GENERAL PROVISIONS, SPECIAL PROVISIONS, AND SUPPLEMENTAL SPECIFICATIONS

For

Project Title: **Temple Avenue Flagpole Installation**

Class(es) of Work: Structures, MOT

Completion Time Limit: **60 Days After Issuance of NTP**

Project Coordinator

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SCHEDULE OF ITEMS

No.	VDOT Code	Road and BR. Spec.	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	BID AMOUNT
1	-	-	Project Lump Sum	LS	1		
						Bid Amount =	

DATE	SIGNATURE	TITLE	COMPANY

PROJECT DESCRIPTION

This project consists of the installation of three (3) flag poles and uplighting within the Temple Ave/I-95 Roundabout in the City of Colonial Heights, Virginia. The limits of construction are:

- The project limits will be the roundabout at the Temple Ave/I-95 interchange and the south side of Temple Ave.

The Temple Ave Flagpole Installation project consists of installation of three (3) new flagpoles including, but not limited to:

- Two (2) flagpoles with a height of 24 feet
- One (1) flagpole with a height of 30 feet
- Uplighting for each flagpole and the necessary electrical conduit

GENERAL REQUIREMENTS

The Supplemental Specifications (SS), Special Provisions (SP) and/or Special Provision Copied Notes (SPCN) contained in this contract document assembly titled “Separate-Cover Contract Documents” are a binding part of the contract document assembly titled “Colonial Heights High School Sidewalk Improvements Bid Specifications” which it accompanies, and each SS, SP, and SPCN carries the same status in the Contract as that stated in Section 105.12 of the Virginia Department of Transportation’s 2022 Supplement to the 2020 Road and Bridge Specifications.

COMPLETION TIME LIMIT

- Completion of all work to be done under the Contract not later than 60 calendar days from issuance of NTP.

QUALITY CONTROL INSPECTION SERVICES

The contractor shall hire an independent material testing agency, acceptable to the Owner, to perform quality control inspection services as required by the current edition of the VDOT LAP Manual. All materials technicians shall be VDOT certified for the testing and inspection required. Testing frequency shall use the Tables of Minimum Requirements for Quality Assurance and Quality Control on Design-Build and P3 Projects published in the latest Minimum Requirements for Quality Assurance and Quality Control on Design Build and Public-Private Transportation Act Projects.

The Owner shall provide a full-time Project Inspector to oversee the work of the Contractor, but this shall in no way relieve the Contractor of his responsibilities required under the contract or VDOT specifications. All test results shall be furnished to the Inspectors and the Engineer upon completion of the individual tests such that records can be kept up to date throughout the project. The contractor shall notify the Inspector immediately upon receipt of a failing test result. Source of materials are required.

DIVISION I – GENERAL PROVISIONS

Comply with Division I of the 2020 Road and Bridge Specifications as amended herein

cn100-000051-00 VDOT SUPPLEMENTAL SPECIFICATIONS (SSs), SPECIAL PROVISIONS (SPs) AND SPECIAL PROVISION COPIED NOTES (SPCNs)

Where Virginia Department of Transportation (VDOT) Supplemental Specifications, Special Provisions and Special Provision Copied Notes are used in this contract, the references therein to “the Specifications” shall refer to the *Virginia Department of Transportation Road and Bridge Specifications*, dated 2020 for both imperial and metric unit projects. References to the “Road and Bridge Standard(s)” shall refer to the *Virginia Department of Transportation Road and Bridge Standards*, dated 2016 for both imperial and metric unit projects. References to the “Virginia Work Area Protection Manual” shall refer to the 2011 edition of the *Virginia Work Area Protection Manual with Revision Number 2.1* incorporated, dated November 1, 2020 for imperial and metric unit projects. References to the “MUTCD” shall refer to the 2009 edition of the *MUTCD with Revision Numbers 1 and 2* incorporated, dated January 12, 2017; and the 2011 edition of the *Virginia Supplement to the MUTCD with Revision Number 1* dated September 30, 2013 for imperial and metric unit projects.

Where the terms “Department”, “Engineer”, “Contract Engineer”, “Construction Engineer”, Materials “Engineer”, and “Operations Engineer” appear in VDOT Supplemental Specifications, Special Provisions and Special Provision Copied Notes used in this contract and the VDOT publication(s) that each references, the authority identified shall be according to the definitions in Section 101.02 of the *Virginia Department of Transportation Road and Bridge Specifications*, dated 2020. Authority identified otherwise for this particular project will be stated elsewhere in this contract.

VDOT Supplemental Specifications, Special Provisions and Special Provision Copied Notes used in this contract and the VDOT publication(s) that each reference are intended to be complementary to the each other. In case of a discrepancy, the order of priority stated in Section 105.12 of the *Virginia Department of Transportation Road and Bridge Specifications*, dated 2020 shall apply.

VDOT Special Provision Copied Notes in this contract are designated with “(SPCN)” after the date of each document. VDOT Supplemental Specifications and Special Provision Copied Notes in this contract are designated as such above the title of each document.

The information at the top and left of each VDOT Special Provision Copied Note in this contract is file reference information for VDOT use only. The information in the upper left corner above the title of each VDOT Supplemental

SECTION 101—DEFINITIONS OF ABBREVIATIONS, ACRONYMS, AND TERMS OF THE SPECIFICATIONS IS AMENDED AS FOLLOWS:

Board. This term shall be interpreted as the Council of the City of Colonial Heights, Virginia.

Commissioner. This term shall be interpreted as the City Manager of the City of Colonial Heights, Virginia.

Commonwealth. Unless otherwise noted, this term shall be interpreted as the City of Colonial Heights, Virginia.

Contract. Replace “Department” with “City of Colonial Heights.”

Contractor. Replace “Department” with “City of Colonial Heights.” Replace “Engineer” with “City Manager.”

Department. Unless otherwise specified, this term shall be interpreted as the Department of Public Works of the City of Colonial Heights.

Engineer. This term shall be interpreted as the City Engineer for the City of Colonial Heights, Virginia.

Laboratory. For this term, “Department” shall be interpreted as the Virginia Department of Transportation.

Liquidated damages. For this term, “Department” shall be interpreted as the City of Colonial Heights.

Prequalification. For this term, “Department” shall be interpreted as the “City of Colonial Heights.

Proposal (Bid Proposal). For this term, “Department” shall be interpreted as the City of Colonial Heights.

Standard drawings. For this term, “Department” shall be interpreted as the Virginia Department of Transportation and the “Road and Bridge Standards” shall be interpreted as the Virginia Department of Transportation Road and Bridge Standards as modified by the Department of Public Works of the City of Colonial Heights.

State Construction Contract Engineer. Unless otherwise specified, this term shall be interpreted as the City Purchasing Agent for the City of Colonial Heights, Virginia.

Vouchered. Replace “State Comptroller” with “Finance Department of the City of Colonial Heights.”

State. This term shall be interpreted as “City”

SECTION 102—BIDDING REQUIREMENTS AND CONDITIONS OF THE SPECIFICATIONS IS AMENDED AS FOLLOWS:

cn102-010100-00

102.01 —Prequalification of Bidders

The Contractor is advised that the provisions of Section 102 of the Specifications requiring Prequalification are waived on this contract.

102.02 —Content of Proposal

In this section, “Department “shall be interpreted as “City Purchasing Agent.”

102.04 —Examination of Site of Work and Proposal

(c) Notice of Alleged Ambiguities

In this section, “Department” shall be interpreted as “City Purchasing Agent.”

Delete the first and second sentences of the first paragraph and replace with the following:

> If a bidder has any questions or doubts about a word, phrase, clause, specification, or any other portion of the Proposal or alleges an ambiguity, conflict, error, or omission, the Bidder shall submit to the City Purchasing Agent a written notice of same at least 5 business days prior to the date of receipt of bids, and request an interpretation thereof.

Delete the phrase “on the CABB” in the first sentence of the second paragraph.

102.05 —Preparation of Bid

In this section, “Department” shall be interpreted as “City Purchasing Agent.”

(a) General

In the first sentence of the first paragraph, delete the word “electronic.”

In first sentence of the third paragraph, delete the phrase “electronically generated.”

In the first sentence of the last paragraph, insert “VDOT” before “Form C-48.”

(c) Debarred Suppliers

In the last sentence of the first paragraph, replace “Department’s Materials Division” with “VDOT’s Material Division.

(e) Acknowledgement of Addenda

In the first sentence, delete the words “electronic” and replace http://cabb.virginiadot.org with “http://www.colonialheightsva.gov/Bids.aspx.”

(f) Signing the Bid

In the first sentence, delete the phrase “with a digital identification.”

102.06 —Irregular Bids

Delete items (c) and (m).

102.07 —Proposal Guaranty

For the purposes of this section, "Department" shall be interpreted as the "City Purchasing Agent."

In the first sentence, replace "$250,000" with "$50,000" and replace "Treasurer of" with "Colonial Heights."

102.08 —Disqualification of Bidders

In item (a-4), replace "Department" with "City Purchasing Agent."

Delete items (a-13) and (a-18)

102.09 —Submission of Bid

In this section, "Department" shall be interpreted as "City Purchasing Agent." In the first paragraph delete the word "electronic" and the last sentence.

102.10 —Withdrawal of Bid

In (a) Standard Withdrawal:

In the first sentence, delete the phrase "as allowed by the electronic bidding system/"

In (b) Conditional Withdrawal:

Replace "completing the portion of the electronic bid for the conditional withdrawal of bids" with "by notifying the City Purchasing Agent."

102.11 —eVA Business-To-Government Vendor Registration

Delete this Subsection.

102.12 —Public Opening of Bids

In the first sentence, replace "Electronic bids will be decrypted, and along with all other" with "Bids will be."

Delete the second and third sentences of this Subsection.

SECTION 103—AWARD AND EXECUTION OF CONTRACTS OF THE SPECIFICATIONS IS AMENDED AS FOLLOWS:

103.01—Consideration of Bids

In this section, "Department" shall be interpreted as "City Purchasing Agent."

103.05 —Requirements of Contract Bond

In the first sentence of the first and second paragraphs, replace "$250,000" with "$50,000."

103.06 —Contract Documents

In this section, "Department" shall be interpreted as "City Purchasing Agent."

103.07 —Failure to Furnish Bonds or Certificate of Insurance

In this section, "Department" shall be interpreted as "City Purchasing Agent."

103.08 —Contract Audit

In this section, "Department" shall be interpreted as "City Purchasing Agent."

103.09 —Execution of Contract

In the first sentence, replace "Department" with "City Purchasing Agent."

cq103-010100-00 **NEGOTIATION WITH THE LOWEST SOLE BIDDER -** In the event the Department receives a single responsive and responsible bid that exceeds available funds, the agency may negotiate with that sole bidder to obtain a contract price within available funds in accordance with the provisions of §2.2-4318 of the Code of Virginia. For the purpose of determining when such negotiations may take place, the term "available funds" shall mean those funds, which were budgeted by the agency for this Contract prior to the issuance of the written Invitation for Bids for the same. Negotiations with the sole bidder may include a change in requirements; including price(s). The agency shall initiate such negotiations by written notice to the sole bidder that its bid exceeded the available funds and that the agency wishes to negotiate a lower contract price within the designated available funds. The time, place, and manner of negotiating shall be agreed to by the agency and the sole bidder.

SECTION 104—SCOPE OF WORK OF THE SPECIFICATIONS IS AMENDED AS FOLLOWS:

cn104-010100-00

SECTION 104.01—INTENT OF CONTRACT of the Specifications is replaced by the following:

The intent of the Contract is to provide for the completion of all work specified therein. The Contractor shall base his bid on the cost of completing all work specified in the Contract. Budgetary constraints as deemed necessary by the Department may be imposed at any time during the life of the Contract. This may affect the length of drainage channel completed and thus the final quantity of work to be performed. If prior to initiating or during the performance of the work, the Engineer determines that the cost of completion of all work specified in the Contract will exceed the limits of the budgeted funds, the Contractor will be notified immediately. With such notice the Engineer will specify which items will be deleted according to the Department’s predetermined listing of priorities. If after items are deleted and work proceeds, budgets revisions indicate that the cost of work to be completed by the Contractor will fall below the limits of the budgeted funds, the Department will determine which of the previously deleted items will be returned to the Schedule to be completed at the contract unit price.

10-21-08; Reissued 7-12-16 (SPCN)

SECTION 105—CONTROL OF WORK OF THE SPECIFICATIONS IS AMENDED AS FOLLOWS:

105.01—Notice to Proceed

Replace this subsection with the following:

The Department will issue Notice to Proceed after the Contract is executed. Contract Time will commence on the date of the Notice to Proceed. In no case shall any work begin before the Department executes the Contract. The Contractor shall notify the Engineer at least 72 hours prior to the date on which he plans to begin onsite work. The Department will contact the Contractor after award of the Contract to arrange a pre-construction conference.

105.03 —Authorities of Project Personnel

(a) Authority of Engineer

Add the following at the end of this list item:

The Engineer may designate a Project Manager as its representative on the Project with authority to enforce the provisions of the Contract. When the Engineer has designated a Project Manager, the Contractor should direct all requests for clarification or interpretation of the Contract, in writing, to the Project Manager. The Project Manager will respond within a reasonable time. Contract clarification or interpretation obtained from persons other than the Project Manager will not be binding on the Agency. The Project Manager shall have the authority to appoint other personnel as required to assist in the administration of the Contract.

105.07—Cooperation of Contractor

Add the following at the end of this subsection

The Contractor shall appoint a single designated representative responsible for the Project described in writing.

The Contractor's failure to provide the superintendence required by these provisions constitutes a material breach of the Contract, and the Engineer may impose any remedies available under the Contract, including but not limited to Contract termination or suspension of Contract performance.

105.10 —Plans and Working Drawings

(a) General

In this subsection "Department" refers to the Virginia Department of Transportation (VDOT). In the last sentence of the first paragraph, "Contract Engineer" shall be interpreted as the appropriate VDOT official.

(b) Plans

Delete the first paragraph including the embedded table.

105.14—Maintenance during Construction

Add the following at the beginning of this subsection:

The Contractor's responsibilities for maintenance during construction begin on the day any onsite work begins within the limits of the Project.

(b) Maintenance of Traffic

6. Connections and Entrances

In the second paragraph, delete the phrase "When specified in the Contract,"

SECTION 105—CONTROL OF WORK

SECTION 105—CONTROL OF WORK OF THE SPECIFICATIONS IS AMENDED AS FOLLOWS:

Section 105.12—Coordination of Plans, Standard Drawings, Specifications, Supplemental Specifications, Special Provisions, and Special Provision Copied Notes of the Specifications is replaced with the following:

The plans, Standard Drawings, Specifications, Supplemental Specifications, Special Provisions, Special Provision Copied Notes, and other Contract Documents defined in Section 103.06 are parts of the Contract. A requirement occurring in one Contract Document shall be as binding as though occurring in all. The Contract Documents are intended to be complementary, and to include, describe and provide all items necessary for the Contractor's proper and complete performance of the Work.

In case of a discrepancy, the following order of priority will apply, with the highest governing item appearing first and the least governing item appearing last:

(a) Special Provision Copied Notes. The Contract items, units and unit prices listed in the Contract's Schedule of Items have the same status as Special Provision Copied Notes.
(b) Special provisions.
(c) Plans.
(d) Supplemental Specifications. Those present in the physical, executed Contract will govern over those published in the annual supplemental volume.
(e) Specifications.
(f) Standard Drawings (including all revisions issued through the date of Advertisement).

Calculated dimensions, unless obviously incorrect, will govern over scaled dimensions.

Drawings (with the exception of Standard Drawings), sketches, general notes, and other written information that are not included in Special Provisions or Special Provision Copied Notes used in No Plan and Minimum Plan Concept projects will have the same status as plans.

The Contractor shall not take advantage of any obvious or apparent ambiguity, conflict, error or omission in the plans or the Contract. If after beginning work the Contractor discovers an ambiguity, conflict, error, or omission in the Contract, he shall immediately notify the Engineer and before proceeding further with the affected work. The Engineer will then make such corrections and interpretations as may be deemed necessary for fulfilling the intent of the Contract.

Section 105.17—Inspection of Work is amended by replacing the third paragraph with the following:

If the Engineer requests it, the Contractor shall remove or uncover such portions of the finished work as may be directed at any time before final acceptance. The Contractor shall restore such portions of the finished work to comply with the appropriate contract specification requirements. If the work exposed does not contain a defect, the uncovering or removing and replacing the covering or making good the parts removed will be paid for as extra work in accordance with Section 104.02 of the Specifications. If the uncovered work contains a defect, the cost of uncovering or removing and replacing the covering or making good the parts removed shall be borne by the Contractor whether or not the Engineer directs the Contractor to mitigate the defective work. Acceptance of substandard work does not negate the presence of the defect. For the purposes of this section, a defect shall mean any part of the Work that does not conform to the Contract

SECTION 106—CONTROL OF MATERIAL

OF THE SPECIFICATIONS IS AMENDED AS FOLLOWS:

106.01—Source of Supply and Quality Requirements

In the first paragraph, replace the third sentence with the following:

> Not later than seven (7) days before the date of the Preconstruction Conference, the Contractor shall submit a statement of the known origin, composition and manufacture of all materials to be used in the work, including optional or alternate items.

In the last sentence of the first paragraph, insert “VDOT” before “Form C-25.”

VIRGINIA DEPARTMENT OF TRANSPORTATION

2020 ROAD AND BRIDGE SUPPLEMENTAL SPECIFICATIONS

SECTION 106—CONTROL OF MATERIAL

SECTION 106—CONTROL OF MATERIAL OF THE SPECIFICATIONS IS AMENDED AS FOLLOWS:

Section 106.08—Storing Materials is amended to replace the third paragraph with the following:

Chemicals, fuels, lubricants, bitumens, paints, raw sewage, and other potential pollutant-generating materials as determined by the Engineer or defined in the VPDES *General Permit For Discharge of Stormwater from Construction Activities* shall not be stored within any flood-prone area unless no other location is available. A flood-prone area is defined as the area adjacent to the main channel of a river, stream or other waterbody that is susceptible to being inundated by water during storm events and includes, but is not limited to, the floodplain, the flood fringe, wetlands, riparian buffers or other such areas adjacent to the main channel. If stored in a flood-prone area, the material shall be stored in one or more secondary containment structures with an impervious liner and be removed entirely from the flood-prone area at least 24 hours prior to an anticipated storm event that could potentially inundate the storage area. Any storage of these materials outside of a flood- prone area that is in proximity to natural or man-made drainage conveyances where the materials could potentially reach a river, stream, or other waterbody if a release or spill were to occur, must be stored in a bermed or diked area or inside a secondary containment structure capable of preventing a release. Any spills, leaks or releases of such materials shall be addressed according to Section 107.16(b) and (e) of the Specifications. Accumulated rain water shall be pumped out of impoundment or containment areas into approved filtering devices. All proposed pollution prevention measures and practices must be identified by the Contractor in his Pollution Prevention Plan as required by the Specifications, other Contract documents and/or the VDPES *General Permit for Discharge of Stormwater from Construction Activities.*

SECTION 107—LEGAL RESPONSIBLILITIES

OF THE SPECIFICATIONS IS AMENDED AS FOLLOWS:

107.14 —Equal Employment Opportunity

In list item (g), insert “VDOT” before “Form C-57.”

107.15 —Use of Small, Women-Owned, and Minority-Owned Businesses (SWaMs)

Delete this subsection in its entirety.

SECTION 108—PROSECUTION AND PROGRESS OF WORK OF THE SPECIFICATIONS IS AMENDED AS FOLLOWS:

108.01—Prosecution of Work

In the third paragraph, replace “24 hours” with “72 hours.”

Add the following at the end of this subsection:

The Contractor shall not commence the Work until Notice to Proceed is issued by the Engineer or City Purchasing Agent.

cn108-010100-00 **SECTION 108.01—PROSECUTION OF WORK**

Once the Contractor has begun work on a given schedule or portion thereof he shall endeavor to prosecute such work fully and continuously according to the details and requirements of the Contract to its completion. In the event the Contractor has to temporarily suspend the work on a given schedule or portion thereof he shall notify the Engineer at least 24 hours in advance of the time and date he plans to pull off the work site. Prior to leaving the work site, the Contractor shall ensure the work site has been properly and safely secured to protect the traveling public according to the provisions of the *Virginia Work Area Protection Manual*, the *MUTCD*, Section 512 of the Specifications, and other requirements included in the Contract.

