in the basin at the time of the incident was in the range of 26-to-30 feet high. Apparently, during previous wet seasons, the water would reach as high as 26 ft.

The structural failure of the east wall was unusual in that the east wall neatly separated from the three orthogonal intersecting walls and overturned away from the basin by pulling away dowels from the footings and the far intersecting walls on the north and the south. The structural drawings Nos. 29 thru 33 prepared by Flynt in 1992 provided details of the proposed construction of the basin. The east wall, approximately 124 ft. long, was 18" thick, reinforced with #9 rebars at 12" o.c. each face horizontally, and #6 rebars at 6" o.c. each face vertically, see Fig. C-3. The project specifications called for the concrete to be 4,000 psi, and for the rebars to conform to ASTM A615, Grade 60. It is understood that the testing of the concrete cores obtained by the City subsequent to the incident indicated the compressive strength to be higher than 4,000 psi. At the bottom, the east wall was dowelled to the footings with one #8 rebars at 6" o.c., at mid-depth see Fig. C-3. On the two far sides, the horizontal reinforcements of the east wall were dowelled into the north and the south walls. There were three orthogonal walls intersecting with the east walls at approximately 20 ft., 40 ft., 40 ft. and 20 ft. from each end. The east wall was designed to be dowelled to the intersecting walls by # 4 rebars at 12" o.c. each face horizontally, see Fig.C-4.

The inspection of the structure after the incident revealed that the contractor cast the walls in a manner that provided a cold joint between the east walls and the intersecting walls. The separation of the east wall occurred at this cold joint, see Fig. 2. Both faces of the joint were observed to be exceptionally smooth and lacked any bondage between the two pours, see Fig. 2. Instead of providing two layers of horizontal dowels of #4 rebars at 12" o.c. from the intersecting walls to the east wall, the contractor provided #5 rebars each face in the east wall and #5 rebars each face in the intersecting walls. The rebars were threaded into a coupler, thus providing continuity between the east wall and the intersecting walls, see Fig. 3. Instead of providing dowels consisting of #4 rebars at 12" o.c, each face the contractor provided #5 rebars each face at 12" o.c, an increase of 50% over what was required by the drawings.

Field measurement of the couplers indicated the following dimensions:

Outside diameter measured: 0.90" corresponding to actual 7/8" (0.875")
Coupler thickness: 0.19” corresponding to actual 3/16" (0.1875")
Length: 2"

The above dimensions closely matched with the coupler D-50 with the product code 77100 manufactured by Dayton Superior., see Figs. C-6 & C-7. For a rebar of ASTM Grade 60, the maximum tensile strength based upon yield strength is 0.31 x 60 = 18.6 kips. Increasing by 125%, the coupler must have a strength of 1.25 x 18.6 = 23 kips. The coupler is made of ASTM A-108 having an ultimate tensile value of 65 ksi which gives a tensile force of 65 x 0.404 = 26 kips greater than the required value of 23 kips.

The coupler required a minimum threaded length of 7/8" which provides a spacing of ¼" between the two rebars threaded in opposite directions. Site inspection revealed that the spacing between the bars was greater than ¼", indicating that the bars were not threaded up to the required lengths. It must be noted, however, that only a few couplers could be inspected at the site.

Although the dowels provided by the contractor were 50% greater than those required, the couplers were continuously exposed to acidic wastewater due to seepage across the smooth cold joint. Thus, the couplers were subject to corrosion, reducing their effectiveness and compromising their structural integrity. Photographs of some of the recovered couplers in Appendix B indicate the extent of corrosion of the couplers.

The DOC's investigation included:

- Review of the original engineering drawings (Project No. 90116 - 50 sheets) prepared by Flynt Engineering Company for the construction of the equalization basin.
- Examining the photographs of the incident site taken during the site visit.
- Performing structural computations to determine whether the original structural design conformed to the design standards and industry practice (Refs. 1, 2, 3, & 4)
- Reviewing the Invitation for Bids, Notice, and Instructions for Bidders, Bid Bond, Bidder's Proposal, Construction Contract Performance and Payments Bonds, and Technical Specifications prepared for modifications to Wastewater Treatment Plant of the City of Gatlinburg, Sevier County, Tennessee by the Flynt Engineering Company, Knoxville, TN (Refs. 5 & 6).

2. Description of the Flow Equalization Basin

The reinforced concrete flow equalization basin at the wastewater treatment plant in the city of Gatlinburg, TN was constructed to regulate the wastewater flow rate to the primary treatment system during peak flow.

The function of a wastewater treatment plant is to improve the quality of wastewater by removing suspended organic and inorganic solids and other materials before discharging it into a waterway (Ref. 8). In treating wastewater, the rate at which the wastewater arrives at the treatment process might vary dramatically during the day, so it is convenient to equalize the flow before feeding it to the various treatment steps. The incoming wastewater flow is regulated prior to being directed to the subsequent treatment systems by a flow equalization basin. The excess sewage stored in the equalization basin is allowed to flow to the primary system for treatment when the incoming flow to the plant subsides. Excess wastewater flow during the peak flow is forced to the equalization basin by the automatic positioning butterfly valve. Therefore, the flow equalization basin helps to allow only a predetermined steady flow rate to flow to the primary treatment system.

The equalization basin was designed by Flynt Engineering of Knoxville in 1992 and built by Charlotte, N.C.-based Crowder Construction Co. in 1995/1996. According to the report from the Division of Occupational Safety and Health in the Department of Labor & Workforce Development of the State of Tennessee, the facility has been operated since 1996 by Veolia Water North America Operating Services under contract with the City of Gatlinburg.

The flow equalization basin at the wastewater treatment plant was an environmental engineering structure with five interior baffle walls. It is a rectangular shaped basin in cross-section. The dimensions of the flow equalization basin were approximately 124 ft. long, 64 ft. wide and 30 ft. deep. The thickness of the external walls was 18" and the five interior baffle walls were each 12" in thick. The thickness of the bottom slab of the basin was 15" and the top slab was 8" thick. The flow equalization basin had a maximum storage capacity of approximately 1.5 million gallons. The level of the raw sewage in the flow equalization basin during the collapse of the east wall was estimated to be in the range of 26-to-30 ft.

The structural design process for a flow equalization basin generally involves consideration of the following loads (Refs. 2, 3 & 8):

1. Dead load
2. Live load
3. Collateral loads (superimposed dead loads such as mechanical and electrical pieces of equipment).
4. Hydrostatic load due to the wastewater.
5. Earth pressure
6. Wind load
7. Snow load
8. Earthquake
9. Thermal stress

The primary load that is considered in the design of a basin is the hydrostatic pressure acting on the walls of the basin (Refs. 2, 3, 8 & 9). The hydrostatic pressure on the walls is assumed to have a triangular distribution. For rectangular-shaped basins that are intended to be monolithically constructed, the design is based on a full continuity between the walls. The basin was designed assuming that the walls were to be supported on three sides. These walls are considered as plates with varying boundary conditions (edge supports) depending on the construction details provided by the designer. The walls modeled as plates and subjected to hydrostatic pressure due to the wastewater will develop either a two-way or one-way action to support the applied loads, depending on the ratio of their spans and their edge support conditions (Ref. 8, 9, & 10).

Wastewater treatment plant components experience corrosion during their operation. The components of a flow equalization basin subject to corrosion include reinforced concrete walls, piping, ladders, mechanical and electrical equipment and other components used to construct the basin (Ref. 11).

Raw sewage is a source of hydrogen sulfide that is released from the surface of the wastewater, enters the atmosphere and then is oxidized on the surface of the wastewater treatment plant. The oxidation of hydrogen sulfide results in the production of sulfuric acid that leads to the corrosion of metallic components of wastewater treatment plants (Ref.11).

Corrosion of reinforced concrete walls and other components is a major problem facing wastewater treatment plants. Non-watertight walls and cold joints provided during construction of walls of flow equalization basins are known to accelerate the corrosion of steel bars and rebar couplers (Ref. 8).

3. Structural Failure Investigation

We conducted a structural investigation of the basin in conjunction with our field observations and review of the documents made available to us.

The technical specifications prepared by Flynt Engineering Company, Knoxville stated that (see Division 3- Concrete in Ref. 6):

1. *Class B concrete is intended principally for reinforced concrete structure designed for high strength and water tightness, and shall be used for columns, walls, beams, slabs and, in general wherever formwork other than simple forms required.*

2. The specifications indicated that Class B concrete is concrete with a 28-day compressive strength of 4,000 psi.

3. *Concrete shall be placed only in the presence of the Engineer and in forms which have been approved by him. Where the procedure is not specifically described herein, the placing of concrete shall be in accordance with the recommendations of ACI Standard 614.*

4. *Construction joints shall be made where indicated or permitted and directed by the Engineer. Such joints shall be located to insure stability, strength, and water tightness. All corners shall be built monolithically and the work on either side shall extend to points shown or directed.*

5. *The placing of concrete shall be carried on continuously between the construction joints shown on the plans. If for any reason it becomes necessary to stop the placing of concrete at locations other than those indicated, such locations and the manner of making the joint shall be subject to the approval of the Engineer.*

6. *Reinforcing steel bars for concrete reinforcement shall meet the requirements of ASTM A615, Grade 60. They shall be free from defects, knits, and from bends that cannot be readily and fully straightened in the field. Test certificates of the chemical and physical properties covering each shipment shall be submitted for approval. All reinforcing steel shall be manufactured in the United States.*

7. *The Contractor shall submit detailed shop drawings and schedules to the Engineer for approval in accordance with the requirements of the General Provisions hereof. The bars shall be supplied in lengths which will allow them to be conveniently placed in the work and provide*

sufficient lap joints. Dowels of proper length, size and shape shall be provided for tying walls, beams, floors, and the like together where shown, specified or ordered.

8. *Reinforcing steel shall be placed and held in position so that the concrete cover, as measured from the surface of the bar to the surface of the concrete, shall be not less than the following, except as otherwise shown, specified or directed.* For walls 12 inches or more in thickness, 2 in. of concrete cover was indicated in the specification.

The connection between the east wall and the baffle walls of the flow equalization basin was not constructed monolithically as required by the structural drawings. Instead of providing horizontal dowels of #4 rebars each face at 12" o.c. (see Fig. C-4) from the intersecting walls to the east wall, the contractor provided #5 rebars each face in the east wall and # 5 rebars each face in the intersecting walls. The rebars were threaded into a coupler, thus providing continuity between the east wall and the intersecting walls.

There was no available document to identify the manufacturer of the couplers used; but the widely used Dayton Superior D-50 DBR Coupler (for # 5 rebars-product code 77100 with 5/8"-11 UNC thread and having an outer diameter of 7/8" and a length of 2") closely matched the geometric properties of the couplers (see Fig C-6).

The thread engagement length specified by the manufacturer for # 5 rebars (product code 77100) was 7/8", but our inspection showed that the full engagement length specified by the manufacturer was not followed to connect the rebars to the couplers in some locations.

The following properties were specified in the structural drawings (sheets 29 to 33 in Ref. 1):

1. The thickness of external walls to be 18" and that of interior baffle walls to be 12".
2. The thickness of bottom slab to be 15" and that of top slab 8".
3. Reinforcement for east and south exterior walls to be # 9 rebars @ 12" o.c., horizontal and # 6 rebars @ 6” o.c., vertical, each face (see Fig. C-3).

4. Reinforcement for west and north exterior walls to be # 9 rebars @ 6" o.c., horizontal and # 7 rebars @ 6" o.c., vertical, each face (see Fig. C-2).
5. Dowel reinforcement between exterior walls and bottom slab to be # 8 rebars @ 6" o.c. (single layer- see Fig. C-3).
6. Reinforcement for interior baffle walls to be # 4 @ 12" horizontal and vertical, each face (see Fig. C-1).
7. Dowel reinforcement between interior walls and baffle walls to be # 4 rebars @ 12" o.c., each face.
8. Reinforcement for bottom slab to be # 5 rebars @ 6" o.c. (Short direction) and # 5 rebars @ 12" o.c. (long direction), each face.
9. Reinforcement for top slab to be # 6 rebars @ 12" o.c. (single layer).
10. 6" PVC waterstop was specified at the joint between the exterior walls and the bottom slab.

In conjunction with the field observations, a structural analysis of the basin was performed to review the structure as designed. We used both the finite element method and hand calculations to determine the force, moment, and displacement distributions for the walls.

The structural computer program STAAD.Pro V8i (Ref. 13) was used for our investigation. A finite element method was used to model the east and north walls. The east and north walls were modeled using quadratic plate finite elements.

We considered different boundary conditions at the wall joints and wall-to-base slab joint, to obtain the distribution of the moments and reactions to the walls. This analysis technique helped to capture the moment and reaction distributions by accounting for the flexibility of the walls at the wall-to-wall and wall-to-bottom slab joints.

We assumed for our analysis that the walls were to be free at the top. The 8" slab with one layer of re-bars at the top of the basin was not accounted for.

