

Truck Rerouting and Pavement Replacement

Final Design Report

05/08/2026



prepared for:

Adam Kofoed – City Administrator

prepared by:

Nick Simpson, Andrew Heim, Sarah Hilgendorf

Table of Contents

Section I Executive Summary	3
Section II Organization Qualifications and Experience	5
Organization and Design Team Description	5
Section III Design Services	5
1. Project Scope.....	5
2. Work Plan	6
Section IV Constraints, Challenges and Impacts	7
1. Constraints	7
2. Challenges	7
3. Societal Impact within the Community and/or State of Iowa.....	8
Section V Alternative Solutions That Were Considered	8
Section VI Final Design Details	16
Section VII Engineer’s Cost Estimate	21
Appendices	25
Appendix A – Project Schedule	25
Appendix B – Bridge Evaluation Calculations	26
Appendix C – Retaining Wall Design Calcs	42
Appendix D – Pipe Sizing Analysis	50

Section I Executive Summary

The City of West Branch, Iowa has identified and expressed a need to improve truck mobility and roadway safety through the downtown corridor. Under current conditions, heavy truck traffic runs directly through the downtown corridor, creating operational challenges for truck drivers such as congestion, inefficient turning movements, and safety concerns involving local traffic and pedestrians. These issues reduce transportation efficiency for truck movement through the town while also negatively impacting the livability, walkability, and historic character of West Branch's downtown area. To help tackle these issues while keeping both trucks and the community in mind, we took a closer look at current conditions and explored some practical improvement options.

We, a student-led civil engineering design team from the University of Iowa's Civil Engineering Project Design and Management (CEE:4850) capstone course, provide an engineering design that evaluates and reroutes the existing truck route. Our team consists of three members with complementary expertise in transportation engineering, structural systems, and urban infrastructure design. Nick Simpson serves as project manager; Andrew Heim leads transportation and roadway design; and Sarah Hilgendorf leads the structural components.

Our objective for this project is to identify a safer and more efficient truck route through the town while maintaining roadway connectivity, minimizing impacts to surrounding residential areas and downtown businesses, and addressing all environmental constraints. This project supports the City's long-term transportation goals by improving safety, enhancing truck operations, and creating a safer, more pedestrian-friendly downtown. We have fully designed two new truck routes that meet all conditions to be a feasible truck route. With the requirement that the project cost does not exceed \$1 million. To meet these goals, our team completed the work during the contract period from February 9th, 2026, through May 8th, 2026.

The project is subject to several key constraints and challenges, including the presence of historically protected buildings that limit intersection improvements on the current truck route, grading restrictions along Fourth Street due to an existing farmhouse, and subsurface utilities that restrict excavation. Additional challenges include required right-of-way acquisition and utility relocations, which may increase project costs and complexity. Both proposed alternatives are also expected to impact nearby residential areas that currently experience little to no truck traffic, potentially leading to community concerns and pushbacks. Construction may result in temporary disruptions, and loss of on-street parking in certain areas, all of which will require attention to minimize impacts on residents and maintain community support. These challenges also introduce broader societal impacts, as changes to traffic patterns, property access, and neighborhood character may affect

residents' quality of life and require careful consideration of community concerns and equity.

To accomplish these goals, our team conducted a thorough evaluation of existing roadway conditions, truck operations, and site limitations. This included a field assessment, review of current truck maneuvering challenges, and identification of geometric and operational issues along the existing route. Based on this information, we developed multiple conceptual route alternatives that provide feasible options for rerouting trucks away from Main Street while maintaining overall network efficiency. Each alternative was evaluated based on factors such as safety, constructability, cost-effectiveness, environmental impacts, community considerations, floodplain constraints, and overall ability to improve truck operations. Special attention was given to aligning potential solutions with the City's goal of maintaining project costs near the \$1 million target while supporting practical, long-term improvements. Following review of the alternatives, the client selected two options to advance further.

Our services includes a comprehensive evaluation and design package to support the proposed improvements. This work involves assessing existing truck routes and traffic operations, mapping current site conditions and infrastructure, and developing demolition and construction plans. The project also includes roadway and intersection design in accordance with SUDAS standards, corridor modeling, and structural evaluation of existing infrastructure. In addition, we prepared quantity estimates, designed necessary retaining walls, and developed two truck rerouting alternatives, along with final plan sets and supporting documentation.

Two alternatives were advanced into the design phase: the Green Street corridor and the Fourth Street corridor. The Green Street alternative introduces a new truck route designed to better meet ideal roadway standards, including flatter grades, improved alignment, and safer truck movements. The design includes roadway reconstruction, updated intersections, stormwater infrastructure, and replacement of an existing retaining wall. This option improves overall truck efficiency and diverts heavy traffic away from more sensitive downtown areas. However, it may impact nearby residential neighborhoods, require removal of on-street parking, and introduce new community concerns.

The Fourth Street alternative focuses on improving the existing route to accommodate truck traffic through geometric upgrades and targeted design improvements. While some grading constraints limit achieving optimal slopes, the design remains within acceptable standards for truck operations and includes evaluation of the existing bridge and construction of a new retaining wall. This option benefits from using an established corridor and may be more cost-effective, but it requires significant earthwork and may result in greater construction complexity and disruption.

The total cost for each project was calculated through quantities gathered in civil 3d and prices were determined through Iowa DOT bid tabs. Our short-term solution (Green Street) stayed under our million-dollar budget with an estimated construction cost of \$424,920. Our long-term (4th Street) solution came out higher than the proposed budget. The estimated construction cost of the 4th street plan is \$3,582,591.

Through sound engineering practice, community-focused planning, and a commitment to client satisfaction, we provide the City of West Branch with a safer, more efficient truck route that improves freight mobility while enhancing the quality of life in the downtown area.

Section II Organization Qualifications and Experience

Organization and Design Team Description

Our team is composed of three members – Nick Simpson, Andrew Heim, and Sarah Hilgendorf, at the University of Iowa in our capstone design course CEE:4850 – Project Design and Management in CEE. Nick Simpson is the project manager and led the hydraulic components of the project as he has a focus area in Urban design. Sarah Hilgendorf is the editor and has led the structural components of the project, having a focus area in Structural Engineering. Andrew Heim oversaw technological support and led the transportation components of the project, with his focus area being in Transportation Engineering.

Section III Design Services

1. Project Scope

The Truck Rerouting and Pavement Replacement project aimed to evaluate the existing truck route's traffic operations and efficiency and to propose a new alternative route that prevented trucks from entering the downtown area while maintaining efficiency along the new route. The existing truck route traveled north on Downey Street after exiting Interstate 80. Previously, Downey Street ran through the town without requiring any turns; however, with the addition of the Herbert Hoover Museum and Library, Downey Street shifted east. As a result, trucks made a left turn onto Main Street and traveled through the downtown area before reconnecting with Downey Street. The client requested that we evaluate the existing truck route and provide alternatives that promote a more pedestrian-friendly downtown. Overall, the primary goal of the project was to redirect trucks from Main Street due to the historical buildings at the intersection that prevent us from redesigning the current route and therefore designing an alternative route bypassing the downtown area.

We proposed four different alternatives to the current truck route and presented them to the client. The client then asked us to continue the design with two of the alternatives provided.

Design outputs consisted of site demolition plans, development of horizontal and vertical alignments, corridor modeling, retaining wall design, bridge evaluation, and drainage design.

All outputs were developed in Civil3D using existing site data available from the Iowa Department of Transportation (DOT). Final deliverables to the client included a PowerPoint presentation, a poster, and Civil3D drawings illustrating the site layout and proposed design.

Our services include a comprehensive evaluation and design package to support the proposed improvements. Key components of the project are as follows:

1. Evaluation of the existing truck routes and overall traffic operations.
2. Development of existing conditions mapping using Google Earth and geolocation data, including roadway alignments, centerlines, sidewalks, and a pipeline network map identifying water and sanitary infrastructure.
3. Preparation of a demolition plan with associated quantity estimates.
4. Development of proposed horizontal and vertical roadway alignments in accordance with SUDAS standards.
5. Design of roadway cross-sections.
6. Corridor modeling and refinement of alignments based on design iterations.
7. Intersection design within the corridor and site grading.
8. Structural evaluation of the existing bridge to verify its capacity to support anticipated truck loads.
9. Earthwork and pavement quantity calculations to support cost estimation.
10. Design of retaining walls, including a new wall for areas of significant cut and reconstruction of the existing retaining wall on site.
11. Development of two final truck rerouting alternatives, including complete plan sheet sets meeting SUDAS standards and client requirements.
12. Preparation of a final design report, presentation, poster, and supporting documentation.

2. Work Plan

The Truck Rerouting and Pavement Replacement project followed a structured, phased approach that progressed from project initiation and data review through concept development, design, refinement, and final deliverables. A detailed project schedule is provided in Table A.1 in Appendix A, in the form of a Gantt chart that illustrates task sequencing, durations, and key milestones.

The design phase began with evaluating existing truck routes and overall traffic operations, followed by mapping current site conditions using geolocation data to document roadway features and underground utilities. Then we started demolition plans and quantity estimates, development of proposed roadway alignments and cross-sections in accordance with SUDAS standards, and iterative corridor modeling. Key design elements include

intersection layouts, site grading, bridge evaluation, earthwork and pavement quantity calculations, and retaining wall design.

The final phase focused on completion of all project deliverables and preparation for client presentations. Biweekly coordination meetings occurred throughout the project to review progress, address questions, and ensure the final design met project goals and client expectations.

Section IV Constraints, Challenges and Impacts

1. Constraints

Our project had a few constraints identified during the site visit. First, the existing intersection has two buildings that are on the National Register of Historic Places. A lot of the issues presented at the current intersection were roadway geometry, which already encroached upon these buildings. As a result, any improvements to the current intersection to improve pedestrian safety and efficiency will have to be made without affecting these landmark buildings. Additional constraints arose along Fourth Street, where a farmhouse located at the top of the hill limited grading options. Specifically, reducing the slope was constrained by the need to maintain a reasonable driveway grade to the residence. Furthermore, design limitations required maintaining existing elevations at certain neighborhood intersections to avoid excessive cuts or fills. Subsurface utilities also imposed restrictions, as a gas line beneath portions of the roadway prevented excavation in those areas.

Finally, the client requested that we stay close to a budget of \$1 million. For the short-term solution, we did our best to only take the necessary steps of a complete design while trying to stay as close to their budget as possible.

2. Challenges

The Fourth Street Alternative requires land acquisition as they are not currently under city jurisdiction. In addition, some right-of-way acquisitions are necessary in addition to utility adjustments due to the road widening that is required. These acquisitions will likely complicate the design moving forward and likely contribute to the project going over budget.

In addition, both alternatives will negatively affect residents who do not currently live along the designated truck route. Each alternative will have a residential impact that does not exist. As a result, resident pushbacks are likely, as the project moves forward to construction.

Mitigation measures will likely be taken to minimize impacts on residents affected throughout the project.

3. Societal Impact within the Community and/or State of Iowa

Both alternatives present potential challenges related to community impacts and constructability. Residential pushbacks are likely, as neighborhoods along both routes have historically experienced little to no truck traffic, and the introduction of heavy vehicles may raise concerns among residents. In addition, both options require new roadway construction, which will involve noise, disruption, and temporary inconveniences. The Green Street alternative may also result in the loss of on-street parking, while improvements along Fourth Street would be more expensive and require a longer construction duration. Furthermore, the farmhouse located at the top of the Fourth Street hill would require a new, longer driveway due to grading changes, which could create concerns for both the resident and the adjacent farmland owner.

Section V Alternative Solutions That Were Considered

Alternative #1 – Going straight from Parkside Drive onto N First Street all the way to Baker, with new road connection N First Street to Baker Ave using Y intersection.

This design alternative provides trucks with a straight, continuous route through town that was not achievable using North Downey Street. Trucks would remain on North First Street before merging onto Baker Avenue, improving maneuverability while minimizing the need for roadway reconstruction in the downtown area, which helps reduce disruption to residents, businesses, and daily activity. An additional benefit is the preservation of existing downtown parking by avoiding the need to widen intersections to accommodate large truck turning movements. However, this alternative may have a higher overall cost due to the construction of a new roadway segment extending into a wetlands area, which would require substantial fill, environmental considerations, and increased construction effort.



Figure 4. North First Street alternative



Figure 1. North First Street south section

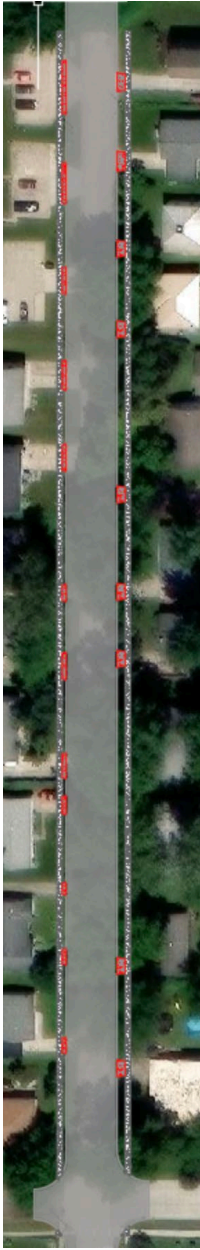


Figure 2. North First Street roadway expansion

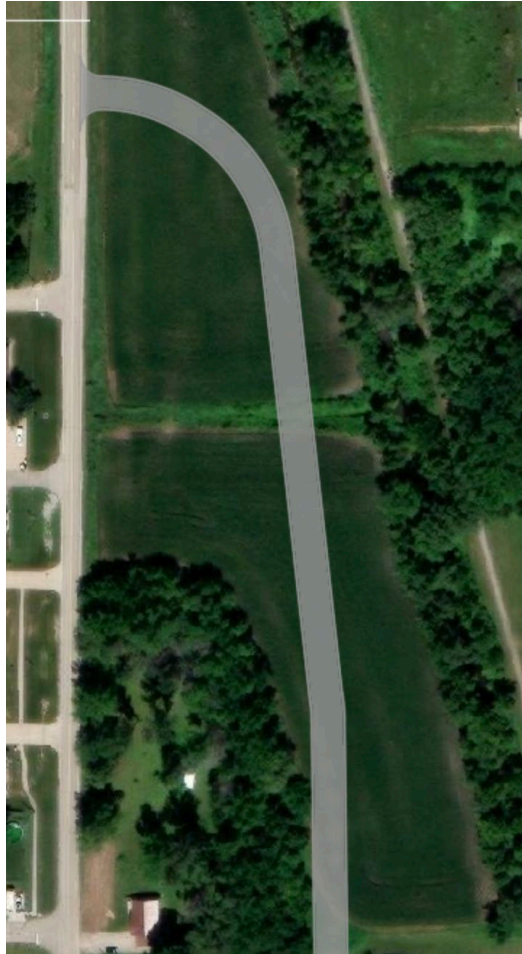


Figure 3. North First Street roadway extension

Alternative #2 – Going straight from Parkside onto N First Street and then turning left onto Green Street and right onto N Downey Street.