8-17-10; Reissued 7-12-16 (SPCN)

108.03 —Progress Schedule

Replace this subsection with the following:

PROGRESS SCHEDULE FOR CATEGORY I

PROJECTS I. GENERAL REQUIREMENTS

The Contractor shall plan and schedule the work and shall submit his initial plan in the form of a Baseline Progress Schedule for the Engineer's review and acceptance. Upon acceptance, the Progress Schedule shall become the project Schedule of Record (SOR). The SOR shall be used by the Engineer for planning and coordination of the Department activities, and for evaluation of the Contractor's progress and the effects of time-related related impacts on the project.

Prior to preparing the schedule, the Engineer or the Contractor may request a schedule development planning meeting to discuss any project specific items required for preparation of the progress schedule. The Contractor shall prepare and submit a practicable schedule to reflect a logical progress of the work. The Progress Schedule shall represent the Contractor's overall work plan to accomplish the entire scope of work in accordance with the requirements of the Contract. It shall include all items of work required for coordination and inspection and to show progress of the work including, but not limited to the controlling items of work and other relevant time-based tasks required for timely completion of the work, including as applicable, the work to be performed by sub-contractors, suppliers, the City, and/or others. When preparing the schedule, the Contractor shall consider all known constraints and restrictions such as holidays, seasonal, weather, traffic, utility, railroad, right-of-way, environmental, permits, or other limitations to the work.

The Contractor may be required, as determined by the Engineer, to attend a pre-construction scheduling conference. If required, the scheduling conference may be held in conjunction with the pre-construction conference or at a separate meeting called by the Engineer. At the scheduling conference, the Contractor shall provide the Project Manager with a Baseline Progress Schedule for review, indicating at a minimum the dates for commencing and completing the Work. The Contractor shall be prepared to discuss his planned or contemplated operations relative to the contract requirements and this special provision. Until the Baseline Progress Schedule is accepted by the Engineer, the Contractor shall keep the Engineer informed of his planned or contemplated operations on a continuing basis.

II. PROGRESS SCHEDULE SUBMITTAL REQUIREMENTS

Baseline Progress Schedule – The Contractor shall submit to the Engineer his initial progress schedule in the form of a Baseline Progress Schedule at least seven (7) calendar days prior to beginning work. The Baseline Progress Schedule shall include a written Progress Schedule Narrative and a Progress Earnings Schedule. *Progress Earnings Schedules will not be required for projects with contract duration of sixty (60) calendar days or less*. The Contractor shall submit three
(3) sets of the written Progress Schedule Narrative and the Progress Earnings Schedule as defined herein:

1. Progress Schedule Narrative: The Progress Schedule Narrative shall consist of the following written information:

a) A description of the Contractor's overall plan of operations including the planned procedures and crew(s) required to complete each feature or major operation;

b) A Tabular Schedule to establish milestone(s) for completing each phase or stage of work, feature, major traffic switch, and other key milestone dates as specified in the Contract or required to assess progress of the work. The schedule shall also indicate the planned sequence and start/finish dates for each operation, maintenance of traffic (MOT) activities, and other relevant time-based tasks required to complete the work;

c) A discussion on the proposed working calendar to indicate the number of working days per week as well as the anticipated number of non-working days per month with considerations for known constraints or restrictions; (i.e. normal weather, traffic, holidays, time of year, utility, etc.);

d) A description of any potential issues that may impact the schedule.

2. Progress Earnings Schedule: The Progress Earnings Schedule shall be prepared on the Form C-13C. The Progress Earnings Schedule shall indicate the Contractor's anticipated cumulative percent complete for each month as of the Contractor's progress estimate date as defined in Section 109.08(a) of the Specifications. The anticipated cumulative percent complete shall be based on the anticipated cumulative progress earnings relative to the total contract value. Total contract value will be considered to mean the original amount of the contract including any authorized adjustments for changes to the work in accordance with, but not limited to, the provisions of Sections 109.04 and 109.05 of the Specifications. Anticipated payments for Material on Hand in accordance with Section 109.09 of the Specifications or for other adjustments including asphalt, fuel, retainage, liquidated damages, incentives, disincentives, etc., will not be considered in the Progress Earnings Schedule.

Revised Progress Schedule - A Revised Progress Schedule will be required when:

• The Contractor proposes to revise his work plan. (The Contractor may revise his Progress Schedule at any time at his discretion.)

• The Engineer determines the Contractor's work plan or the progress of the work differs or deviates significantly from the SOR. Differs or deviates significantly will be construed to mean major deviations from the SOR that will affect the schedule milestone(s), progress earnings, or project completion.

• The Engineer issues a written request for changes or a directive for changes

• Any of the above conditions impacts or will impact the progress earnings or scheduled dates of any project milestones including project completion Examples of changes, relative to the above, that will prompt the Engineer to require a Revised Progress schedule include but are not limited to: major deviations from the SOR such as changes to phasing, changes to the general sequence, changes to the proposed method or means, additions or deletions to the work, unanticipated changes deemed beyond the Contractor's control such as those caused by other parties (utilities and railroads) or changes as defined in Section 104 of the Specifications.

When required by the Engineer, the Contractor shall submit the Revised Progress Schedule within ten (10) calendar days of receipt of the Engineer's written request. The Revised Progress Schedule shall be prepared and submitted in the form of a Baseline Progress Schedule; however, it shall reflect the actual progress of accomplished work, including actual dates for completed work or work in progress, any impact of a change, and the proposed plan for completing the remaining work. The Revised Progress Schedule submittal will be reviewed by the Engineer for acceptance as specified herein.

Failure to Furnish Progress Schedules – Work shall not commence until the Contractor submits his complete Baseline Progress Schedule in accordance with the requirements of this special provision, unless otherwise approved in writing by the Engineer.

Delays in work resulting from the Contractor’s failure to provide the progress schedule will not be considered just cause for extension of the contract time limit or for additional compensation.

III. REVIEW AND ACCEPTANCE

The Engineer will review all progress schedule submittals within seven (7) calendar days of receipt of the Contractor’s complete submittal. The progress schedule submittal shall be considered complete only when all required submittal items and schedule information as defined herein are provided.

Acceptance by the Engineer will be based on completeness and conformance with the requirements of this provision and the Contract. Such contract requirements may include phasing, sequence of construction, Maintenance of Traffic (MOT), interim milestone(s), or other specified constraints or restrictions.

If the Contractor’s progress schedule is deemed to be unacceptable, the Engineer will issue a written notification of non-conformance or incompleteness with a request for resubmission. The Engineer’s response will include comments describing the deficiencies prompting the Engineer’s decision.

If the Contractor’s progress schedule is deemed to be acceptable, the Engineer will issue a written notice of acceptance that may include comments or concerns on the schedule or a request for clarification. When the Engineer’s responses include any comments, concerns, or requests for clarification, the Contractor shall respond accordingly within seven (7) calendar days of receipt of the Engineer’s response. Failure on the part of the Contractor to respond to the Engineer may adversely affect the Engineer’s ability to completely evaluate the Contractor’s schedule.

Upon acceptance, the Progress Schedule will become the Schedule of Record (SOR) and will replace any previous SOR. For the purposes of this Special Provision the SOR is defined as the currently accepted progress schedule by which all schedule references will be made and progress will be compared. The SOR will be basis for evaluating the effects of any time-related changes or impacts on the work.

Review and acceptance by the Engineer will not constitute a waiver of any contract requirements and will in no way assign responsibilities of the work plan, scheduling assumptions, and validity of the schedule to the Department. Failure of the Contractor to include in the Progress Schedule any element of work required by contract for timely completion of the project shall not excuse the Contractor from completing the entire scope of work within the contract specified completion milestone(s).

IV. MONITORING THE WORK AND ASSESSING PROGRESS

Monitoring The Work – The Engineer will monitor the work regularly to identify any deviations from the Contractor's scheduled performance relative to the SOR. The Engineer may request a meeting with the Contractor to discuss the Contractor's current progress or to review the approximate date for starting each critical inspection stage during the following thirty (30) calendar days. At least once a week, the Contractor shall advise the Engineer of the approximate timing for anticipated critical stages for the subsequent week. The Engineer shall be advised at least twenty-four (24) hours in advance of any changes in the Contractor's planned operations or critical stage work requiring Department inspection.

Progress Evaluation – Progress will be evaluated by the Engineer at the time of the monthly progress estimate relative to the currently accepted Baseline or Revised Progress Schedule. The Contractor's actual progress may be considered unsatisfactory if any of the following conditions occurs:

1. The actual Total earnings to date percentage for work completed is more than ten (10) percentage points behind the cumulative earnings percentage for work scheduled; or

2. Any interim milestone is later than the scheduled milestone by fourteen (14) calendar days or the projected project completion date is later than the contract completion date by fourteen (14) calendar days or ten (10) percent of the contract duration, whichever is less.

Progress Deficiency and Schedule Slippage – When the Contractor's actual progress is trending toward unsatisfactory status, the Engineer will encourage the Contractor to meet to specifically and substantially discuss reversing this trend and the steps he is taking to recover satisfactory progress.

If the Contractor is temporarily disqualified from bidding on contracts with the Department, the Contractor will not be reinstated until either the Engineer deems that his progress has improved to the extent that the work can be completed within the contract time limit or the project has received final acceptance in accordance with the provisions of Section 108.09 of the Specifications.

V. MEASUREMENT AND PAYMENT

Category I progress schedule submittals including the baseline and any subsequent revisions requested by the Engineer as described herein, will not be measured or paid for separately. All associated costs to prepare, revise, and/or furnish the progress schedules for Category 1 projects in accordance with the requirements herein shall be considered incidental to the work.

SECTION 109—MEASUREMENT AND PAYMENT OF THE SPECIFICATIONS IS AMENDED AS FOLLOWS:

109.01—Measurement of Quantities

(b) Measurement by Weight:

In this subsection, “Department” shall be interpreted as the Virginia Department of Transportation.

109.08 —Partial Payments

(a) General

Replace the second paragraph with the following:

The monthly progress estimate will be prepared on the 5th business day of each month, beginning on the first 5th business day following the date of the Notice to Proceed, and on the same day of the succeeding months as the work progresses.

DIVISION II – MATERIALS

Comply with Division II of the 2020 Road and Bridge Specifications.

DIVISION III – ROADWAY CONSTRUCTION

Comply with Division III of the 2020 Road and Bridge Specifications.

DIVISION V – INCIDENTAL CONSTRUCTION

Comply with Division V of the 2020 Road and Bridge Specifications.

DIVISION VI – ROADSIDE DEVELOPMENT

Comply with Division VI of the 2020 Road and Bridge Specifications.

APPENDIX A

<u>Special Provisions:</u>

Page 18 – Modifications to AASHTO's Sign Structure Specification

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION FOR
MODIFICATIONS TO AASHTO'S SIGN STRUCTURE SPECIFICATION

I. GENERAL REQUIREMENTS

Lighting (conventional and high mast), signal (overhead, mast arm and span wire), pedestal poles, overhead (span, cantilever and butterfly) sign structures, and ITS structures (camera poles, dynamic message signs (DMS), etc.) shall conform to the requirements of the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, 6th Edition (LTS-6), 2013 with 2015 and 2019 interims* as modified by this Special Provision. Any AASHTO Specification optional design parameter noted as "may be used at the discretion of the owner" that are not addressed in this document shall not be used for design.

Square tube sign post (STP-1 and STP-2), wood post, SSP-VA and SSP-VIA structures shall be provided in accordance with the requirements as shown in the Standard Drawings.

II. WIND LOADING (LTS-6 Article 3.8 and Appendix C)

1. The alternate method for wind pressures provided in AASHTO Appendix C shall be used. Linear interpolation between wind contours is not permitted. The next higher contour shall be used for design. Reduced forces shall not be used for free swinging traffic signal and free swinging sign wind loadings.

2. **LTS-6 Article C.2** is supplemented with the following: Wind speeds using 50-year mean recurrence shall be used for all conventional light poles, high mast light poles, ITS device support poles, and overhead sign structures (span, cantilever and butterfly).

3. Mast arm signal poles, mast arms, and strain poles shall be designed using the following wind speeds:

District	Design Wind Speed for strain poles, mast arms, and mast arm poles
Bristol, Salem, Lynchburg, Staunton and Culpeper	70 mph
Richmond, Northern Virginia and Fredericksburg	80 mph
Hampton Roads	90 mph

   Ancillary structures procured under regional signal contracts that encompass multiple districts shall be designed for the District with the greatest wind speed within that Region.

   Mast arm signal pole and strain pole foundations shall be designed for wind speeds at the foundation location using the 25-year mean recurrence.

4. For special wind regions in Bristol District shown in Figure 3.8.3-2 of LTS-6, the selection of the design wind speed shall consider localized effects. The minimum design wind speed for 50 year mean in these areas is 90 MPH, 25 year mean in these areas is 80 MPH and 10 year mean in these areas is 70 MPH.

5. For structures elevated above the surrounding terrain (e.g. bridge mounted light pole, overhead sign, and other structures), the height factor shall be increased to account for the increased wind effects.

III. STEEL DESIGN

1. **Laminated Structures (LTS-6 Article C5.1):** Laminated or multi-ply structures shall only be used in tapered sections.

2. **Holes and Cutouts, Unreinforced and Reinforced (LTS-6 Article 5.14.5):** The location and size of hand holes and cutouts shall be in accordance with the details shown in the Standard Drawings. For high mast light poles, the width of unreinforced and reinforced holes and cutouts in the cross-sectional plane of the tube shall not be greater than 50 percent of the tube diameter at that section.

3. **Welding:** A connection detail using a full penetration groove weld with a backing ring may be considered for all traffic structures. For tubes 18” diameter and greater, the backing ring shall be attached at the top and bottom face of the ring using a continuous fillet weld. For tubes less than 18” diameter, the backing ring shall be attached at the bottom face using a continuous fillet weld and the top shall be caulked to provide a thick durable continuous seal. The caulk shall be a durable material approved by the Engineer which is formulated for this type of Industrial application.

4. **Diameter:** Mast arm signal pole structures shall have the following maximum column and arm outside diameters, unless otherwise approved by the Engineer.

Configuration	Arm Length	Design Loading	Max. column diameter at base of column	Max. arm diameter at base of arm
Dual arm	Length of one arm exceeds 70 feet or total length of both arms exceeds 130 feet	Varies (Project specific loads will be provided on the Plans)	22 inches	20 inches
	All other dual-arm structures	Design loading does not exceed Standard Drawing MP-3	20 inches	18 inches
Single arm	> 75 feet	Varies (Project specific loads will be provided on the Plans)	22 inches	20 inches
	≤ 75 feet	“Case 2” loading as per Standard Drawing MP-3	22 inches	20 inches
		“Case 1” loading as per Standard Drawing MP-3	20 inches	18 inches

IV. FATIGUE DESIGN

1. **Fatigue Importance Categories (LTS-6 Article 11.6):** The following fatigue importance categories shall apply to structures:

Fatigue Importance Categories

Structure Type	Span Length[1], ft.	Fatigue Category

All structures supporting dynamic message signs or partial dynamic message signs[3]	All span lengths	Category I
Overhead sign span structure	> 150	Category I
	≤ 150	Category II
Overhead sign cantilever structure	> 50	Category I
	≤ 50	Category II
Overhead sign butterfly structure	All span lengths	Category II
Signal mast arm structure[2]	> 75	Category I and an approved mitigation device
	50 to ≤ 75	Category II
	< 50	No fatigue design required
Overhead signal structure	> 190	Category I
	≤ 190	Category II
High mast light poles	All lengths	Category I
Signal span wires, conventional lights poles and ITS device support poles (excluding DMS)		No fatigue design required

[1]Span length is defined as center-to-center of column(s) for span structure and face-of-column to tip of arm for cantilever and signal structures.
[2]For twin mast arms, the pole, arms and connections shall be designed for the applicable fatigue category for the longest arm attached.
[3]For signs that are a combination of primarily static sign panels and thin dynamic message elements, if less than 40% of the sign consist of thin dynamic message elements, the sign may be treated as a static sign for the purposes of determining appropriate fatigue category as long as the thickness of the partial dynamic sign does not exceed 14 inches. A special design is required for the attachment of these structures; the weight and thickness of the thin dynamic message sign element shall be included in the structural analysis.

2. **Mitigation Devices (LTS-6 Article 11.6 and 11.7.1):** Mitigation devices shall not be used in lieu of designing for fatigue. Approved mitigation devices shall be used for Signal Mast Arm Structures greater than 75 feet in addition to Fatigue Category I design.

3. **Aluminum light poles (LTS-6 Article 11.6 and 11.7.1):** Internal first and second mode vibration dampeners shall be provided and installed according to the manufacturer's instructions in all cases. External dampeners may be used if approved by the Engineer.

4. **Galloping Loads (LTS-6 Article 11.7.1):** Galloping loads shall not be considered in the design of overhead sign cantilevered structures with four chord trusses, signal mast arm structures, and multi-chord overhead signal structures.

5. **Truck-Induced Gust Loads (LTS-6 Article 11.7.1.3):** Truck induced gust loads shall not be considered in the design of signal mast arm and overhead signal structures.

6. **Vertical Deflection (LTS-6 Article 11.8):** The vertical deflection of the free end of the arm for overhead sign cantilevered structures due to the wind load effects of galloping or truck-induced gusts shall not exceed 8".

V. FOUNDATION DESIGN

The AASHTO Standard Specifications for Highway Bridges, 1996, and the 1997 and 1998 Interim Specifications, as referenced in the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*, are modified as follows:

1. **Geotechnical Design:** The factor of safety shall be as follows:

MINIMUM FACTORS OF SAFETY[1]

	Drilled Shaft		
	Overhead Sign Structures and all other types of ancillary structures except for Mast arm traffic Signals	**Mast arm traffic Signals**	**Spread Footing**
Axial resistance/ Bearing pressure	1.75	1.75	2.0
Torsion/Sliding/Skin Friction	1.75[2]	1.3[2]	1.2[3]
Overturning (Broms Method)	See horiztonal deflection limits	See horizontal deflection limits	1.5

[1]The factors of safety shown above already account for the 1.33/1.40 group overload/overstress factor. No reduction shall be applied to the design loading used in the analysis.
[2]Torsion Resistance may be evaluated using the rational method as presented in FHWA-NHI-10-016 Drilled Shafts for Construction Procedures and LRFD design methods. A value of 1.0 shall be used in lieu of the resistance factors.
[3]Passive resistance shall be reduced by 50% to limit foundation movement.

In capacity calculations for the foundation design of a drilled shaft, the soil resistance of the top 2.0 feet shall be neglected in the analysis for torsion/skin friction/overturning. Soil resistance from the shaft bottom shall not be included in either torsional or axial resistance of the shaft.

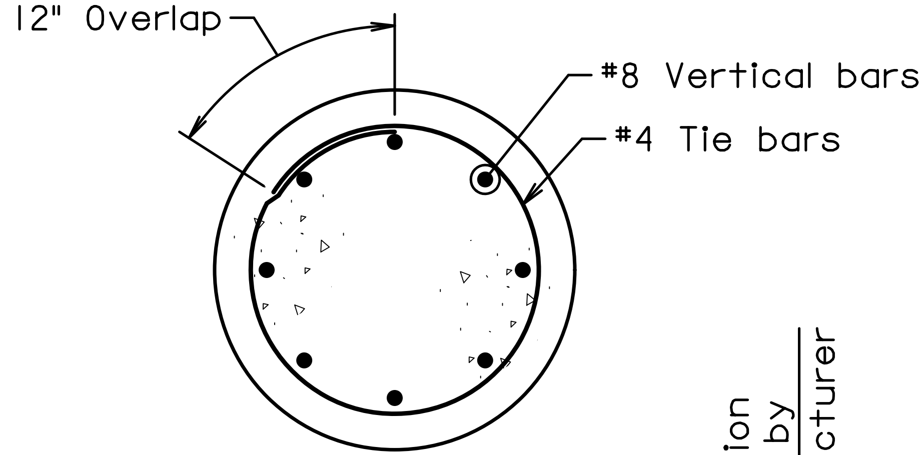
2. **Horizontal Deflection Limits:** In lieu of Broms method, COM624P or other commercially available software may be used to evaluate the overturning of shafts and to estimate shaft deflections. For mast arm signals and span wire signals, the total horizontal deflection shall be limited to 0.75 inches at the ground level and the tip of the pile deflection shall not exceed -0.25 inches. For other structures, the total horizontal deflection shall be limited to 0.50 inches at the ground level and the tip of the pile deflection shall not exceed -0.15 inches. The loading used in the analysis shall not be reduced by the allowable overload/overstress factor. The shafts shall be modeled such that the nonlinear flexural rigidity (non-linear EI, or “cracked” section) is accounted for when the horizontal deflections are calculated.

3. **Reinforcement:** Where tremie placement of concrete is anticipated, a minimum spacing of 5 inches or 10 times the size of the largest coarse aggregate whichever is greater shall be provided in both horizontal and vertical direction. For dry shafts, a smaller space of 5 times the size of the largest coarse aggregate may be considered. A dry shaft is when the amount of standing water in the base of the shaft prior to concreting is less than or equal to 3 inches and water is entering the shaft at a rate of less than 12 inches/hour.