The following assumptions were made for our structural analysis:

1) The height of the reinforced concrete wall was 30' from the ground surface.
2) Reinforcing steel bars used conformed to ASTM A615, Grade 60 (Specification Division 3 – Concrete -03210-1 General in Ref. 6).
3) The unit weight of concrete was 150 pcf.
4) The 28-day cylinder compressive strength of concrete was 4 ksi. (see Specification Division 3 – Concrete -03000-2 Strength in Ref. 6).
5) The modulus of elasticity of concrete was assumed to be 3605 ksi.
6) The Poisson's ratio for concrete was assumed to be 0.17.
7) The unit weight of raw sewage was assumed to be 62.4 pcf (Ref. 8).
8) Good-quality concrete (Class B concrete) and reinforcing bars were used as per the specification (Specification Division 3 –Concrete -03210-1 General in Ref. 6).
9) The rebar couplers used were assumed to be Dayton Superior D-50 DBR Coupler for # 5 bars (product code 77100) with 5/8"-11 UNC thread and having an outer diameter of 7/8'' and a length of 2" (see attached Figs. C-6 & C-7).
10) The thickness of the couplers was assumed to be 3/16".
11) The material from which the couplers were made was assumed to be ASM A-108 as specified by the manufacturer (Dayton Superior, see Fig. C-6).
12) ASTM A-108 has a minimum tensile stress of 65 ksi (see Ref. 14).

We considered in our structural analysis the level of wastewater above the base slab in the flow equalization basin to be 26 & 30 ft. and the boundary conditions for the walls to be either fixed or hinged. The various scenarios that were considered in our structural analysis were summarized in Tables 1 and 2, below:

Table 1. Boundary conditions and depth of wastewater considered for the east wall.

	East Wall level of wastewater @ ft.	Support at bottom	Support at north and south wall	Support at Intersecting walls	Moment Contour shown in Appendix A
1	26	hinged	fixed	hinged	Fig. A-1
2	30	hinged	fixed	hinged	Fig. A-2
3	26	hinged	fixed	No support	Figs. A-3 & A-4
4	30	hinged	fixed	No support	Figs. A-5 & A-6
5	26	fixed	fixed	hinged	Fig. A-7
6	30	fixed	fixed	hinged	Fig. A-8

Table 2. Boundary conditions and depth of wastewater considered for the north wall.

	North Wall level of wastewater @ ft.	Support at bottom	Support at east and west wall	Moment Contour shown in Appendix A
1	26	hinged	fixed	Fig. A-9
2	30	hinged	fixed	Fig. A-10
3	26	hinged	hinged	Fig. A-12
4	30	hinged	hinged	Fig. A-13

The dowel reinforcements provided to transfer the moment from the east walls to the base slab as per the structural drawings were # 8 dowels @ 6" o.c. (see Figs. 4 & 5). The moment capacity of these dowels was computed to be 61.8 ft-kips/ft.

The maximum positive moment for the east wall in the vertical direction was determined to be 40.3 ft-kips/ft (Fig. A-2). The reinforcement provided in the design was # 6 rebars @ 6" o.c., each face. The moment capacity of the reinforcement was computed to be 65.98 ft-kips/ft. Therefore, the design of the east wall was found to be satisfactory, provided that the east wall is supported by the three intersecting walls.

The maximum positive moment for the north wall in the horizontal direction was determined to be 93.1 ft-kips/ft (Fig. A-10). The reinforcement provided in the design was # 9 rebars @ 6" o.c, each face. The moment capacity of the reinforcement in the horizontal direction was computed to be 139.6 ft-kips/ft. Therefore, the design of the north wall was also found to be satisfactory.

If the flow equalization basin was built as per the structural drawings in a monolithic manner, the cold joint at the intersection of the east wall and the interior orthogonal walls would have been eliminated. In this case the interior orthogonal walls would have acted integrally with the east wall. Since the interior orthogonal walls were cast with rebar couplers connecting the rebars of the interior orthogonal walls to that of the east wall, the connections were modeled as hinged connections. The reaction and the flexural moments were computed under this condition.

If the depth of the water is considered to be 30 ft., the maximum reaction of the east wall at the intersecting walls was determined to be 41 kips. If the couplers are assumed to be in their original condition with the required engagement of # 5 rebars, each coupler has a maximum tensile capacity of 26 kips or 52 kips for two couplers. However, the couplers had undergone severe corrosion over a number of years due to which their capacities were significantly reduced. Post-incident inspection indicated that the couplers factured and failed in tension due to overstress. If due to corrosive damage one set of coupler failed, the adjoining coupler would be subject to an even higher load, thus creating a chain reaction. All couplers examined at the site were observed to have suffered extensive corrosion damage (see Appendix B).

With the loss of the supports of the intermediate baffle walls, the east wall then spanned a distance of approximately 124 ft. between the north and south walls. At the hydrostatic pressure of 26 ft. of water, the maximum flexural moments in the horizontal direction and vertical directions were determined to be

95 and 74 ft-kips/ft, respectively, without considering any load factors. The maximum moment capacities of the east wall in the horizontal and vertical directions were computed to be 73 ft-kips/ft (30% overstress) and 65 ft-kips/ft (13% overstress), respectively, without considering any capacity reduction factors. The east wall was, therefore, subjected to forces beyond its capacity. If the water is considered to be 30 ft. high in the basin, then the flexural moments in the horizontal and vertical directions would be 146 ft-kips/ft. (100% overstress) and 97 ft-kips/ft (50% overstress). The outward maximum displacement of the wall was computed to be approximately 10".

If the level of water in the basin was in fact 26 ft. and not 30 ft., then the east wall having lost the support of the intersecting walls would be overstressed by 30% and 13% in the horizontal and vertical directions, respectively. The magnitude of overstress, though undesirable, is not considered to be catastrophic. What became catastrophic was the inadequate connection of the east wall at the north and south walls, see Figs. 6, 7 & 8. The east wall was dowelled into the north and south walls by # 9 rebars which required a development length of 21" with a 90 degree hook. Inspection of the failed connection of the east wall at the north and south walls indicated that the development lengths of the # 9 rebars were grossly deficient.

4. Conclusions

Based upon our investigation, we concluded that:

1. The cause of the failure was the deficiency in the concrete wall construction. Walls were cast in a manner that produced a cold joint between the wall that fell and the three intersecting walls. The intersecting walls were critical to the structural integrity of the east wall. The cold smooth joint facilitated the leakage of the acidic wastewater across the joint, and as a result corroded the rebar splice over a number of years.

2. The contractor used splicing couplers instead of dowels as required by the original drawings. The use of the couplers, although a deviation from the design, was not itself not a causal factor, but

the formation of the cold joint resulted in corrosion of the couplers. Also the rebars were not threaded to the required length inside the coupler at all locations.

3. The couplers are not believed to have failed all at one time, but gradually over the life of the basin. With the loss of the support of the intersecting walls, the east wall that fell was subjected to an overturning moment well in excess of its capacity, and, therefore, the wall separated and fell over. The wall was originally designed to support the contents of the basin with the support of the intersecting walls.

4. The original design of the basin was reviewed. The design of the walls was adequate. The detail of the horizontal dowels between the north wall and the orthogonal east and west intersecting walls provided in the drawings reduced the efficiency of the joints, but was adequate.

5. The rebars and the couplers were neither galvanized nor epoxy-coated, which would have prolonged the life of the basin.

6. Concrete strength and the quality of the rebars were not the causal factors.

5. References

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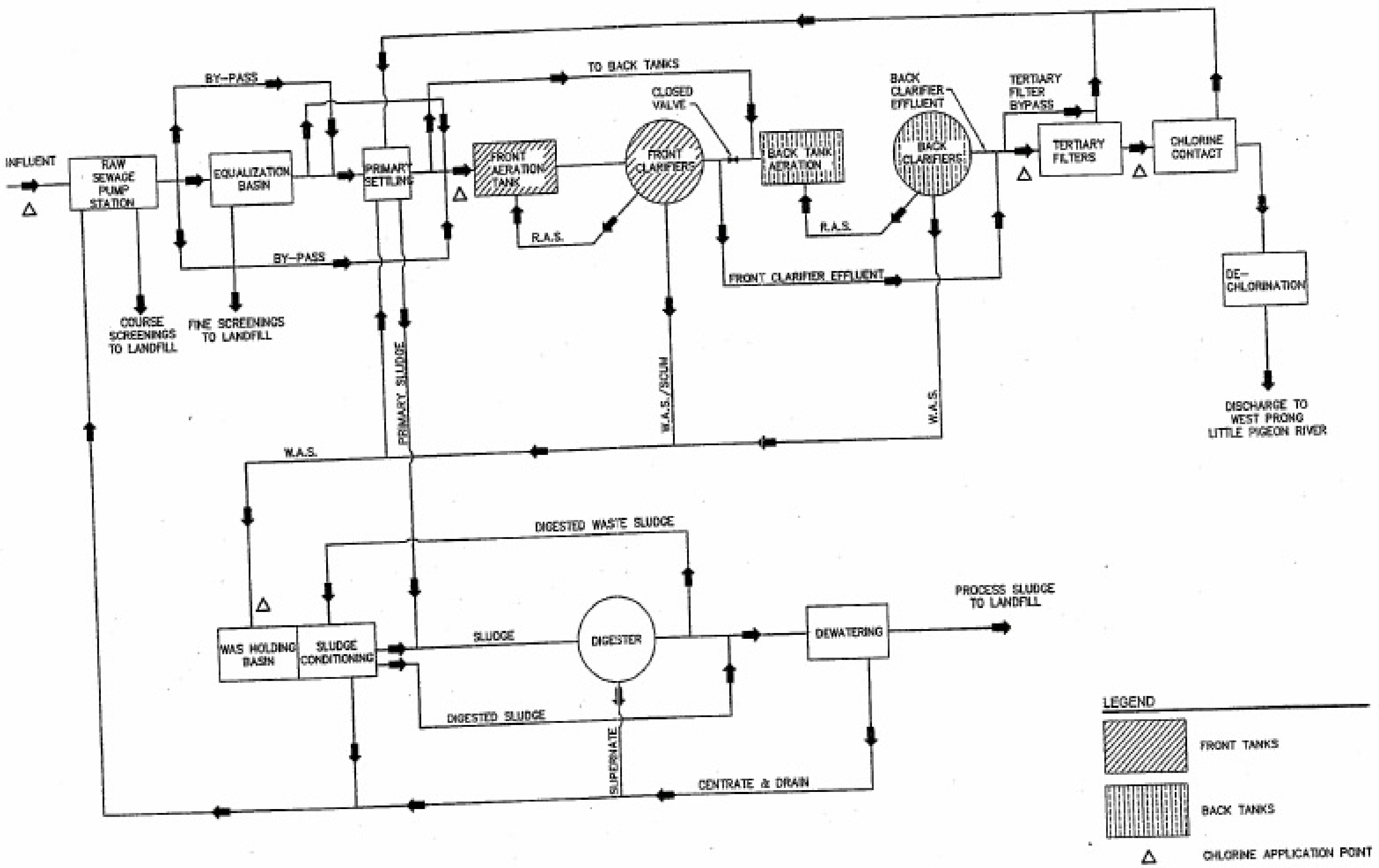


Fig. 1 Process Flow Diagram

Fig. 2 Cold Joint between a Baffle Wall and the East Wall

Fig. 3 Rebar Couplers used between the Baffle wall and the East Wall (Typical)

Fig. 4 # 8 Dowel bars @ 6" o.c. (single layer) at the Interface of East Wall and Bottom Slab