This Design Alternative Allows the Trucks to still go directly through downtown and get them onto N Downey Street as soon as possible which gets them straight out of town. To accommodate truck turning movements, several streets would need to be widened, and downtown intersections reconstructed to meet minimum turning radius requirements. An advantage of this alternative is the lower overall cost compared to Alternative 1, since it primarily relies on improving existing roadways rather than constructing new ones. However, a key disadvantage is the increased impact on the downtown area, including construction disruption, potential loss of on-street parking, and greater inconvenience to local businesses and residents due to roadway widening and intersection modifications.



Figure 6. Green Street Alternative



Figure 5. Green Street Intersection Geometry

Alternative #3 – Similar to Alternative #2, going straight from Parkside onto N First Street but then turning onto E College Street before turning right onto N Downey Street.

This alternative is like Alternative 2 in that it primarily uses existing roadways, which helps keep overall costs relatively low. However, the steep roadway slopes would increase construction complexity and cost, making it less practical from a design and constructability standpoint. As a result, this option was not considered one of the preferred alternatives, but it was still evaluated to address a route specifically mentioned by the client and to ensure all reasonable options were considered.

Alternative #4 – Turning right off Parkside Drive onto E Main Street and then left onto N Fourth Street all through town until left onto 280th Street and then Finally right onto Baker Street.

This alternative allows trucks to completely bypass the downtown area, which improves pedestrian safety and overall downtown livability. One advantage of this option is that it primarily utilizes an existing roadway that appears sufficiently wide, limiting the need for major geometric or structural improvements. In addition, diverting trucks away from downtown and nearby residential areas reduces both construction-related disruption and long-term noise and traffic impacts. A disadvantage of this alternative is that the full bypass results in a longer travel route compared to other options, which can increase travel time and operating costs for freight traffic and reduce overall route efficiency.

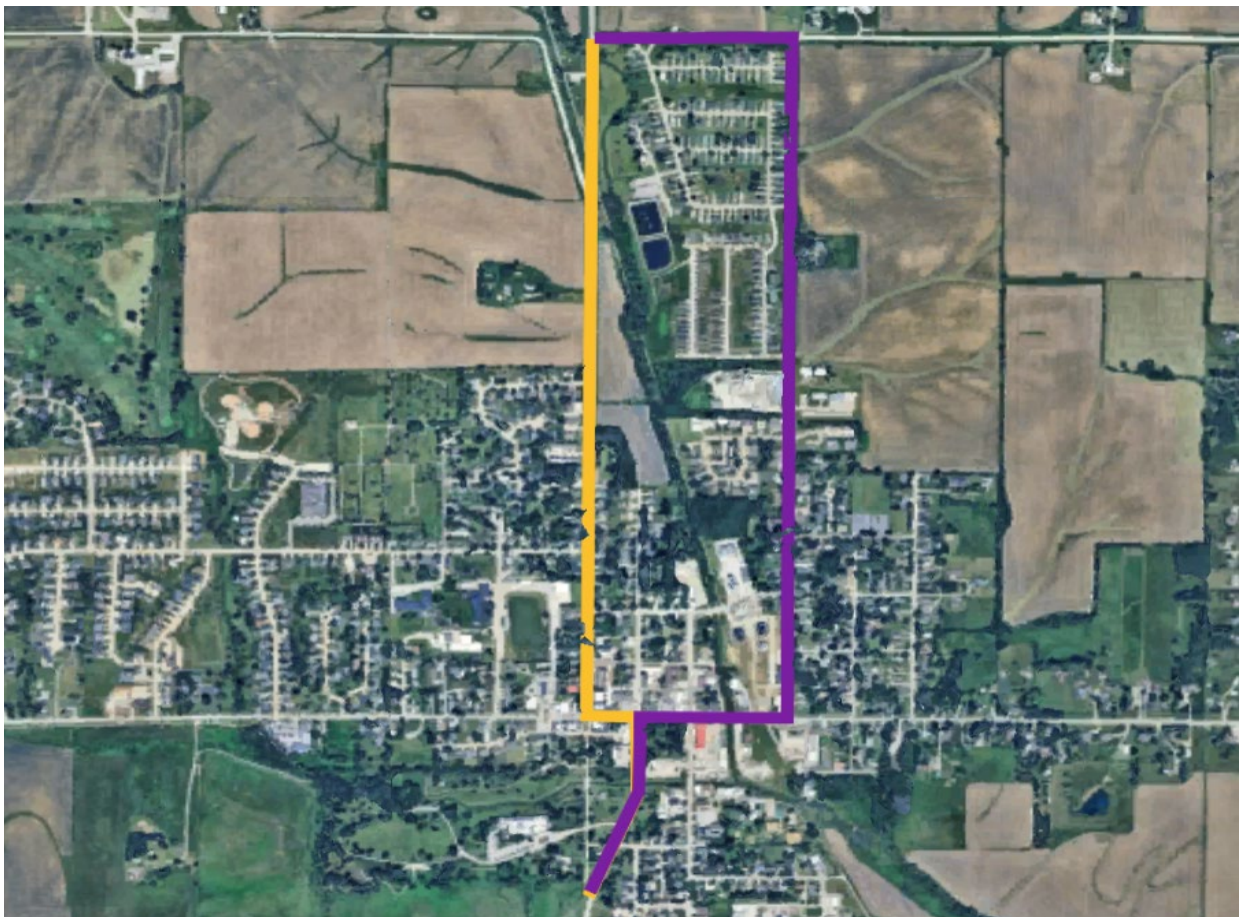


Figure 9. Fourth Street Alternative



Figure 7. Fourth Street North Section



Figure 8. Fourth Street South Section

After presenting all four alternatives to the client, they selected Alternative #2 Green Street and Alternative #4 Fourth Street to advance into the design phase, as these options provided the most feasible balance of improved truck mobility, safety, and cost while minimizing impacts to the downtown corridor. The Fourth Street alternative was chosen over First Street due to anticipated community pushbacks associated with routing heavy truck traffic through a more residential area, as well as the fact that portions of Fourth Street have already been previously reconstructed, which reduced the overall project scope. This option was

ultimately carried forward as the long-term solution despite its higher overall cost and more extensive construction requirements.

Green Street was selected over College Street because the College Street alignment included excessively steep grades that would require significant earthwork and grading to accommodate truck operations. In comparison, Green Street provided a more practical and constructible alignment that better supports consistent truck movement while requiring fewer extreme geometric adjustments.

Section VI Final Design Details

1. Roadway Alignment and Geometry

The proposed roadway alignment for Green Street was developed using Autodesk Civil 3D based on existing site conditions and project constraints. Both horizontal and vertical alignments were designed to safely and efficiently accommodate heavy truck traffic in accordance with SUDAS design standards. A posted design speed of 35 mph was used, which governs the minimum allowable vertical curve lengths and resulted in K-values of 29 for crest curves and 49 for sag curves. These values ensure adequate sight distance for safe stopping and comfortable vehicle transitions. The vertical alignment maintains roadway slopes below 5%, meeting optimal design criteria for truck operations. Horizontal geometry includes a minimum curve radius of 25 ft to accommodate truck turning movements, and the roadway width was set at 30 ft to provide adequate space for safe and efficient travel. The Alignment profiles for Green Street are shown in the drawing set sheets E.01A-E.03A.

The Fourth Street alignment was also developed in Civil 3D based on existing conditions and site limitations. A 35-mph design speed was used for this corridor as well, which established the required vertical curve standards and resulted in K-values of 29 for crest curves and 49 for sag curves. These values are necessary to provide sufficient stopping sight distance and maintain safe driver comfort at the selected speed. Horizontal alignment was designed using a minimum curve radius of 25 ft to accommodate truck turning movements, with a 30 ft roadway width to support safe truck passage. The vertical alignment was more constrained due to existing grading conditions and adjacent properties, resulting in slopes ranging from 5.17% to 8.68%. While these grades exceed the optimal 5% condition outlined in SUDAS guidelines, they remain within acceptable limits for truck routes at the selected design speed. The Alignment profiles for Fourth Street are shown in the drawing set sheets E.01B - E.09B.

2. Roadway Cross Sections and Pavement Design

Roadway cross sections were determined by previous design drawings and existing conditions. For 4th Street, the cross section was given from prior design drawings. This cross section was used for 280th Street, and Baker Ave as all streets needed the same pavement design. This design is 7" PCC Pavement, 6" Modified Subbase, and 18" of Imported Fill due to soil issues in the previous 4th street project. Cross sections such as First Street, Downey, and Farmhouse driveway were determined based on what already existed. The goals for these roads were not geometry improvement but putting them back the way they were. Green Street was designed to support new truck loads thus taking on the same pavement structure as the previously reconstructed 4th street. The road was given width to accommodate truck traffic. Sidewalks were also reconfigured to make pedestrian safety a priority by backing them off of the roads by 5 feet. Along with width changes and pushing the sidewalks back, it was determined that removing all parking on this street would be best to allow safe truck travel and a decreased chance of obstructions in the way of that traffic. The typical sections are shown on the B sheets, and the typical cross sections are shown in the W sheets of the drawing set.

All roadways were regraded to fall within the SUDAS acceptable slope range of < 11 feet. Along the roadway certain elevations were held steady to prevent extra intersection work and to allow for smooth transitions into the existing roadway network.

3. Intersection Design

Intersections were designed to accommodate truck turning movements throughout the town. At each intersection, a minimum curb radius of 25' was used to allow truck passage without interruption of other vehicles during the process. While running vehicle tracking, it was found that all intersections at a curb radius of 25' satisfied the truck movements. Thus 25' was kept decreasing the cost and work of widening the intersections further. During the design process we found 8 intersections that needed to redesign; all but one required a full redesign. Green Street – First Street intersection only needed a partial redesign to accommodate truck traffic turning onto Green. This intersection was also recently re-done in a project that occurred before thus we decided to redo as little as possible. The remaining 7 intersections were designed to be as close to the existing elevation levels as possible while also meeting the SUDAS acceptable standard. This allows for minimized work needed at these intersections. At the intersection of 280th and 4th street stops signs were added to each leg. This was done as a preemptive measure to ensure extra safety at this intersection due to the hilly nature of this area and the increased traffic. We also determined that milled rumble strips were to be added at each leg as well. Due to the hills in the area, stopping sight distance was a concern thus we added rumble strips to alert the drivers. In addition to the hills, this stop sign is very new to the area, so the rumble strips were also added to alert drivers that are not used to stopping at the intersection.

4. Earthwork

The earthwork quantities were estimated using Civil 3D corridor modeling and the volume dashboard. The primary goal for both alternatives was to balance cut and fill as much as possible while still achieving acceptable roadway slopes for truck operations. For Green Street, the total cut is 91.59 CY, and the total fill is 339.19 CY. For Fourth Street, the total cut is 4,607 CY, and the total fill is 7,505 CY.

The Fourth Street alternative required extensive grading along the roadway edges, particularly near the farmhouse property and adjacent farmland. The inclusion of the retaining wall significantly reduced the amount of slope encroachment, helping limit impacts on the homeowner's property and surrounding land. In addition to the earthwork operations, the existing subgrade will be properly prepared and compacted to ensure a stable foundation for the proposed roadway sections. Earthwork tables generated from Civil 3D are included in the T sheets of the drawing set.

5. Stormwater Management

The proposed stormwater improvements along Green Street include the installation of curb and gutter to enhance surface drainage and direct runoff into a new storm sewer system. This system will consist of approximately 504 linear feet of pipe and five intakes positioned to efficiently capture roadway runoff. The network will connect to the existing storm sewer system along 1st Street, maintaining consistency with the surrounding drainage infrastructure. All intakes will be 4' by 8' square intakes, like the intakes along First Street. Pipe sizing was performed using a 5-year design storm with a 15-minute intensity of 3.88 inches/hour and a runoff coefficient of 0.90 and an assumed inlet time of 10 minutes. Pipe slopes and lengths were determined based on existing and proposed elevations. Although calculated pipe diameters were less than 15 inches, all pipes were increased to a minimum diameter of 15 inches to meet standard design criteria. Detailed calculations are provided in Appendix D.

Improvements along 4th Street and 280th Street include the replacement of two deteriorated metal culverts with new concrete culverts of the same five-foot diameter, addressing structural deficiencies while maintaining existing hydraulic capacity. The new PCC culverts were decided due to their higher strength than the metal culverts to support the new truck loads on the road. Curb and gutter will also be installed along 4th Street, and three storm sewer networks will be constructed, including systems along 4th Street and 280th Street and a connection to the southern segment of 4th Street. These systems will total approximately 6,406 linear feet of pipe and 42 intakes, discharging into nearby existing streams. Pipe sizing and hydraulic design were performed using a 10-year design storm with a 15-minute intensity of 4.52 inches/hour, and assumptions as described for Green Street, with all pipes ultimately sized to a minimum diameter of 15 inches. We decided to use a 10-year design storm rather than a 5-year like Green Street with 4th Street bringing the long-term alternative and not concerned as much about cost saving measures. The storm intakes are designed to be 4' by 8' rectangular intakes, to match the existing 4th street intakes. Faired end

sections will be installed at all outlets and be 18” in diameter. Supporting calculations are included in Appendix D.

6. Retaining Wall Design

A retaining wall is required for both the Green Street and Fourth Street alternatives. On Green Street, the existing retaining wall is in poor condition; however, only the section impacted by the new intersection construction will be removed and replaced. This approach was selected to minimize construction cost and duration while still addressing necessary improvements within the disturbed area.

For the Fourth Street alternative, 6 feet of hillside excavation is required, which necessitates the construction of a new retaining wall. Rather than the alternative of extensive grading that would lead into the farmhouse property as well as the farmland. The proposed design uses Keystone Compac segmental blocks, measuring 8 inches in height by 12 inches in depth, with gravel-filled cells to increase unit weight and stability. The blocks are connected using shear pins, providing adequate connection strength to resist lateral soil forces with a backfill unit weight of 120 pcf. Stability analyses for overturning, sliding, and bearing capacity confirmed that the system is sufficient without the need for geogrid reinforcement. The allowable soil bearing pressure was also verified and found to be adequate, resulting in a final wall height of 6 feet. Supporting calculations are provided in Appendix D – Retaining Wall Calculations.