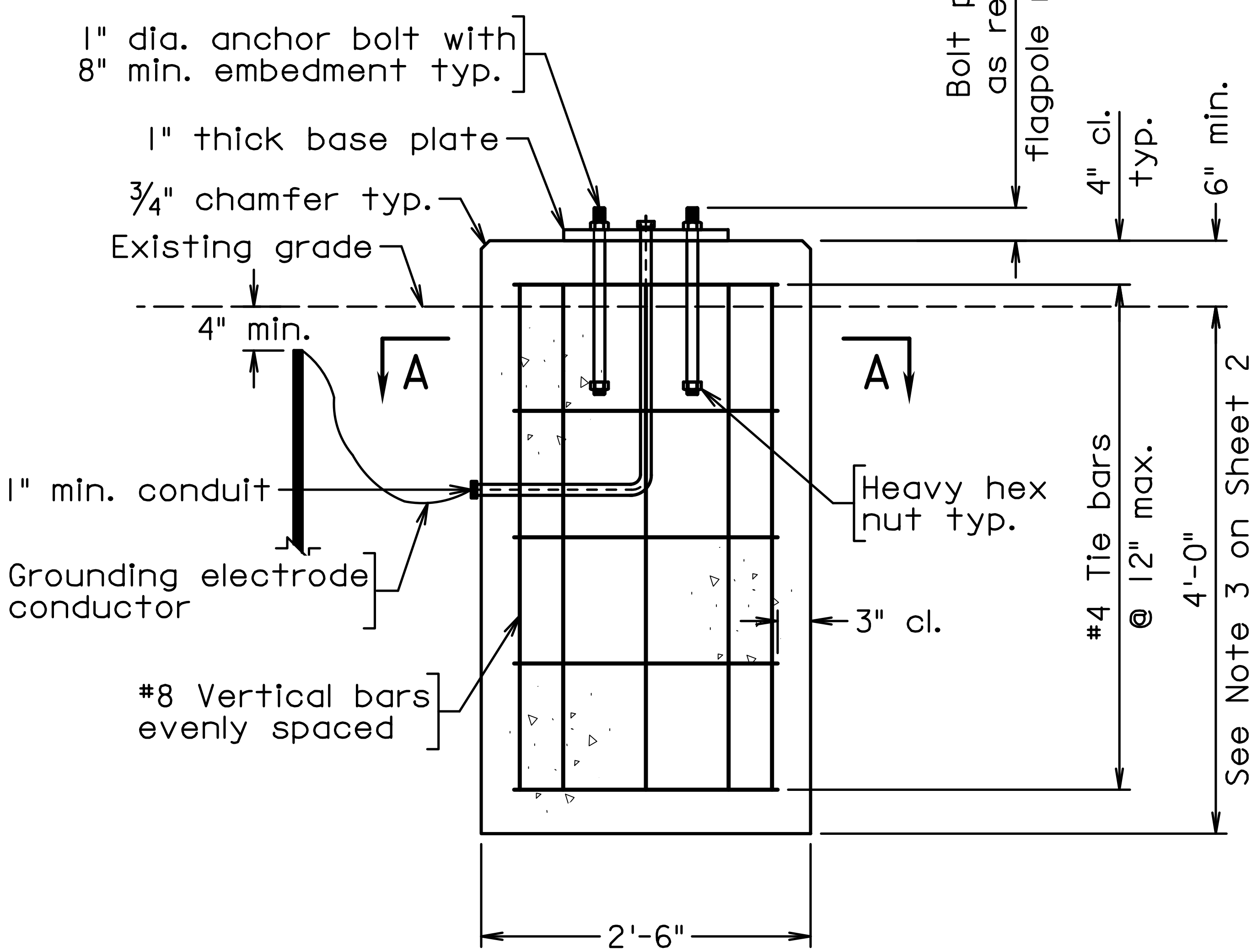
4. **Drilled Shafts:** For mast arm traffic signals with an arm 60 feet or greater, the minimum length of drilled shaft shall be 10 feet of embedment unless a spread footing is proposed.

APPENDIX B

Flagpole Foundation Details:

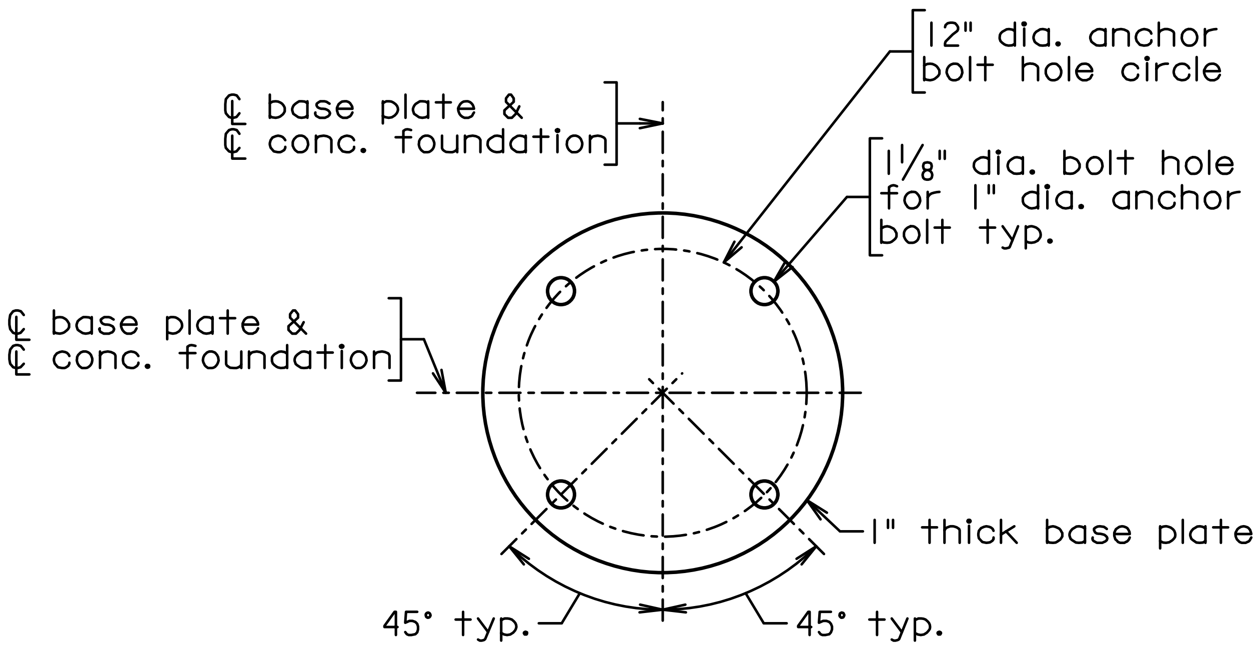


SECTION A-A



ELEVATION

FLAGPOLE FOUNDATION DETAILS 1	Scale: ¾" = 1'-0"



BASE PLATE DETAIL

Notes:

1. Concrete for foundation shall have a minimum compressive strength of 3,000 psi.

2. Steel for base plate shall confirm to A36, Grade 36. Anchor bolts and nuts shall conform to and be galvanized in accordance with 226.02(c) of the Standard Specifications.

3. Top of foundation shall be sloped to drain.

4. The required depth of the foundation shall be measured from the bottom of the foundation to the lowest grade elevation adjacent to the foundation.

5. The bolt template shall be furnished by the flagpole manufacturer. Flag pole shall be centered on foundation and attached to the base plate as determined by the flag pole manufacturer.

6. Anchor bolts shall be straight. Threaded reinforcing steel is not allowed. ¼" anchor ring plate may be used to keep anchor bolts plumb during installation. For additional details, see Standard AB-1.

7. No mortar, grout, or concrete shall be placed between bottom of base plate and top of foundation.

FLAGPOLE FOUNDATION DETAILS 2	Scale: 1½" = 1'-0"

APPENDIX C

Structural Design Details:

DESIGN CALCULATIONS FOR:

Concord Industries

Exit 54 Roundabout

Colonial Heights, VA

30' Flagpole

Analysis	**Concord Industries**
Reviewed by:	**Darren S. Antle, P.E.**
Comm#:	**240209-078-02**

MBI Companies Inc.
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Phone: (865) 584-0999

April 3, 2025

CONCORD AMERICAN FLAGPOLE
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Round Pole Design Calculations & Loading Analysis

CAFP Pole Design: *ESR30C61-SAT*
Calculation Date: *09/17/2024*
Calculations Prepared By: *Jonathan Pinchback, Product Design Engineer*

These calculations are based on the *Guide Specifications For Design Of Metal Flagpoles, ANSI/NAAMM FP 1001-7.*

AASHTO LTS-6 AND VDOT SP700-000180-03

Wind Loading Criteria:

$U_D := 90 \cdot mph$	Design Wind Speed (*3-Second Gust*)
$G_{eff} := 1.14$	Gust Effect Factor
$\alpha := 9.5$	Height Exponent (*Exposure Cat. C*)
$z_g := 900 \cdot ft$	Boundary Layer Height (*Exposure Cat. C*)
$H_{Pier} := 0 \cdot ft + 0 \cdot in$	Pier Height (*Above Grade*)

Load & Safety Factors:

$\gamma_D := 1.00$	Dead Load Factor
$\gamma_W := 1.00$	Wind Load Factor

Shaft Dimensional Parameters:

$D_B := 6 \cdot in$	Bottom Diameter
$D_T := 3.5 \cdot in$	Top Diameter
$t_w := 0.156 \cdot in$	Nominal Wall Thickness
$L_{botst} := 16 \cdot ft + 3 \cdot in$	Bottom Straight Length
$L_{taper} := 13 \cdot ft + 9 \cdot in$	Tapered Length
$L_{topst} := 0 \cdot ft + 0 \cdot in$	Top Straight Length

$L_{total} := L_{botst} + L_{taper} + L_{topst}$

$L_{total} = 30.000\ ft$ Total Shaft Length

$n_{taper} := 1$	Taper Exponent
$k_{eff} := 2.00$	Effective Length Factor

Shaft Material Properties:

The pole shaft is made of 6063-T6 aluminum.

$E_{6063} := 10100 \cdot ksi$	Modulus of Elasticity (*6063 Al.*)
$\rho_{6063} := 0.1 \cdot pci$	Material Density (*6063 Al.*)
$Ftu_{6063} := 30 \cdot ksi$	Ultimate Tensile Strength (*6063-T6*)
$Fty_{6063} := 25 \cdot ksi$	Tensile Yield Strength (*6063-T6*)
$Fcy_{6063} := 25 \cdot ksi$	Compressive Yield Strength (*6063-T6*)
$Fsu_{6063} := 18 \cdot ksi$	Ultimate Shear Strength (*6063-T6*)
$Fsy_{6063} := 15 \cdot ksi$	Yield Shear Strength (*6063-T6*)
$kt_{6063} := 1.00$	Tension Coefficient (*6063-T6*)

Unreinforced Handhole Parameters:

$z_{cut} := 0 \cdot ft + 0 \cdot in$	Height to Center of Cutout
$\theta_{cut} := 0 \cdot deg$	Angle to Cutout (*CCW from front*)
$w_{cut} := 0 \cdot in$	Cutout Width
$l_{cut} := 0 \cdot in$	Cutout Length

Loading Inputs:

The loading inputs shown below have been either provided to CAFP or assumed. If any loads appear to be incorrect, unaccounted for, or have changed since these calculations were produced, please contact CAFP Engineering for revised calculations.

Flag 1:

$V_{F_1} := 6 \cdot ft$ Flag Vertical Dimension

$H_{F_1} := 10 \cdot ft$ Flag Horizontal Dimension

$\gamma_{F_1} := 0.0010 \cdot lbf$ Flag Material Load Factor

$z_{F_1} := 27 \cdot ft + 0 \cdot in$ z Coordinate of Flag

Flag 2:

$V_{F_2} := 5 \cdot ft$ Flag Vertical Dimension

$H_{F_2} := 8 \cdot ft$ Flag Horizontal Dimension

$\gamma_{F_2} := 0.0010 \cdot lbf$ Flag Material Load Factor

$z_{F_2} := 21 \cdot ft + 6 \cdot in$ z Coordinate of Flag

Flag 3:

$V_{F_3} := 0 \cdot ft$ Flag Vertical Dimension

$H_{F_3} := 0 \cdot ft$ Flag Horizontal Dimension

$\gamma_{F_3} := 0.0010 \cdot lbf$ Flag Material Load Factor

$z_{F_3} := 0 \cdot ft + 0 \cdot in$ z Coordinate of Flag

Yard Arm:

$D_{YA} := 0 \cdot in$ Diameter of Yard Arm

$L_{YA} := 0 \cdot ft + 0 \cdot in$ Length of Yard Arm

$t_{YA} := 0 \cdot in$ Thickness of Yard Arm

$z_{YA} := 0 \cdot ft + 0 \cdot in$ z Coordinate of Yard Arm

$V_{F.YA} := 0 \cdot ft$ Yard Arm Flag Vertical Dimension

$H_{F.YA} := 0 \cdot ft$ Yard Arm Flag Horizontal Dimension

$\gamma_{F.YA} := 0.0010 \cdot lbf$ Yard Arm Flag Material Load Factor

Gaff:

$D_{GA} := 0 \cdot in$ Diameter of Gaff

$L_{GA} := 0 \cdot ft + 0 \cdot in$ Length of Gaff

$t_{GA} := 0 \cdot in$ Thickness of Gaff

$\theta_{GA} := 0 \cdot deg$ Angle of Gaff

$z_{GA} := 0 \cdot ft + 0 \cdot in$ z Coordinate of Gaff

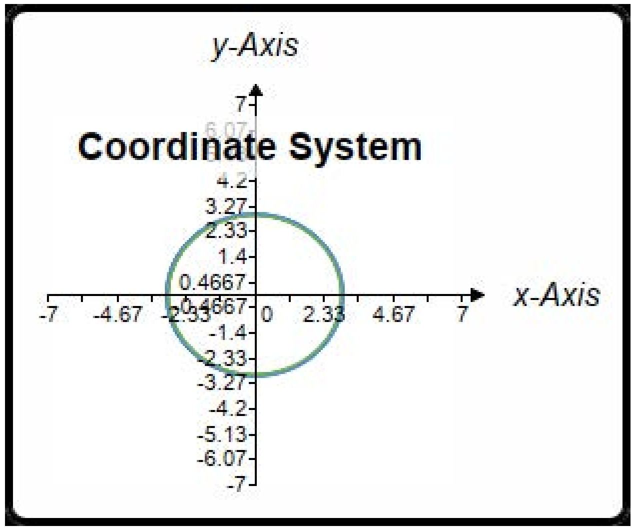
$V_{F.GA} := 0 \cdot ft$ Gaff Flag Vertical Dimension

$H_{F.GA} := 0 \cdot ft$ Gaff Flag Horizontal Dimension

$\gamma_{F.GA} := 0.0010 \cdot lbf$ Gaff Flag Material Load Factor

Coordinate System Information:

In this analysis, a standard x,y,z coordinate system is used. The coordinate system is placed at the base of the pole shaft, with the z-axis moving positive along the pole's longitudinal axis. The x-axis will move left(-) to right(+), and the y-axis will move backwards(-) and forwards(+) from the pole's diametric center.



Flag Material Load Factor:

Refer to Section 4.1 of NAAMM FP 1001-07 for information regarding Flag Wind Loads. Flags made of nylon and/or cotton will have a load factor of $\gamma_{Nylon} := 0.0010 \cdot lbf$ in accordance with Equation 4. Flags made of polyester will have a load factor of $\gamma_{Poly} := 0.0014 \cdot lbf$ in accordance with Equation 5.

Attachment 1: XXXXXX

$EPA_1 := 0 \cdot ft^2$ Effective Projected Area

$xEPA_1 := 0 \cdot ft + 0 \cdot in$ x Coordinate of EPA

$xCG_1 := 0 \cdot ft + 0 \cdot in$ x Coordinate of Weight

$zEPA_1 := 0 \cdot ft + 0 \cdot in$ z Coordinate of Attachment

$wEPA_1 := 0 \cdot lbf$ Weight of Attachment

Attachment 2: XXXXXX

$EPA_2 := 0 \cdot ft^2$ Effective Projected Area

$xEPA_2 := 0 \cdot ft + 0 \cdot in$ x Coordinate of EPA

$xCG_2 := 0 \cdot ft + 0 \cdot in$ x Coordinate of Weight

$zEPA_2 := 0 \cdot ft + 0 \cdot in$ z Coordinate of Attachment

$wEPA_2 := 0 \cdot lbf$ Weight of Attachment

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Shaft Calculations:

Shaft Geometry:

$$D(z) := \begin{cases} D_B & \text{if } z \le L_{botst} \\ D_T + (D_B - D_T) \cdot \left(\dfrac{L_{botst} + L_{taper} - z}{L_{taper}} \right)^{n_{taper}} & \text{else if } z < L_{botst} + L_{taper} \\ D_T & \text{else} \end{cases}$$

Shaft Diameter Function:

$D(0) = 6.000\ in$ Diameter at Bottom

$D\left(\dfrac{L_{total}}{2}\right) = 6.000\ in$ Diameter at Middle

$D(L_{total}) = 3.500\ in$ Diameter at Top

$Ro_S(z) := \dfrac{D(z)}{2}$ $Ri_S(z) := Ro_S(z) - t_w$ Outer and Inner Shaft Radii Functions, Respectively

$$\phi_{cut}(z) := \begin{cases} 2 \cdot \operatorname{asin}\left(\dfrac{w_{cut}}{D(z)}\right) & \text{if } \dfrac{-l_{cut}}{2} < z - z_{cut} < \dfrac{l_{cut}}{2} \\ 0 \cdot deg & \text{else} \end{cases}$$

Function for Angle Swept by Cutout:

$\phi_{cut}(0) = 0.000\ deg$

$\phi_{cut}(z_{cut}) = 0.000\ deg$

$$\phi_i(z) := \begin{array}{l} \phi \leftarrow \theta_{cut} - \dfrac{\pi + \phi_{cut}(z)}{2} \\ \text{if } \phi \le 0 \cdot deg \\ \quad \phi \leftarrow \phi + 2 \cdot \pi \\ \phi \end{array}$$

Angle to Start of Cut from (+)x-Axis:

$\phi_i(0) = 270.000\ deg$

$\phi_i(z_{cut}) = 270.000\ deg$

$\phi_f(z) := \phi_i(z) + \phi_{cut}(z)$

Angle to End of Cut from (+)x-Axis:

$\phi_f(0) = 270.000\ deg$ $\phi_f(z_{cut}) = 270.000\ deg$

$A(z) := \left(\pi - \dfrac{\phi_{cut}(z)}{2}\right) \cdot \left(Ro_S(z)^2 - Ri_S(z)^2\right)$ Shaft Cross-Sectional Area Function:

$A(0) = 2.864\ in^2$ $A(z_{cut}) = 2.864\ in^2$ $A(L_{total}) = 1.639\ in^2$

$x_{cg}(z) := \dfrac{Ro_S(z)^3 - Ri_S(z)^3}{3 \cdot A(z)} \cdot \left(\sin(\phi_i(z)) - \sin(\phi_f(z))\right)$ x-Coordinate of Cross-Section Centroid:

$x_{cg}(0) = 0.000\ in$ $x_{cg}(z_{cut}) = 0.000\ in$ $x_{cg}(L_{total}) = 0.000\ in$

$y_{cg}(z) := \dfrac{Ro_S(z)^3 - Ri_S(z)^3}{3 \cdot A(z)} \cdot \left(\cos(\phi_f(z)) - \cos(\phi_i(z))\right)$ y-Coordinate of Cross-Section Centroid:

$y_{cg}(0) = 0.000\ in$ $y_{cg}(z_{cut}) = 0.000\ in$ $y_{cg}(L_{total}) = 0.000\ in$

$$Ixx(z) := \frac{Ro_S(z)^4 - Ri_S(z)^4}{4} \cdot \left(\pi - \frac{\phi_f(z) - \phi_i(z)}{2} + \frac{1}{4} \cdot \left(\sin\left(2 \cdot \phi_f(z)\right) - \sin\left(2 \cdot \phi_i(z)\right)\right)\right) + \frac{2 \cdot \left(Ro_S(z)^3 - Ri_S(z)^3\right)}{3} \cdot y_{cg}(z) \cdot \left(\cos\left(\phi_i(z)\right) - \cos\left(\phi_f(z)\right)\right) + \frac{Ro_S(z)^2 - Ri_S(z)^2}{2} \cdot y_{cg}(z)^2 \cdot \left(2 \cdot \pi + \phi_i(z) - \phi_f(z)\right)$$