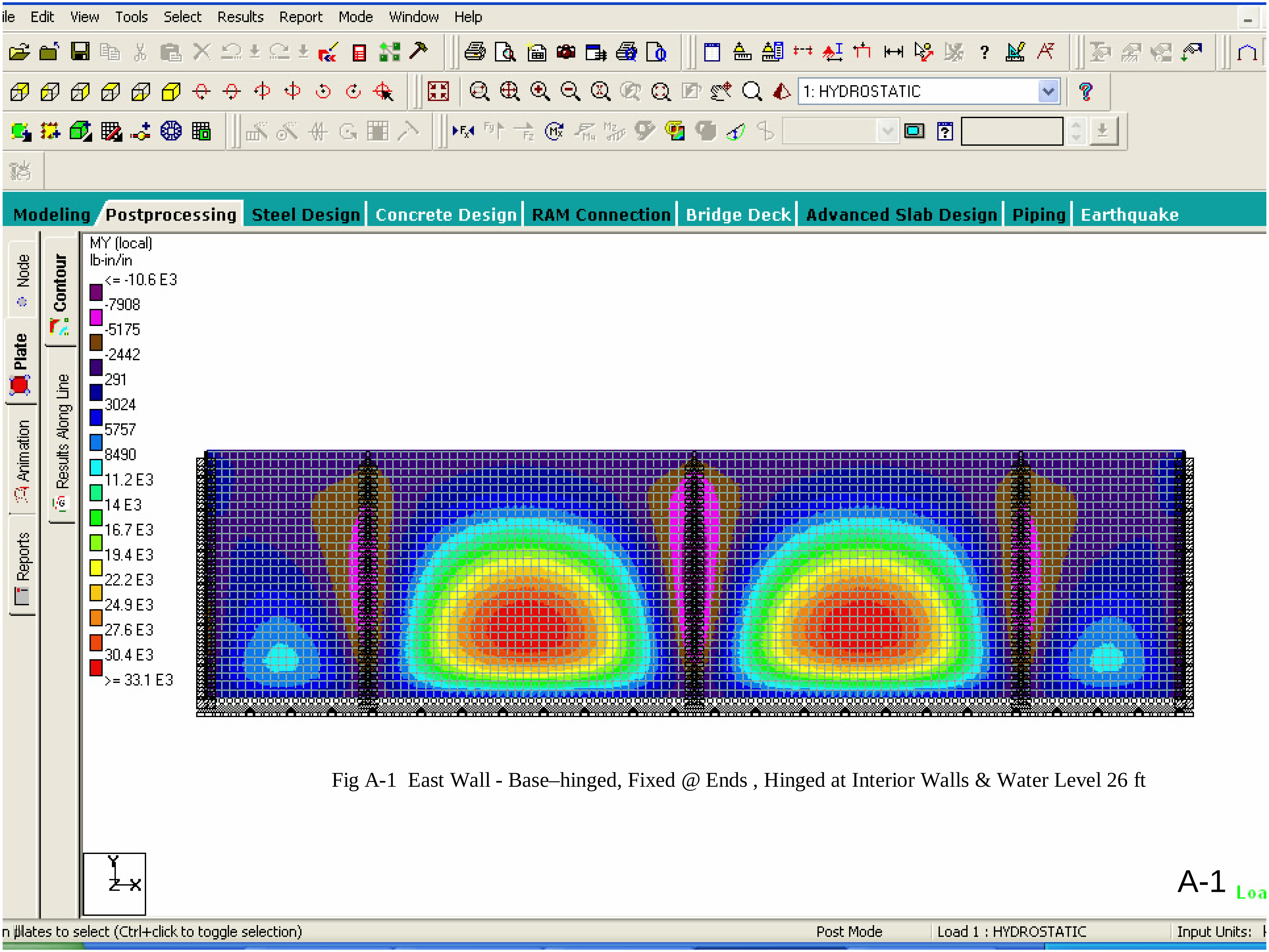
Fig. 5 Close-up View of Fig. 4

Fig. 6 Dowel Bars at the Corner Joint between the East Wall and North Wall
(# 9 rebar @ 6’’ o.c., each face)

Fig. 7 Close-up View of Fig. 6

Fig. 8 Dowel Bars at the Corner Joint between the East Wall and South Wall

APPENDIX A



n plates to select (Ctrl+click to toggle selection)

Post Mode

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Input Units:

Fig A-1 East Wall - Base–hinged, Fixed @ Ends , Hinged at Interior Walls & Water Level 26 ft

A-1

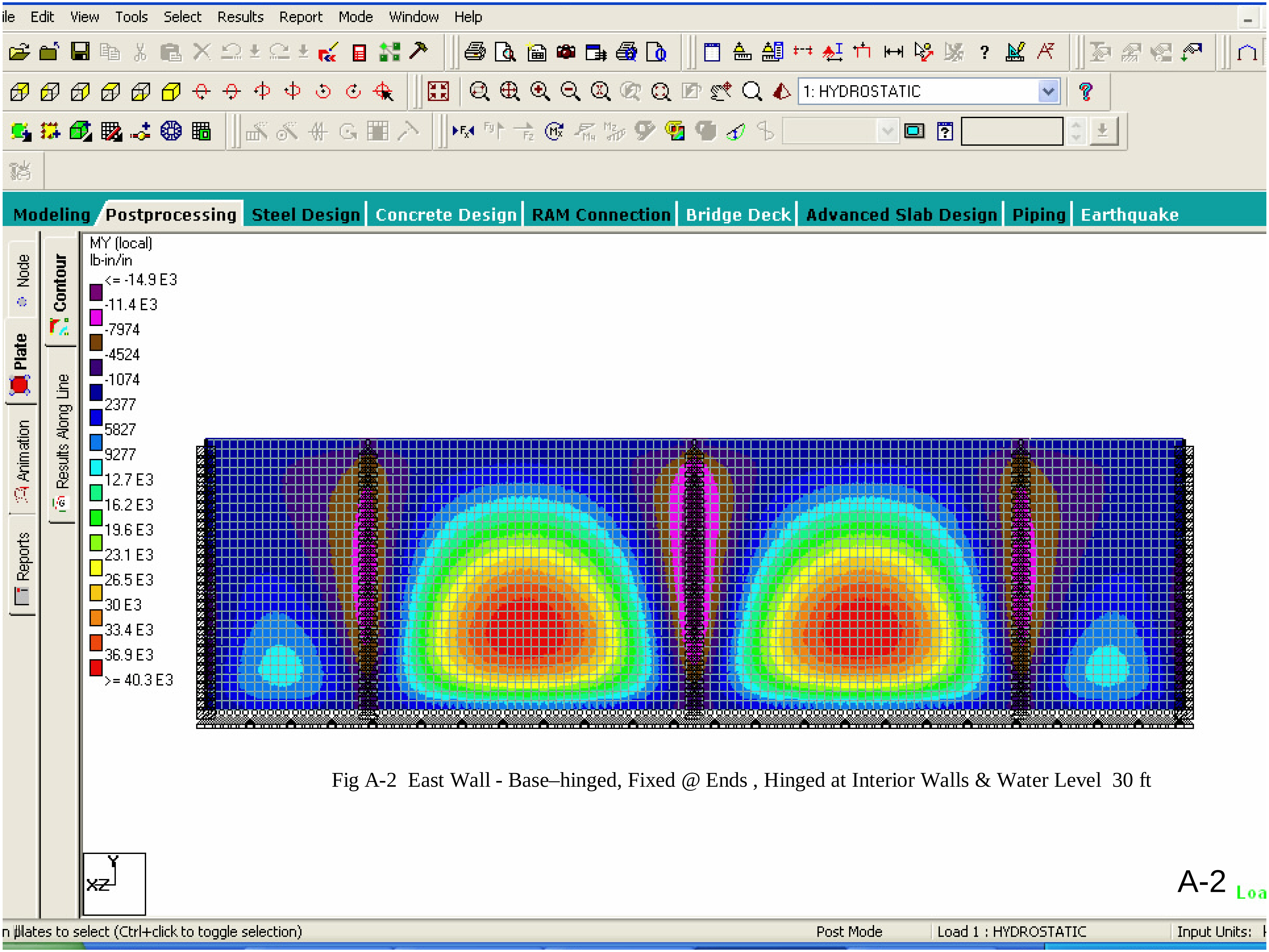

Fig A-2 East Wall - Base–hinged, Fixed @ Ends , Hinged at Interior Walls & Water Level 30 ft

A-2 Loa

n plates to select (Ctrl+click to toggle selection)   Post Mode   Load 1 : HYDROSTATIC   Input Units:

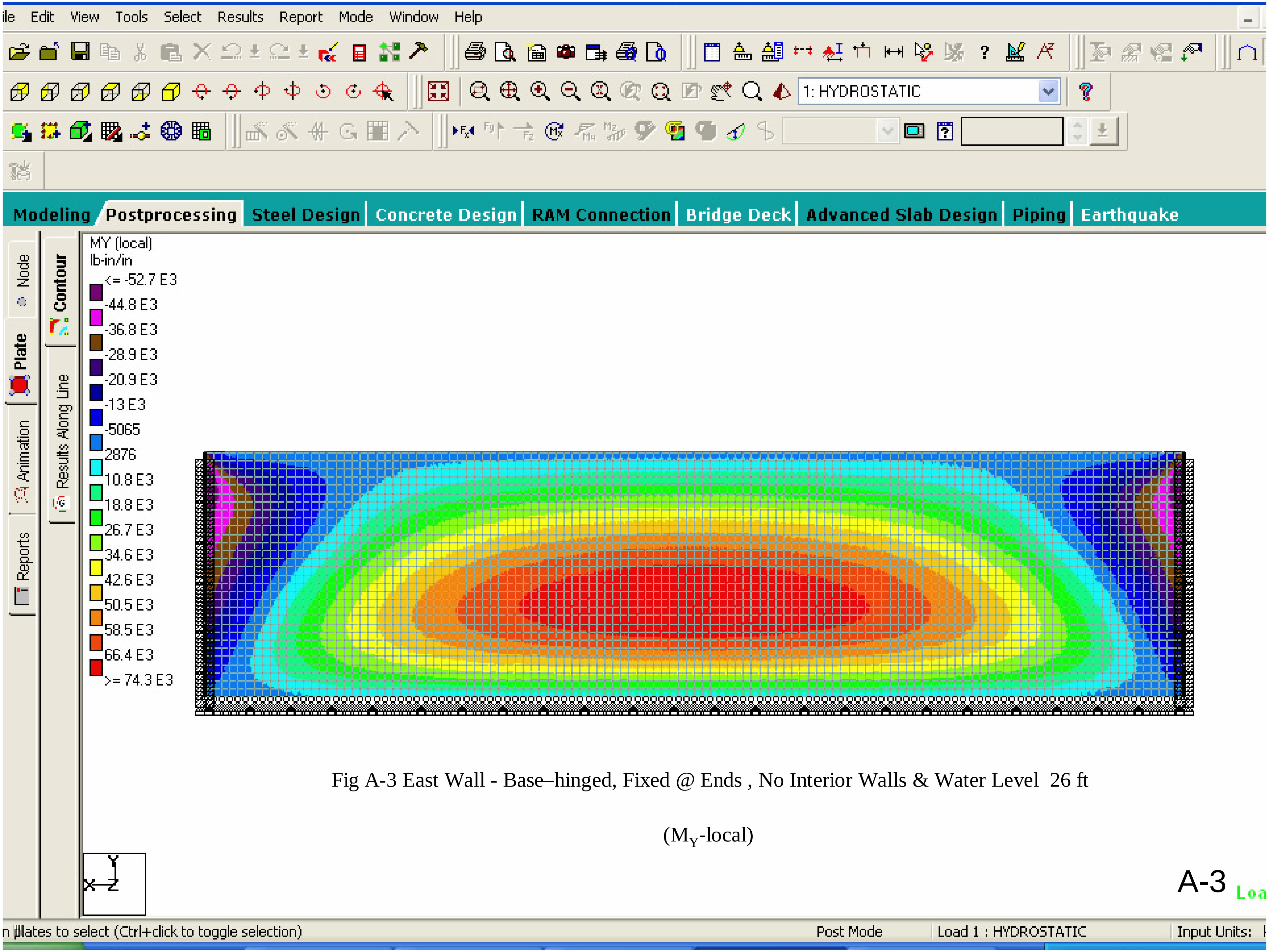

Fig A-3 East Wall - Base–hinged, Fixed @ Ends , No Interior Walls & Water Level 26 ft

(M_Y-local)

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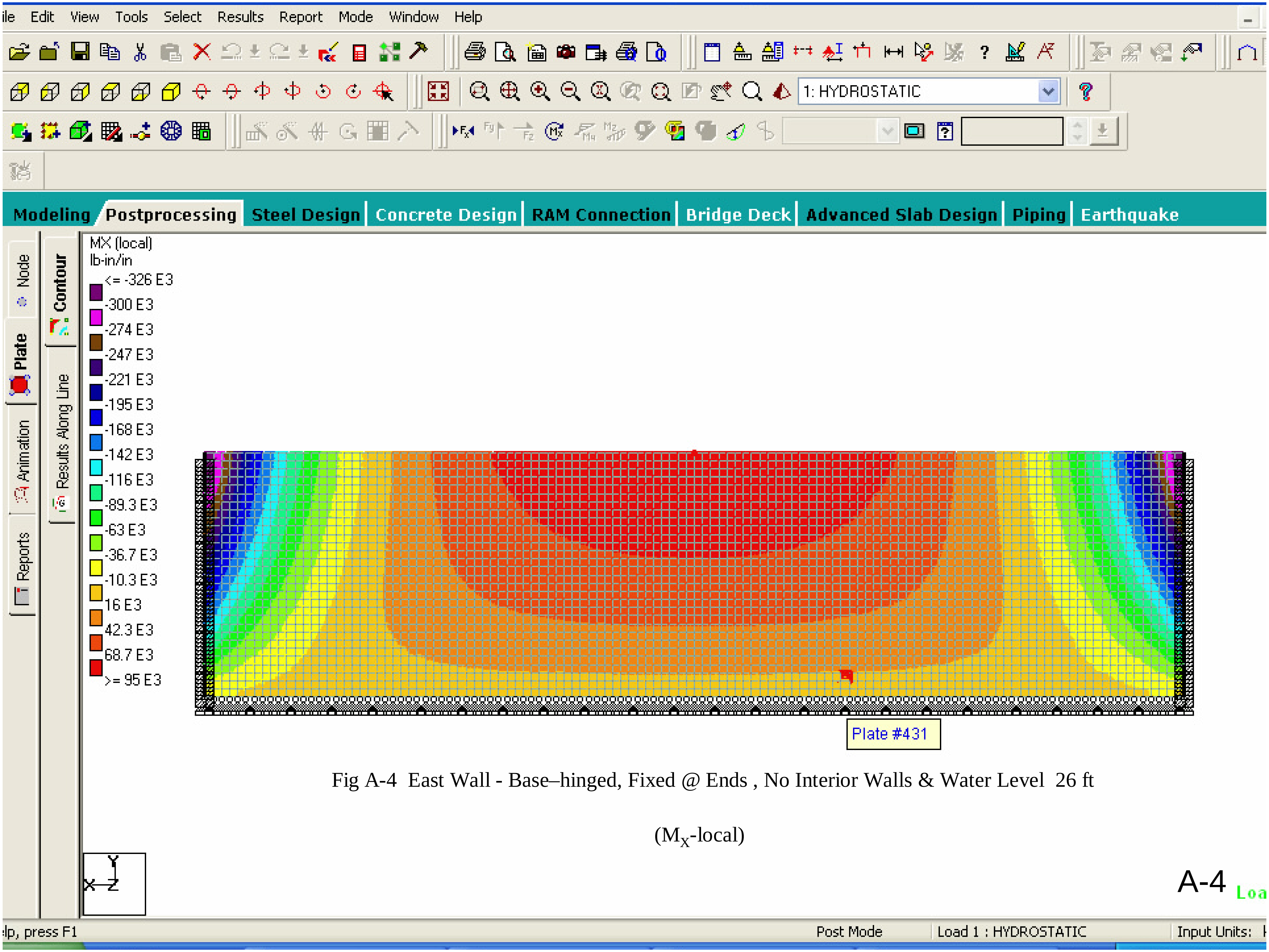