7. Bridge Evaluation

The existing two-span slab bridge on Main Street, which is part of the Fourth Street alternative, was evaluated to determine whether it is adequate to support the proposed truck route. The bridge geometry is shown in the figure below. The structure has an 18.5-inch slab thickness and was assumed to include a 2.5-inch hot-mix asphalt wearing surface. The total bridge width is 64 feet, which includes sidewalks, railings, and traffic barriers, with an effective roadway width of 44 feet.

Dead loads were calculated based on the self-weight of the concrete slab, traffic barriers, railings, and the assumed asphalt wearing surface. Structural analysis was then performed using Robot Structural Analysis in combination with AASHTO and Iowa DOT loading requirements. The live load consisted of five design truck types—Type 4, Type 3S3A, Type 3-3, Type 4S3B, and Type 4S3—to represent critical loading scenarios.

These trucks were positioned along the bridge to identify the governing load case, with the maximum moment and shear occurring at critical locations along the span. This governing condition was then combined with the calculated dead loads to determine the maximum

demand on the structure. The results were used to develop an equivalent design section on a per-foot basis of bridge width, allowing for the determination of required reinforcing steel.

By comparing the factored demand to the section capacity, the load rating was effectively checked by ensuring the total applied moment did not exceed the maximum allowable moment capacity of the slab. The analysis indicated that the existing bridge requires a minimum of four #6 reinforcing bars per foot of slab width to safely support the proposed truck loads. Supporting calculations and Robot Structural Analysis outputs are provided in Appendix C – Bridge Evaluation Calculations.

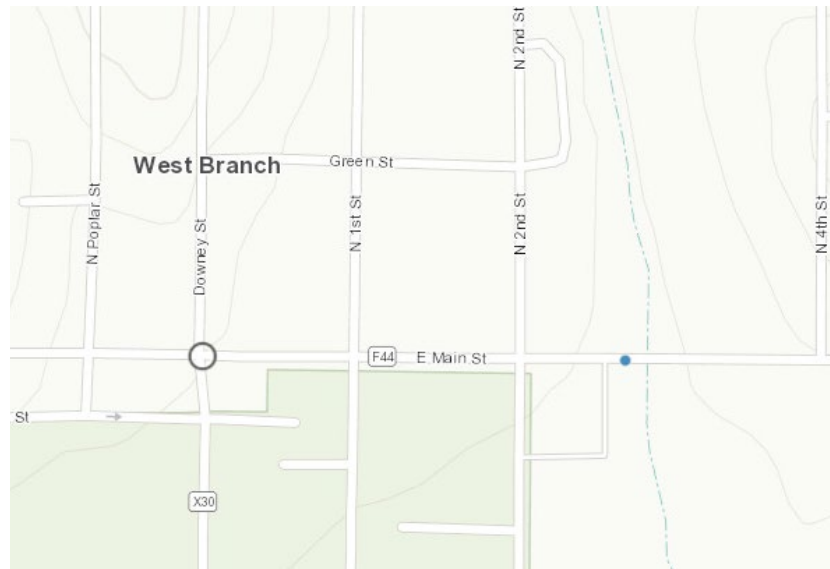


Figure 9. Bridge Location

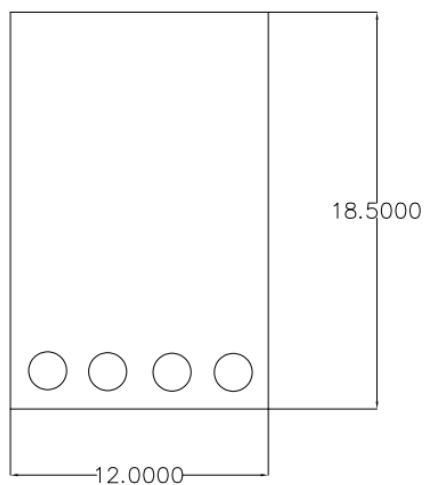


Figure 10. 12" Cross Section

Section VII Engineer's Cost Estimate

Using Iowa DOT Bid tabs cost of materials per unit were gathered. Quantities were then gathered into a full estimate for Green and 4th Street.

Green Street Construction Cost Estimate

DEMO				
ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
CLEARING AND GRUBBING	392	SF	\$0.09	\$33.32
REMOVAL OF SEAL COAT	1442	SY	\$14.00	\$20,188.00
REMOVAL OF HMA PAVEMENT	445	SY	\$16.00	\$7,120.00
REMOVAL OF PCC PAVEMENT	230	SY	\$15.33	\$3,525.90
REMOVAL OF CURB AND GUTTER	148	LF	\$16.00	\$2,368.00
REMOVAL OF SIDEWALK	373	SY	\$11.73	\$4,375.29
REMOVAL OF RETAINING WALL	123	SF	\$37.50	\$4,612.50
REMOVAL OF FIRE HYDRANTS	2	EA	\$1,085.85	\$2,171.70
REMOVAL OF TRAFFIC SIGNS	4	EA	\$106.77	\$427.08
REMOVAL OF TREES	2	EA	\$950.00	\$1,900.00
REMOVAL OF LIGHT POLE	1	EA	\$742.28	\$742.28
REMOVAL OF INTAKE	1	EA	\$808.59	\$808.59
COST OF DEMO				\$48,272.66
CONTIGENCY 10%				\$4,827.27
TOTAL COST OF DEMO				\$53,099.93
PROPOSED				
ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST

CUT	91.59	CY	\$4.43	\$405.74
FILL	339.19	CY	\$4.43	\$1,502.61
SUBBASE GRANULAR 6"	259.5	CY	\$50.28	\$13,047.66
PCC PAVEMENT 7"	303	CY	\$180.00	\$54,540.00
PCC SIDEWALK 4"	375	SY	\$66.72	\$25,020.00
ADA SIDEWALK RAMP	5	EA	\$4,000.00	\$20,000.00
CURB AND GUTTER	797	LF	\$27.49	\$21,909.53
SEEDING RESTORATION	5585.7	SF	\$0.55	\$3,072.14
TRAFFIC SIGNS	4	EA	\$450.00	\$1,800.00
PAVEMENT MARKINGS	1	LS	\$2,000.00	\$2,000.00
LIGHT POLE INSALLATION	1	EA	\$3,450.00	\$3,450.00
FIRE HYDRANT INSTALLATION	2	EA	\$9,137.08	\$18,274.16
RETAINING WALL	123	SF	\$65.73	\$8,084.79
INTAKES	5	EA	\$4,707.55	\$23,537.75
PIPE REPLACEMENT	504	LF	\$120.00	\$60,480.00
COST OF PROPOSED				\$257,124.38
CONTIGENCY 10%				\$25,712.44
TOTAL COST OF DEMO				\$282,836.82
OTHER				
CONSTRUCTION ADMINISTRATION	1	LS		\$67,187.35
MOBILIZATION	1	LS		\$33,593.67
TRAFFIC CONTROL	1	LS	\$5,000.00	\$5,000.00
TOTAL COST				\$441,717.77

4th Street Construction Cost Estimate

DEMO				

ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
CLEARING AND GRUBBING	37756	SF	\$0.09	\$3,209.26
REMOVAL OF SEAL COAT	10282	SY	\$14.00	\$143,948.00
REMOVAL OF HMA PAVEMENT	1876	SY	\$16.00	\$30,016.00
REMOVAL OF PCC PAVEMENT	360	SY	\$15.33	\$5,518.80
REMOVAL OF CURB AND GUTTER		LF	\$16.00	\$-
REMOVAL OF GRAVEL DRIVEWAY	161	SY	\$5.50	\$885.50
REMOVAL OF TRAFFIC SIGNS	8	EA	\$106.77	\$854.16
REMOVAL OF TREES	65	EA	\$950.00	\$61,750.00
REMOVAL OF MAILBOX	1	EA	\$100.00	\$100.00
REMOVAL OF CULVERT	112	CY	\$9.44	\$1,057.28
REMOVAL OF PIPE	185	LF	\$23.36	\$4,321.60
REMOVAL OF INLET	4	EA	\$808.59	\$3,234.36
REMOVAL OF FLARED END SECTION	1	EA	\$325.00	\$325.00
COST OF DEMO				\$255,219.96
CONTINGENCY 10%				\$25,522.00
TOTAL COST OF DEMO				\$280,741.96
PROPOSED				
ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
CUT	4607	CY	\$4.43	\$20,409.01
FILL	7505	CY	\$4.43	\$33,247.15
SUBBASE GRANULAR 6"	2345	CY	\$50.28	\$117,906.60
IMPORTED FILL 18"	7034	CY	\$43.60	\$306,682.40
PCC PAVEMENT 7"	2748	CY	\$180.00	\$494,640.00
GRAVEL DRIVEWAY REPLACEMENT	39	CY	\$37.50	\$1,462.50
CURB AND GUTTER	7583	LF	\$27.49	\$208,456.67
MILLED RUMBLE STRIP	6	PANEL	\$634.03	\$3,804.18
SEEDING RESTORATION	220180	SF	\$0.55	\$121,104.50

TREE REPLACEMENT	52	EA	\$519.38	\$27,007.76
TRAFFIC SIGNS	10	EA	\$450.00	\$4,500.00
MAILBOX RELOCATION	1	EA	\$319.53	\$319.53
PAVEMENT MARKINGS	1	LS	\$8,000.00	\$8,000.00
RETAINING WALL	293	SF	\$65.73	\$19,258.89
INTAKES	42	EA	\$4,707.55	\$197,717.10
PIPE REPLACEMENT	6406	LF	\$120.00	\$768,720.00
BOX CULVERT	112	LF	\$348.00	\$38,976.00
COST OF PROPOSED				\$2,372,212.29
CONTINGENCY 10%				\$237,221.23
TOTAL COST OF PROPOSED				\$2,609,433.52
OTHER				
CONSTRUCTION ADMINISTRATION	1	LS		\$525,486.45
MOBILIZATION	1	LS		\$300,000.00
TRAFFIC CONTROL	1	LS	\$10,000.00	\$10,000.00
TOTAL COST				\$3,725,661.93

Appendices

Appendix A – Project Schedule

Table 1A – Project Schedule

Project Name: Truck Rerouting and Road Extension					1/20/26	1/27/26	2/3/26	2/10/26	2/17/26	2/24/26	3/3/26	3/10/26	3/17/26	3/24/26	3/31/26	4/7/26	4/14/26	4/21/26	4/28/26	5/5/26
Project Start: 1/20/26					Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8	Wk 9	Wk 10	Wk 11	Wk 12	Wk 13	Wk 14	Wk 15	Wk 16
Current Date: 4/10/26																				
Weeks in progress: Wk 12																				
Task	Task Lead	Start date	end date	days																
Project Kick off																				
Client Contact and background	All	1/20/26	2/5/26	13																
Design																				
Initial Proposal & Report	All	2/2/26	2/5/26	4																
Final Proposal	ALL	2/9/26	2/13/26	5																
Task 1 - Demo Sheets	Nick	2/9/26	2/10/26	2																
Task 2 - Site Linework	ALL	2/16/26	2/20/26	5																
Task 3 - Vert. & Horiz. Alignments	Andrew	2/16/26	2/27/26	10																
Task 4 - Corridors	Andrew	2/23/26	3/14/26	15																
Task 5 - Bridge Evaluation	Sarah	3/9/26	3/14/26	5																
Task 6 - Retaining Wall Work	Sarah	3/16/26	3/20/26	5																
Task 7 - Pipe Networks	Nick	3/24/26	3/28/26	4																
Redesign & Polish																				
Plotting and Annotations	ALL	3/30/26	4/5/26	5																
Final Deliverables																				
Draft Design Report	ALL	4/6/26	4/10/26	5																
Draft Poster	ALL	4/6/26	4/10/26	5																
Presentation and slides	ALL	4/10/26	4/24/26	11																
Poster to Client	ALL	4/10/26	5/8/26	21																
Design Report	ALL	4/10/26	5/8/26	21																
Present to Client	ALL	5/8/26	5/8/26	1																

Appendix B – Bridge Evaluation Calculations

Bridge ID : 012371

Lat := 41.671386

Condition rating : Fair

long := -91.343364

Speed limit = 20mph

Bridge Geometry

 $L := 70 \text{ ft}$ $W_{slab} := 64 \text{ ft}$ $N_{spans} := 2$ $t_{ws} := 2.5 \text{ in}$ $W_{road} := 44 \text{ ft}$ $L_{span} := 35 \text{ ft}$ $t_{slab} := 18.5 \text{ in} - t_{ws}$ **Summary:**

$$\gamma_{DW} \cdot DW + \gamma_{DC} \cdot DC + \gamma_{LL} \cdot (LL + IM) \leq \phi_c \cdot \phi_s \cdot \phi M_n$$

$$-93.9454 \text{ kip} \cdot \text{ft} \text{ per foot}$$

Dist	Normal	Area	Avg	Pressure	Weight
ft	ft ²	ft ²	ft ²	ft ²	ft ²
2	0.250	0.250	3.203	0.700	3.147
3	0.175	0.175	3.113	1.000	3.158
4	0.200	0.200	3.200	1.570	3.003
5	0.1625	0.1625	3.113	1.800	1.985
6	0.1500	0.1500	3.040	2.000	1.762
7	0.1375	0.1375	2.963	2.150	2.044
8	0.1250	0.1250	2.793	2.300	2.073
9	0.1125	0.1125	2.900	2.540	2.409
10	0.1000	0.1000	2.710	2.800	3.144
11	0.1250	0.1250	2.900	4.400	5.112
12	0.1375	0.1375	2.793	5.830	7.691
13	0.1500	0.1500	2.963	7.800	11.630

$$\phi M_n := -93.9454 \text{ kip} \cdot \text{ft} \quad M_n := 93.9454 \text{ kip} \cdot \text{ft}$$

$$\phi M_n = A_s \cdot f_y \left(d - \frac{a}{2} \right)$$

Assume $f_y := 60 \text{ ksi}$ Assume $f'_c := 4000 \text{ psi}$

$$a = \frac{A_s \cdot f_y}{0.85 \cdot f'_c \cdot b}$$

$$NA := \frac{18.5 \text{ in}}{2} = 9.25 \text{ in}$$

$$c := NA$$

$$C_c := 3 \text{ in}$$

$$d := 18.5 \text{ in} - C_c - 0.5 \text{ in} = 15 \text{ in}$$

$$\beta_1 := \max \left(.65, .85 - .05 \cdot \frac{(f'_c - 4000 \text{ psi})}{1000 \text{ psi}} \right) = 0.85$$

$$a := \beta_1 \cdot c = 7.863 \text{ in}$$

$$A_s := \frac{(M_n)}{f_y \cdot \left(d - \frac{a}{2} \right)} = 1.697 \text{ in}^2$$

$$b := 12 \text{ in}$$

For every 1ft of slab:

$$B := 12 \text{ in}$$

9 #4 Bars

$$A_s := 1.8 \text{ in}^2$$

6 #5 Bars

$$A_s := 1.86 \text{ in}^2$$

4 #6 Bars

$$A_{s6} := 1.76 \text{ in}^2$$

3 #7 Bars

$$A_s := 1.8 \text{ in}^2$$

$$A_{b6} := 0.440 \text{ in}^2$$

$$d_{rebar6} := 0.750 \text{ in}$$

$$\phi V_n := 14.6598 \text{ kip} \cdot \text{ft}$$

$$s := \frac{B}{(n_b) - 1} = 4 \text{ in} \quad n_b := \frac{A_{s6}}{A_{b6}}$$

$$\phi V_n := \sqrt{f'_c} \cdot b \cdot d$$

$$\bar{d} := \frac{\phi V_n}{\sqrt{f'_c} \cdot b} = 15 \text{ in}$$

$$s_{max} := \min \left((t_{slab} - C_c - d_{rebar6}), 3 \cdot t_{slab} \right) = 12.25 \text{ in}$$