$Ixx(0) = 12.236\ in^4$ $\quad Ixx(z_{cut}) = 12.236\ in^4$ $\quad Ixx(L_{total}) = 2.296\ in^4$

Shaft Area Moment of Inertia w.r.t. the x-Axis:

$$Iyy(z) := \frac{Ro_S(z)^4 - Ri_S(z)^4}{4} \cdot \left(\pi - \frac{\phi_f(z) - \phi_i(z)}{2} - \frac{1}{4} \cdot \left(\sin\left(2 \cdot \phi_f(z)\right) - \sin\left(2 \cdot \phi_i(z)\right)\right)\right) + \frac{2 \cdot \left(Ro_S(z)^3 - Ri_S(z)^3\right)}{3} \cdot x_{cg}(z) \cdot \left(\sin\left(\phi_f(z)\right) - \sin\left(\phi_i(z)\right)\right) + \frac{Ro_S(z)^2 - Ri_S(z)^2}{2} \cdot x_{cg}(z)^2 \cdot \left(2 \cdot \pi + \phi_i(z) - \phi_f(z)\right)$$

$Iyy(0) = 12.236\ in^4$ $\quad Iyy(z_{cut}) = 12.236\ in^4$ $\quad Iyy(L_{total}) = 2.296\ in^4$

Shaft Area Moment of Inertia w.r.t. the y-Axis:

$$Ixy(z) := \frac{Ro_S(z)^4 - Ri_S(z)^4}{8} \cdot \left(\cos\left(\phi_f(z)\right)^2 - \cos\left(\phi_i(z)\right)^2\right) + \frac{Ro_S(z)^3 - Ri_S(z)^3}{3} \cdot \left(x_{cg}(z) \cdot \left(\cos\left(\phi_i(z)\right) - \cos\left(\phi_f(z)\right)\right) + y_{cg}(z) \cdot \left(\sin\left(\phi_f(z)\right) - \sin\left(\phi_i(z)\right)\right)\right) + \frac{Ro_S(z)^2 - Ri_S(z)^2}{2} \cdot x_{cg}(z) \cdot y_{cg}(z) \cdot \left(2 \cdot \pi + \phi_i(z) - \phi_f(z)\right)$$

$Ixy(0) = 0.000\ in^4$ $\quad Ixy(z_{cut}) = 0.000\ in^4$ $\quad Ixy(L_{total}) = 0.000\ in^4$

Shaft Product of Inertia:

Shaft Area Moment of Inertia w.r.t. the z-Axis: (*Approximation for Polar Moment of Inertia*)

$Izz(z) := Ixx(z) + Iyy(z)$ $\quad Izz(0) = 24.471\ in^4$ $\quad Izz(z_{cut}) = 24.471\ in^4$ $\quad Izz(L_{total}) = 4.592\ in^4$

$rxx(z) := \sqrt{\frac{Ixx(z)}{A(z)}}$ Radius of Gyration w.r.t. the x-Axis:

$rxx(0) = 2.067\ in$

$rxx(z_{cut}) = 2.067\ in$

$rxx(L_{total}) = 1.184\ in$

$ryy(z) := \sqrt{\frac{Iyy(z)}{A(z)}}$ Radius of Gyration w.r.t. the y-Axis:

$ryy(0) = 2.067\ in$

$ryy(z_{cut}) = 2.067\ in$

$ryy(L_{total}) = 1.184\ in$

Elastic Section Moduli w.r.t. the x-Axis:

$Sxx_U(z) := \frac{Ixx(z)}{Ro_S(z) - y_{cg}(z)}$

Elastic Section Moduli Above Centroidal x-Axis:

$Sxx_U(0) = 4.079\ in^3$ $Sxx_U(z_{cut}) = 4.079\ in^3$ $Sxx_U(L_{total}) = 1.312\ in^3$

$Sxx_L(z) := \frac{Ixx(z)}{Ro_S(z) + y_{cg}(z)}$

Elastic Section Moduli Below Centroidal x-Axis:

$Sxx_L(0) = 4.079\ in^3$ $Sxx_L(z_{cut}) = 4.079\ in^3$ $Sxx_L(L_{total}) = 1.312\ in^3$

$Sxx_{max}(z) := \max(Sxx_U(z), Sxx_L(z))$ Maximum Elastic Section Modulus w.r.t. the x-Axis

Elastic Section Moduli w.r.t. the y-Axis:

$Syy_U(z) := \frac{Iyy(z)}{Ro_S(z) - x_{cg}(z)}$

Elastic Section Moduli Above Centroidal y-Axis:

$Syy_U(0) = 4.079\ in^3$ $Syy_U(z_{cut}) = 4.079\ in^3$ $Syy_U(L_{total}) = 1.312\ in^3$

$Syy_L(z) := \frac{Iyy(z)}{Ro_S(z) + x_{cg}(z)}$

Elastic Section Moduli Below Centroidal y-Axis:

$Syy_L(0) = 4.079\ in^3$ $Syy_L(z_{cut}) = 4.079\ in^3$ $Syy_L(L_{total}) = 1.312\ in^3$

$Syy_{max}(z) := \max(Syy_U(z), Syy_L(z))$ Maximum Elastic Section Modulus w.r.t. the y-Axis

$\phi_{xi.i}(z) := \operatorname{asin}\left(\frac{y_{cg}(z)}{Ri_S(z)}\right)$ $\phi_{xi.i}(z_{cut}) = 0.000\ deg$ Angle from Geometric Center to Inner Radius on Centroidal (+)x-Axis:

$\phi_{xo.i}(z) := \operatorname{asin}\left(\frac{y_{cg}(z)}{Ro_S(z)}\right)$ $\phi_{xo.i}(z_{cut}) = 0.000\ deg$ Angle from Geometric Center to Outer Radius on Centroidal (+)x-Axis:

$\phi_{xi.f}(z) := \pi - \operatorname{asin}\left(\frac{y_{cg}(z)}{Ri_S(z)}\right)$ $\phi_{xi.f}(z_{cut}) = 180.000\ deg$ Angle from Geometric Center to Inner Radius on Centroidal (-)x-Axis:

$\phi_{xo.f}(z) := \pi - \operatorname{asin}\left(\frac{y_{cg}(z)}{Ro_S(z)}\right)$ $\phi_{xo.f}(z_{cut}) = 180.000\ deg$ Angle from Geometric Center to Outer Radius on Centroidal (-)x-Axis:

$\phi_{yi.i}(z) := \frac{\pi}{2} - \operatorname{asin}\left(\frac{x_{cg}(z)}{Ri_S(z)}\right)$ $\phi_{yi.i}(z_{cut}) = 90.000\ deg$ Angle from Geometric Center to Inner Radius on Centroidal (+)y-Axis:

$\phi_{yo.i}(z) := \frac{\pi}{2} - \operatorname{asin}\left(\frac{x_{cg}(z)}{Ro_S(z)}\right)$ $\phi_{yo.i}(z_{cut}) = 90.000\ deg$ Angle from Geometric Center to Outer Radius on Centroidal (+)y-Axis:

$\phi_{yi.f}(z) := \frac{3 \cdot \pi}{2} + \operatorname{asin}\left(\frac{x_{cg}(z)}{Ri_S(z)}\right)$ $\phi_{yi.f}(z_{cut}) = 270.000\ deg$ Angle from Geometric Center to Inner Radius of Centroidal (-)y-Axis:

$\phi_{yo.f}(z) := \frac{3 \cdot \pi}{2} + \operatorname{asin}\left(\frac{x_{cg}(z)}{Ro_S(z)}\right)$ $\phi_{yo.f}(z_{cut}) = 270.000\ deg$ Angle from Geometric Center to Outer Radius on Centroidal (-)y-Axis:

$$f\phi_c(\phi_l, \phi_u, \phi_c) := \begin{cases} \text{if } \phi_c \le \phi_l \\ \quad \phi_l \\ \text{else if } \phi_c \ge \phi_u \\ \quad \phi_u \\ \text{else} \\ \quad \phi_c \end{cases}$$

Function to Find Angle Limits of Cutout w.r.t. Centroidal Axes:

$\phi_{cxi.i}(z) := f\phi_c(\phi_{xi.i}(z), \phi_{xi.f}(z), \phi_i(z))$	$\phi_{cxi.i}(z_{cut}) = 180.000\ deg$	Initial Inner Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:
$\phi_{cxo.i}(z) := f\phi_c(\phi_{xo.i}(z), \phi_{xo.f}(z), \phi_i(z))$	$\phi_{cxo.i}(z_{cut}) = 180.000\ deg$	Initial Outer Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:
$\phi_{cxi.f}(z) := f\phi_c(\phi_{xi.i}(z), \phi_{xi.f}(z), \phi_f(z))$	$\phi_{cxi.f}(z_{cut}) = 180.000\ deg$	Final Inner Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:
$\phi_{cxo.f}(z) := f\phi_c(\phi_{xo.i}(z), \phi_{xo.f}(z), \phi_f(z))$	$\phi_{cxo.f}(z_{cut}) = 180.000\ deg$	Final Outer Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:
$\phi_{cyi.i}(z) := f\phi_c(\phi_{yi.i}(z), \phi_{yi.f}(z), \phi_i(z))$	$\phi_{cyi.i}(z_{cut}) = 270.000\ deg$	Initial Inner Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:
$\phi_{cyo.i}(z) := f\phi_c(\phi_{yo.i}(z), \phi_{yo.f}(z), \phi_i(z))$	$\phi_{cyo.i}(z_{cut}) = 270.000\ deg$	Initial Outer Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:
$\phi_{cyi.f}(z) := f\phi_c(\phi_{yi.i}(z), \phi_{yi.f}(z), \phi_f(z))$	$\phi_{cyi.f}(z_{cut}) = 270.000\ deg$	Final Inner Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:
$\phi_{cyo.f}(z) := f\phi_c(\phi_{yo.i}(z), \phi_{yo.f}(z), \phi_f(z))$	$\phi_{cyo.f}(z_{cut}) = 270.000\ deg$	Final Outer Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$$Qxx(z) := \frac{Ro_S(z)^3}{3} \cdot (\cos(\phi_{xo.i}(z)) - \cos(\phi_{xo.f}(z)) + \cos(\phi_{cxo.f}(z)) - \cos(\phi_{cxo.i}(z))) + \frac{Ri_S(z)^3}{3} \cdot (\cos(\phi_{cxi.i}(z)) - \cos(\phi_{cxi.f}(z)) + \cos(\phi_{xi.f}(z)) - \cos(\phi_{xi.i}(z))) + \frac{y_{cg}(z)}{2} \cdot \left(Ro_S(z)^2 \cdot (\phi_{cxo.f}(z) - \phi_{cxo.i}(z) + \phi_{xo.i}(z) - \phi_{xo.f}(z)) + Ri_S(z)^2 \cdot (\phi_{xi.f}(z) - \phi_{xi.i}(z) + \phi_{cxi.i}(z) - \phi_{cxi.f}(z)) \right)$$

$Qxx(0) = 2.665\ in^3$ $Qxx(z_{cut}) = 2.665\ in^3$ $Qxx(L_{total}) = 0.873\ in^3$ First Moment of Area w.r.t. Centroidal x-Axis:

$$Qyy(z) := \frac{Ro_S(z)^3}{3} \cdot (\sin(\phi_{yo.f}(z)) - \sin(\phi_{yo.i}(z)) + \sin(\phi_{cyo.i}(z)) - \sin(\phi_{cyo.f}(z))) + \frac{Ri_S(z)^3}{3} \cdot (\sin(\phi_{cyo.f}(z)) - \sin(\phi_{cyo.i}(z)) + \sin(\phi_{yo.i}(z)) - \sin(\phi_{yo.f}(z))) + \frac{x_{cg}(z)}{2} \cdot \left(Ro_S(z)^2 \cdot (\phi_{cyo.f}(z) - \phi_{cyo.i}(z) + \phi_{yo.i}(z) - \phi_{yo.f}(z)) + Ri_S(z)^2 \cdot (\phi_{yi.f}(z) - \phi_{yi.i}(z) + \phi_{cyi.i}(z) - \phi_{cyi.f}(z)) \right)$$

$Qyy(0) = 2.665\ in^3$ $Qyy(z_{cut}) = 2.665\ in^3$ $Qyy(L_{total}) = 0.873\ in^3$ First Moment of Area w.r.t. Centroidal y-Axis:

$Zxx(z) := 2 \cdot Qxx(z)$ Plastic Section Modulus w.r.t. Centroidal x-Axis:

$Zxx(0) = 5.329\ in^3$ $Zxx(z_{cut}) = 5.329\ in^3$ $Zxx(L_{total}) = 1.746\ in^3$

$Zyy(z) := 2 \cdot Qyy(z)$ Plastic Section Modulus w.r.t. Centroidal y-Axis:

$Zyy(0) = 5.329\ in^3$ $Zyy(z_{cut}) = 5.329\ in^3$ $Zyy(L_{total}) = 1.746\ in^3$

Shaft Wind Loads:

$$C_h(z) := 2.01 \cdot \left(\frac{\max(16.4 \cdot ft, z + H_{Pier})}{z_g} \right)^{\frac{2}{\alpha}}$$

Coefficient of Height:
(*Ref. Section 3.2.3 of NAAMM FP 1001-07*)

$C_h(0) = 0.865$ $C_h(L_{total}) = 0.982$

$$C_d(d) := \begin{cases} 1.10 & \text{if } U_D \cdot d \le 39 \cdot mph \cdot ft \\ \dfrac{129}{\left(\dfrac{U_D \cdot d}{mph \cdot ft}\right)^{1.3}} & \text{else if } 39 \cdot mph \cdot ft < U_D \cdot d < 78 \cdot mph \cdot ft \\ 0.45 & \text{else} \end{cases}$$

Drag Coefficient:
(*Ref. Table 3.2.4 of NAAMM FP 1001-07*)

$C_d(D(0)) = 0.915$

$C_d(D(L_{total})) = 1.100$

$$P_z(z) := 0.00256 \cdot \left(\frac{U_D}{mph}\right)^2 \cdot C_h(z) \cdot G_{eff} \cdot psf$$

Design Wind Pressure:
(*Ref. Section 3.2.1 of NAAMM FP 1001-07*)

$P_z(0) = 20.447\ psf$ $P_z(L_{total}) = 23.220\ psf$

$$V_{Shaft}(z) := \int_z^{L_{total}} P_z(z) \cdot C_d(D(z)) \cdot D(z)\, dz$$

Function for Wind Shear on Pole Shaft:
(*Function of Height*)

$$M_{Shaft}(z) := \int_z^{L_{total}} (\varepsilon - z) \cdot P_z(\varepsilon) \cdot C_d(D(\varepsilon)) \cdot D(\varepsilon)\, d\varepsilon$$

Function for Wind Moment on Pole Shaft:
(*Function of Height*)

$$V_{Flag}(z,i) := \begin{cases} \gamma_{F_i} \cdot \left(\dfrac{U_D}{mph}\right)^2 \cdot \sqrt{\dfrac{V_{F_i} \cdot H_{F_i}}{ft^2}} \cdot C_h(z) \cdot G_{eff} & \text{if } z \le z_{F_i} \\ 0 \cdot lbf & \text{else} \end{cases}$$

Function for Wind Shear of *ith* Flag:

$$V_{EPA}(z,i) := \begin{cases} EPA_i \cdot P_z(zEPA_i) & \text{if } z \le zEPA_i \\ 0 \cdot lbf & \text{else} \end{cases}$$

Function for Wind Shear of *ith* Attachment:

$$V_{Gaff}(z) := \begin{cases} P_z\left(z_{GA} + \frac{L_{GA}}{2}\cdot\cos(\theta_{GA})\right)\cdot C_d(D_{GA})\cdot D_{GA}\cdot L_{GA} & \text{if } z \le z_{GA} \\ 0\cdot lbf & \text{else} \end{cases}$$

Function for Wind Shear of Gaff:

$$V_{F.Gaff}(z) := \begin{cases} z_0 \leftarrow L_{GA}\cdot\cos(\theta_{GA}) \\ \gamma_{F.GA}\cdot\left(\frac{U_D}{mph}\right)^2\cdot\sqrt{\frac{V_{F.GA}\cdot H_{F.GA}}{ft^2}}\cdot C_h(z_{GA}+z_0)\cdot G_{eff} & \text{if } z \le z_{GA} \\ 0\cdot lbf & \text{else} \end{cases}$$

Function for Wind Shear of Gaff Flag:

$$V_{Yard}(z) := \begin{cases} P_z(z_{YA})\cdot C_d(D_{YA})\cdot D_{YA}\cdot L_{YA} & \text{if } z \le z_{YA} \\ 0\cdot lbf & \text{else} \end{cases}$$

Function for Wind Shear of Yard Arm:

$$V_{F.Yard}(z) := \begin{cases} \gamma_{F.YA}\cdot\left(\frac{U_D}{mph}\right)^2\cdot\sqrt{\frac{V_{F.YA}\cdot H_{F.YA}}{ft^2}}\cdot C_h(z_{YA})\cdot G_{eff} & \text{if } z \le z_{YA} \\ 0\cdot lbf & \text{else} \end{cases}$$

Function for Wind Shear of Single Yard Arm Flag:

$$\Sigma Vw_{Flags}(z) := V_{F.Gaff}(z) + 2\cdot V_{F.Yard}(z) + \sum_{i=1}^{\text{length}(V_F)} V_{Flag}(z,i)$$

Total Wind Shear from Flags: (*Unfactored*)

$$\Sigma Vw_{Attachments}(z) := V_{Gaff}(z) + V_{Yard}(z) + \sum_{i=1}^{\text{length}(EPA)} V_{EPA}(z,i)$$

Total Wind Shear from Attachments: (*Unfactored*)

$$\Sigma V_{Wind}(z) := \gamma_W\cdot\left(V_{Shaft}(z) + \Sigma Vw_{Flags}(z) + \Sigma Vw_{Attachments}(z)\right)$$

Total Wind Shear: (*Factored*)

$\Sigma V_{Wind}(0\cdot in) = 390.678\ lbf$

Total Wind Moment from Flags: (*Unfactored*)

$$\Sigma Mw_{Flags}(z) := 0.95\cdot V_{F.Gaff}(z)\cdot(z_{GA}-z) + 1.90\cdot V_{F.Yard}(z)\cdot(z_{YA}-z) + \sum_{i=1}^{\text{length}(V_F)} V_{Flag}(z,i)\cdot\left(z_{F_i}-z\right)$$

Total Wind Moment from Attachments: (*Unfactored*)

$$\Sigma Mw_{Attachments}(z) := V_{Gaff}(z)\cdot(z_{GA}-z) + V_{Yard}(z)\cdot(z_{YA}-z) + \sum_{i=1}^{\text{length}(EPA)} V_{EPA}(z,i)\cdot\left(zEPA_i - z\right)$$

$$\Sigma M_{Wind}(z) := \gamma_W\cdot\left(M_{Shaft}(z) + \Sigma Mw_{Flags}(z) + \Sigma Mw_{Attachments}(z)\right)$$

Total Wind Moment: (*Factored*)

$\Sigma M_{Wind}(0) = 6875.730\ ft\cdot lbf$

$\Sigma Tw_{Flags} := 0.95 \cdot V_{Gaff}(0) \cdot L_{GA} \cdot \sin(\theta_{GA})$ Total Wind Torsion from Flags: (*Unfactored*)

$\Sigma Tw_{Attachments} := \frac{1}{2} \cdot V_{Gaff}(0) \cdot L_{GA} \cdot \sin(\theta_{GA}) + \sum_{i=1}^{\text{length}(EPA)} V_{EPA}(0, i) \cdot xEPA_i$ Total Wind Torsion from Attachments: (*Unfactored*)

$\Sigma T_{Wind} := \gamma_W \cdot (\Sigma Tw_{Flags} + \Sigma Tw_{Attachments})$ Total Wind Torsion: (*Factored*) $\Sigma T_{Wind} = 0.000 \; ft \cdot lbf$

Shaft Dead Loads:

$\rho_{Shaft} := 1.125$ Weight Factor:
Note: This weight factor helps to account for the weight of miscellaneous parts associated with a flag pole. It is applied directly to the calculated shaft weight.