Fig A-4 East Wall - Base–hinged, Fixed @ Ends , No Interior Walls & Water Level 26 ft

(M_X-local)

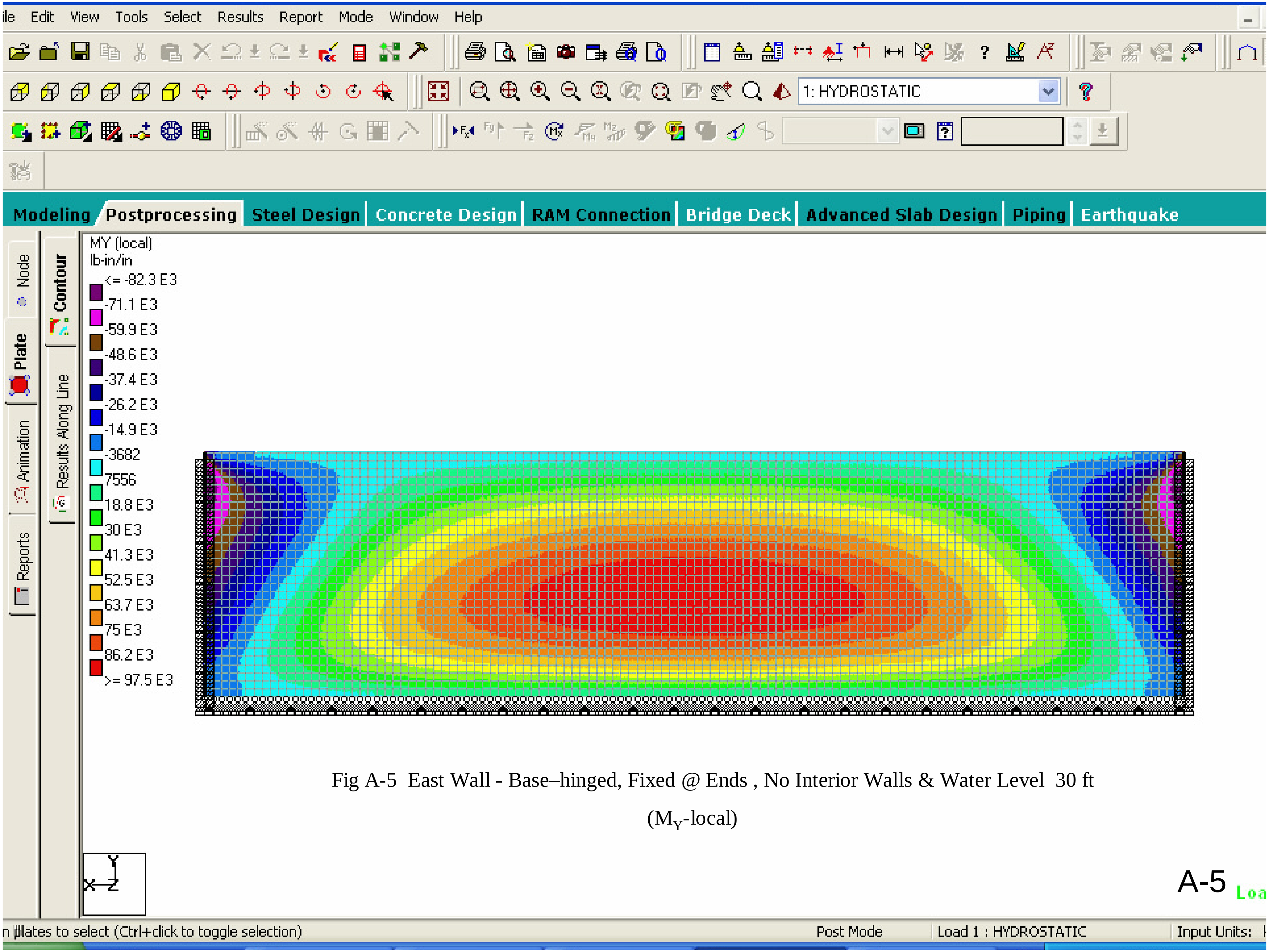
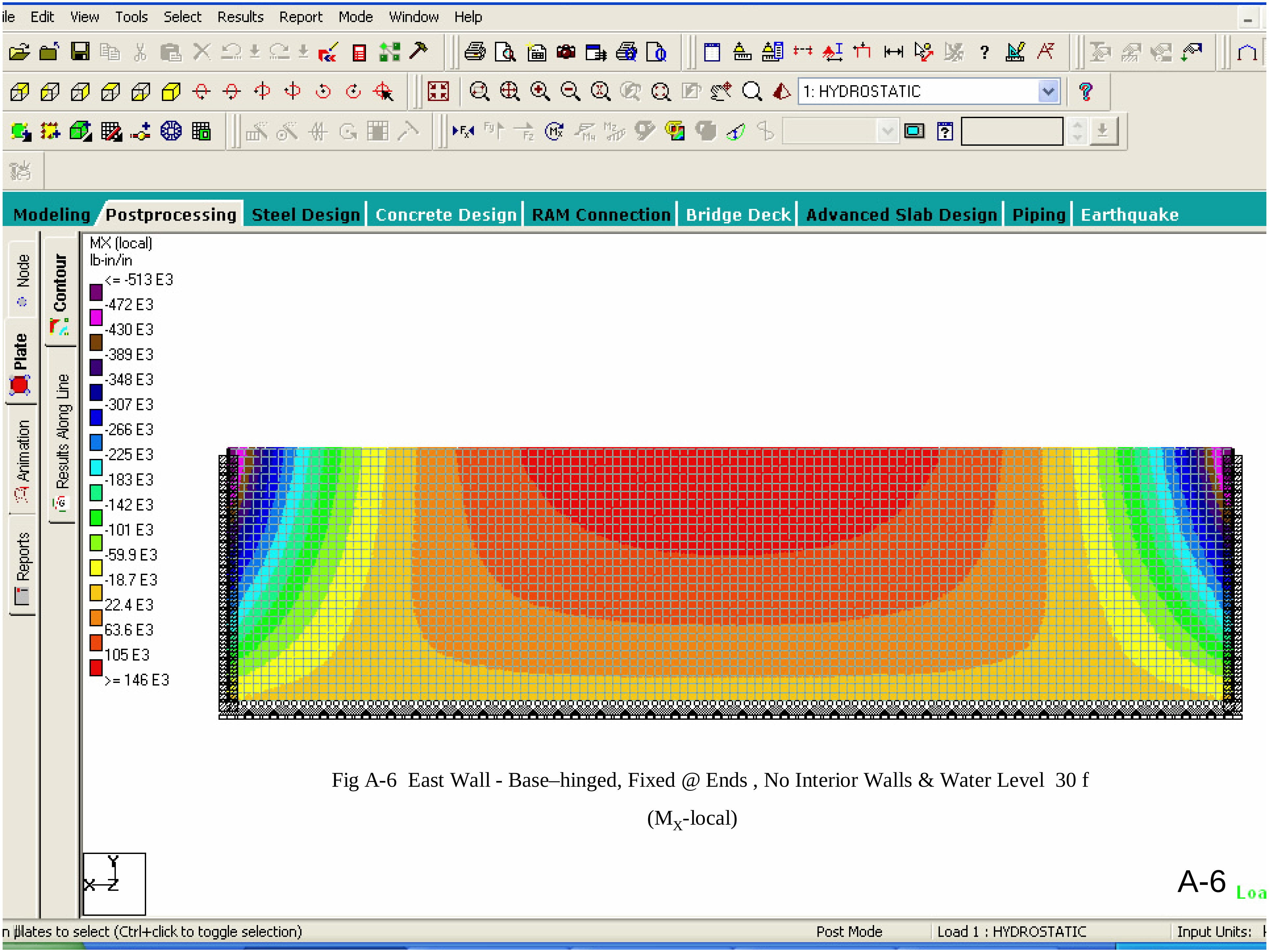


Fig A-5 East Wall - Base–hinged, Fixed @ Ends , No Interior Walls & Water Level 30 ft

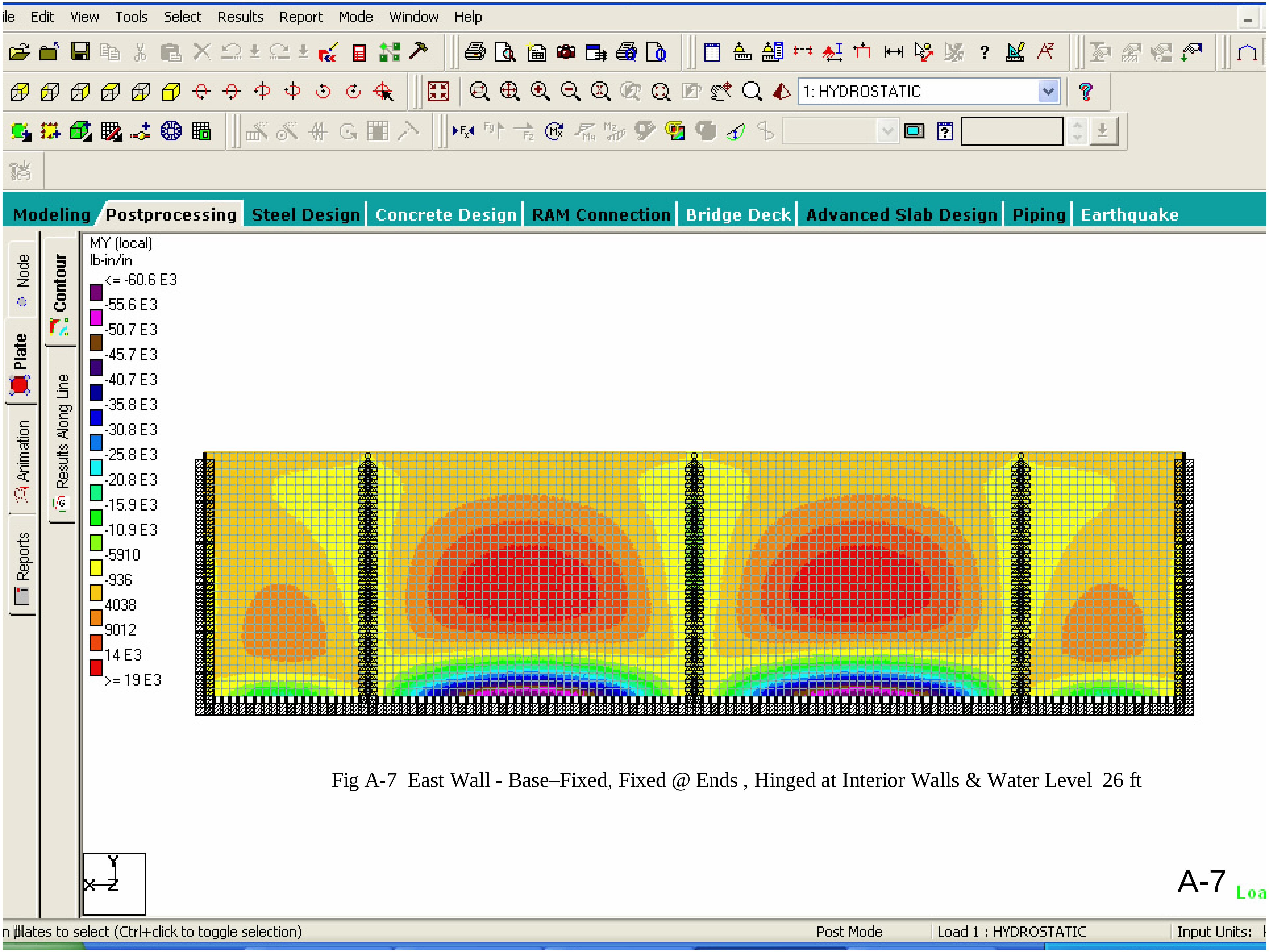
(M_Y-local)



n plates to select (Ctrl+click to toggle selection)