Dead loads

DC - Dead loads of components

Slab -

$$A_{slab} := W_{slab} \cdot t_{slab} = 85.333 \text{ ft}^2$$

$$w_{slab} := A_{slab} \cdot \gamma_{NWCs} \cdot \frac{1}{60 \text{ ft}} = 0.213 \text{ ksf}$$

Traffic barriers-

$$A_{barrier} := 2 \cdot 8 \text{ in} \cdot 24 \text{ in} = 2.667 \text{ ft}^2$$

$$w_{barrier} := A_{barrier} \cdot \gamma_{NWC} \cdot \frac{1}{60 \text{ ft}} = 0.006 \text{ ksf}$$

Railing-

$$w_{railing} := 50 \text{ plf} \cdot 3 \cdot \frac{1}{60 \text{ ft}} = 0.003 \text{ ksf}$$

$$w_{DC} := w_{slab} + w_{railing} + w_{barrier} = 0.222 \frac{\text{klf}}{\text{ft}}$$

$$\gamma_{NWCs} := .145 \cdot \frac{\text{kip}}{\text{ft}^3} + 0.005 \cdot \frac{\text{kip}}{\text{ft}^3}$$

**Normal Weight Concrete + steel reinforcement

$$\gamma_{NWC} := 0.145 \frac{\text{kip}}{\text{ft}^3}$$

DW - Dead load of wearing surface

$$q := t_{ws} \cdot \gamma_{HMA} = 0.029 \text{ ksf}$$

$$w_{DW} := q \cdot W_{slab} \cdot \frac{1}{60 \text{ ft}} = 0.031 \frac{\text{klf}}{\text{ft}}$$

Assumptions:

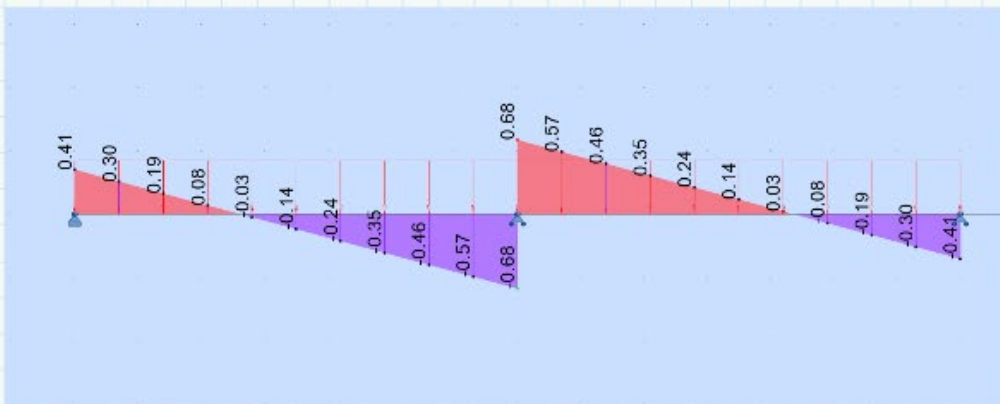
$$t_{ws} := 2.5 \text{ in}$$

Wearing surface is HMA

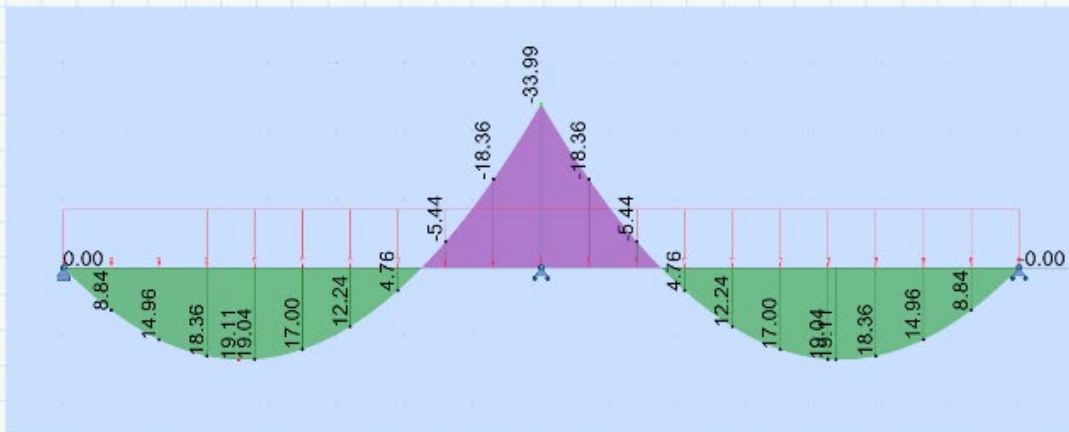
$$\gamma_{HMA} := 0.140 \frac{\text{kip}}{\text{ft}^3}$$



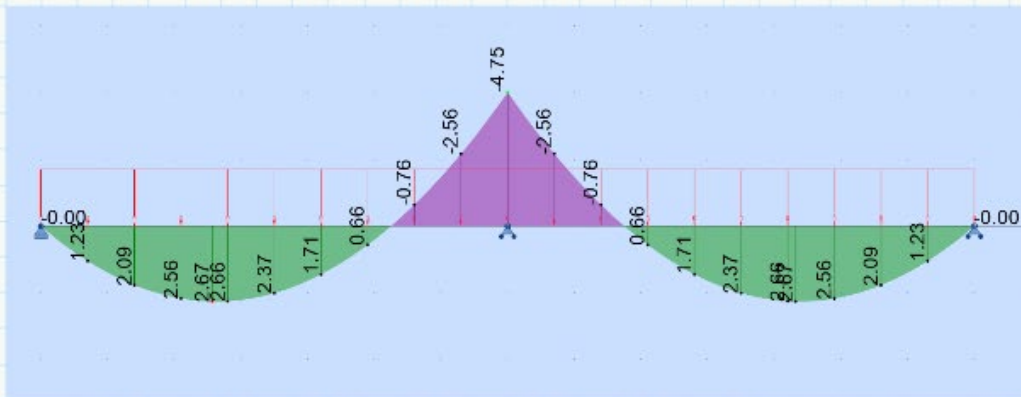
Shear - DC



Shear - DW



Flexure - DC



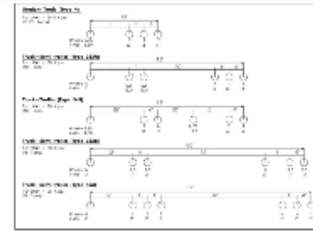
Flexure - DW

Live Load

from Iowa Dot Bridge Rating Manual-

Truck loads

Type 4
Type 3S3A
Type 3-3
Type 4S3B
Type 4S3



For reinforced concrete slab bridge

One Lane Loaded

$$E = 10.0 + 5.0 \cdot \sqrt{L_1 \cdot W_1}$$

$$E := 10 + 5 \cdot \sqrt{35 \cdot 30} = 172.019$$

$$\boxed{E} := 172.019 \text{ in} = 14.335 \text{ ft}$$

$$L_1 := \min(L_{\text{span}}, 60 \text{ ft})$$

$$W_1 := \min(W_{\text{slab}}, 30 \text{ ft})$$

Multiple lanes Loaded

$$E = 84.0 + 1.44 \cdot \sqrt{L_1 \cdot W_1} \leq \frac{12.0 \cdot W}{N_L}$$

$$\boxed{E} := 84.0 + 1.44 \cdot \sqrt{35 \cdot 60} = 149.989 <= \frac{12.0 \cdot 60}{3} = 240$$

$$\boxed{E} := 149.989 \text{ in} = 12.499 \text{ ft}$$

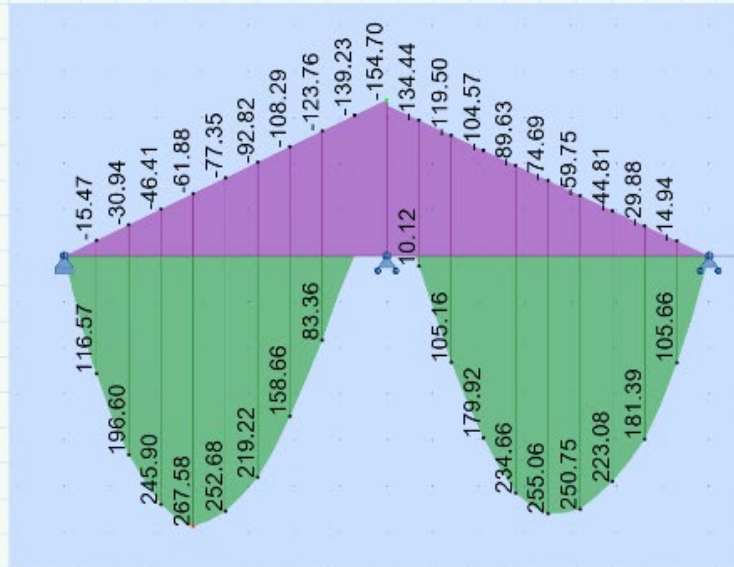
$$\boxed{W_1} := \min(W_{\text{slab}}, 60 \text{ ft})$$