$P_{Shaft}(z) := \rho_{Shaft} \cdot \rho_{6063} \cdot \int_z^{L_{total}} A(z) \, dz$ Function for Shaft Weight: $P_{Shaft}(0) = 104.599 \; lbf$

Function for Yard Arm Weight:

$$P_{Yard}(z) := \begin{cases} \pi \cdot t_{YA} \cdot (D_{YA} - t_{YA}) \cdot L_{YA} \cdot \rho_{6063} & \text{if } z \le z_{YA} \\ 0 \cdot lbf & \text{else} \end{cases}$$

Function for Gaff Weight:

$$P_{Gaff}(z) := \begin{cases} \pi \cdot t_{GA} \cdot (D_{GA} - t_{GA}) \cdot L_{GA} \cdot \rho_{6063} & \text{if } z \le z_{GA} \\ 0 \cdot lbf & \text{else} \end{cases}$$

$$P_{EPA}(z, i) := \begin{cases} wEPA_i & \text{if } z \le zEPA_i \\ 0 \cdot lbf & \text{else} \end{cases}$$

Function for Weight of *ith* Attachment:

$\Sigma P(z) := \gamma_D \cdot \left(P_{Shaft}(z) + P_{Gaff}(z) + P_{Yard}(z) + \sum_{i=1}^{\text{length}(EPA)} P_{EPA}(z, i) \right)$ Total Weight: (*Factored*) $\Sigma P(0) = 104.599 \; lbf$

$\Sigma M_{Dead}(z) := \gamma_D \cdot \left(\frac{1}{2} \cdot P_{Gaff}(z) \cdot L_{GA} \cdot \sin(\theta_{GA}) + \sum_{i=1}^{\text{length}(EPA)} P_{EPA}(z, i) \cdot xCG_i \right)$ Total Dead Load Moment: (*Factored*) $\Sigma M_{Dead}(0) = 0.000 \; ft \cdot lbf$

Shaft Combined Loads:

$V_x(z) := 0 \cdot lbf$ Total Shear in x-Direction: $V_x(0) = 0.000 \; lbf$

$V_y(z) := \Sigma V_{Wind}(z)$ Total Shear in y-Direction: $V_y(0) = 390.678 \; lbf$

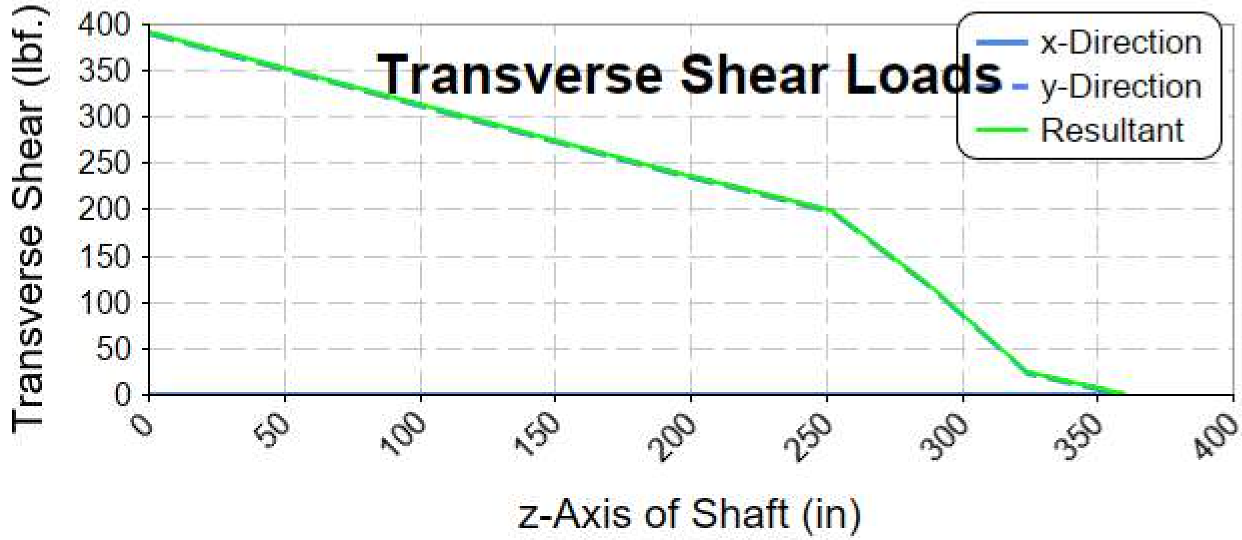
$V_c(z) := \sqrt{V_x(z)^2 + V_y(z)^2}$ Total Resultant Shear: $V_c(0) = 390.678 \; lbf$

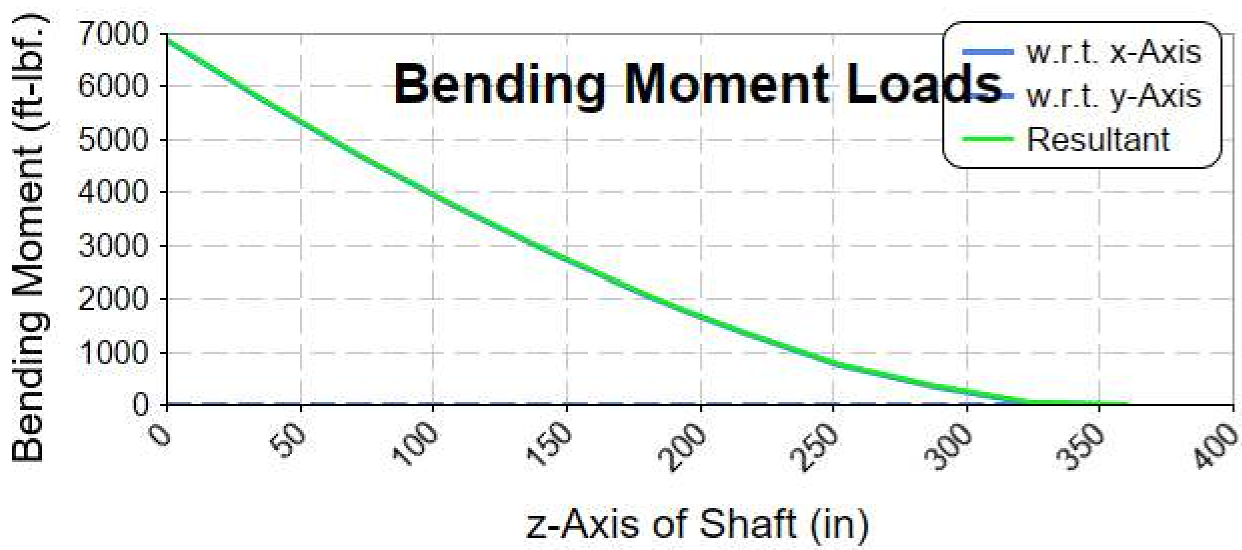
$M_{xx}(z) := \Sigma M_{Wind}(z)$ Total Moment w.r.t. x-Axis: $M_{xx}(0) = 6875.730 \; ft \cdot lbf$

$M_{yy}(z) := \Sigma M_{Dead}(z)$ Total Moment w.r.t. y-Axis: $M_{yy}(0) = 0.000 \; ft \cdot lbf$

$M_c(z) := \sqrt{M_{xx}(z)^2 + M_{yy}(z)^2}$ Total Resultant Moment: $M_c(0) = 6875.730 \; ft \cdot lbf$

$T_c := \Sigma T_{Wind}$ Total Torsion: $T_c = 0.000 \; ft \cdot lbf$





Shaft Stresses:

Axial Stresses:

$$fa(z) := \frac{\Sigma P(z)}{A(z)}$$

Axial Stress Function:

$fa(0) = 0.037\ ksi$

Bending Stresses:

$$fb_{xx}(z) := \frac{M_{xx}(z) \cdot Iyy(z) - M_{yy}(z) \cdot Ixy(z)}{Ixx(z) \cdot Iyy(z) - Ixy(z)^2} \cdot \max\left(Ro_S(z) - y_{cg}(z), Ro_S(z) + y_{cg}(z)\right)$$

Bending Stress w.r.t. x-Axis: $fb_{xx}(0) = 20.230\ ksi$ $fb_{xx}(L_{total}) = 0.000\ ksi$

$$fb_{yy}(z) := \frac{M_{yy}(z) \cdot Ixx(z) - M_{xx}(z) \cdot Ixy(z)}{Ixx(z) \cdot Iyy(z) - Ixy(z)^2} \cdot \max\left(Ro_S(z) - x_{cg}(z), Ro_S(z) + x_{cg}(z)\right)$$

Bending Stress w.r.t. y-Axis: $fb_{yy}(0) = 0.000\ ksi$ $fb_{yy}(L_{total}) = 0.000\ ksi$

Shear Stresses:

$$fs(z) := \sqrt{\left(\frac{V_x(z) \cdot Qxx(z)}{2 \cdot Ixx(z) \cdot t_w}\right)^2 + \left(\frac{V_y(z) \cdot Qyy(z)}{2 \cdot Iyy(z) \cdot t_w}\right)^2} + \frac{|T_c| \cdot \left(Ro_S(z) + \sqrt{x_{cg}(z)^2 + y_{cg}(z)^2}\right)}{Izz(z)}$$

Total Shear Stress: $fs(0) = 0.273\ ksi$ $fs(L_{total}) = 0.000\ ksi$

Shaft Allowable Stresses:

$$Fa(z) := \begin{array}{l} \lambda \leftarrow \dfrac{k_{eff} \cdot z}{min\left(rxx\left(\frac{z}{2}\right), ryy\left(\frac{z}{2}\right)\right)} \\ \lambda_C \leftarrow \dfrac{\pi}{1.08} \cdot \sqrt{\dfrac{E_{6063}}{Fcy_{6063}}} \\ \text{if } \lambda \le \lambda_C \\ \quad 0.6 \cdot Fcy_{6063} \\ \text{else} \\ \quad \dfrac{\pi^2 \cdot E_{6063}}{1.95 \cdot \lambda^2} \end{array}$$

Allowable Axial Stress:
(Ref. Section 6.7 of NAAMM FP 1001-07)

$Fa(0 \cdot in) = 15.000\ ksi$

$Fa(L_{total}) = 0.421\ ksi$

$$Fb(z) := \begin{array}{l} \lambda \leftarrow \dfrac{D(z) - t_w}{2 \cdot t_w} \\ F \leftarrow \text{if } \lambda \le 33 \\ \quad\quad 24 \cdot ksi \\ \quad\quad \text{else} \\ \quad\quad (27.7 - 1.70 \cdot \sqrt{\lambda}) \cdot ksi \\ F \end{array}$$

Allowable Bending Stress:
(Ref. Section 6.8.2 of NAAMM FP 1001-07)

$Fb(0) = 24.000\ ksi$

$Fb(L_{total}) = 24.000\ ksi$

$Fs(z) := 11.330 \cdot ksi$

Allowable Shear Stress:
(Ref. Table 6.8.2 of NAAMM FP 1001-07)

$Fs(0) = 11.330\ ksi$

$Fs(L_{total}) = 11.330\ ksi$

Coefficient of Amplification: (Second Order Effects)

Refer to Section 6.6 of NAAMM FP 1001-07 for details on the coefficient of amplification.

$$Ca_{xx} := \begin{array}{l} \text{if } Fa\left(\dfrac{L_{total}}{2}\right) \le 0.26 \cdot Fcy_{6063} \\ \quad 1 - \dfrac{1}{0.52} \cdot \dfrac{\left(0.38 \cdot \Sigma P(0) + \Sigma P(L_{total}) \cdot \sqrt[3]{\dfrac{Ixx(0)}{Ixx(L_{total})}}\right) \cdot L_{total}^2}{2.46 \cdot E_{6063} \cdot Ixx(0)} \\ \text{else} \\ \quad 1 - \dfrac{1}{0.52} \cdot \dfrac{0.38 \cdot \Sigma P(0) \cdot L_{total}^2}{2.46 \cdot E_{6063} \cdot Ixx(0)} \end{array}$$

Coefficient of Amplification
w.r.t. x-Axis:

$Ca_{xx} = 0.967$

$$Ca_{yy} := \begin{cases} 1 - \frac{1}{0.52} \cdot \frac{\left(0.38 \cdot \Sigma P(0) + \Sigma P(L_{total}) \cdot \sqrt[3]{\frac{Iyy(0)}{Iyy(L_{total})}}\right) \cdot L_{total}^{2}}{2.46 \cdot E_{6063} \cdot Iyy(0)} & \text{if } Fa\left(\frac{L_{total}}{2}\right) \le 0.26 \cdot Fcy_{6063} \\ 1 - \frac{1}{0.52} \cdot \frac{0.38 \cdot \Sigma P(0) \cdot L_{total}^{2}}{2.46 \cdot E_{6063} \cdot Iyy(0)} & \text{else} \end{cases}$$

Coefficient of Amplification w.r.t. y-Axis:

$Ca_{yy} = 0.967$

Combined Stress Ratio of Shaft:

Refer to Section 6.6 of NAAMM FP 1001-07 for details on the combined Stress Ratio.

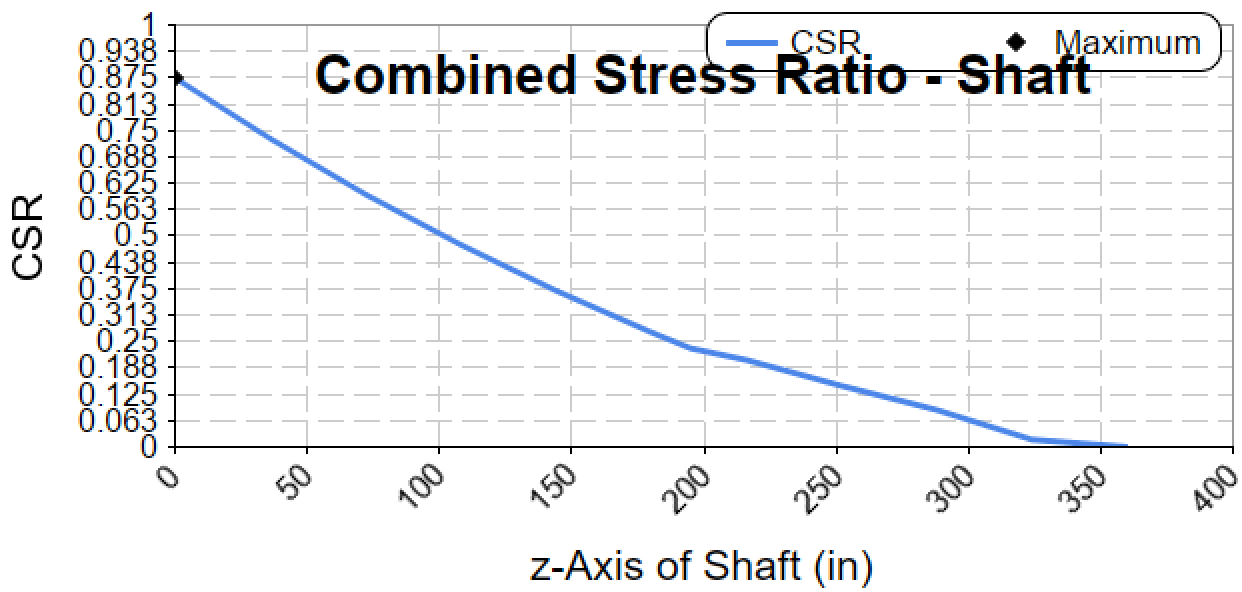
$$CSR(z) := \frac{fa(z)}{Fa(z)} + \frac{\sqrt{\left(\frac{fb_{xx}(z)}{Ca_{xx}}\right)^2 + \left(\frac{fb_{yy}(z)}{Ca_{yy}}\right)^2}}{Fb(z)} + \left(\frac{fs(z)}{Fs(z)}\right)^2$$

Maximum Pole Shaft CSR:

$Status_{Shaft} = $ "Pass"

$CSR_{Max} = 0.874$ — Maximum Pole Shaft CSR (*Must be less than or equal to 1*)

$CSR_{Location} = 0.000\ in$ — Location of Maximum CSR (*Along z-Axis*)



Summary of Pole Design Calculations for Pole ESR30C61-SAT

Design Specification:

These calculations are based on *Guide Specifications For Design Of Metal Flagpoles, ANSI/NAAMM FP 1001-7*.

Loading Parameters:

Design Wind Speed: $U_D = 90.000\ mph$

Height Above Grade: $H_{Pier} = 0.000\ ft$

Gust Effect Factor: $G_{eff} = 1.140$

Size and Material Type of Flags:

$$V_F = \begin{bmatrix} 6.000 \\ 5.000 \\ 0.000 \end{bmatrix} ft \qquad H_F = \begin{bmatrix} 10.000 \\ 8.000 \\ 0.000 \end{bmatrix} ft$$

$$\gamma_F = \begin{bmatrix} 0.001 \\ 0.001 \\ 0.001 \end{bmatrix} lbf \qquad z_F = \begin{bmatrix} 27.000 \\ 21.500 \\ 0.000 \end{bmatrix} ft$$

Yard Arm Properties:

Flag Vertical: $V_{F.YA} = 0.000\ ft$

Flag Horizontal: $H_{F.YA} = 0.000\ ft$

Material Factor: $\gamma_{F.YA} = 0.001\ lbf$

Arm Length: $L_{YA} = 0.000\ ft$

Arm Diameter: $D_{YA} = 0.000\ in$

Mount Location: $z_{YA} = 0.000\ ft$

Gaff Properties:

Flag Vertical: $V_{F.GA} = 0.000\ ft$

Flag Horizontal: $H_{F.GA} = 0.000\ ft$

Material Factor: $\gamma_{F.GA} = 0.001\ lbf$

Arm Length: $L_{GA} = 0.000\ ft$

Arm Diameter: $D_{GA} = 0.000\ in$

Arm Angle: $\theta_{GA} = 0.000\ deg$

Mount Location: $z_{GA} = 0.000\ ft$

EPA, Weight, and Location of Attachments:

$$EPA = \begin{bmatrix} 0.000 \\ 0.000 \end{bmatrix} ft^2 \qquad wEPA = \begin{bmatrix} 0.000 \\ 0.000 \end{bmatrix} lbf$$

$$xEPA = \begin{bmatrix} 0.000 \\ 0.000 \end{bmatrix} ft \qquad xCG = \begin{bmatrix} 0.000 \\ 0.000 \end{bmatrix} ft$$

$$zEPA = \begin{bmatrix} 0.000 \\ 0.000 \end{bmatrix} ft$$

Design Parameters:

Bottom Diameter: $D_B = 6.000\ in$

Top Diameter: $D_T = 3.500\ in$

Wall Thickness: $t_w = 0.156\ in$

Bottom Straight: $L_{botst} = 16.250\ ft$

Taper Length: $L_{taper} = 13.750\ ft$

Top Straight: $L_{topst} = 0.000\ ft$

Total Length: $L_{total} = 30.000\ ft$

Taper Exponent: $n_{taper} = 1.000$

Shaft Tensile Strength: $Ftu_{6063} = 30.000\ ksi$

Shaft Yield Strength: $Fty_{6063} = 25.000\ ksi$

Pole Base Reactions:

Axial: $\Sigma P(0) = 104.599\ lbf$

Moment: $M_c(0) = 6875.730\ ft \cdot lbf$

Shear: $V_c(0) = 390.678\ lbf$

Design Checks:

Shaft:

$Status_{Shaft} = \text{“Pass”}$ $\qquad CSR_{Max} = 87.433\%$

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--------------------------------------------------------------------------------
                             Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\Engineering\Signs\Projects\2024\240209\240209-078\

Name of input data file:
240209-078-01_Lpile.lp11d

Name of output report file:
240209-078-01_Lpile.lp11o

Name of plot output file:
240209-078-01_Lpile.lp11p

Name of runtime message file:
240209-078-01_Lpile.lp11r
```

NOTE:
LPile analysis contained herein applies to the 30'-0" OAH flagpole and relative reactions at grade. Foundation design used also for 24'-0" OAH flagpoles, which imposes lower reactions at grade and therefore foundation design is adequate for all flagpoles associated with this project.