Fig A-6 East Wall - Base–hinged, Fixed @ Ends , No Interior Walls & Water Level 30 f

(M_X-local)



n plates to select (Ctrl+click to toggle selection)

Post Mode

Load 1 : HYDROSTATIC

Input Units:

Fig A-7 East Wall - Base–Fixed, Fixed @ Ends , Hinged at Interior Walls & Water Level 26 ft

A-7

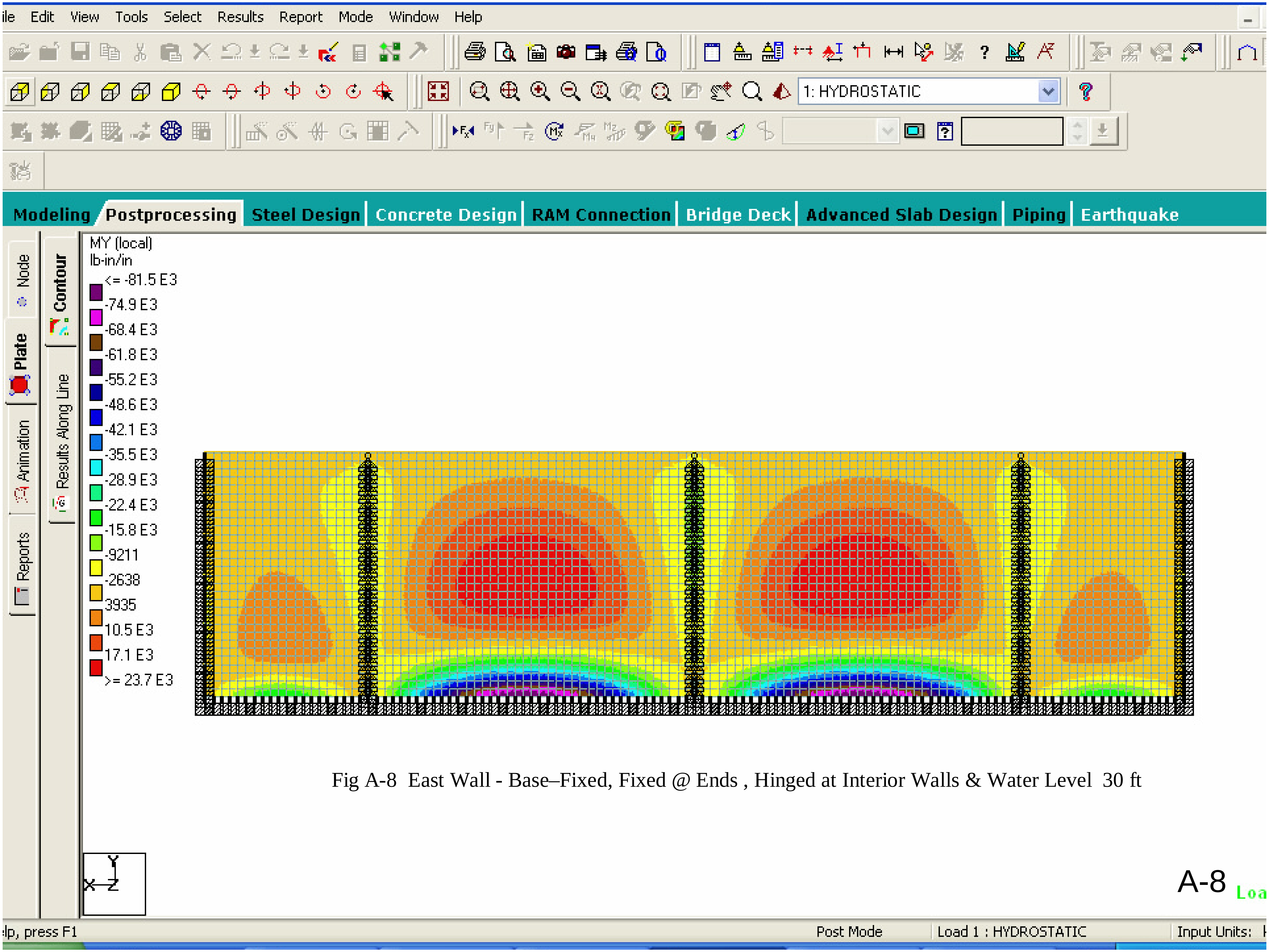


Fig A-8 East Wall - Base–Fixed, Fixed @ Ends , Hinged at Interior Walls & Water Level 30 ft

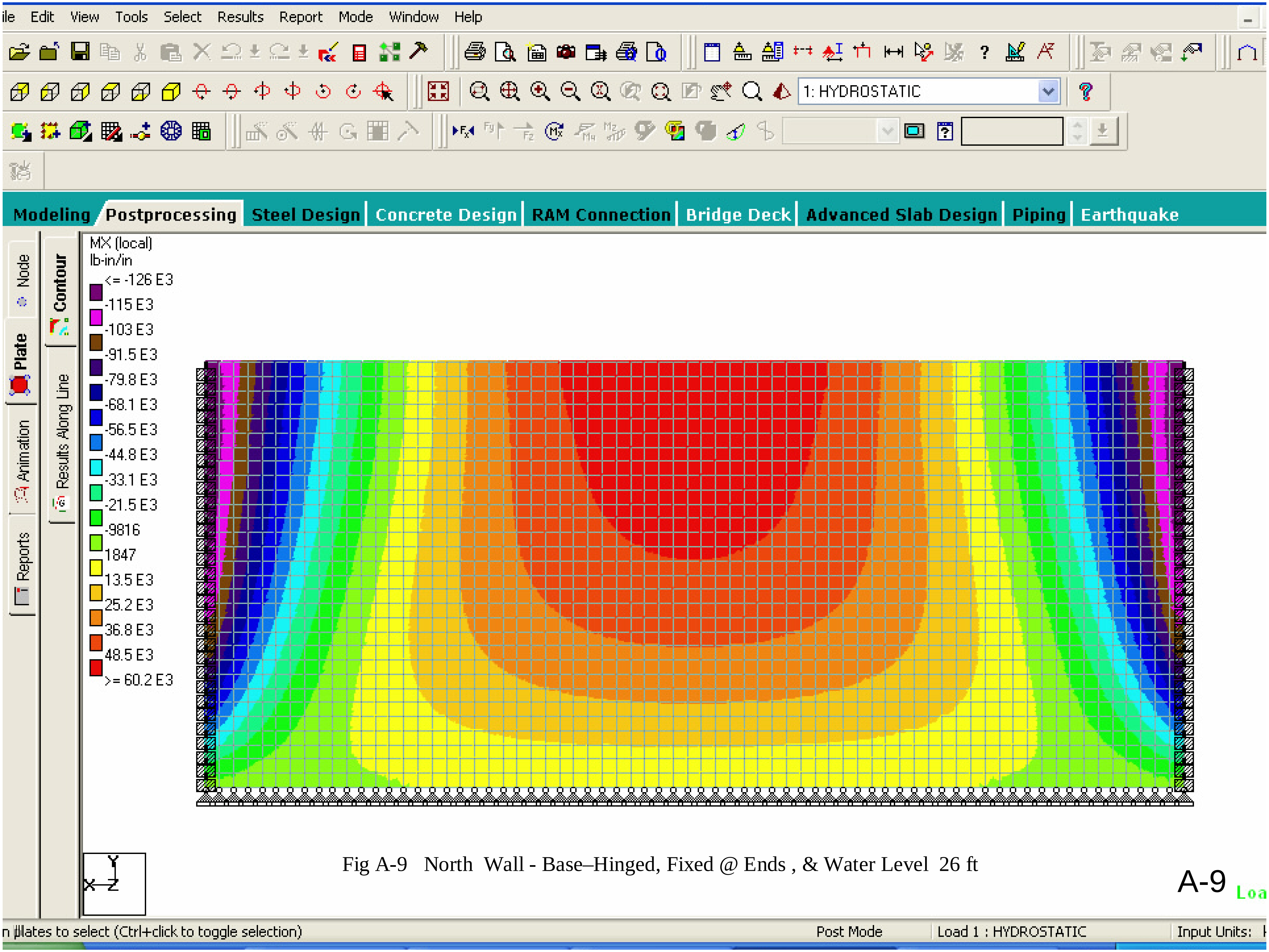


Fig A-9 North Wall - Base–Hinged, Fixed @ Ends , & Water Level 26 ft

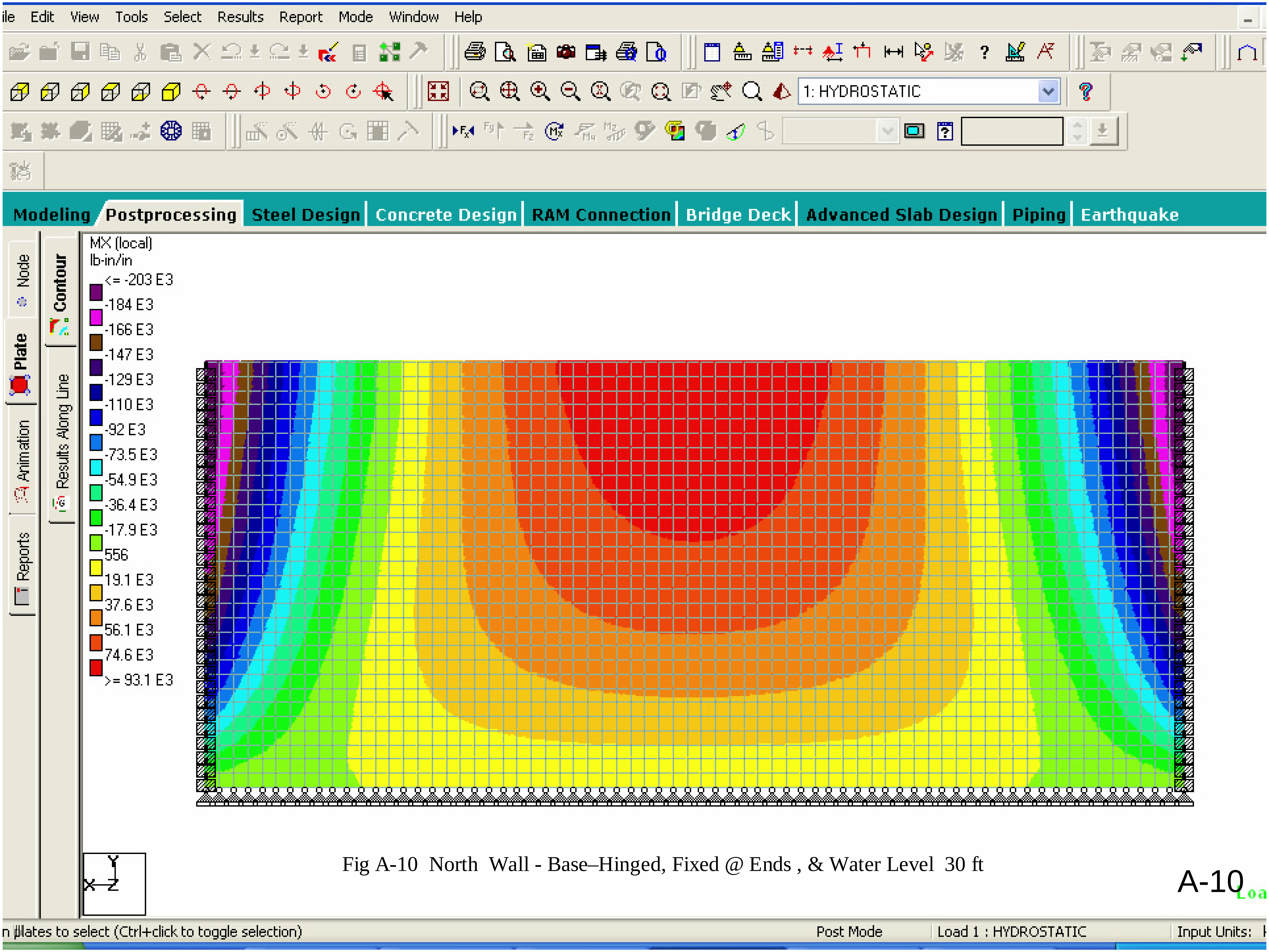
A-9

n plates to select (Ctrl+click to toggle selection)

Post Mode

Load 1 : HYDROSTATIC

Input Units:



1: HYDROSTATIC

n plates to select (Ctrl+click to toggle selection)

Post Mode

Load 1 : HYDROSTATIC

Input Units:

Fig A-10 North Wall - Base–Hinged, Fixed @ Ends , & Water Level 30 ft

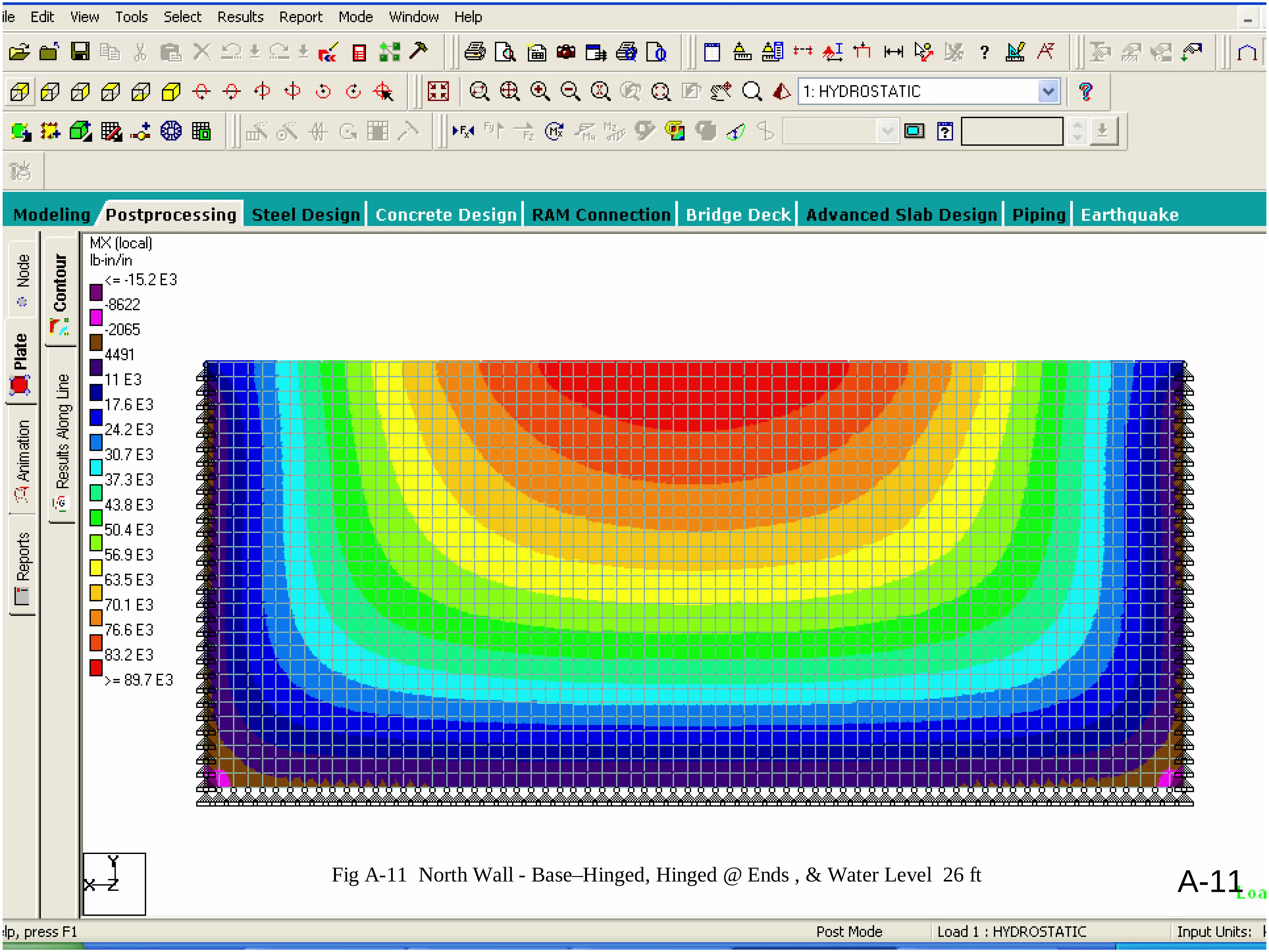


Fig A-11 North Wall - Base–Hinged, Hinged @ Ends , & Water Level 26 ft

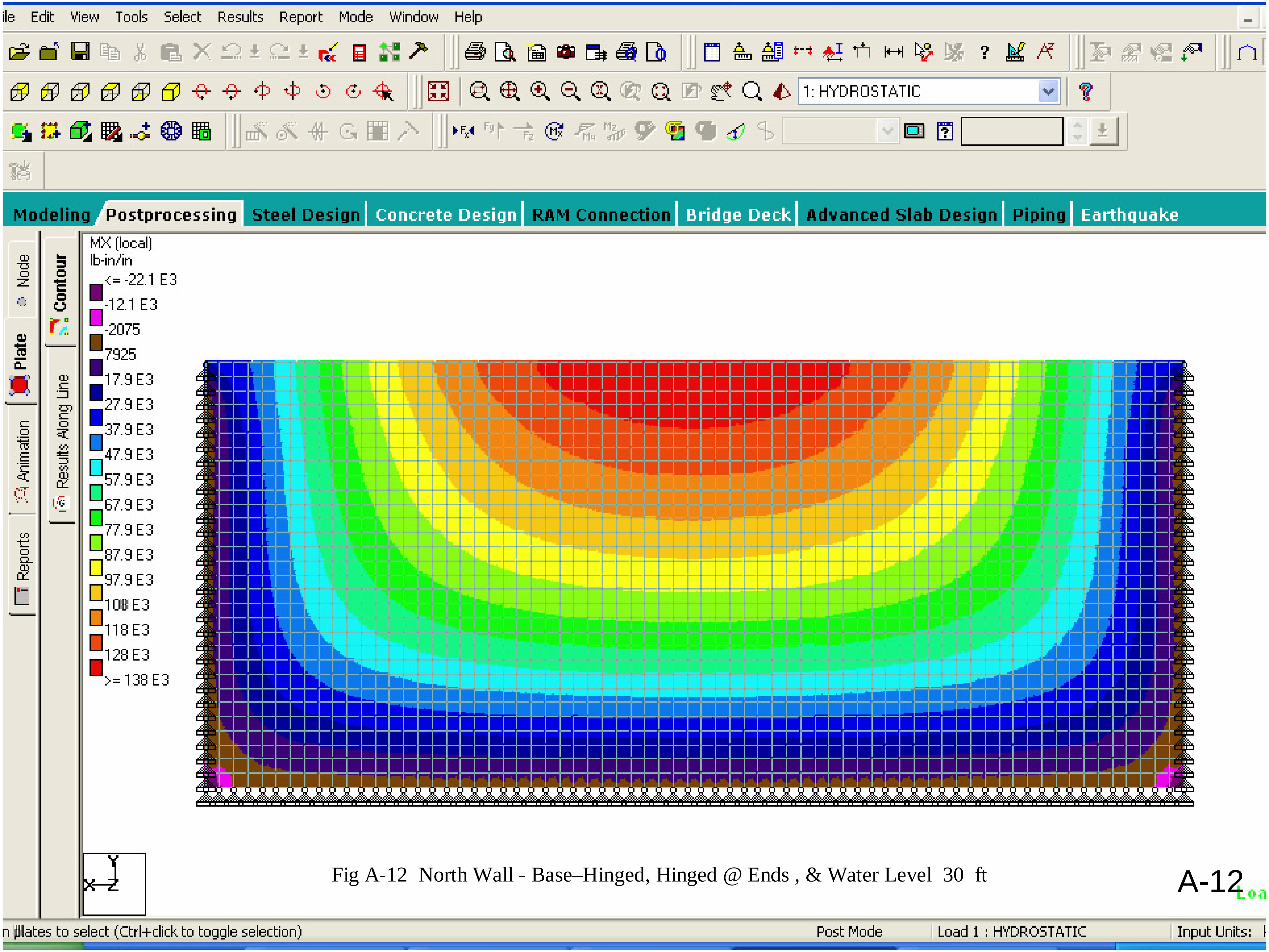


Fig A-12 North Wall - Base–Hinged, Hinged @ Ends , & Water Level 30 ft

A-12

n plates to select (Ctrl+click to toggle selection)

Post Mode

Load 1 : HYDROSTATIC

Input Units:

APPENDIX B

B-1

B-2


ME&T
#49591


ME&T
49595


ME&T
49595


ME&T
#49592


ME&T
#49592


ME&T
#49592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APPENDIX C

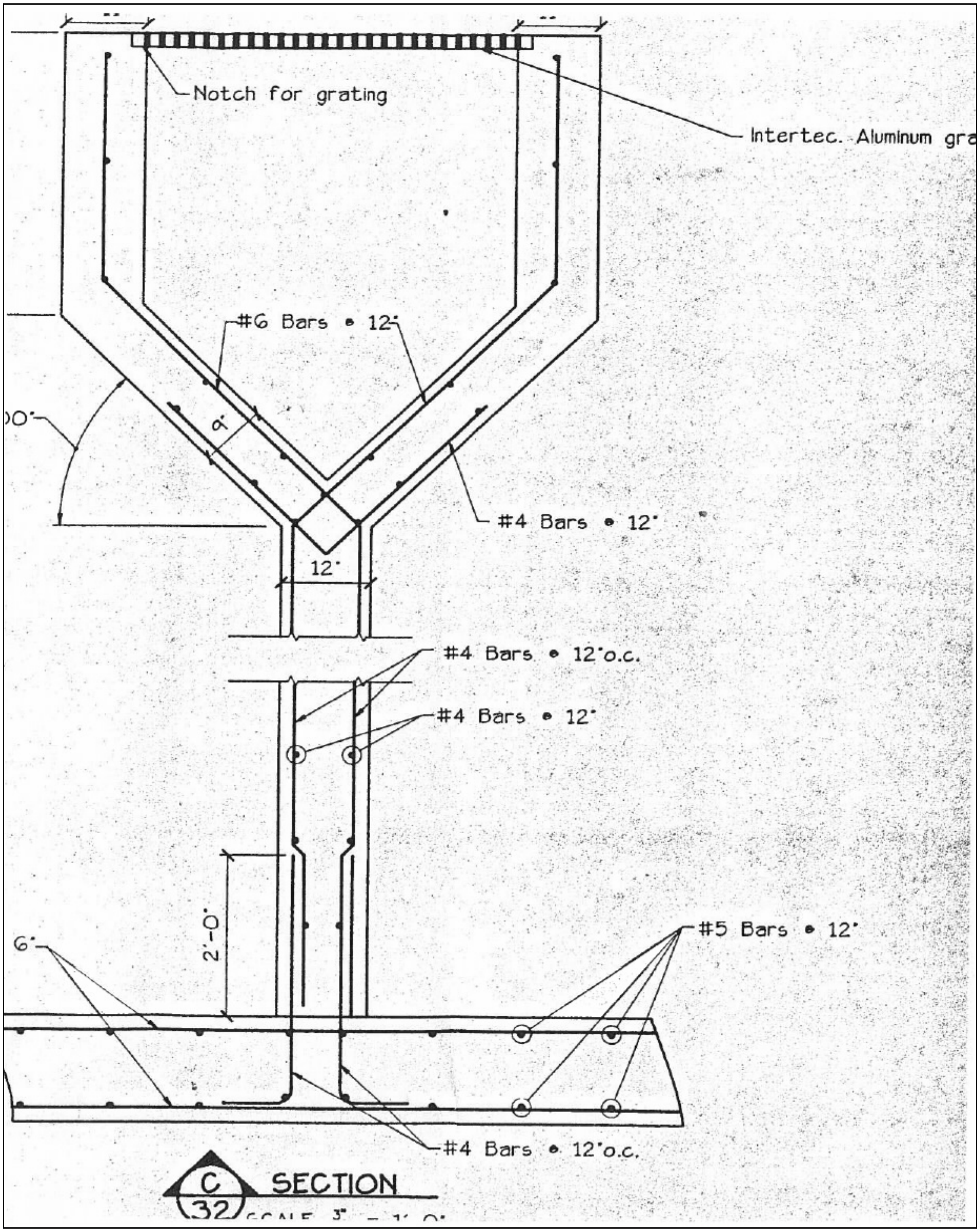


Fig. C-1 Vertical Section Showing Reinforcement for Interior Baffle Wall Connected to the East Wall