$$N_L := \frac{44}{12} = 3.667$$

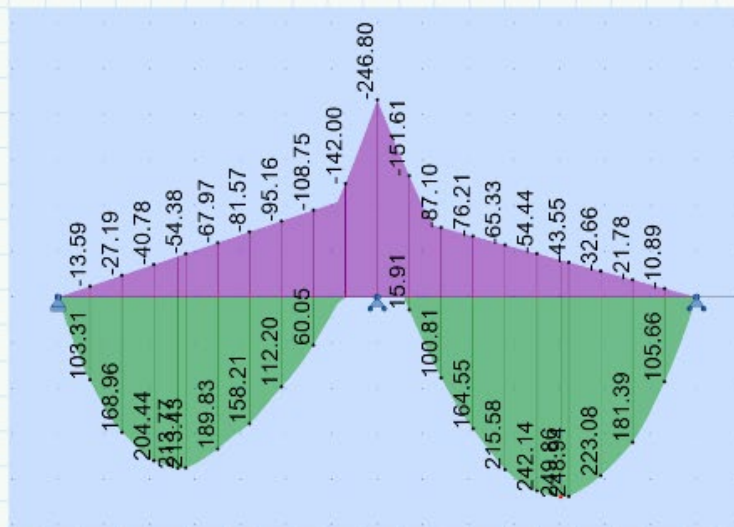
Use minimum

$$\boxed{E} := 12.499 \text{ ft}$$

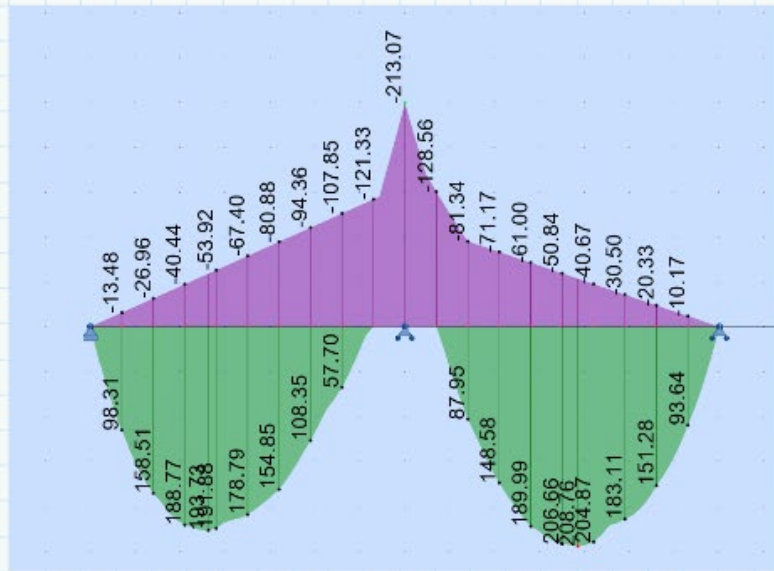
Maximum Moment Envelopes



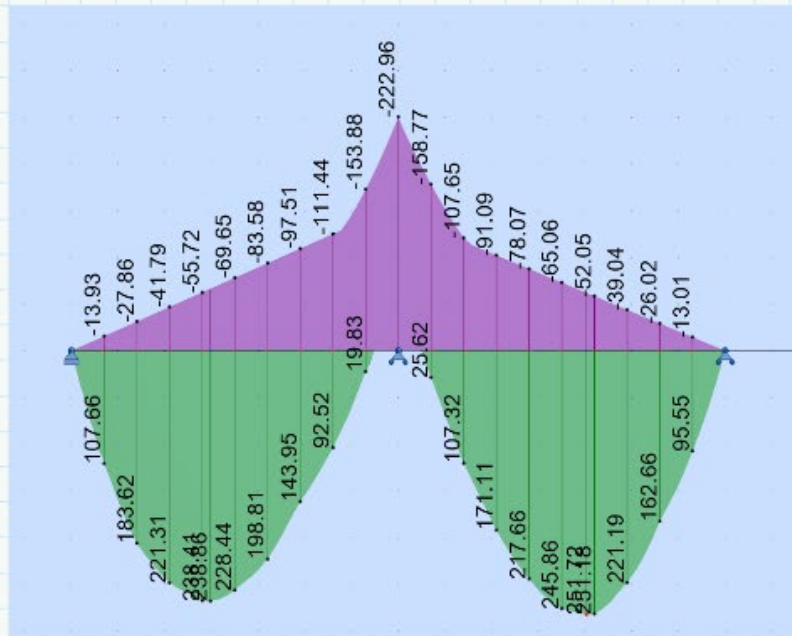
Type 4 Truck



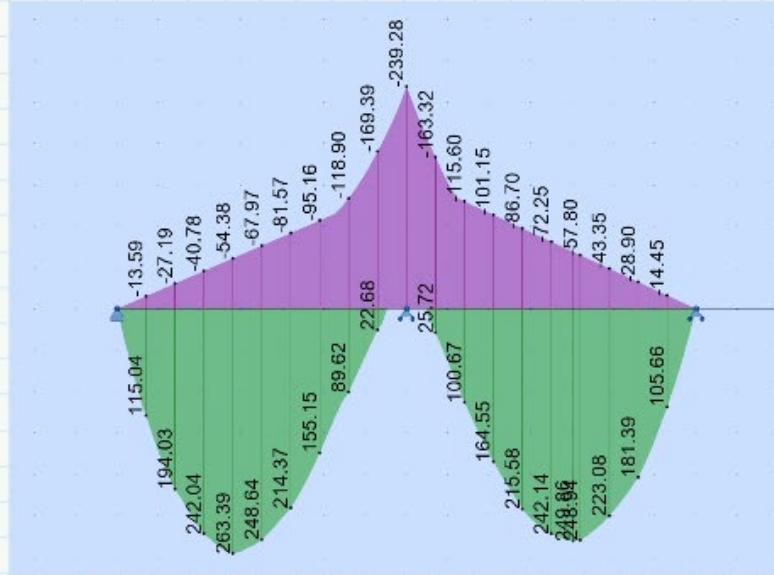
Type 3S3A Truck



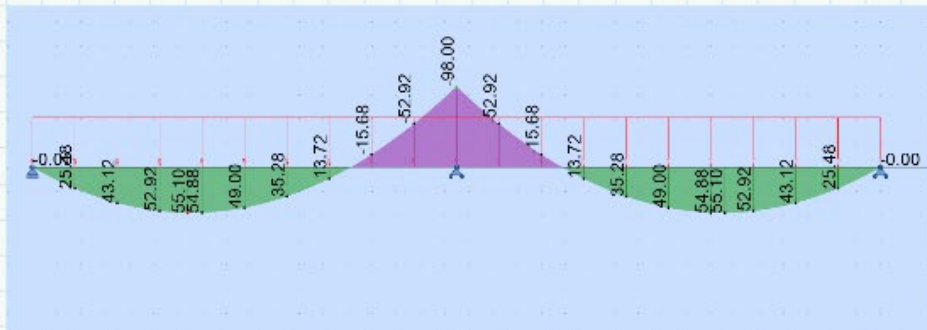
Type 3-3 Truck



Type 3S3B Truck

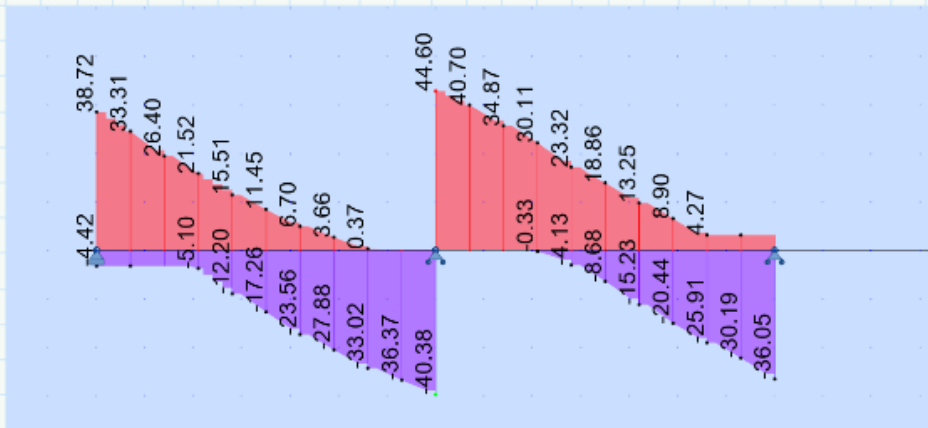


Type 4S3 Truck

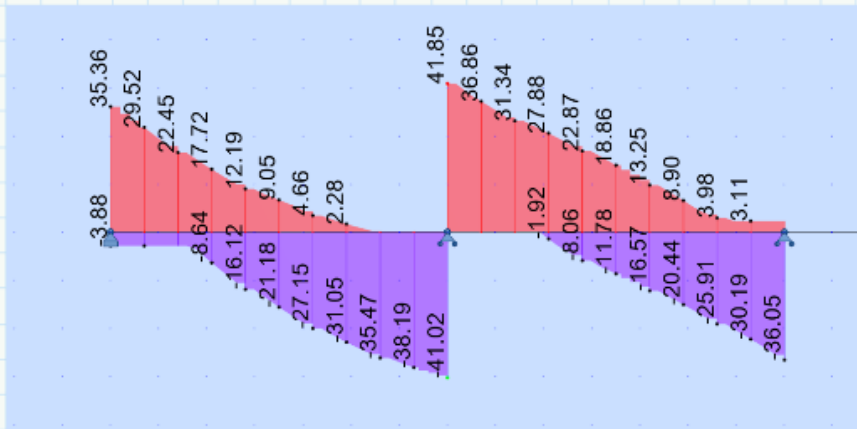


Lane Loading

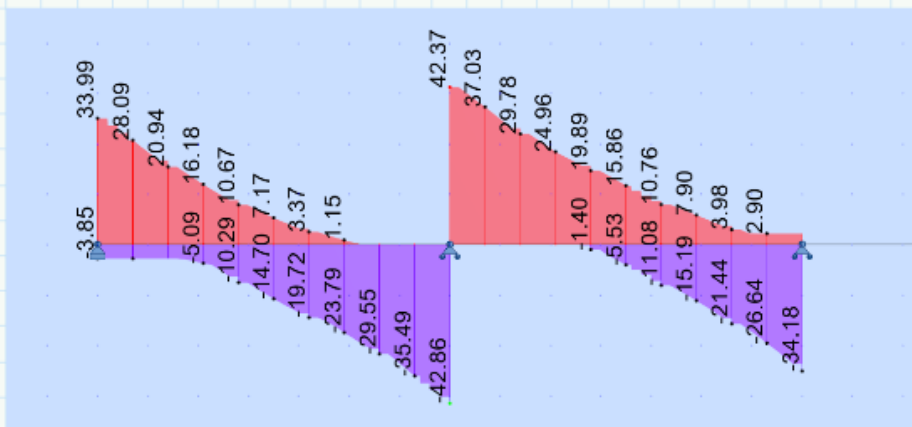
Maximim Shear Envelopes



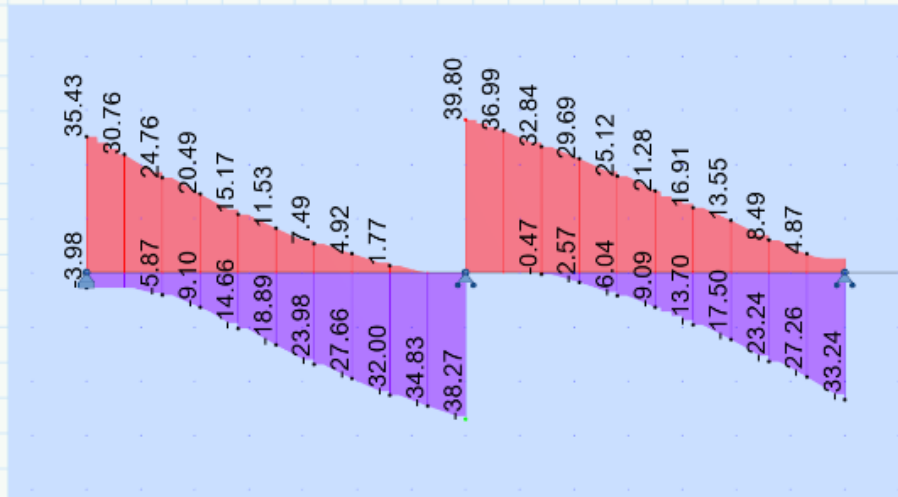
Type 4 Truck



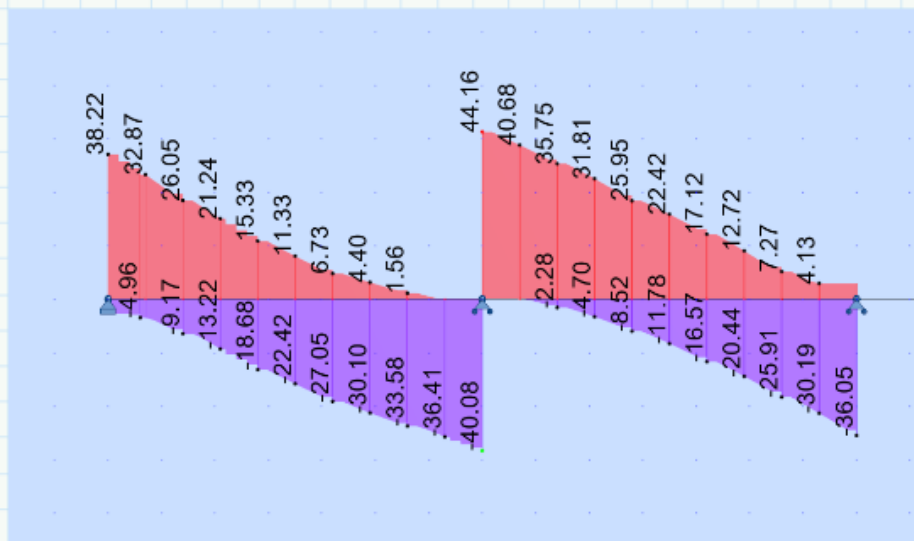
Type 3S3A Truck



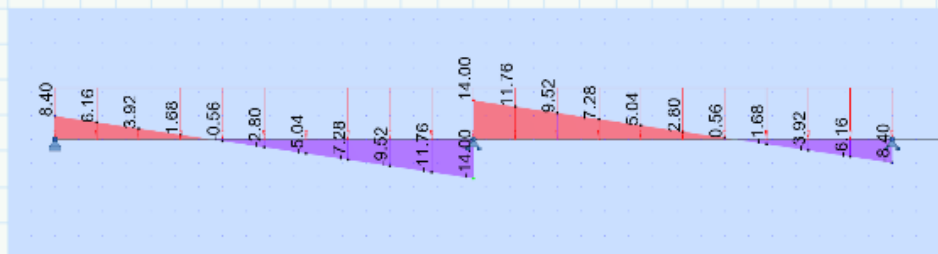
Type 3-3 Truck



Type 3S3B Truck



Type 4S3 Truck



Lane Loading

Table A.1 Moment values from Robot Analysis

Analysis Results - Flexure (kip-ft)																							
XL	DC	DW	LL Type 4	(LL+M) - Type 4	LL Type 3SSA	(LL+M) - Type 3SSA	LL Type 3-3	(LL+M) - Type 3-3	LL Type 3SB	(LL+M) - Type 3SB	LL Type 4S3	(LL+M) - Type 4S3											
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00											
0.1	0.84	1.23	116.57	-16.47	14.44200341	-	103.31	-13.59	13.03162653	-	86.31	-13.48	12.49958397	-	107.66	-13.93	13.49450356	-	115.04	-13.57	14.27979638	-	
0.2	14.96	2.09	196.60	-30.94	24.39978958	-	168.96	-27.19	21.42685829	-	158.51	-26.96	20.31668934	-	183.62	-27.86	22.96860709	-	194.03	-27.19	24.09631971	-	
0.3	18.36	2.56	245.90	-48.41	30.39979198	-7.70480208	204.44	-40.78	25.98099505	-0.16540043	188.77	-40.44	24.20087265	-0.08622154	221.31	-1.19	27.78230666	-	242.04	-40.78	29.99955512	-	
0.4	19.04	2.66	287.58	-61.88	32.86354108	-2.1593075	213.43	-54.38	27.10152012	-1.39574366	191.86	-53.92	24.80541667	-0.12829628	238.66	-55.72	29.79620689	-1.43833107	263.39	-54.38	32.41789942	-1.39574366	
0.5	17.00	2.37	252.68	-77.35	30.80781981	-4.31038483	189.83	-67.97	24.11884187	-3.12272390	179.79	-67.4	22.94589161	-3.25162013	228.44	-89.65	28.22827426	-3.49103928	248.64	-67.97	30.37726202	-3.12272390	
0.6	12.24	1.71	219.22	-97.82	26.14949999	-7.58252549	158.21	-81.57	19.85751668	-5.82711657	154.85	-80.88	19.299984	-5.78396817	198.81	-83.58	23.93772222	-6.07897868	214.37	-81.57	25.83341887	-5.82711657	
0.7	2.76	0.66	158.66	-108.29	17.98042444	-10.42529	112.2	-95.16	13.03872294	-9.02814625	108.35	-94.36	12.82780516	-8.94301944	143.95	-97.51	16.41519322	-9.27820626	155.15	-95.16	17.60696856	-9.02814625	
0.8	-5.44	-0.76	83.36	-123.76	7.615713257	-14.4238179	60.05	-108.75	5.133530826	-12.8264261	56.7	-107.87	4.778862309	-12.7309585	92.52	-111.44	6.599415232	-13.112665	89.62	-118.9	8.281830546	-13.9844725	
0.9	-18.36	-2.56	-139.23	-139.23	-18.0481989	-	0.00	-142	-18.3434975	-	0.00	-121.23	-17.1444836	-	19.83	-153.88	-20.80808086	-	22.68	-169.39	-22.584767	-	
1.0	-33.99	-4.75	-154.70	-154.70	-24.3020242	-	0.00	-246.8	-24.68	-	0.00	-213.07	-20.513089	-	0.00	-222.96	-30.513089	-	0.00	-239.29	-33.301202	-	
1.1	-18.36	-2.56	10.12	-134.44	-18.5384992	-	15.91	-151.61	-20.3866333	-	0.00	-128.56	-17.9138171	-	25.62	-158.77	-18.1284183	-	25.72	-163.32	-21.612577	-	
1.2	-5.44	-0.76	105.16	-119.53	9.93418834	-13.9702116	100.01	-97.11	9.472541803	-10.5228018	87.96	-81.34	8.18412833	-9.89078876	107.32	-107.65	10.1625122	-12.7057088	109.67	-115.6	9.47646412	-13.9533244	
1.3	4.76	0.66	179.92	-104.57	20.2427042	-10.0294504	164.55	-76.21	18.60720858	-7.01178494	148.58	-71.17	16.90789463	-6.47540031	171.11	-91.09	19.30524842	-8.9590361	164.55	-101.15	18.60720858	-8.9590361	
1.4	12.24	1.71	234.66	-89.63	27.7924474	-6.71478918	215.56	-53.33	25.78217297	-2.95468437	189.99	-61	23.03917913	-3.86629346	217.66	-78.07	25.98330289	-5.48468877	215.58	-66.7	25.76217297	-6.40299204	
1.5	17.00	2.37	255.96	-74.89	31.88888887	-4.02733819	242.14	-54.44	29.68807889	-1.2258581	206.66	-50.84	25.91089686	-1.40849516	245.86	-65.66	30.80189155	-3.00282421	242.14	-72.25	29.68807889	-3.78770142	
1.6	19.04	2.66	250.75	-59.75	31.89028722	-1.94855596	248.86	-43.55	30.88917513	-0.22573806	204.87	-40.67	26.20824666	-	251.18	-52.05	31.13664288	-1.1302104	248.94	-57.8	30.89788782	-1.74205936	
1.7	18.36	2.56	223.08	-44.81	27.87154972	-0.53422674	223.06	-32.88	27.97154972	-	183.11	-30.5	23.7840147	-	221.19	-39.04	27.77043764	-	223.08	-43.35	27.87154972	-0.37887031	
1.8	14.96	2.09	181.39	-39.88	22.8713997	-0.8737018	181.93	-21.78	22.32877033	-	151.28	-20.33	19.49749839	-	162.66	-26.02	20.67827828	-	181.93	-28.9	22.7287703	-	
1.9	8.84	1.23	105.66	-14.94	13.28168653	-	105.66	-10.89	13.28168653	-	93.64	-10.17	12.00285621	-	95.55	-13.01	12.20589647	-	105.66	-14.45	13.28168653	-	
2.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A.2 Shear values from Robot Analysis