```
--------------------------------------------------------------------------------
                            Date and Time of Analysis
--------------------------------------------------------------------------------
```

Date: March 11, 2025 Time: 15:30:44

Problem Title

Project Name: Temple Avenue Roundabout

Job Number: 240209-078-01

Client: Concord Industries

Engineer: DSA

Description: Augered foundation

Program Options and Settings

Computational Options:
- Conventional Analysis

Engineering Units Used for Data Input and Computations:
- US Customary System Units (pounds, feet, inches)

Analysis Control Options:

- Maximum number of iterations allowed	=	500
- Deflection tolerance for convergence	=	1.0000E-05 in
- Maximum allowable deflection	=	100.0000 in
- Number of pile increments	=	100

Loading Type and Number of Cycles of Loading:
- Static loading specified

- Use of p-y modification factors for p-y curves not selected

- Analysis uses layering correction (Method of Georgiadis)
- No distributed lateral loads are entered
- Loading by lateral soil movements acting on pile not selected
- Input of shear resistance at the pile tip not selected
- Input of moment resistance at the pile tip not selected
- Input of side resistance moment along pile not selected
- Computation of pile-head foundation stiffness matrix not selected
- Push-over analysis of pile not selected
- Buckling analysis of pile not selected

Output Options:
- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

Pile Structural Properties and Geometry

```
Number of pile sections defined                          =            1
Total length of pile                                     =        4.750 ft
Depth of ground surface below top of pile                =       0.0000 ft
```

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over the length of the pile. A summary of values of pile diameter vs. depth follows.

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	36.0000
2	4.750	36.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

```
   Section 1 is a round drilled shaft, bored pile, or CIDH pile
   Length of section                                     =     4.750000 ft
   Shaft Diameter                                        =    36.000000 in
```

```
   Shear capacity of section                              =      0.0000 lbs



--------------------------------------------------------------------------------
                       Ground Slope and Pile Batter Angles
--------------------------------------------------------------------------------

Ground Slope Angle                                        =       0.000 degrees
                                                          =       0.000 radians

Pile Batter Angle                                         =       0.000 degrees
                                                          =       0.000 radians


--------------------------------------------------------------------------------
                       Soil and Rock Layering Information
--------------------------------------------------------------------------------

The soil profile is modelled using 3 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer              =      0.0000 ft
   Distance from top of pile to bottom of layer           =    7.000000 ft
   Effective unit weight at top of layer                  =  125.000000 pcf
   Effective unit weight at bottom of layer               =  125.000000 pcf
   Friction angle at top of layer                         =   32.000000 deg.
   Friction angle at bottom of layer                      =   32.000000 deg.
   Subgrade k at top of layer                             =      0.0000 pci
   Subgrade k at bottom of layer                          =      0.0000 pci

   NOTE: Default values for subgrade k will be computed for this layer.

Layer 2 is stiff clay without free water

   Distance from top of pile to top of layer              =    7.000000 ft
   Distance from top of pile to bottom of layer           =    9.000000 ft
   Effective unit weight at top of layer                  =  115.000000 pcf
   Effective unit weight at bottom of layer               =  115.000000 pcf
   Undrained cohesion at top of layer                     =       1500. psf
   Undrained cohesion at bottom of layer                  =       1500. psf
   Epsilon-50 at top of layer                             =      0.0000
   Epsilon-50 at bottom of layer                          =      0.0000

   NOTE: Default values for Epsilon-50 will be computed for this layer.

Layer 3 is sand, p-y criteria by Reese et al., 1974
```

```
Distance from top of pile to top of layer          =     9.000000 ft
Distance from top of pile to bottom of layer       =    15.000000 ft
Effective unit weight at top of layer              =   120.000000 pcf
Effective unit weight at bottom of layer           =   120.000000 pcf
Friction angle at top of layer                     =    32.000000 deg.
Friction angle at bottom of layer                  =    32.000000 deg.
Subgrade k at top of layer                         =       0.0000 pci
Subgrade k at bottom of layer                      =       0.0000 pci
```

NOTE: Default values for subgrade k will be computed for this layer.

(Depth of the lowest soil layer extends 10.250 ft below the pile tip)

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Undrained Cohesion psf	Angle of Friction deg.	E50 or krm	kpy pci
1	Sand	0.00	125.0000	--	32.0000	--	default
	(Reese, et al.)	7.0000	125.0000	--	32.0000	--	default
2	Stiff Clay	7.0000	115.0000	1500.	--	default	--
	w/o Free Water	9.0000	115.0000	1500.	--	default	--
3	Sand	9.0000	120.0000	--	32.0000	--	default
	(Reese, et al.)	15.0000	120.0000	--	32.0000	--	default

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	1	V = 400.000000 lbs	M = 82510. in-lbs	110.000000000	No	Yes

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Dimensions and Properties of Drilled Shaft (Bored Pile):

Length of Section	=	4.750000 ft
Shaft Diameter	=	36.000000 in
Concrete Cover Thickness (to edge of long. rebar)	=	3.000000 in
Number of Reinforcing Bars	=	8 bars
Yield Stress of Reinforcing Bars	=	60000. psi
Modulus of Elasticity of Reinforcing Bars	=	29000000. psi
Gross Area of Shaft	=	1018. sq. in.
Total Area of Reinforcing Steel	=	6.320000 sq. in.
Area Ratio of Steel Reinforcement	=	0.62 percent
Edge-to-Edge Bar Spacing	=	10.097820 in
Maximum Concrete Aggregate Size	=	0.750000 in

Ratio of Bar Spacing to Aggregate Size = 13.46
Offset of Center of Rebar Cage from Center of Pile = 0.0000 in

Axial Structural Capacities:

Nom. Axial Structural Capacity = 0.85 Fc Ac + Fy As = 3818.490 kips
Tensile Load for Cracking of Concrete = -441.861 kips
Nominal Axial Tensile Capacity = -379.200 kips

Reinforcing Bar Dimensions and Positions Used in Computations:

Bar Number	Bar Diam. inches	Bar Area sq. in.	X inches	Y inches
1	1.000000	0.790000	14.500000	0.00000
2	1.000000	0.790000	10.253048	10.253048
3	1.000000	0.790000	0.00000	14.500000
4	1.000000	0.790000	-10.253048	10.253048
5	1.000000	0.790000	-14.500000	0.00000
6	1.000000	0.790000	-10.253048	-10.253048
7	1.000000	0.790000	0.00000	-14.500000
8	1.000000	0.790000	10.253048	-10.253048

NOTE: The positions of the above rebars were computed by LPile

Minimum spacing between any two bars not equal to zero = 10.098 inches between bars 3 and 4.

Ratio of bar spacing to maximum aggregate size = 13.46

Concrete Properties:

Compressive Strength of Concrete = 4000. psi
Modulus of Elasticity of Concrete = 3604997. psi
Modulus of Rupture of Concrete = -474.341649 psi
Compression Strain at Peak Stress = 0.001886
Tensile Strain at Fracture of Concrete = -0.0001154
Maximum Coarse Aggregate Size = 0.750000 in

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

Number	Axial Thrust Force kips

1 0.110

Definitions of Run Messages and Notes:

C = concrete in section has cracked in tension.
Y = stress in reinforcing steel has reached yield stress.
T = ACI 318 criteria for tension-controlled section met, tensile strain in reinforcement exceeds 0.005 while simultaneously compressive strain in concrete more than 0.003. See ACI 318, Section 10.3.4.
Z = depth of tensile zone in concrete section is less than 10 percent of section depth.

Bending Stiffness (EI) = Computed Bending Moment / Curvature.
Position of neutral axis is measured from edge of compression side of pile.
Compressive stresses and strains are positive in sign.
Tensile stresses and strains are negative in sign.

Axial Thrust Force = 0.110 kips

Bending Curvature rad/in.	Bending Moment in-kip	Bending Stiffness kip-in2	Depth to N Axis in	Max Comp Strain in/in	Max Tens Strain in/in	Max Conc Stress ksi	Max Steel Stress ksi	Run Msg
6.25000E-07	228.4286825	365485892.	18.0394878	0.00001127	-0.00001123	0.0472007	0.2715032	
0.00000125	455.9792995	364783440.	18.0198166	0.00002252	-0.00002248	0.0940181	0.5422934	
0.00000188	682.6518404	364080982.	18.0132598	0.00003377	-0.00003373	0.1405567	0.8130835	
0.00000250	908.4463051	363378522.	18.0099816	0.00004502	-0.00004498	0.1868163	1.0838737	
0.00000313	1133.	362676062.	18.0080148	0.00005628	-0.00005622	0.2327971	1.3546639	
0.00000375	1357.	361973602.	18.0067037	0.00006753	-0.00006747	0.2784989	1.6254540	
0.00000438	1581.	361271141.	18.0057674	0.00007878	-0.00007872	0.3239218	1.8962443	
0.00000500	1803.	360568681.	18.0050652	0.00009003	-0.00008997	0.3690658	2.1670345	
0.00000563	2024.	359866220.	18.0045192	0.0001013	-0.0001012	0.4139309	2.4378247	
0.00000625	2245.	359163759.	18.0040824	0.0001125	-0.0001125	0.4585171	2.7086150	

```
0.00000688          2245.    326512508.     7.4692564    0.00005135    -0.0001961
0.2097172    -5.0782295 C
0.00000750          2245.    299303133.     7.4693410    0.00005602    -0.0002140
0.2285050    -5.5398684 C
0.00000813          2245.    276279815.     7.4696734    0.00006069    -0.0002318
0.2472549    -6.0014458 C
0.00000875          2245.    256545542.     7.4702008    0.00006536    -0.0002496
0.2659667    -6.4629616 C
0.00000938          2245.    239442506.     7.4708849    0.00007004    -0.0002675
0.2846404    -6.9244157 C
0.00001000          2245.    224477349.     7.4716969    0.00007472    -0.0002853
0.3032761    -7.3858080 C
0.00001063          2245.    211272800.     7.4726145    0.00007940    -0.0003031
0.3218735    -7.8471382 C
0.00001125          2245.    199535422.     7.4736207    0.00008408    -0.0003209
0.3404328    -8.3084063 C
0.00001188          2245.    189033557.     7.4747019    0.00008876    -0.0003387
0.3589538    -8.7696121 C
0.00001250          2245.    179581880.     7.4758472    0.00009345    -0.0003566
0.3774366    -9.2307555 C
0.00001313          2245.    171030362.     7.4770479    0.00009814    -0.0003744
0.3958809    -9.6918362 C
0.00001375          2245.    163256254.     7.4782968     0.0001028    -0.0003922
0.4142869   -10.1528543 C
0.00001438          2245.    156158156.     7.4795881     0.0001075    -0.0004100
0.4326545   -10.6138094 C
0.00001500          2245.    149651566.     7.4809166     0.0001122    -0.0004278
0.4509836   -11.0747014 C
0.00001563          2245.    143665504.     7.4822784     0.0001169    -0.0004456
0.4692742   -11.5355303 C
0.00001625          2245.    138139907.     7.4836698     0.0001216    -0.0004634
0.4875261   -11.9962958 C
0.00001688          2245.    133023615.     7.4850880     0.0001263    -0.0004812
0.5057395   -12.4569978 C
0.00001750          2245.    128272771.     7.4865303     0.0001310    -0.0004990
0.5239142   -12.9176361 C
0.00001813          2245.    123849572.     7.4879945     0.0001357    -0.0005168
0.5420502   -13.3782106 C
0.00001875          2245.    119721253.     7.4894788     0.0001404    -0.0005346
0.5601475   -13.8387211 C
0.00001938          2245.    115859277.     7.4909814     0.0001451    -0.0005524
0.5782059   -14.2991675 C
0.00002000          2245.    112238675.     7.4925010     0.0001499    -0.0005701
0.5962255   -14.7595497 C
0.00002063          2245.    108837503.     7.4940362     0.0001546    -0.0005879
0.6142061   -15.2198673 C
0.00002125          2245.    105636400.     7.4955859     0.0001593    -0.0006057
0.6321479   -15.6801204 C
0.00002188          2245.    102618217.     7.4971492     0.0001640    -0.0006235
0.6500506   -16.1403087 C
```

0.00002250	2245.	99767711.	7.4987251	0.0001687	-0.0006413	0.6679143	-16.6004321	C
0.00002313	2245.	97071286.	7.5003129	0.0001734	-0.0006591	0.6857389	-17.0604905	C
0.00002375	2245.	94516779.	7.5019118	0.0001782	-0.0006768	0.7035243	-17.5204835	C
0.00002438	2245.	92093272.	7.5035212	0.0001829	-0.0006946	0.7212706	-17.9804112	C
0.00002563	2245.	87600917.	7.5067695	0.0001924	-0.0007301	0.7566453	-18.9000697	C
0.00002688	2245.	83526456.	7.5100538	0.0002018	-0.0007657	0.7918628	-19.8194647	C
0.00002813	2245.	79814169.	7.5133709	0.0002113	-0.0008012	0.8269224	-20.7385948	C
0.00002938	2245.	76417821.	7.5167181	0.0002208	-0.0008367	0.8618239	-21.6574586	C
0.00003063	2245.	73298726.	7.5200934	0.0002303	-0.0008722	0.8965669	-22.5760549	C
0.00003188	2245.	70424267.	7.5234949	0.0002398	-0.0009077	0.9311510	-23.4943823	C
0.00003313	2245.	67766747.	7.5269210	0.0002493	-0.0009432	0.9655756	-24.4124394	C
0.00003438	2245.	65302502.	7.5303705	0.0002589	-0.0009786	0.9998406	-25.3302249	C
0.00003563	2245.	63011186.	7.5338421	0.0002684	-0.0010141	1.0339453	-26.2477373	C
0.00003688	2245.	60875213.	7.5373351	0.0002779	-0.0010496	1.0678895	-27.1649752	C
0.00003813	2245.	58879305.	7.5408485	0.0002875	-0.0010850	1.1016726	-28.0819373	C
0.00003938	2245.	57010121.	7.5443817	0.0002971	-0.0011204	1.1352943	-28.9986221	C
0.00004063	2245.	55255963.	7.5479341	0.0003066	-0.0011559	1.1687542	-29.9150281	C
0.00004188	2245.	53606531.	7.5515052	0.0003162	-0.0011913	1.2020518	-30.8311539	C
0.00004313	2245.	52052719.	7.5550944	0.0003258	-0.0012267	1.2351866	-31.7469980	C
0.00004438	2245.	50586445.	7.5587015	0.0003354	-0.0012621	1.2681584	-32.6625589	C
0.00004563	2245.	49200515.	7.5623261	0.0003450	-0.0012975	1.3009665	-33.5778354	C
0.00004688	2245.	47888501.	7.5659679	0.0003547	-0.0013328	1.3336106	-34.4928254	C
0.00004813	2289.	47556875.	7.5696267	0.0003643	-0.0013682	1.3660902	-35.4075278	C
0.00004938	2347.	47540879.	7.5733022	0.0003739	-0.0014036	1.3984050	-36.3219409	C
0.00005063	2406.	47524866.	7.5769944	0.0003836	-0.0014389	1.4305543	-37.2360632	C

0.00005188 2465. 47508835. 7.5807029 0.0003932 -0.0014743
1.4625379 -38.1498931 C
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1.4943551 -39.0634290 C
0.00005438 2582. 47476708. 7.5881688 0.0004126 -0.0015449
1.5260057 -39.9766693 C
0.00005563 2640. 47460608. 7.5919260 0.0004223 -0.0015802
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1.5888046 -41.8022566 C
0.00005813 2757. 47428325. 7.5994884 0.0004417 -0.0016508
1.6199521 -42.7146003 C
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1.6509310 -43.6266419 C
0.00006063 2873. 47395922. 7.6071146 0.0004612 -0.0017213
1.6817407 -44.5383796 C
0.00006188 2932. 47379671. 7.6109515 0.0004709 -0.0017566
1.7123809 -45.4498117 C
0.00006313 2990. 47363387. 7.6148044 0.0004807 -0.0017918
1.7428510 -46.3609366 C
0.00006438 3048. 47347066. 7.6186731 0.0004905 -0.0018270
1.7731505 -47.2717524 C
0.00006563 3106. 47330709. 7.6225578 0.0005002 -0.0018623
1.8032790 -48.1822575 C
0.00006688 3164. 47314314. 7.6264584 0.0005100 -0.0018975
1.8332359 -49.0924500 C
0.00006813 3222. 47297881. 7.6303750 0.0005198 -0.0019327
1.8630208 -50.0023281 C
0.00006938 3280. 47281407. 7.6343076 0.0005296 -0.0019679
1.8926330 -50.9118901 C
0.00007063 3338. 47264892. 7.6382562 0.0005395 -0.0020030
1.9220722 -51.8211342 C
0.00007188 3396. 47248336. 7.6422209 0.0005493 -0.0020382
1.9513378 -52.7300584 C
0.00007313 3454. 47231737. 7.6462018 0.0005591 -0.0020734
1.9804293 -53.6386609 C
0.00007438 3512. 47215094. 7.6501989 0.0005690 -0.0021085
2.0093461 -54.5469398 C
0.00007938 3742. 47148069. 7.6663507 0.0006085 -0.0022490
2.1232562 -58.1767815 C
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2.2319903 -60.0000000 CY
0.00008938 4116. 46048042. 7.6462720 0.0006834 -0.0025341
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2.4246302 -60.0000000 CY
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 0.0001094         4545.     41555578.      7.4528169      0.0008152     -0.0031223
2.6623351   -60.0000000 CY
 0.0001144         4594.     40163418.      7.3826180      0.0008444     -0.0032731
2.7309276   -60.0000000 CY
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2.7967063   -60.0000000 CY
 0.0001244         4689.     37702233.      7.2526374      0.0009020     -0.0035755
2.8608636   -60.0000000 CY
 0.0001294         4737.     36612182.      7.1960115      0.0009310     -0.0037265
2.9234367   -60.0000000 CY
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2.9844129   -60.0000000 CY
 0.0001394         4831.     34662813.      7.0966725      0.0009891     -0.0040284
3.0437790   -60.0000000 CY
 0.0001444         4878.     33787481.      7.0530098      0.0010183     -0.0041792
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3.1574622   -60.0000000 CY
 0.0001544         4971.     32200884.      6.9722575      0.0010763     -0.0044812
3.2110569   -60.0000000 CY
 0.0001594         5017.     31479740.      6.9353083      0.0011053     -0.0046322
3.2630472   -60.0000000 CY
 0.0001644         5063.     30801357.      6.9011374      0.0011344     -0.0047831
3.3134187   -60.0000000 CY
 0.0001694         5109.     30161934.      6.8695063      0.0011635     -0.0049340
3.3621571   -60.0000000 CY
 0.0001744         5154.     29558106.      6.8402042      0.0011928     -0.0050847
3.4092478   -60.0000000 CY
 0.0001794         5198.     28977044.      6.8115880      0.0012218     -0.0052357
3.4542665   -60.0000000 CY
 0.0001844         5232.     28375916.      6.7772982      0.0012496     -0.0053879
3.4954966   -60.0000000 CY
 0.0001894         5251.     27729345.      6.7333135      0.0012751     -0.0055424
3.5319518   -60.0000000 CY
 0.0001944         5261.     27067545.      6.6842829      0.0012993     -0.0056982
3.5650555   -60.0000000 CY
 0.0001994         5269.     26427223.      6.6342029      0.0013227     -0.0058548
3.5960028   -60.0000000 CY
 0.0002044         5276.     25815901.      6.5846067      0.0013457     -0.0060118
3.6252866   -60.0000000 CY
 0.0002094         5283.     25233484.      6.5376455      0.0013688     -0.0061687
3.6535384   -60.0000000 CY
 0.0002144         5290.     24677946.      6.4931370      0.0013920     -0.0063255
3.6807503   -60.0000000 CY
 0.0002194         5297.     24147447.      6.4509154      0.0014152     -0.0064823
3.7069144   -60.0000000 CY
 0.0002244         5304.     23640308.      6.4108298      0.0014384     -0.0066391
3.7320227   -60.0000000 CY
 0.0002294         5311.     23154998.      6.3727423      0.0014617     -0.0067958
3.7560670   -60.0000000 CY
```

0.0002344	5318.	22690115.	6.3365271	0.0014851	-0.0069524	3.7790390	-60.0000000	CY
0.0002394	5325.	22244378.	6.3020688	0.0015086	-0.0071089	3.8009305	-60.0000000	CY
0.0002444	5331.	21814326.	6.2659368	0.0015312	-0.0072663	3.8210046	-60.0000000	CY
0.0002494	5337.	21401147.	6.2312665	0.0015539	-0.0074236	3.8400152	-60.0000000	CY
0.0002544	5343.	21003974.	6.1981831	0.0015767	-0.0075808	3.8580041	-60.0000000	CY
0.0002594	5349.	20621884.	6.1665970	0.0015995	-0.0077380	3.8749636	-60.0000000	CY
0.0002644	5355.	20254018.	6.1364252	0.0016223	-0.0078952	3.8908856	-60.0000000	CY
0.0002694	5360.	19899577.	6.1075910	0.0016452	-0.0080523	3.9057617	-60.0000000	CY
0.0002744	5366.	19557834.	6.0800233	0.0016682	-0.0082093	3.9195838	-60.0000000	CY
0.0003044	5399.	17738582.	5.9375612	0.0018072	-0.0091503	3.9798697	-60.0000000	CY
0.0003344	5428.	16232482.	5.8136957	0.0019440	-0.0100935	3.9999930	-60.0000000	CY
0.0003644	5454.	14967600.	5.7171809	0.0020832	-0.0110343	3.9999484	-60.0000000	CY
0.0003944	5477.	13888874.	5.6419910	0.0022251	-0.0119724	3.9997068	-60.0000000	CY
0.0004244	5499.	12957415.	5.5833472	0.0023694	-0.0129081	3.9970124	-60.0000000	CY
0.0004544	5518.	12143469.	5.5307172	0.0025130	-0.0138445	3.9865600	-60.0000000	CY
0.0004844	5535.	11427322.	5.4886385	0.0026586	-0.0147789	3.9998272	-60.0000000	CY
0.0005144	5551.	10791747.	5.4561456	0.0028065	-0.0157110	3.9891526	-60.0000000	CY
0.0005444	5566.	10224441.	5.4304688	0.0029562	-0.0166413	3.9999294	-60.0000000	CY
0.0005744	5580.	9714120.	5.4114958	0.0031082	-0.0175693	3.9832450	-60.0000000	CYT
0.0006044	5592.	9253222.	5.3969759	0.0032618	-0.0184957	3.9983153	-60.0000000	CYT
0.0006344	5604.	8834376.	5.3869574	0.0034174	-0.0194201	3.9853764	-60.0000000	CYT
0.0006644	5615.	8452188.	5.3804012	0.0035746	-0.0203429	3.9874921	-60.0000000	CYT
0.0006944	5626.	8102214.	5.3764034	0.0037332	-0.0212643	3.9991285	-60.0000000	CYT
0.0007244	5636.	7780064.	5.3754592	0.0038938	-0.0221837	3.9837705	-60.0000000	CYT

Summary of Results for Nominal Moment Capacity for Section 1

Moment values interpolated at maximum compressive strain = 0.003
or maximum developed moment if pile fails at smaller strains.