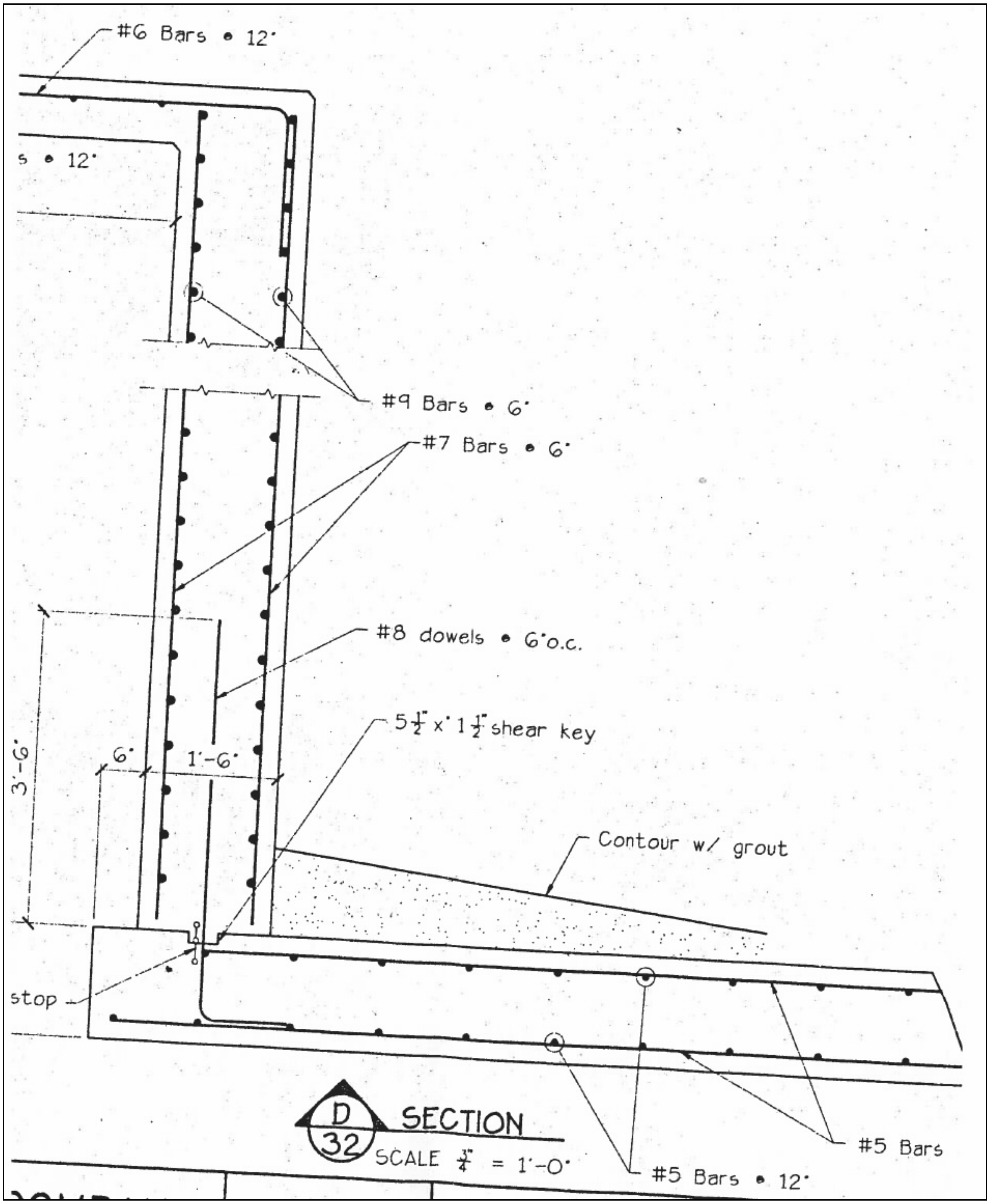


Fig. C-2 Vertical Section Showing Reinforcement for North Wall

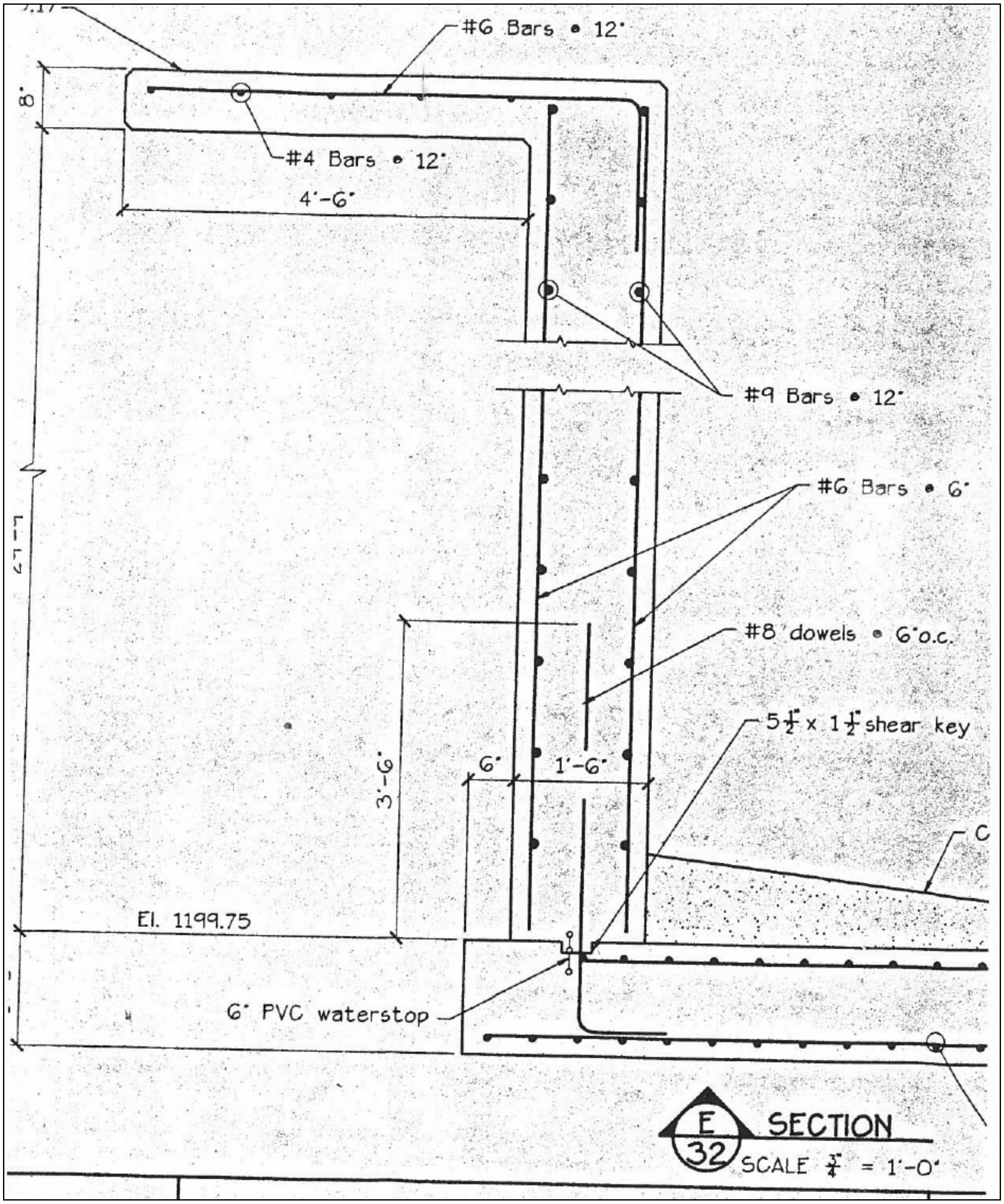


Fig. C-3 Vertical Section Showing Reinforcement for East Wall

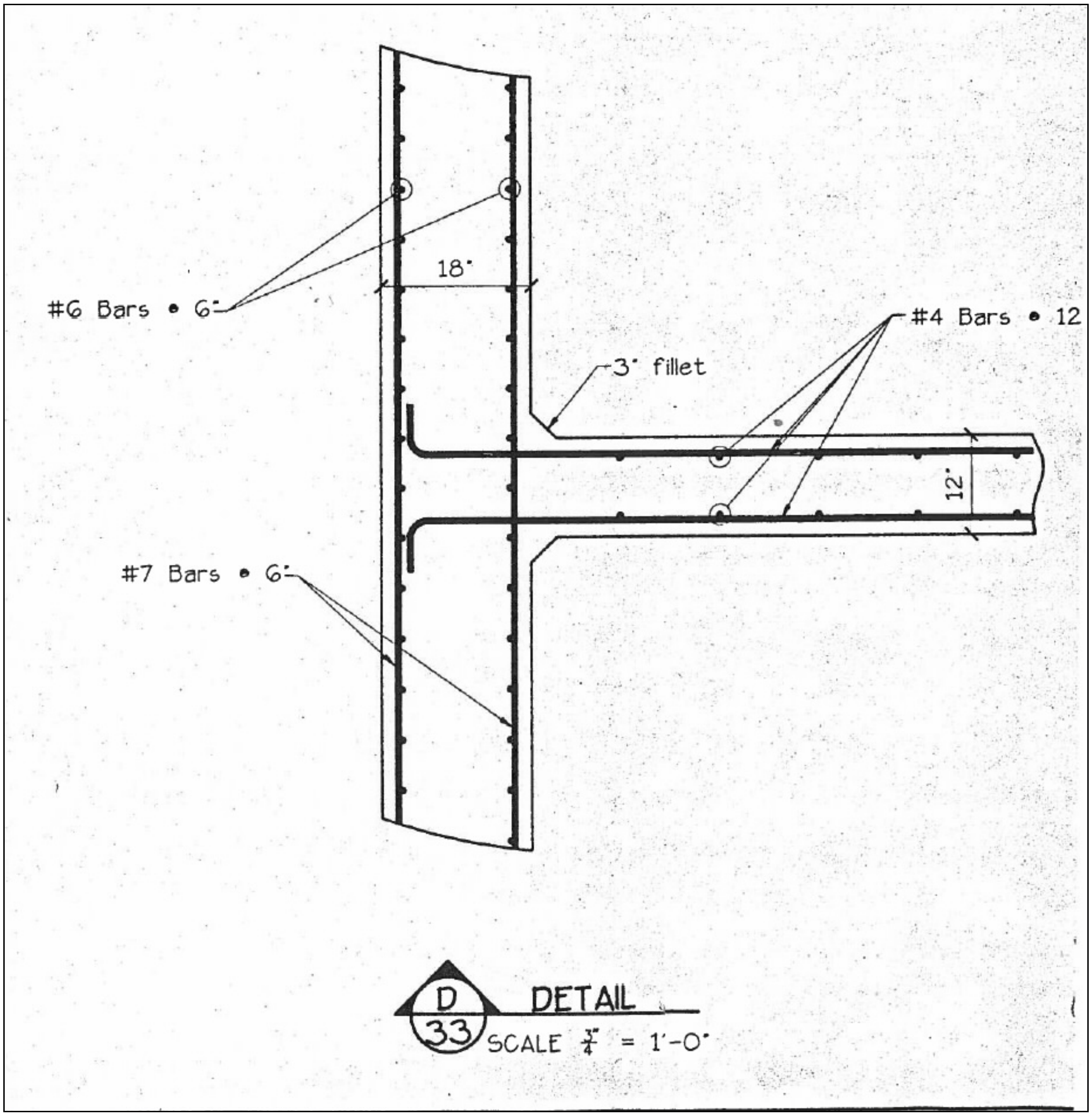


Fig. C-4 Plan Showing Reinforcement at the Wall Intersections

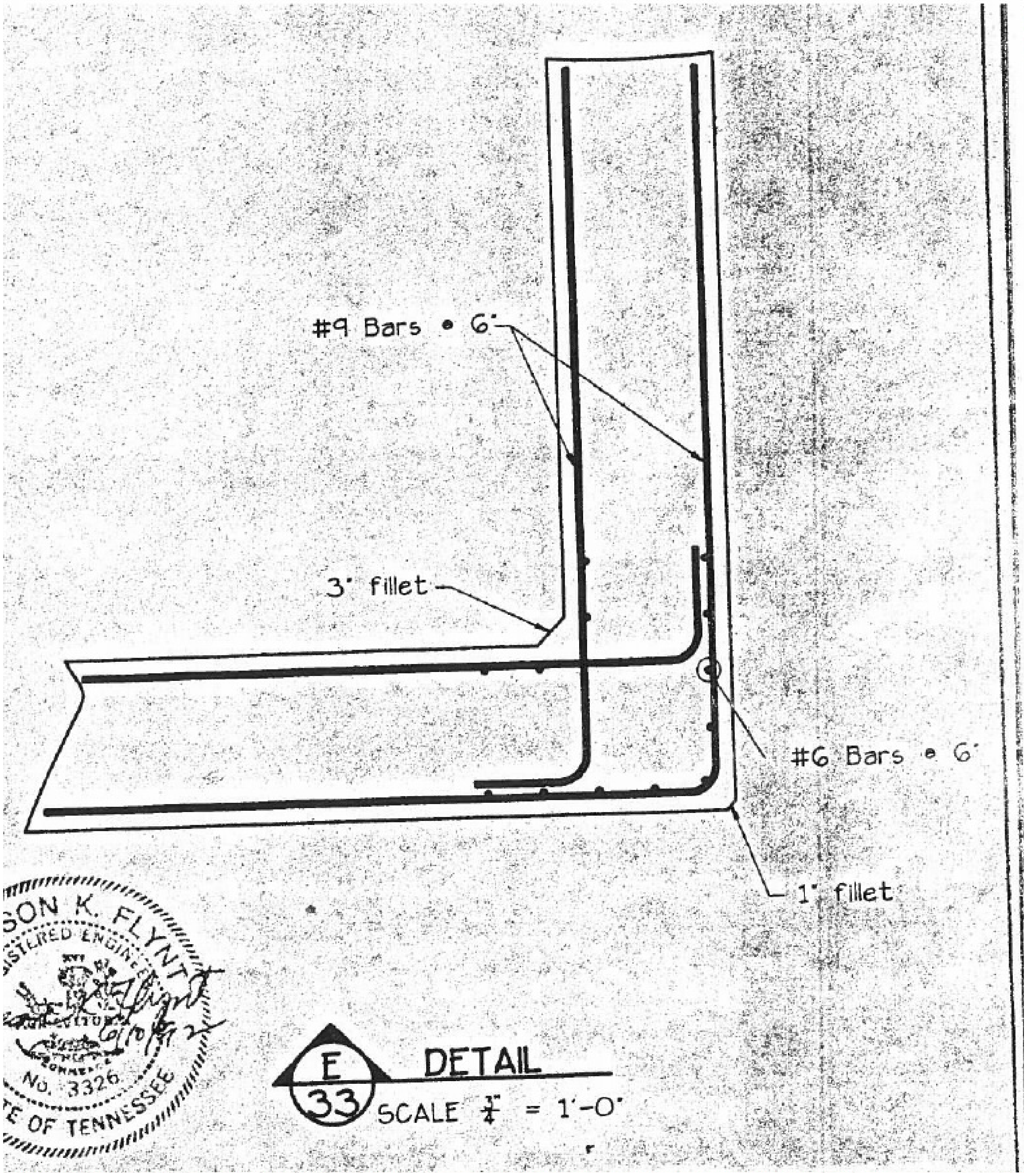
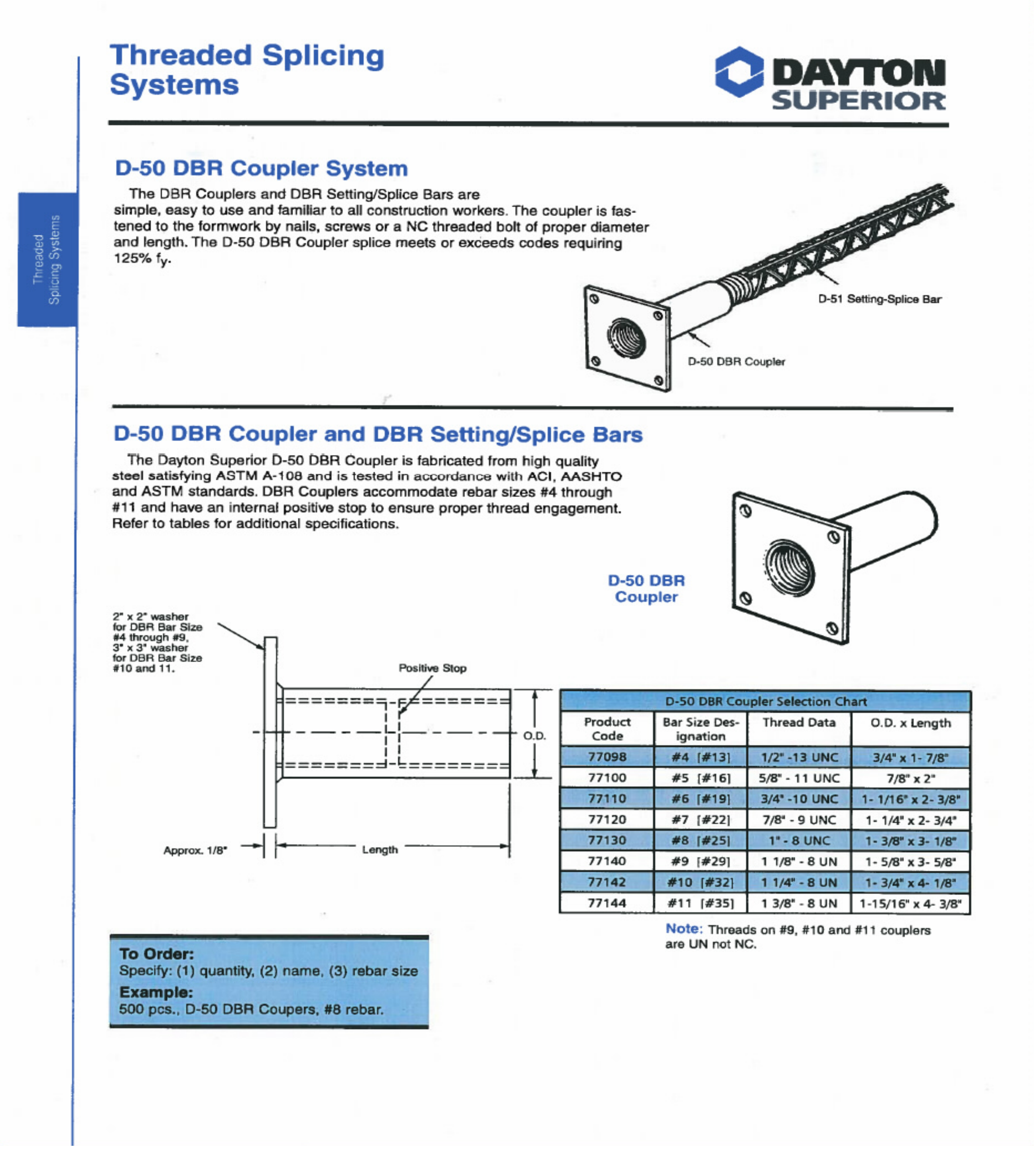


Fig. C-5 Plan Showing Reinforcement at Corners



Threaded Splicing Systems

DAYTON SUPERIOR

D-50 DBR Coupler System

The DBR Couplers and DBR Setting/Splice Bars are simple, easy to use and familiar to all construction workers. The coupler is fastened to the formwork by nails, screws or a NC threaded bolt of proper diameter and length. The D-50 DBR Coupler splice meets or exceeds codes requiring 125% f_y.

D-50 DBR Coupler and DBR Setting/Splice Bars

The Dayton Superior D-50 DBR Coupler is fabricated from high quality steel satisfying ASTM A-108 and is tested in accordance with ACI, AASHTO and ASTM standards. DBR Couplers accommodate rebar sizes #4 through #11 and have an internal positive stop to ensure proper thread engagement. Refer to tables for additional specifications.

D-50 DBR Coupler

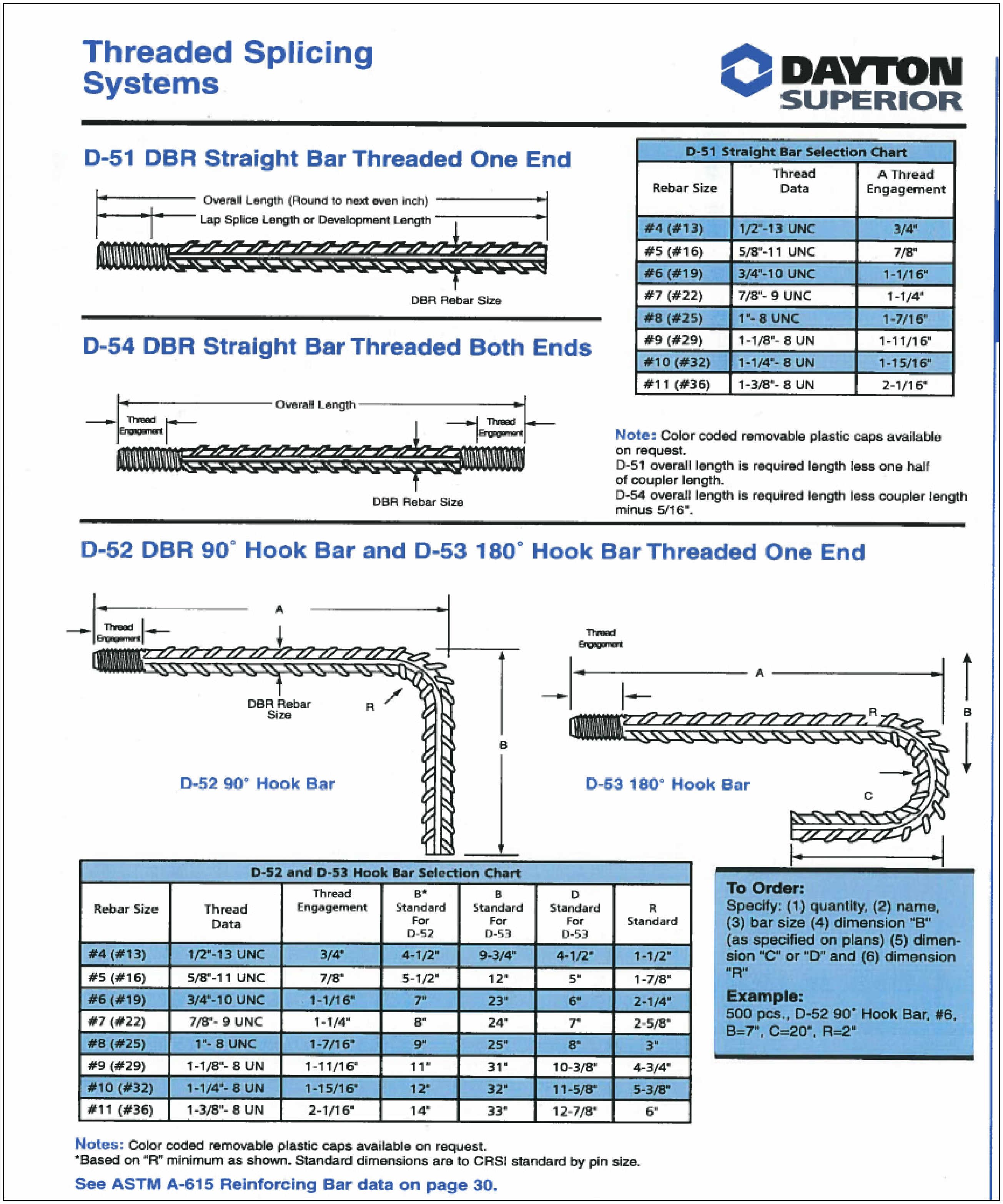
D-50 DBR Coupler Selection Chart			
Product Code	Bar Size Designation	Thread Data	O.D. x Length
77098	#4 [#13]	1/2" -13 UNC	3/4" x 1- 7/8"
77100	#5 [#16]	5/8" - 11 UNC	7/8" x 2"
77110	#6 [#19]	3/4" -10 UNC	1- 1/16" x 2- 3/8"
77120	#7 [#22]	7/8" - 9 UNC	1- 1/4" x 2- 3/4"
77130	#8 [#25]	1" - 8 UNC	1- 3/8" x 3- 1/8"
77140	#9 [#29]	1 1/8" - 8 UN	1- 5/8" x 3- 5/8"
77142	#10 [#32]	1 1/4" - 8 UN	1- 3/4" x 4- 1/8"
77144	#11 [#35]	1 3/8" - 8 UN	1-15/16" x 4- 3/8"

Note: Threads on #9, #10 and #11 couplers are UN not NC.

To Order:
Specify: (1) quantity, (2) name, (3) rebar size

Example:
500 pcs., D-50 DBR Coupers, #8 rebar.

Fig. C-6 Re-bar Couplers



Threaded Splicing Systems

D-51 DBR Straight Bar Threaded One End

D-51 Straight Bar Selection Chart		
Rebar Size	Thread Data	A Thread Engagement
#4 (#13)	1/2"-13 UNC	3/4"
#5 (#16)	5/8"-11 UNC	7/8"
#6 (#19)	3/4"-10 UNC	1-1/16"
#7 (#22)	7/8"- 9 UNC	1-1/4"
#8 (#25)	1"- 8 UNC	1-7/16"
#9 (#29)	1-1/8"- 8 UN	1-11/16"
#10 (#32)	1-1/4"- 8 UN	1-15/16"
#11 (#36)	1-3/8"- 8 UN	2-1/16"

D-54 DBR Straight Bar Threaded Both Ends

Note: Color coded removable plastic caps available on request.
D-51 overall length is required length less one half of coupler length.
D-54 overall length is required length less coupler length minus 5/16".

D-52 DBR 90° Hook Bar and D-53 180° Hook Bar Threaded One End

D-52 and D-53 Hook Bar Selection Chart						
Rebar Size	Thread Data	Thread Engagement	B* Standard For D-52	B Standard For D-53	D Standard For D-53	R Standard
#4 (#13)	1/2"-13 UNC	3/4"	4-1/2"	9-3/4"	4-1/2"	1-1/2"
#5 (#16)	5/8"-11 UNC	7/8"	5-1/2"	12"	5"	1-7/8"
#6 (#19)	3/4"-10 UNC	1-1/16"	7"	23"	6"	2-1/4"
#7 (#22)	7/8"- 9 UNC	1-1/4"	8"	24"	7"	2-5/8"
#8 (#25)	1"- 8 UNC	1-7/16"	9"	25"	8"	3"
#9 (#29)	1-1/8"- 8 UN	1-11/16"	11"	31"	10-3/8"	4-3/4"
#10 (#32)	1-1/4"- 8 UN	1-15/16"	12"	32"	11-5/8"	5-3/8"
#11 (#36)	1-3/8"- 8 UN	2-1/16"	14"	33"	12-7/8"	6"

To Order:
Specify: (1) quantity, (2) name, (3) bar size (4) dimension "B" (as specified on plans) (5) dimension "C" or "D" and (6) dimension "R"

Example:
500 pcs., D-52 90° Hook Bar, #6, B=7", C=20", R=2"

Notes: Color coded removable plastic caps available on request.
*Based on "R" minimum as shown. Standard dimensions are to CRSI standard by pin size.

See ASTM A-615 Reinforcing Bar data on page 30.

Fig. C-7 Threaded Re-bars used with the Couplers