Analysis Results - Shear (kip-ft)																							
XL	DC	DW	LL Type 4	(LL+M) - Type 4	LL Type 3SSA	(LL+M) - Type 3SSA	LL Type 3-3	(LL+M) - Type 3-3	LL Type 3SB	(LL+M) - Type 3SB	LL Type 4S3	(LL+M) - Type 4S3											
0.0	2.91	0.41	38.72	-4.42	4.792191375	-	35.36	-3.88	4.344658773	-	33.99	-3.85	4.268897911	-	35.43	-3.98	1.128427011	-	38.22	-4.96	4.738987119	-	
0.1	2.14	0.36	33.31	-4.42	4.037369865	-	28.52	-3.88	3.634018721	-	28.09	-3.85	3.481684548	-	30.76	-3.98	0.865338391	-	32.87	-4.96	3.98447239	-0.0349488	
0.2	1.36	0.19	26.40	-4.42	3.123808825	-0.15670054	22.45	-3.88	2.7024962	-0.09923994	20.84	-3.85	2.541819348	-0.09604788	24.76	-5.87	0.58496306	-0.31098288	26.05	-6.17	3.05856845	-0.66214097	
0.3	0.58	0.08	21.52	-5.10	2.424321946	-0.40827268	17.72	-8.64	2.019699598	-0.78495388	16.18	-8.09	1.85010488	-0.40720858	20.49	-9.1	0.331915645	-0.63390871	21.24	-13.22	2.384527862	-1.27230978	
0.4	-0.19	-0.63	15.51	-12.20	1.605592447	-1.34288744	12.19	-16.12	1.26218185	-1.78018981	10.67	-19.28	1.09263246	-1.13974718	15.17	-14.66	0.07420664	-1.60475288	15.33	-16.68	1.588438915	-1.81897878	
0.5	-0.97	-1.14	11.45	-17.26	0.984359549	-2.06062885	9.05	-21.18	0.738979118	-2.47775022	7.17	-14.7	0.538931114	-1.78822306	11.53	-18.89	-	-2.2407473	11.33	-22.24	0.981595227	-2.59645214	
0.6	-1.75	-0.24	6.70	-23.58	0.311304904	-2.90861869	4.86	-27.15	0.094231539	-3.29025325	3.37	-19.72	-	-2.500008	7.49	-23.98	-	-2.8533026	6.73	-27.05	0.314449716	-3.2798204	
0.7	2.53	-0.25	3.66	-27.86	-3.54811583	-	2.28	-31.05	-3.88843091	-	1.15	-23.78	-	4.92	-27.66	-	-3.52519086	4.4	-30.1	-	-3.78534293	-	
0.8	-3.30	-0.46	0.37	-33.02	-4.27527002	-	-	-35.47	-4.52591888	-	-	-29.55	-	-3.98003248	1.77	-32	-	-4.16673334	5.56	-33.58	-	-4.3485879	-
0.9	-4.08	-0.57	-	-38.37	-	-	-	-38.19	-0.00481637	-	-	-35.49	-	-4.71731339	-	-34.83	-	-4.64763377	4.16	-38.41	-	-4.8120022	-
1.0	4.86	0.66	-	-40.38	-3.17068613	-	41.85	-41.02	5.73285893	-3.24478758	42.37	-42.88	5.62818289	-3.4407025	39.9	-38.27	1.719022508	-2.95216417	44.16	-40.88	5.818089527	-3.14476368	
1.1	4.08	0.57	44.80	-	5.68684936	-	36.86	-	4.86393047	-	37.03	-	4.88112495	-	36.99	-	1.480274639	-	40.68	-	5.28973566	-	
1.2	3.30	0.46	40.70	-	4.062487399	-	31.34	-	4.09803072	-	29.78	-	3.930508441	-	32.84	-0.47	1.179902077	-	35.75	-2.28	4.68765281	-	
1.3	2.53	0.35	34.87	-0.33	4.202911433	-	27.88	-1.92	3.481159209	-	24.86	-	3.204403072	-	29.98	-2.57	0.92740205	-	31.81	-4.7	3.987801884	-	
1.4	1.75	0.24	30.11	-1.13	3.697192575	-0.0362349	22.87	-8.06	2.838794844	-0.45442035	19.89	-1.4	2.518997576	-	25.12	-6.04	0.67134963	-0.23947516	25.95	-8.52	3.164531363	-0.5033827	
1.5	0.97	0.14	23.32	-8.88	2.785484437	-0.89907897	18.06	-11.79	2.250828471	-1.03053844	15.86	-15.53	1.911686933	-0.36444115	21.26	-9.69	0.427434482	-0.74202846	22.42	-11.78	2.699696776	-0.82947436	
1.6	0.19	0.03	18.88	-15.23	2.051669133	-1.57578868	13.25	-16.57	1.454716377	-1.1838547	10.78	-11.68	1.18979161	-1.13420274	16.91	-15.7	0.171404089	-1.4288304	17.12	-8.57	1.866511521	-0.85430034	
1.7	-0.58	-0.08	13.25	-20.44	1.27550204	-2.30940075	8.9	-20.44	0.81282501	-2.30940075	7.9	-15.19	0.708216497	-1.75075608	13.55	-17.5	-	-1.98659272	12.72	-20.44	1.219105528	-2.30940075	
1.8	-1.36	-0.19	8.80	-25.91	0.633410673	-3.07069895	3.88	-25.91	0.10988079	-3.07069895	3.98	-24.44	0.10988079	-2.5950238	8.49	-23.24	-	-2.78858882	7.27	-25.91	0.459964797	-3.07069895	
1.9	-2.14	-0.20	4.27	-30.18	-3.76531242	-	3.11	-30.18	-3.76531242	-	2.9	-28.84	-	-3.3276602	4.86	-27.26	-	-3.9353546	4.13	-30.19	-	-3.78511342	-
2.0	-2.91	-0.41	4.27	-36.05	-4.50808085	-	3.11	-36.05	-4.50808085	-	2.9	-34.18	-	-4.30989673	4.86	-33.24	-	-4.20907273	4.13	-36.05	-	-4.50808085	-

Table A.3 Lane Loading values from Robot Analysis

Lane Loading		
	Moment	Shear
0.0	0	8.4
0.1	25.48	6.16
0.2	43.12	3.92
0.3	52.92	1.68
0.4	54.88	-0.56
0.5	49	-2.8
0.6	35.28	-5.02
0.7	13.72	-7.28
0.8	-15.68	-9.52
0.9	-52.92	-11.76
1.0	-98	14
1.1	-52.92	11.76
1.2	-15.68	9.52
1.3	13.72	7.28
1.4	35.28	5.04
1.5	49	2.8
1.6	55.1	0.56
1.7	52.92	-1.68
1.8	42.12	-3.92
1.9	25.48	-6.16
2.0	0	-8.4

Table A.4 Type 4 Flexure Calcs

Type 4 Flexure							
X/L	$\phi \cdot \phi_r (\phi Mn)$	$\gamma_{bc}(DC)$	$\gamma_{bw}(DW)$	$\gamma_{LL}(LL+IM)$		sum	sum
				+	-	+	-
0.0		0	0	0	0	0	0
0.1		11.05	1.845	18.77538443		31.67038443	12.895
0.2		18.7	3.135	31.68072646		53.51572646	21.835
0.3		22.95	3.84	39.51972958	-0.91582447	66.30972958	25.87417553
0.4		23.8	3.99	42.72260341	-2.85194976	70.51260341	24.93805024
0.5		21.25	3.555	40.04990159	-5.60350028	64.85490159	19.20149972
0.6		15.3	2.565	33.99434995	-9.86213137	51.85934995	8.002868629
0.7		3.45	0.99	23.37460117	-13.552877	27.81460117	-9.11287703
0.8		-6.8	-1.14	9.900427234	-18.7507033	1.960427234	-26.6907033
0.9		-22.95	-3.84		-24.7639547	-26.79	-51.5539547
0.1		-42.4875	-7.125		-31.5926314	-49.6125	-81.2051314
1.1		-22.95	-3.84		-24.1013489	-26.79	-50.8913489
1.2		-6.8	-1.14	12.91604448	-18.1614129	4.976044484	-26.1014129
1.3		5.95	0.99	26.31551964	-13.0382855	33.25551964	-6.09828546
1.4		15.3	2.565	36.13018161	-8.72919994	53.99518161	9.135800064
1.5		21.25	3.555	40.37912953	-5.23553964	65.18412953	19.56946036
1.6		23.8	3.99	40.41737339	-2.53442275	68.20737339	25.25557725
1.7		22.95	3.84	36.36301464	-0.69449476	63.15301464	26.09550524
1.8		18.7	3.135	29.47270262	-1.13581246	51.30770262	20.69918754
1.9		11.05	1.845	17.2661925		30.1611925	12.895
2.0		0	0	0	0	0	0

Table A.5 Type 4 Shear Calcs

Type 4 Shear							
X/L	$\phi \cdot \phi_r (\phi Mn)$	$\gamma_{bc}(DC)$	$\gamma_{bw}(DW)$	$\gamma_{LL}(LL+IM)$		sum	sum
				+	-	+	-
0.0		3.6375	0.615	6.229848788		10.48234879	4.2525
0.1		2.675	0.45	5.24849908		8.37349908	3.125
0.2		1.7	0.285	4.059652772	-0.2037107	6.044652772	1.781289303
0.3		0.725	0.12	3.151618529	-0.53075446	3.996618529	0.31424554
0.4		-0.2375	-0.045	2.087270182	-1.74588367	1.804770182	-2.02838367
0.5		-1.2125	-0.21	1.292667413	-2.67881751	-0.12983259	-4.10131751
0.6		-2.1875	-0.36	0.404696376	-3.7812017	-2.14280362	-6.3287017
0.7		3.1625	-0.525		-4.61385071	2.6375	-1.97635071
0.8		-4.125	-0.69		-5.55785103	-4.815	-10.372851
0.9		-5.1	-0.855		-6.25423874	-5.955	-12.2092387
0.1		6.075	1.02		-4.12969198	7.095	2.965308025
1.1		5.1	0.855	7.392703416		13.34770342	5.955
1.2		4.125	0.69	6.620233619		11.43523362	4.815
1.3		3.1625	0.525	5.580784863		9.268284863	3.6875
1.4		2.1875	0.36	4.689350348	-0.04710537	7.236850348	2.500394632
1.5		1.2125	0.21	3.517103768	-0.90949036	4.939603768	0.513009641
1.6		0.2375	0.045	2.667168573	-2.04853748	2.949668573	-1.76603748
1.7		-0.725	-0.12	1.658152652	-3.00222098	0.813152652	-3.84722098
1.8		-1.7	-0.285	0.823433875	-3.99187055	-1.16156613	-5.97687055
1.9		-2.675	-0.45		-4.81690615	-3.125	-7.94190615
2.0		-3.6375	-0.615		-5.86050484	-4.2525	-10.1130048

Table A.6 Type 3S3A Flexure Calcs

Type 3S3A							
Flexure							
X/L	$\phi_s \phi_r (\phi Mn)$	$\gamma_{DC}(DC)$	$\gamma_{DW}(DW)$	$\gamma_{LL}(LL+IM)$		sum	sum
				+	-	+	-
0.0		0	0	0	0	0	0
0.1		11.05	1.845	16.94111449		29.83611449	12.895
0.2		18.7	3.135	27.85725578		49.69225578	21.835
0.3		22.95	3.84	33.78452356	-0.13702056	60.57452356	26.65297944
0.4		23.8	3.99	35.23197616	-1.81446676	63.02197616	25.97553324
0.5		21.25	3.555	31.35579406	-4.30595488	56.16079406	20.49904512
0.6		15.3	2.565	25.55477158	-7.61425154	43.41977158	10.25074846
0.7		3.45	0.99	16.94773982	-11.7365901	21.38773982	-7.29659013
0.8		-6.8	-1.14	6.675930074	-16.6743539	-1.26406993	-24.6143539
0.9		-22.95	-3.84		-25.1471318	-26.79	-51.9371318
0.1		-42.4875	-7.125		-44.3329226	-49.6125	-93.9454226
1.1		-22.95	-3.84		-26.4764933	-26.79	-53.2664933
1.2		-6.8	-1.14	12.31430434	-13.6794864	4.374304344	-21.6194864
1.3		5.95	0.99	24.18937115	-9.11521642	31.12937115	-2.17521642
1.4		15.3	2.565	33.49082487	2.932108969	51.35582487	20.79710897
1.5		21.25	3.555	38.59189215	-2.43433555	63.39689215	22.37066445
1.6		23.8	3.99	40.15592767	-0.29345948	67.94592767	27.49654052
1.7		22.95	3.84	36.36301464		63.15301464	26.79
1.8		18.7	3.135	29.54740139		51.38240139	21.835
1.9		11.05	1.845	17.2661925		30.1611925	12.895
2.0		0	0	0	0	0	0