Load No.	Axial Thrust kips	Nominal Mom. Cap. in-kip	Max. Comp. Strain
1	0.110	5569.852	0.00300000

Note that the values of moment capacity in the table above are not factored by a strength reduction factor (phi-factor).

In ACI 318, the value of the strength reduction factor depends on whether the transverse reinforcing steel bars are tied hoops (0.65) or spirals (0.75).

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to ACI 318, or the value required by the design standard being followed.

The following table presents factored moment capacities and corresponding bending stiffnesses computed for common resistance factor values used for reinforced concrete sections.

Axial Load No.	Resist. Factor	Nominal Ax. Thrust kips	Nominal Moment Cap in-kips	Ult. (Fac) Ax. Thrust kips	Ult. (Fac) Moment Cap in-kips	Bend. Stiff. at Ult Mom kip-in^2
1	0.65	0.110000	5570.	0.071500	3620.	47183498.
1	0.75	0.110000	5570.	0.082500	4177.	45746737.
1	0.90	0.110000	5570.	0.099000	5013.	31545737.

Layering Correction Equivalent Depths of Soil & Rock Layers

Top of   Equivalent

Layer No.	Layer Below Pile Head ft	Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	0.00	0.00	N.A.	No	0.00	45412.
2	7.0000	7.0000	No	No	45412.	0.00
3	9.0000	9.0000	No	No	0.00	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

Pile-head conditions are Shear and Moment (Loading Type 1)

Shear force at pile head = 400.0 lbs
Applied moment at pile head = 82510.0 in-lbs
Axial thrust load on pile head = 110.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	0.1556	82510.	400.0000	-0.00402	0.00	3.65E+11	0.00	0.00	0.00
0.04750	0.1533	82738.	398.0940	-0.00402	0.00	3.65E+11	-6.6281	24.6462	0.00
0.09500	0.1510	82964.	392.4344	-0.00402	0.00	3.65E+11	-13.2898	50.1670	0.00
0.1425	0.1487	83186.	382.9524	-0.00402	0.00	3.65E+11	-19.9800	76.5838	0.00
0.1900	0.1464	83401.	369.6503	-0.00402	0.00	3.65E+11	-26.6938	103.9189	0.00
0.2375	0.1441	83608.	352.5162	-0.00402	0.00	3.65E+11	-33.4261	132.1963	0.00
0.2850	0.1418	83804.	331.5408	-0.00402	0.00	3.65E+11			

```
-40.1718   161.4411       0.00
    0.3325     0.1395     83986.   306.9012   -0.00402       0.00   3.65E+11
-46.2831   189.0544       0.00
    0.3800     0.1373     84154.   278.8830   -0.00402       0.00   3.65E+11
-52.0266   216.0621       0.00
    0.4275     0.1350     84305.   247.6527   -0.00402       0.00   3.65E+11
-57.5530   243.0699       0.00
    0.4750     0.1327     84437.   213.3342   -0.00402       0.00   3.65E+11
-62.8624   270.0777       0.00
    0.5225     0.1304     84549.   176.0513   -0.00402       0.00   3.65E+11
-67.9548   297.0854       0.00
    0.5700     0.1281     84638.   135.9277   -0.00402       0.00   3.65E+11
-72.8301   324.0932       0.00
    0.6175     0.1258     84704.    93.0870   -0.00402       0.00   3.65E+11
-77.4884   351.1010       0.00
    0.6650     0.1235     84745.    47.6528   -0.00402       0.00   3.65E+11
-81.9297   378.1087       0.00
    0.7125     0.1212     84759.    -0.2510   -0.00402       0.00   3.65E+11
-86.1541   405.1165       0.00
    0.7600     0.1189     84745.   -50.5009   -0.00402       0.00   3.65E+11
-90.1614   432.1243       0.00
    0.8075     0.1166     84702.  -102.9731   -0.00402       0.00   3.65E+11
-93.9518   459.1320       0.00
    0.8550     0.1143     84628.  -157.5440   -0.00402       0.00   3.65E+11
-97.5252   486.1398       0.00
    0.9025     0.1121     84523.  -214.0899   -0.00402       0.00   3.65E+11
-100.8817   513.1476       0.00
    0.9500     0.1098     84385.  -272.4872   -0.00402       0.00   3.65E+11
-104.0212   540.1553       0.00
    0.9975     0.1075     84213.  -332.6121   -0.00402       0.00   3.65E+11
-106.9438   567.1631       0.00
    1.0450     0.1052     84006.  -394.3412   -0.00402       0.00   3.65E+11
-109.6494   594.1709       0.00
    1.0925     0.1029     83764.  -457.5506   -0.00402       0.00   3.65E+11
-112.1382   621.1786       0.00
    1.1400     0.1006     83485.  -522.1169   -0.00402       0.00   3.65E+11
-114.4101   648.1864       0.00
    1.1875     0.09832    83169.  -587.9163   -0.00402       0.00   3.65E+11
-116.4650   675.1942       0.00
    1.2350     0.09603    82815.  -654.8252   -0.00402       0.00   3.65E+11
-118.3031   702.2020       0.00
    1.2825     0.09374    82423.  -722.7200   -0.00402       0.00   3.65E+11
-119.9244   729.2097       0.00
    1.3300     0.09145    81992.  -791.4772   -0.00402       0.00   3.65E+11
-121.3287   756.2175       0.00
    1.3775     0.08916    81521.  -860.9730   -0.00402       0.00   3.65E+11
-122.5162   783.2253       0.00
    1.4250     0.08687    81011.  -931.0839   -0.00402       0.00   3.65E+11
-123.4869   810.2330       0.00
    1.4725     0.08458    80460.     -1002.   -0.00402       0.00   3.65E+11
```

-124.2408	837.2408	0.00				
1.5200	0.08230	79869.	-1073.	-0.00402	0.00	3.65E+11
-124.7778	864.2486	0.00				
1.5675	0.08001	79238.	-1144.	-0.00402	0.00	3.65E+11
-125.0981	891.2563	0.00				
1.6150	0.07772	78566.	-1215.	-0.00402	0.00	3.65E+11
-125.2015	918.2641	0.00				
1.6625	0.07543	77853.	-1287.	-0.00402	0.00	3.65E+11
-125.0881	945.2719	0.00				
1.7100	0.07314	77100.	-1358.	-0.00402	0.00	3.65E+11
-124.7580	972.2796	0.00				
1.7575	0.07085	76306.	-1429.	-0.00402	0.00	3.65E+11
-124.2110	999.2874	0.00				
1.8050	0.06856	75471.	-1499.	-0.00402	0.00	3.65E+11
-123.4474	1026.	0.00				
1.8525	0.06627	74597.	-1569.	-0.00401	0.00	3.65E+11
-122.4669	1053.	0.00				
1.9000	0.06399	73683.	-1639.	-0.00401	0.00	3.65E+11
-121.2697	1080.	0.00				
1.9475	0.06170	72729.	-1708.	-0.00401	0.00	3.65E+11
-119.8558	1107.	0.00				
1.9950	0.05941	71737.	-1775.	-0.00401	0.00	3.65E+11
-118.2251	1134.	0.00				
2.0425	0.05712	70706.	-1842.	-0.00401	0.00	3.65E+11
-116.3777	1161.	0.00				
2.0900	0.05483	69637.	-1908.	-0.00401	0.00	3.65E+11
-114.3136	1188.	0.00				
2.1375	0.05254	68531.	-1973.	-0.00401	0.00	3.65E+11
-112.0328	1215.	0.00				
2.1850	0.05026	67389.	-2036.	-0.00401	0.00	3.65E+11
-109.5353	1242.	0.00				
2.2325	0.04797	66211.	-2097.	-0.00401	0.00	3.65E+11
-106.8210	1269.	0.00				
2.2800	0.04568	64998.	-2157.	-0.00401	0.00	3.65E+11
-103.8901	1296.	0.00				
2.3275	0.04339	63752.	-2216.	-0.00401	0.00	3.65E+11
-100.7425	1323.	0.00				
2.3750	0.04110	62473.	-2272.	-0.00401	0.00	3.65E+11
-97.3782	1350.	0.00				
2.4225	0.03882	61162.	-2327.	-0.00401	0.00	3.65E+11
-93.7973	1377.	0.00				
2.4700	0.03653	59821.	-2379.	-0.00401	0.00	3.65E+11
-89.9996	1404.	0.00				
2.5175	0.03424	58451.	-2429.	-0.00401	0.00	3.65E+11
-85.9853	1431.	0.00				
2.5650	0.03195	57052.	-2477.	-0.00401	0.00	3.65E+11
-81.7544	1458.	0.00				
2.6125	0.02966	55627.	-2522.	-0.00401	0.00	3.65E+11
-77.3067	1485.	0.00				
2.6600	0.02738	54177.	-2565.	-0.00401	0.00	3.65E+11

-72.6425	1512.	0.00				
2.7075	0.02509	52704.	-2605.	-0.00401	0.00	3.65E+11
-67.7615	1539.	0.00				
2.7550	0.02280	51208.	-2642.	-0.00401	0.00	3.65E+11
-62.6639	1566.	0.00				
2.8025	0.02051	49692.	-2676.	-0.00401	0.00	3.65E+11
-57.3497	1593.	0.00				
2.8500	0.01823	48157.	-2708.	-0.00401	0.00	3.65E+11
-51.8189	1620.	0.00				
2.8975	0.01594	46606.	-2735.	-0.00401	0.00	3.65E+11
-46.0714	1647.	0.00				
2.9450	0.01365	45039.	-2760.	-0.00401	0.00	3.65E+11
-40.1072	1674.	0.00				
2.9925	0.01137	43460.	-2781.	-0.00401	0.00	3.65E+11
-33.9265	1701.	0.00				
3.0400	0.00908	41869.	-2799.	-0.00401	0.00	3.65E+11
-27.5290	1728.	0.00				
3.0875	0.00679	40270.	-2812.	-0.00401	0.00	3.65E+11
-20.9150	1756.	0.00				
3.1350	0.00450	38664.	-2822.	-0.00401	0.00	3.65E+11
-14.0843	1783.	0.00				
3.1825	0.00222	37053.	-2828.	-0.00401	0.00	3.65E+11
-7.0370	1810.	0.00				
3.2300	-7.04E-05	35440.	-2830.	-0.00401	0.00	3.65E+11
0.2269	1837.	0.00				
3.2775	-0.00236	33827.	-2828.	-0.00401	0.00	3.65E+11
7.7075	1864.	0.00				
3.3250	-0.00464	32216.	-2822.	-0.00401	0.00	3.65E+11
15.4047	1891.	0.00				
3.3725	-0.00693	30611.	-2811.	-0.00401	0.00	3.65E+11
23.3185	1918.	0.00				
3.4200	-0.00922	29013.	-2795.	-0.00401	0.00	3.65E+11
31.4490	1945.	0.00				
3.4675	-0.01151	27425.	-2775.	-0.00401	0.00	3.65E+11
39.7961	1972.	0.00				
3.5150	-0.01379	25850.	-2749.	-0.00401	0.00	3.65E+11
48.3598	1999.	0.00				
3.5625	-0.01608	24291.	-2719.	-0.00401	0.00	3.65E+11
57.1402	2026.	0.00				
3.6100	-0.01837	22751.	-2684.	-0.00401	0.00	3.65E+11
66.1372	2053.	0.00				
3.6575	-0.02065	21232.	-2644.	-0.00401	0.00	3.65E+11
75.3508	2080.	0.00				
3.7050	-0.02294	19737.	-2598.	-0.00401	0.00	3.65E+11
84.7811	2107.	0.00				
3.7525	-0.02523	18270.	-2547.	-0.00401	0.00	3.65E+11
94.4280	2134.	0.00				
3.8000	-0.02751	16834.	-2491.	-0.00401	0.00	3.65E+11
104.2916	2161.	0.00				
3.8475	-0.02980	15431.	-2428.	-0.00401	0.00	3.65E+11

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114.3719      2188.       0.00
    3.8950   -0.03209    14066.     -2360.   -0.00401       0.00   3.65E+11
124.6687      2215.       0.00
    3.9425   -0.03437    12741.     -2286.   -0.00401       0.00   3.65E+11
135.1823      2242.       0.00
    3.9900   -0.03666    11460.     -2206.   -0.00401       0.00   3.65E+11
145.9125      2269.       0.00
    4.0375   -0.03895    10227.     -2120.   -0.00401       0.00   3.65E+11
156.8593      2296.       0.00
    4.0850   -0.04123     9044.     -2027.   -0.00401       0.00   3.65E+11
168.0229      2323.       0.00
    4.1325   -0.04352     7917.     -1928.   -0.00401       0.00   3.65E+11
179.4030      2350.       0.00
    4.1800   -0.04581     6847.     -1823.   -0.00401       0.00   3.65E+11
190.9999      2377.       0.00
    4.2275   -0.04809     5839.     -1710.   -0.00401       0.00   3.65E+11
202.8134      2404.       0.00
    4.2750   -0.05038     4898.     -1591.   -0.00401       0.00   3.65E+11
214.8437      2431.       0.00
    4.3225   -0.05267     4026.     -1465.   -0.00401       0.00   3.65E+11
227.0905      2458.       0.00
    4.3700   -0.05495     3228.     -1332.   -0.00401       0.00   3.65E+11
239.5541      2485.       0.00
    4.4175   -0.05724     2508.     -1192.   -0.00401       0.00   3.65E+11
252.2344      2512.       0.00
    4.4650   -0.05953     1869.     -1045.   -0.00401       0.00   3.65E+11
265.1313      2539.       0.00
    4.5125   -0.06181     1317.  -889.8293   -0.00401       0.00   3.65E+11
278.2449      2566.       0.00
    4.5600   -0.06410   855.3069  -727.4305   -0.00401       0.00   3.65E+11
291.5753      2593.       0.00
    4.6075   -0.06639   488.2894  -557.3718   -0.00401       0.00   3.65E+11
305.1223      2620.       0.00
    4.6550   -0.06867   220.4061  -379.5294   -0.00401       0.00   3.65E+11
318.8860      2647.       0.00
    4.7025   -0.07096    56.1289  -193.7800   -0.00401       0.00   3.65E+11
332.8664      2674.       0.00
    4.7500   -0.07325      0.00       0.00   -0.00401       0.00   3.65E+11
347.0635      1350.       0.00
```

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

```
Pile-head deflection             =     0.15558165 inches
Computed slope at pile head      =    -0.00402000 radians
Maximum bending moment           =         84759. inch-lbs
Maximum shear force              =         -2830. lbs
Depth of maximum bending moment  =     0.71250000 feet below pile head
Depth of maximum shear force     =     3.23000000 feet below pile head
Number of iterations             =              6
Number of zero deflection points =              1


--------------------------------------------------------------------------------
            Summary of Pile-head Responses for Conventional Analyses
--------------------------------------------------------------------------------

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians


Load Load                Load                  Axial    Pile-head  Pile-head  Max
Shear Max Moment
Case Type   Pile-head    Type     Pile-head   Loading  Deflection  Rotation    in
Pile    in Pile
 No.  1      Load 1       2        Load 2       lbs      inches     radians      lbs
     in-lbs
---- ----- ---------- ---------- ---------- ---------- ---------- ----------
---------- ----------
  1  V, lb   400.0000  M, in-lb      82510.   110.0000     0.1556   -0.00402
-2830.     84759.

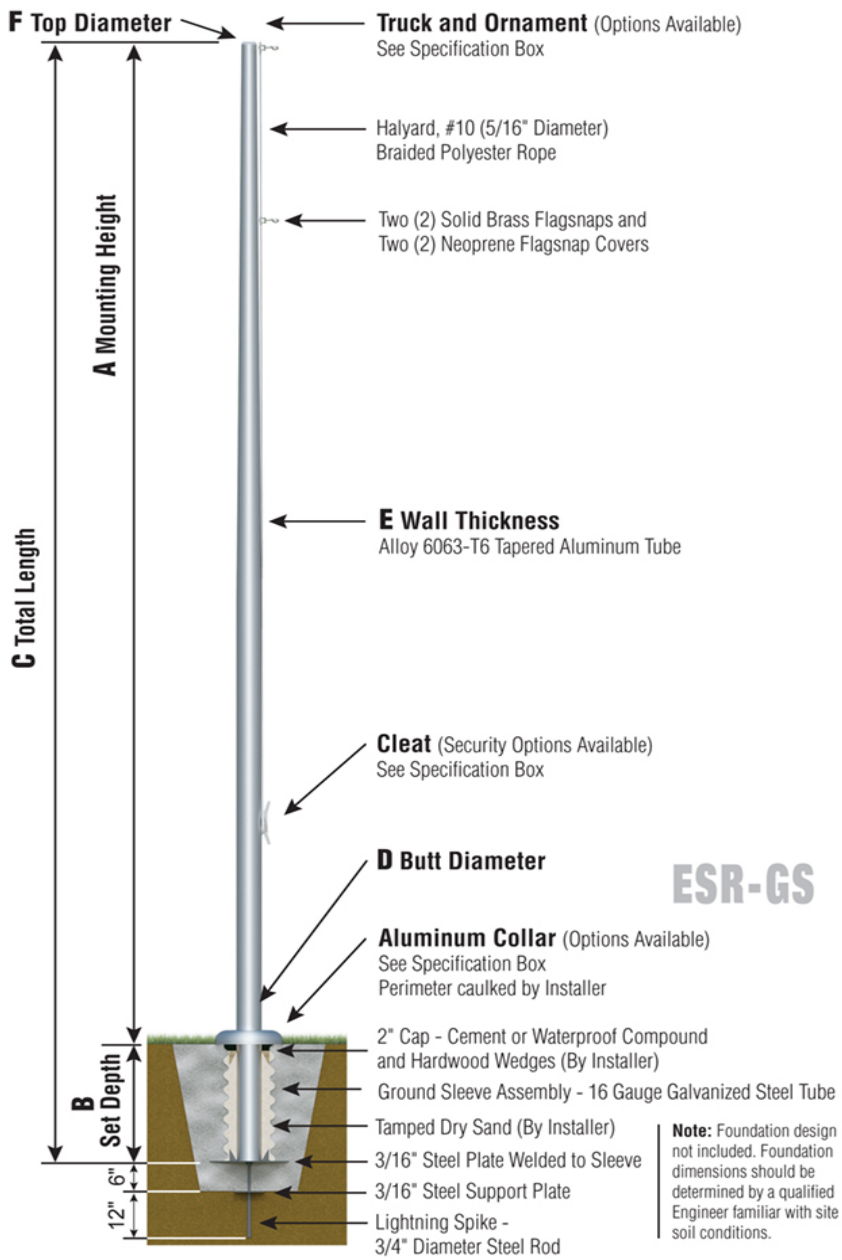

Maximum pile-head deflection = 0.1555816504 inches
Maximum pile-head rotation   = -0.0040199994 radians = -0.230329 deg.