Table A.7 Type 3S3A Shear Calcs

Type 3S3A							
Shear							
X/L	$\phi_s \phi_r (\phi Mn)$	$\gamma_{DC}(DC)$	$\gamma_{DW}(DW)$	$\gamma_{LL}(LL+IM)$		sum	sum
				+	-	+	-
0.0		3.6375	0.615	5.765056405		10.0175564	4.2525
0.1		2.675	0.45	4.724224338		7.849224338	3.125
0.2		1.7	0.285	3.51324506	-0.12901192	5.49824506	1.855988079
0.3		0.725	0.12	2.625960477	-1.02044644	3.470960477	-0.17544644
0.4		-0.2375	-0.045	1.628011041	-2.28814145	1.345511041	-2.57064145
0.5		-1.2125	-0.21	0.960672854	-3.22107529	-0.46182715	-4.64357529
0.6		-2.1875	-0.36	0.122501	-4.27781022	-2.424999	-6.82531022
0.7		3.1625	-0.525		-5.05236019	2.6375	-2.41486019
0.8		-4.125	-0.69		-5.89676214	-4.815	-10.7117621
0.9		-5.1	-0.855		-6.50600128	-5.955	-12.4610013
0.1		6.075	1.02	7.245271622	-4.21822386	14.34027162	2.876776142
1.1		5.1	0.855	6.322020962		12.27702096	5.955
1.2		4.125	0.69	5.325454836		10.14045484	4.815
1.3		3.1625	0.525	4.613850708		8.301350708	3.6875
1.4		2.1875	0.36	3.687833427	-0.59074646	6.235333427	1.95675354
1.5		1.2125	0.21	2.900147212	-1.33969998	4.322647212	0.082800024
1.6		0.2375	0.045	1.891131291	-2.23390111	2.173631291	-1.95140111
1.7		-0.725	-0.12	1.056412513	-3.00222098	0.211412513	-3.84722098
1.8		-1.7	-0.285	0.142845028	-3.99187055	-1.84215497	-5.97687055
1.9		-2.675	-0.45		-4.81690615	-3.125	-7.94190615
2.0		-3.6375	-0.615		-5.86050484	-4.2525	-10.1130048

Table A.8 Type 3-3 Flexure Calcs

Type 3-3 Flexure							
X/L	$\phi_s \phi_r (\phi Mn)$	$\gamma_{DC}(DC)$	$\gamma_{DW}(DW)$	$\gamma_{LL}(LL+IM)$		sum	sum
				+	-	+	-
0.0		0	0	0	0	0	0
0.1		11.05	1.845	16.24945916		29.14445916	12.895
0.2		18.7	3.135	26.41169614		48.24669614	21.835
0.3		22.95	3.84	31.61687575	-0.089988	58.40687575	26.700012
0.4		23.8	3.99	32.25094168	13.16678774	60.04094168	40.95678774
0.5		21.25	3.555	29.82861909	-4.22710617	54.63361909	20.57789383
0.6		15.3	2.565	25.0899792	-7.5188031	42.9549792	10.3461969
0.7		3.45	0.99	16.41516521	-11.6259253	20.85516521	-7.18592527
0.8		-6.8	-1.14	6.212521002	-16.549856	-1.727479	-24.489856
0.9		-22.95	-3.84		-22.2878286	-26.79	-49.0778286
0.1		-42.4875	-7.125		-39.6670158	-49.6125	-89.2795158
1.1		-22.95	-3.84		-23.2879622	-26.79	-50.0779622
1.2		-6.8	-1.14	10.53536683	-12.8826994	2.595366829	-20.8226994
1.3		5.95	0.99	21.98022402	-8.41802784	28.92022402	-1.47802784
1.4		15.3	2.565	29.95093287	-4.7687815	47.81593287	13.0962185
1.5		21.25	3.555	33.68390591	-1.93634371	58.48890591	22.86865629
1.6		23.8	3.99	34.07074406		61.86074406	27.79
1.7		22.95	3.84	30.83392191		57.62392191	26.79
1.8		18.7	3.135	25.3075542		47.1425542	21.835
1.9		11.05	1.845	15.60345308		28.49845308	12.895
2.0		0	0	0	0	0	0

Table A.9 Type 3-3 Shear Calcs

Type 3-3 Shear							
X/L	$\phi_s \phi_r (\phi Mn)$	$\gamma_{DC}(DC)$	$\gamma_{DW}(DW)$	$\gamma_{LL}(LL+IM)$		sum	sum
				+	-	+	-
0.0		3.6375	0.615	5.575542843		9.828042843	4.2525
0.1		2.675	0.45	4.526410913		7.651410913	3.125
0.2		1.7	0.285	3.304365149	-0.12486199	5.289365149	1.860138011
0.3		0.725	0.12	2.412930634	-0.52937115	3.257930634	0.31562885
0.4		-0.2375	-0.045	1.41774782	-1.48167133	1.13524782	-1.76417133
0.5		-1.2125	-0.21	0.700610449	-2.32468998	-0.72188955	-3.74718998
0.6		-2.1875	-0.36		-3.2500104	-2.5475	-5.7975104
0.7		3.1625	-0.525		-4.04807665	2.6375	-1.41057665
0.8		-4.125	-0.69		-5.07784223	-4.815	-9.89284223
0.9		-5.1	-0.855		-6.1325074	-5.955	-12.0875074
0.1		6.075	1.02	7.317203776	-4.47275302	14.41220378	2.62224698
1.1		5.1	0.855	6.345537243		12.30053724	5.955
1.2		4.125	0.69	5.109658373		9.924658373	4.815
1.3		3.1625	0.525	4.209923994		7.897423994	3.6875
1.4		2.1875	0.36	3.275606849		5.823106849	2.5475
1.5		1.2125	0.21	2.485154012	-0.4737475	3.907654012	0.9487525
1.6		0.2375	0.045	1.546686935	-1.47446356	1.829186935	-1.19196356
1.7		-0.725	-0.12	0.918081447	-2.27598288	0.073081447	-3.12098288
1.8		-1.7	-0.285	0.142845028	-3.37353068	-1.84215497	-5.35853068
1.9		-2.675	-0.45		-4.32583087	-3.125	-7.45083087
2.0		-3.6375	-0.615		-5.60182575	-4.2525	-9.85432575

Table A.10 Type 3S3B Flexure Calcs

Type 3S3B Flexure							
X/L	$\phi \leq \phi_r (\phi Mn)$	$\gamma_{DC}(DC)$	$\gamma_{DW}(DW)$	$\gamma_{LL}(LL+IM)$		sum	sum
				+	-	+	-
0.0		0	0	0	0	0	0
0.1		11.05	1.845	17.54285463		30.43785463	12.895
0.2		18.7	3.135	29.88518922		51.72018922	21.835
0.3		22.95	3.84	36.11816865		62.90816865	26.79
0.4		23.8	3.99	38.72206897	-1.99983039	66.51206897	25.79016961
0.5		21.25	3.555	36.69675654	-4.53835107	61.50175654	20.26664893
0.6		15.3	2.565	31.17101288	-7.89229698	49.03601288	9.972703016
0.7		3.45	0.99	21.33975118	-12.0616681	25.77975118	-7.62166813
0.8		-6.8	-1.14	11.1675398	-17.0464645	3.227539803	-24.9864645
0.9		-22.95	-3.84		-26.7905048	-26.79	-53.5805048
0.1		-42.4875	-7.125		-41.03511	-49.6125	-90.64761
1.1		-22.95	-3.84		-27.4669438	-26.79	-54.2569438
1.2		-6.8	-1.14	13.21483959	-16.5221898	5.274839587	-24.4621898
1.3		5.95	0.99	25.09682295	-11.1735827	32.03682295	-4.23358269
1.4		15.3	2.565	33.77855348	-7.13009281	51.64355348	10.73490719
1.5		21.25	3.555	39.10648372	-3.90341147	63.91148372	20.90158853
1.6		23.8	3.99	40.47685575	-1.46927354	68.26685575	26.32072646
1.7		22.95	3.84	36.10156893		62.89156893	26.79
1.8		18.7	3.135	26.88176174		48.71676174	21.835
1.9		11.05	1.845	15.86766541		28.76266541	12.895
2.0		0	0	0	0	0	0

Table A.11 Type 3S3B Shear Calcs

Type 3S3B Shear							
X/L	$\phi \leq \phi_r (\phi Mn)$	$\gamma_{DC}(DC)$	$\gamma_{DW}(DW)$	$\gamma_{LL}(LL+IM)$		sum	sum
				+	-	+	-
0.0		3.6375	0.615	1.466955115		5.719455115	4.2525
0.1		2.675	0.45	1.122339908		4.247339908	3.125
0.2		1.7	0.285	0.759325198	-0.40429074	2.744325198	1.580709257
0.3		0.725	0.12	0.431490339	-1.08407873	1.276490339	-0.23907873
0.4		-0.2375	-0.045	0.092615777	-2.08617809	-0.18988422	-2.36867809
0.5		-1.2125	-0.21		-2.90429714	-1.4225	-4.32679714
0.6		-2.1875	-0.36		-3.83930074	-2.5475	-6.38680074
0.7		3.1625	-0.525		-4.58341787	2.6375	-1.94591787
0.8		-4.125	-0.69		-5.41675334	-4.815	-10.2317533
0.9		-5.1	-0.855		-6.0412089	-5.955	-11.9962089
0.1		6.075	1.02	2.23472926	-3.83781343	9.32972926	3.257186575
1.1		5.1	0.855	1.898357031		7.853357031	5.955
1.2		4.125	0.69	1.53387036		6.34887036	4.815
1.3		3.1625	0.525	1.205152325		4.892652325	3.6875
1.4		2.1875	0.36	0.872754389	-0.31131771	3.420254389	2.236182295
1.5		1.2125	0.21	0.55566484	-0.9662061	1.97816484	0.456293904
1.6		0.2375	0.045	0.222825316	-1.83689095	0.505325316	-1.55439095
1.7		-0.725	-0.12		-2.59552764	-0.845	-3.44052764
1.8		-1.7	-0.285		-3.6225266	-1.985	-5.6075266
1.9		-2.675	-0.45		-4.41159613	-3.125	-7.53659613
2.0		-3.6375	-0.615		-5.47179454	-4.2525	-9.72429454

Table A.12 Type 4S3 Flexure Calcs

Type 4S3 Flexure							
X/L	$\phi_c \phi_s (\phi Mn)$	$\gamma_{DC}(DC)$	$\gamma_{DW}(DW)$	$\gamma_{LL}(LL+IM)$		sum	sum
				+	-	+	-
0.0		0	0	0	0	0	0
0.1		11.05	1.845	18.5637379		31.4587379	12.895
0.2		18.7	3.135	31.32521562		53.16021562	21.835
0.3		22.95	3.84	38.98577166		65.77577166	26.79
0.4		23.8	3.99	42.14299624	-1.81446676	69.93299624	25.97553324
0.5		21.25	3.555	39.49104408	-4.30595488	64.29604408	20.49904512
0.6		15.3	2.565	33.32344428	-7.61425154	51.18844428	10.25074846
0.7		3.45	0.99	22.88905912	-11.7365901	27.32905912	-7.29659013
0.8		-6.8	-1.14	10.76637971	-18.0784143	2.82637971	-26.0184143
0.9		-22.95	-3.84		-28.9360197	-26.79	-55.7260197
0.1		-42.4875	-7.125		-43.2940563	-49.6125	-92.9065563
1.1		-22.95	-3.84		-28.0963501	-26.79	-54.8863501
1.2		-6.8	-1.14	12.294938	-17.6219218	4.354937995	-25.5619218
1.3		5.95	0.99	24.18937115	-12.5651932	31.12937115	-5.62519322
1.4		15.3	2.565	33.49082487	-8.32388991	51.35582487	9.541110089
1.5		21.25	3.555	38.59189215	-4.89801184	63.39689215	19.90698816
1.6		23.8	3.99	40.16699416	-2.26467717	67.95699416	25.52532283
1.7		22.95	3.84	36.36301464	-0.4925314	63.15301464	26.2974686
1.8		18.7	3.135	29.54740139		51.38240139	21.835
1.9		11.05	1.845	17.2661925		30.1611925	12.895
2.0		0	0	0	0	0	0

Table A.13 Type 4S3 Shear Calcs

Type 4S3 Shear							
X/L	$\phi_c \phi_s (\phi Mn)$	$\gamma_{DC}(DC)$	$\gamma_{DW}(DW)$	$\gamma_{LL}(LL+IM)$		sum	sum
				+	-	+	-
0.0		3.6375	0.615	6.160683255		10.41318325	4.2525
0.1		2.675	0.45	5.187633411	-0.04543083	8.312633411	3.079569166
0.2		1.7	0.285	4.011236899	-0.86078326	5.996236899	1.124216737
0.3		0.725	0.12	3.112885831	-1.65400272	3.957885831	-0.80900272
0.4		-0.2375	-0.045	2.06237059	-2.36560685	1.77987059	-2.64810685
0.5		-1.2125	-0.21	1.276067685	-3.36770622	-0.14643231	-4.79020622
0.6		-2.1875	-0.36	0.408846308	-4.26397712	-2.13865369	-6.81147712
0.7		3.1625	-0.525		-4.92094568	2.6375	-2.28344568
0.8		-4.125	-0.69		-5.63531643	-4.815	-10.4503164
0.9		-5.1	-0.855		-6.25977198	-5.955	-12.214772
0.1		6.075	1.02	7.564816385	-4.08819266	14.65981639	3.006807345
1.1		5.1	0.855	6.850445636		12.80544564	5.955
1.2		4.125	0.69	5.93549484		10.75049484	4.815
1.3		3.1625	0.525	5.157491799		8.844991799	3.6875
1.4		2.1875	0.36	4.113893111	-0.65437875	6.661393111	1.89312125
1.5		1.2125	0.21	3.392605808	-1.33831667	4.815105808	0.084183335
1.6		0.2375	0.045	2.426472518	-0.85059045	2.708972518	-0.56809045
1.7		-0.725	-0.12	1.584837187	-3.00222098	0.739837187	-3.84722098
1.8		-1.7	-0.285	0.597954236	-3.99187055	-1.38704576	-5.97687055
1.9		-2.675	-0.45		-4.81690615	-3.125	-7.94190615
2.0		-3.6375	-0.615		-5.86050484	-4.2525	-10.1130048

Table A.14 Unknowns for Calcs

ϕ_c	1	γ_{DC}	1.25
ϕ_s	1	γ_{DW}	1.5
(ϕMn)	93.94542263	γ_{LL}	1.3
			AADT<1000

Appendix C – Retaining Wall Design Calcs

4th Street Segmental Retaining Wall Design

Wall Height $H := 6 \text{ ft}$
 Embedment $d := 1 \text{ ft}$
 Backfill Slope $\beta := 0 \text{ deg}$

Backfill Soil $\phi_b := 33 \text{ deg}$ $\gamma_b := 120 \text{ pcf}$
 $\delta_b := \frac{2}{3} \cdot \phi_b = 22 \text{ deg}$

In situ Soil $\phi_i := 32 \text{ deg}$ $\gamma_i := 110 \text{ pcf}$
 $\delta_i := \phi_i$

Use coulomb method:
 $DL := 50 \text{ psf}$ $LL := 100 \text{ psf}$

Block selection: Keystone Compac
 offsets 1"
 $H_b := 8 \text{ in}$
 $D_b := 12 \text{ in}$ $\gamma := 120 \text{ psf}$

$batter := 7.1 \text{ deg}$
 $\alpha := 90 \text{ deg} + batter = 97.1 \text{ deg}$

Active Earth Pressure in backfill zone

$$K_a := \frac{\sin(\alpha + \phi_b)^2}{\sin(\alpha)^2 \cdot \sin(\alpha - \delta_b) \cdot \left(1 + \sqrt{\frac{(\sin(\phi_b + \delta_b) \cdot \sin(\phi_b - \beta))}{\sin(\alpha - \delta_b) \cdot \sin(\alpha - \beta)}}\right)^2} = 0.217$$

$$K_{ahoriz} := K_a \cdot \cos(\delta_b - batter) = 0.21$$

Geogrid Placement

Lowest layer at 1st block joint $s_1 := 0.67 \text{ ft}$
 space subsequent layers $s_2 := s_1 \cdot 2 = 1.34 \text{ ft}$
 ever 2nd block o.c.

Tension to bottom layer

$$T_u := K_{ahoriz} \cdot \gamma_b \cdot (H - s_1) \cdot \left(\frac{(s_1 + s_2) - 0}{2} \right) = 134.99 \frac{\text{lb}}{\text{ft}}$$

Select Geogrid Titan Earth Grid 15 $FS := 1.5$

$$LTDS := 15 \frac{\text{kN}}{\text{m}} = 1027.826 \frac{\text{lb}}{\text{ft}} \quad \frac{LTDS}{FS} = 685.218 \frac{\text{lb}}{\text{ft}} > T_u \text{ OK}$$

Check Connection Strength

$$N := (H - s_1) \cdot \gamma = 639.6 \frac{\text{lb}}{\text{ft}}$$

Peak Connect $peak := \frac{889 \frac{\text{lb}}{\text{ft}} + 0.31 \cdot N}{FS} = 724.851 \frac{\text{lb}}{\text{ft}}$

3/4" serviceability $service := \frac{519 \frac{\text{lb}}{\text{ft}} + 0.14 \cdot N}{1} = 608.544 \frac{\text{lb}}{\text{ft}}$

*BOTH need to be $> T_u$ OK

Safety factor

$$SF := \frac{\min(LTDS, peak, service)}{T_u} = 4.508 > 1.5 \text{ OK}$$

check embedment depth

$$H_{ov} := (H - s_1) \cdot \gamma_b = 639.6 \frac{1}{\text{ft}^2} \cdot \text{lb}$$

$$C_i := 0.9$$

$$L_e := \frac{T_u}{2 \cdot H_{ov} \cdot \tan(\phi_b) \cdot C_i} = 0.181 \text{ ft}$$

$$\bar{L}_e := L_e + 1 \text{ ft} = 1.181 \text{ ft}$$

+1 ft per NCMA

$$L_{eAASHTO} := L_e + 3 \text{ ft} = 4.181 \text{ ft}$$

AASHTO requirement

Tension to layer #2

$$T_u := K_{ahoriz} \cdot \gamma_b \cdot (H - (s_1 + s_2)) \cdot \left(\frac{(2 \cdot s_2 + s_1) - s_1}{2} \right) = 134.737 \frac{\text{lb}}{\text{ft}}$$

Select Geogrid Titan Earth Grid 15 $FS := 1.5$

$$LTDS := 15 \frac{\text{kN}}{\text{m}} = 1027.826 \frac{\text{lb}}{\text{ft}} \quad \frac{LTDS}{FS} = 685.218 \frac{\text{lb}}{\text{ft}} > T_u \text{ OK}$$

Check Connection Strength

$$N := (H - (s_1 + s_2)) \cdot \gamma = 478.8 \frac{\text{lb}}{\text{ft}}$$

Peak Connect $peak := \frac{889 \frac{\text{lb}}{\text{ft}} + 0.31 \cdot N}{FS} = 691.619 \frac{\text{lb}}{\text{ft}}$

3/4" serviceability $service := \frac{519 \frac{\text{lb}}{\text{ft}} + 0.14 \cdot N}{1} = 586.032 \frac{\text{lb}}{\text{ft}}$

*BOTH need to be $> T_u$ OK

Tension to Top layer

$$T_u := K_{ahoriz} \cdot \gamma_b \cdot (H - (H - s_1)) \cdot (H - (H - (s_1 + s_2))) = 33.937 \frac{\text{lb}}{\text{ft}}$$

Select Geogrid Titan Earth Grid 15 $FS := 1.5$

$$LTDS := 15 \frac{\text{kN}}{\text{m}} = 1027.826 \frac{\text{lb}}{\text{ft}} \quad \frac{LTDS}{FS} = 685.218 \frac{\text{lb}}{\text{ft}} > T_u \text{ OK}$$

Check Connection Strength

$$N := (H - (H - s_1)) \cdot \gamma = 80.4 \frac{\text{lb}}{\text{ft}}$$

$$\text{Peak Connect} \quad \text{peak} := \frac{889 \frac{\text{lb}}{\text{ft}} + 0.31 \cdot N}{FS} = 609.283 \frac{\text{lb}}{\text{ft}}$$

$$3/4" \text{ serviceability} \quad \text{service} := \frac{519 \frac{\text{lb}}{\text{ft}} + 0.14 \cdot N}{1} = 530.256 \frac{\text{lb}}{\text{ft}}$$

*BOTH need to be $> T_u$ OK

check embedment debth

$$H_{ov} := (H - (H - s_1)) \cdot \gamma_b = 80.4 \frac{1}{\text{ft}^2} \cdot \text{lb}$$

$$L_e := \frac{T_u}{2 \cdot H_{ov} \cdot \tan(\phi_b) \cdot C_i} = 0.361 \text{ ft}$$

$$C_i := 0.9$$

$$\bar{L}_e := L_e + 1 \text{ ft} = 1.361 \text{ ft}$$

$$L_{eAASHTO} := L_e + 3 \text{ ft} = 4.361 \text{ ft}$$

+ 1 ft per NCMA

AASHTO requirement

Check available embedment debth

coulomb rupture angle $\phi_{CRA} := 52.1 \text{ deg}$

$$L_{available} := (10 \text{ ft} - 1 \text{ ft}) + (H - s_1) \cdot \tan(\text{batter}) - \frac{(H - s_1)}{\tan(\phi_{CRA})} = 5.515 \text{ ft}$$

Overtuning Moments

$$\text{Effective Height } H_e := H + \frac{2}{3} \cdot H \cdot \tan(\beta) = 6 \text{ ft}$$

$$\alpha := 90 \text{ deg}$$

$$K_e := \frac{\sin(\alpha + \phi_i)^2}{\sin(\alpha)^2 \cdot \sin(\alpha - \delta_i) \cdot \left(1 + \sqrt{\frac{(\sin(\phi_i + \delta_i) \cdot \sin(\phi_i - \beta))}{\sin(\alpha - \delta_i) \cdot \sin(\alpha - \beta)}} \right)^2} = 0.277$$

$$K_{ehoriz} := K_e \cdot \cos(\delta_i) = 0.235$$

Earth Pressure

Base Width (trial)

$$W := .1 \cdot H = 0.6 \text{ ft}$$

$$\text{Force } F_{EP} := K_{ehoriz} \cdot \gamma_i \cdot \frac{H_e^2}{2} = 465.284 \frac{\text{lb}}{\text{ft}}$$

$$\text{Distance } D_{EP} := 4 \text{ ft}$$

$$\text{Moment } M_{EP} := F_{EP} \cdot D_{EP} = 1861.138 \frac{\text{lb} \cdot \text{ft}}{\text{ft}}$$

Resisting Moments

$$\text{Force } F_{Wwall} := H \cdot \gamma = 720 \frac{\text{lb}}{\text{ft}}$$

$$F_{Wearth} := H \cdot W \cdot \gamma_b = 432 \frac{\text{lb}}{\text{ft}}$$

$$\text{Distance } D_{Wwall} := 4 \text{ ft}$$

$$D_{Wearth} := 4 \text{ ft}$$

$$\text{Moment } M_{Wwall} := F_{Wwall} \cdot D_{Wwall} = 2880 \frac{\text{lb} \cdot \text{ft}}{\text{ft}} \quad M_{Wearth} := F_{Wearth} \cdot D_{Wearth} = 1728 \frac{\text{lb} \cdot \text{ft}}{\text{ft}}$$

$$F_{total} := F_{Wwall} + F_{Wearth} = 1152 \frac{\text{lb}}{\text{ft}}$$

$$M_{total} := M_{Wwall} + M_{Wearth} = 4608 \frac{\text{lb} \cdot \text{ft}}{\text{ft}}$$

$$\text{Overtuning Safety factor Ratio } OSF := \frac{M_{total}}{M_{EP}} = 2.476 > 2 \text{ so OK}$$

Check Sliding at base $\phi_e := .9$

$$\text{Sliding Resistance } R_s := F_{total} \cdot \tan(\phi_e) = 1451.702 \frac{\text{lb}}{\text{ft}}$$

$$\text{Sliding Safety Factor } SSF := \frac{R_s}{F_{EP}} = 3.12 \quad \text{OK}$$

Check Soil Pressure $B := W = 0.6 \text{ ft}$

$$\text{Eccentricity } e := \frac{B}{2} - \frac{M_{total} - M_{EP}}{F_{total}} = -2.084 \text{ ft}$$

$$\text{Effective bearing length } L_{eb} := B - 2 \cdot e = 4.769 \text{ ft}$$

$$\text{Bearing pressure } q := \frac{F_{total}}{L_{eb}} = 241.567 \text{ psf}$$

Allowable Bearing Pressure

Assume no cohesion $c=0$

For $\phi = 32 \text{ deg}$ $N_q := 23.2$

$N_\gamma := 30.2$

$$q_{ult} := \gamma_i \cdot d \cdot N_q + 0.5 \cdot \gamma_i \cdot L_{eb} \cdot N_\gamma = 10473.074 \text{ psf}$$

$$\text{Soil Bearing Ratio } SBR := \frac{q_{ult}}{q} = 43.355 \quad \text{OK}$$

** Trial W can be 0.1 of H so now testing having no Geogrid and just using the block.

$$W := 12 \text{ in}$$

Resisting Moments

Force $F_{Wwall} := H \cdot \gamma = 720 \frac{\text{lb}}{\text{ft}}$

$$F_{Wearth} := H \cdot W \cdot \gamma_i = 660 \frac{\text{lb}}{\text{ft}}$$

Distance $D_{Wwall} := 4 \text{ ft}$

$$D_{Wearth} := 4 \text{ ft}$$

Moment $M_{Wwall} := F_{Wwall} \cdot D_{Wwall} = 2880 \frac{\text{lb} \cdot \text{ft}}{\text{ft}}$

$$M_{Wearth} := F_{Wearth} \cdot D_{Wearth} = 2640 \frac{\text{lb} \cdot \text{ft}}{\text{ft}}$$

$$F_{total} := F_{Wwall} + F_{Wearth} = 1380 \frac{\text{lb}}{\text{ft}}$$

$$M_{total} := M_{Wwall} + M_{Wearth} = 5520 \frac{\text{lb} \cdot \text{ft}}{\text{ft}}$$

Overtuning Safety factor Ratio $OSF := \frac{M_{total}}{M_{EP}} = 2.966 > 2 \text{ so OK}$

Check Sliding at base $\phi_e := .9$

Sliding Resistance $R_s := F_{total} \cdot \tan(\phi_e) = 1739.018 \frac{\text{lb}}{\text{ft}}$

Sliding Safety Factor $SSF := \frac{R_s}{F_{EP}} = 3.738 \text{ OK}$

Check Soil Pressure

$$B := W = 1 \text{ ft}$$

Eccentricity

$$e := \frac{B}{2} - \frac{M_{total} - M_{EP}}{F_{total}} = -2.151 \text{ ft}$$

Effective bearing length

$$L_{eb} := B - 2 \cdot e = 5.303 \text{ ft}$$

Bearing pressure

$$q := \frac{F_{total}}{L_{eb}} = 260.245 \text{ psf}$$

Allowable Bearing Pressure

Assume no cohesion $c=0$

For $\phi = 32$ deg

$$N_q := 23.2$$

$$N_\gamma := 30.2$$

$$q_{ult} := \gamma_i \cdot d \cdot N_q + 0.5 \cdot \gamma_i \cdot L_{eb} \cdot N_\gamma = 11359.783 \text{ psf}$$

Soil Bearing Ratio

$$SBR := \frac{q_{ult}}{q} = 43.65 \quad \text{OK}$$

Appendix D – Pipe Sizing Analysis

From	To	Area, <i>A</i>		Total (ac)	<i>A</i> x <i>C</i>			<i>t_i</i> (min)	<i>t_e</i> (min)	(Design)				<i>D</i> (in)	(Full)	(Full)	(Design)	<i>T_r</i> (min)	U/S	D/S	<i>D_r</i> (ft)	<i>S_o</i> (\circ)
		<i>L</i> (ft)	Inc (ac)		<i>C</i> (\circ)	Inc (ac)	Total (ac)			Inlet (min)	System (min)	<i>i</i> (in/h)	<i>Q</i> (cfs)		<i>D*</i> (in)	<i>Q</i> (cfs)	<i>V</i> (ft/s)		<i>V</i> (ft/s)	<i>E</i> (ft)		
Green Street																						
2	4	235	0.05	0.05	0.90	0.05	0.05	10.0	10.0	3.88	0.18	2.893668705	15	14.5974	5.96	6.77	0.58	717.00	705.00	12.00	0.05106383	
4	5	34	0.27	0.27	0.90	0.24	0.24	10.0	10.1	3.88	0.94	7.310714586	15	6.3641	5.47	5.98	0.09	704.90	704.57	0.33	0.009705882	
1	3	235	0.05	0.05	0.90	0.05	0.05	10.0	10.0	3.88	0.18	2.907550114	15	13.9759	5.26	4.81	0.81	717.00	706.00	11.00	0.046808511	
4th Street																						
2	3	200	0.41	0.41	0.90	0.37	0.37	10.0	12.0	4.53	1.68	6.761469552	15	14.0788	6.29	5.95	0.56	737.90	728.40	9.50	0.0475	
21	23	51	2.07	2.07	0.90	1.86	1.86	10.0	12.0	4.53	8.49	11.34624283	15	17.8635	6.53	6.91	0.12	729.90	726.00	3.90	0.076470588	
42	43	46	1.38	1.38	0.90	1.24	1.24	10.0	12.0	4.53	5.66	11.58353577	15	11.2695	6.45	6.16	0.12	718.40	717.00	1.40	0.03043	

Table D.1 – Stormwater Pipe Sizing