The analysis ended normally.
```

Continental Series

ESR - External Single Revolving
Rope Halyard
Ground Set Installation

ESR30C61 - SAT

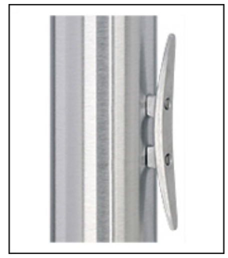


TRK-9610

In-Line Truck
Single Revolving

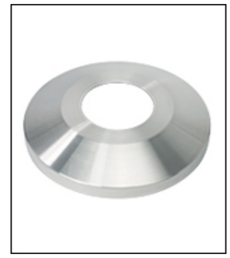
BAL-0612-GLD-ES

HD Gold Anodized
Aluminum Ball



CLA-9090-SAT | 7.5' from bottom

Cleat Only



COL1-A06S

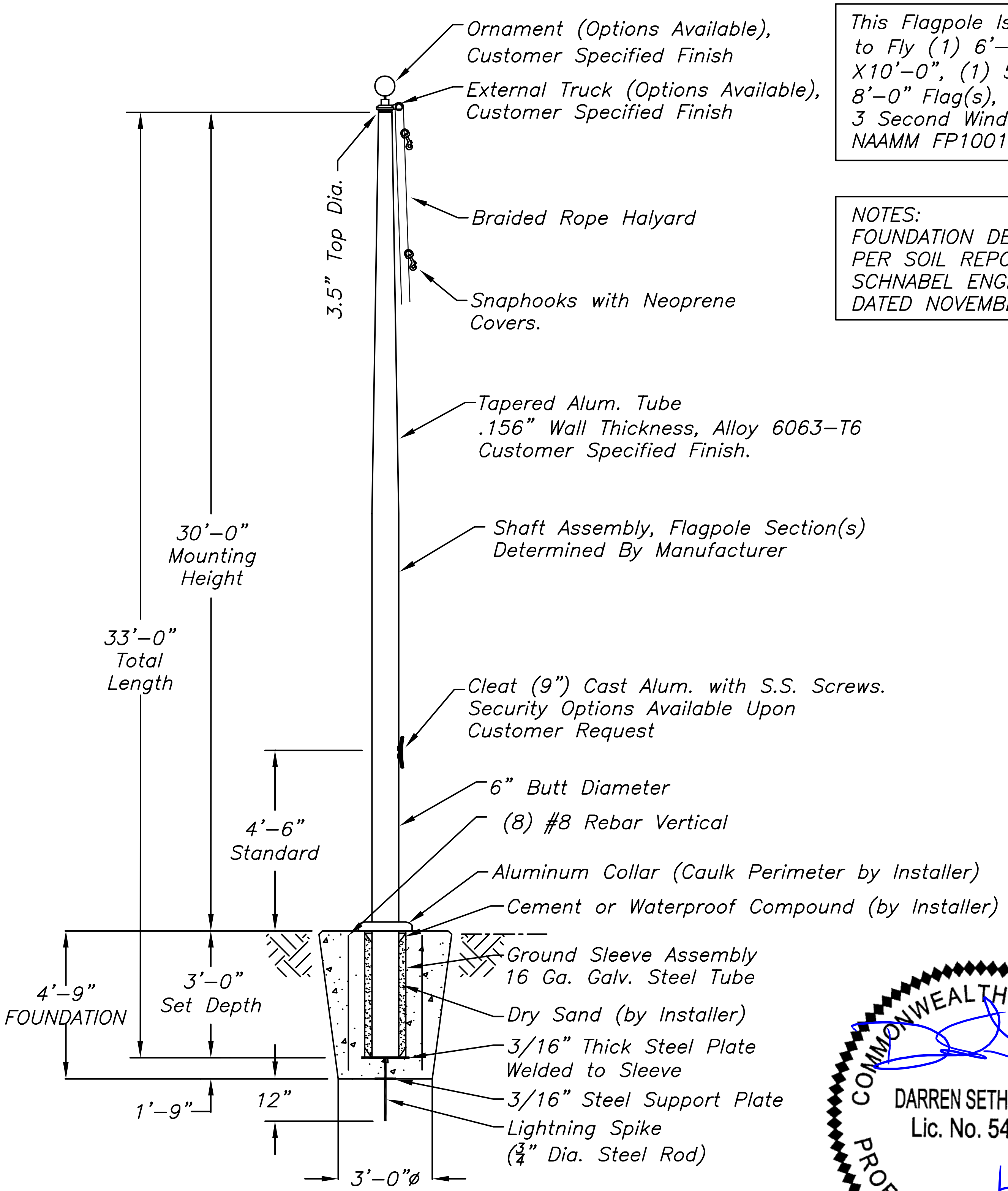
FC-11 Spun Alum
1-Piece

SAT

Satin Finish

Specifications
A. Mounting Height: 30'
B. Set Depth: 3'-0"
C. Total Length: 33'-0"
D. Butt Diameter: 6"
E. Wall Thickness: .156"
F. Top Diameter: 3.5"
Flagpole Sections: 1
Shaft Weight: 135 lbs.
Hardware Weight: 10 lbs.
Ground Sleeve Weight: 36 lbs.
* Rated Flag Size: (1) 6' x 10' & (1) 5' x 8'
* Rated Wind Speed w/Nylon Flag: 90 mph
* Wind Speed Specifications from ANSI/NAAMM FP 1001-07

Customer Name:			
Dealer:	Gates Flag & Banner	Qty: 1	
Project:	Exit 54 Roundabout Flagpoles	Location:	Colonial Heights, VA 23834
Notes: EPT95377			



This Flagpole Is Designed to Fly (1) 6'–0" X10'–0", (1) 5'–0"X 8'–0" Flag(s), At 90 MPH. 3 Second Wind Gusts Per NAAMM FP1001–07.

NOTES:
FOUNDATION DESIGNED PER SOIL REPORTS BY SCHNABEL ENGINEERING DATED NOVEMBER 6, 2024

NO.	REVISIONS	DATE

CONCORD AMERICAN FLAGPOLE
Abingdon, Va.

TITLE:	External Halyard Flagpole
PROJECT:	EXIT 54 ROUNDABOUT
LOCATION:	COLONIAL HEIGHTS, VA
CUSTOMER OR REP.:	
DATE:	04.03.25
SCALE:	NTS
DWG #:	ESR30C61–SAT
PT#:	EPT–95377

MBI Companies Inc.
299 North Weisgarber Road
Knoxville, TN 37919
Phone: (865) 584-0999
Fax: (865) 584-5213

www.sign-engineer.com

Project	**Exit 54 Roundabout**		
Client	**Concord Industries**		
Location	**Colonial Heights, VA**		
Comm. No.	**240209-078-02**		
Designed by	**Concord Industries**	Date	**4/3/2025**
Reviewed by	**DSA**	Date	**4/3/2025**

DESIGN CALCULATIONS FOR:

Concord Industries

Exit 54 Roundabout

Colonial Heights, VA

24' Flagpole

Analysis	**Concord Industries**
Reviewed by:	**Darren S. Antle, P.E.**
Comm#:	**240209-078-02**

MBI Companies Inc.
299 North Weisgarber Road
Knoxville, TN 37919
Phone: (865) 584-0999

April 3, 2025

CONCORD AMERICAN FLAGPOLE
Pride. Quality. Tradition.

Round Pole Design Calculations & Loading Analysis

CAFP Pole Design: *ESR25C51-SAT*
Calculation Date: *09/17/2024*
Calculations Prepared By: *Jonathan Pinchback, Product Design Engineer*

These calculations are based on the *Guide Specifications For Design Of Metal Flagpoles, ANSI/NAAMM FP 1001-7.*

AASHTO LTS-6 AND VDOT SP700-000180-03

Wind Loading Criteria:

$U_D := 90 \cdot mph$	Design Wind Speed (*3-Second Gust*)
$G_{eff} := 1.14$	Gust Effect Factor
$\alpha := 9.5$	Height Exponent (*Exposure Cat. C*)
$z_g := 900 \cdot ft$	Boundary Layer Height (*Exposure Cat. C*)
$H_{Pier} := 0 \cdot ft + 0 \cdot in$	Pier Height (*Above Grade*)

Load & Safety Factors:

$\gamma_D := 1.00$	Dead Load Factor
$\gamma_W := 1.00$	Wind Load Factor

Shaft Dimensional Parameters:

$D_B := 5 \cdot in$	Bottom Diameter
$D_T := 3 \cdot in$	Top Diameter
$t_w := 0.156 \cdot in$	Nominal Wall Thickness
$L_{botst} := 13 \cdot ft + 0 \cdot in$	Bottom Straight Length
$L_{taper} := 11 \cdot ft + 0 \cdot in$	Tapered Length
$L_{topst} := 0 \cdot ft + 0 \cdot in$	Top Straight Length

$L_{total} := L_{botst} + L_{taper} + L_{topst}$

$L_{total} = 24.000\ ft$ Total Shaft Length

$n_{taper} := 1$	Taper Exponent
$k_{eff} := 2.00$	Effective Length Factor

Shaft Material Properties:

The pole shaft is made of 6063-T6 aluminum.

$E_{6063} := 10100 \cdot ksi$	Modulus of Elasticity (*6063 Al.*)
$\rho_{6063} := 0.1 \cdot pci$	Material Density (*6063 Al.*)
$Ftu_{6063} := 30 \cdot ksi$	Ultimate Tensile Strength (*6063-T6*)
$Fty_{6063} := 25 \cdot ksi$	Tensile Yield Strength (*6063-T6*)
$Fcy_{6063} := 25 \cdot ksi$	Compressive Yield Strength (*6063-T6*)
$Fsu_{6063} := 18 \cdot ksi$	Ultimate Shear Strength (*6063-T6*)
$Fsy_{6063} := 15 \cdot ksi$	Yield Shear Strength (*6063-T6*)
$kt_{6063} := 1.00$	Tension Coefficient (*6063-T6*)

Unreinforced Handhole Parameters:

$z_{cut} := 0 \cdot ft + 0 \cdot in$	Height to Center of Cutout
$\theta_{cut} := 0 \cdot deg$	Angle to Cutout (*CCW from front*)
$w_{cut} := 0 \cdot in$	Cutout Width
$l_{cut} := 0 \cdot in$	Cutout Length

Loading Inputs:

The loading inputs shown below have been either provided to CAFP or assumed. If any loads appear to be incorrect, unaccounted for, or have changed since these calculations were produced, please contact CAFP Engineering for revised calculations.

Flag 1:

$V_{F_1} := 5 \cdot ft$	Flag Vertical Dimension
$H_{F_1} := 8 \cdot ft$	Flag Horizontal Dimension
$\gamma_{F_1} := 0.0010 \cdot lbf$	Flag Material Load Factor
$z_{F_1} := 21 \cdot ft + 6 \cdot in$	z Coordinate of Flag

Flag 2:

$V_{F_2} := 4 \cdot ft$	Flag Vertical Dimension
$H_{F_2} := 6 \cdot ft$	Flag Horizontal Dimension
$\gamma_{F_2} := 0.0010 \cdot lbf$	Flag Material Load Factor
$z_{F_2} := 17 \cdot ft + 0 \cdot in$	z Coordinate of Flag

Flag 3:

$V_{F_3} := 0 \cdot ft$	Flag Vertical Dimension
$H_{F_3} := 0 \cdot ft$	Flag Horizontal Dimension
$\gamma_{F_3} := 0.0010 \cdot lbf$	Flag Material Load Factor
$z_{F_3} := 0 \cdot ft + 0 \cdot in$	z Coordinate of Flag

Yard Arm:

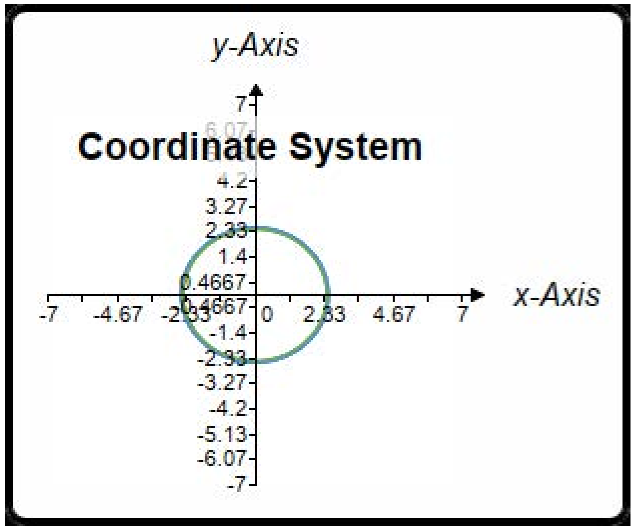
$D_{YA} := 0 \cdot in$	Diameter of Yard Arm
$L_{YA} := 0 \cdot ft + 0 \cdot in$	Length of Yard Arm
$t_{YA} := 0 \cdot in$	Thickness of Yard Arm
$z_{YA} := 0 \cdot ft + 0 \cdot in$	z Coordinate of Yard Arm
$V_{F.YA} := 0 \cdot ft$	Yard Arm Flag Vertical Dimension
$H_{F.YA} := 0 \cdot ft$	Yard Arm Flag Horizontal Dimension
$\gamma_{F.YA} := 0.0010 \cdot lbf$	Yard Arm Flag Material Load Factor

Gaff:

$D_{GA} := 0 \cdot in$	Diameter of Gaff
$L_{GA} := 0 \cdot ft + 0 \cdot in$	Length of Gaff
$t_{GA} := 0 \cdot in$	Thickness of Gaff
$\theta_{GA} := 0 \cdot deg$	Angle of Gaff
$z_{GA} := 0 \cdot ft + 0 \cdot in$	z Coordinate of Gaff
$V_{F.GA} := 0 \cdot ft$	Gaff Flag Vertical Dimension
$H_{F.GA} := 0 \cdot ft$	Gaff Flag Horizontal Dimension
$\gamma_{F.GA} := 0.0010 \cdot lbf$	Gaff Flag Material Load Factor

Coordinate System Information:

In this analysis, a standard x,y,z coordinate system is used. The coordinate system is placed at the base of the pole shaft, with the z-axis moving positive along the pole's longitudinal axis. The x-axis will move left(-) to right(+), and the y-axis will move backwards(-) and forwards(+) from the pole's diametric center.



Flag Material Load Factor:

Refer to Section 4.1 of NAAMM FP 1001-07 for information regarding Flag Wind Loads. Flags made of nylon and/or cotton will have a load factor of $\gamma_{Nylon} := 0.0010 \cdot lbf$ in accordance with Equation 4. Flags made of polyester will have a load factor of $\gamma_{Poly} := 0.0014 \cdot lbf$ in accordance with Equation 5.

Attachment 1: XXXXXX

$EPA_1 := 0 \cdot ft^2$	Effective Projected Area
$xEPA_1 := 0 \cdot ft + 0 \cdot in$	x Coordinate of EPA
$xCG_1 := 0 \cdot ft + 0 \cdot in$	x Coordinate of Weight
$zEPA_1 := 0 \cdot ft + 0 \cdot in$	z Coordinate of Attachment
$wEPA_1 := 0 \cdot lbf$	Weight of Attachment

Attachment 2: XXXXXX

$EPA_2 := 0 \cdot ft^2$	Effective Projected Area
$xEPA_2 := 0 \cdot ft + 0 \cdot in$	x Coordinate of EPA
$xCG_2 := 0 \cdot ft + 0 \cdot in$	x Coordinate of Weight
$zEPA_2 := 0 \cdot ft + 0 \cdot in$	z Coordinate of Attachment
$wEPA_2 := 0 \cdot lbf$	Weight of Attachment

Shaft Calculations:

Shaft Geometry:

$$D(z) := \begin{cases} D_B & \text{if } z \le L_{botst} \\ D_T + (D_B - D_T)\cdot\left(\dfrac{L_{botst}+L_{taper}-z}{L_{taper}}\right)^{n_{taper}} & \text{else if } z < L_{botst}+L_{taper} \\ D_T & \text{else} \end{cases}$$

Shaft Diameter Function:

$D(0) = 5.000\ in$ Diameter at Bottom

$D\left(\dfrac{L_{total}}{2}\right) = 5.000\ in$ Diameter at Middle

$D(L_{total}) = 3.000\ in$ Diameter at Top

$$Ro_S(z) := \frac{D(z)}{2} \qquad Ri_S(z) := Ro_S(z) - t_w$$

Outer and Inner Shaft Radii Functions, Respectively

$$\phi_{cut}(z) := \begin{cases} 2\cdot \operatorname{asin}\left(\dfrac{w_{cut}}{D(z)}\right) & \text{if } \dfrac{-l_{cut}}{2} < z - z_{cut} < \dfrac{l_{cut}}{2} \\ 0\cdot deg & \text{else} \end{cases}$$

Function for Angle Swept by Cutout:

$\phi_{cut}(0) = 0.000\ deg$

$\phi_{cut}(z_{cut}) = 0.000\ deg$

$$\phi_i(z) := \begin{array}{l} \phi \leftarrow \theta_{cut} - \dfrac{\pi + \phi_{cut}(z)}{2} \\ \text{if } \phi \le 0\cdot deg \\ \quad \phi \leftarrow \phi + 2\cdot\pi \\ \phi \end{array}$$

Angle to Start of Cut from (+)x-Axis:

$\phi_i(0) = 270.000\ deg$

$\phi_i(z_{cut}) = 270.000\ deg$

$$\phi_f(z) := \phi_i(z) + \phi_{cut}(z)$$

Angle to End of Cut from (+)x-Axis:

$\phi_f(0) = 270.000\ deg$ $\phi_f(z_{cut}) = 270.000\ deg$

$$A(z) := \left(\pi - \frac{\phi_{cut}(z)}{2}\right)\cdot\left(Ro_S(z)^2 - Ri_S(z)^2\right)$$

Shaft Cross-Sectional Area Function:

$A(0) = 2.374\ in^2$ $A(z_{cut}) = 2.374\ in^2$ $A(L_{total}) = 1.394\ in^2$

$$x_{cg}(z) := \frac{Ro_S(z)^3 - Ri_S(z)^3}{3\cdot A(z)}\cdot\left(\sin(\phi_i(z)) - \sin(\phi_f(z))\right)$$

x-Coordinate of Cross-Section Centroid:

$x_{cg}(0) = 0.000\ in$ $x_{cg}(z_{cut}) = 0.000\ in$ $x_{cg}(L_{total}) = 0.000\ in$

$$y_{cg}(z) := \frac{Ro_S(z)^3 - Ri_S(z)^3}{3\cdot A(z)}\cdot\left(\cos(\phi_f(z)) - \cos(\phi_i(z))\right)$$

y-Coordinate of Cross-Section Centroid:

$y_{cg}(0) = 0.000\ in$ $y_{cg}(z_{cut}) = 0.000\ in$ $y_{cg}(L_{total}) = 0.000\ in$

$$Ixx(z) := \frac{Ro_S(z)^4 - Ri_S(z)^4}{4} \cdot \left(\pi - \frac{\phi_f(z) - \phi_i(z)}{2} + \frac{1}{4} \cdot \left(\sin\left(2 \cdot \phi_f(z)\right) - \sin\left(2 \cdot \phi_i(z)\right)\right)\right) + \frac{2 \cdot \left(Ro_S(z)^3 - Ri_S(z)^3\right)}{3} \cdot y_{cg}(z) \cdot \left(\cos\left(\phi_i(z)\right) - \cos\left(\phi_f(z)\right)\right) + \frac{Ro_S(z)^2 - Ri_S(z)^2}{2} \cdot y_{cg}(z)^2 \cdot \left(2 \cdot \pi + \phi_i(z) - \phi_f(z)\right)$$

$Ixx(0) = 6.970\ in^4$ $Ixx(z_{cut}) = 6.970\ in^4$ $Ixx(L_{total}) = 1.413\ in^4$ Shaft Area Moment of Inertia w.r.t. the x-Axis:

$$Iyy(z) := \frac{Ro_S(z)^4 - Ri_S(z)^4}{4} \cdot \left(\pi - \frac{\phi_f(z) - \phi_i(z)}{2} - \frac{1}{4} \cdot \left(\sin\left(2 \cdot \phi_f(z)\right) - \sin\left(2 \cdot \phi_i(z)\right)\right)\right) + \frac{2 \cdot \left(Ro_S(z)^3 - Ri_S(z)^3\right)}{3} \cdot x_{cg}(z) \cdot \left(\sin\left(\phi_f(z)\right) - \sin\left(\phi_i(z)\right)\right) + \frac{Ro_S(z)^2 - Ri_S(z)^2}{2} \cdot x_{cg}(z)^2 \cdot \left(2 \cdot \pi + \phi_i(z) - \phi_f(z)\right)$$

$Iyy(0) = 6.970\ in^4$ $Iyy(z_{cut}) = 6.970\ in^4$ $Iyy(L_{total}) = 1.413\ in^4$ Shaft Area Moment of Inertia w.r.t. the y-Axis:

$$Ixy(z) := \frac{Ro_S(z)^4 - Ri_S(z)^4}{8} \cdot \left(\cos\left(\phi_f(z)\right)^2 - \cos\left(\phi_i(z)\right)^2\right) + \frac{Ro_S(z)^3 - Ri_S(z)^3}{3} \cdot \left(x_{cg}(z) \cdot \left(\cos\left(\phi_i(z)\right) - \cos\left(\phi_f(z)\right)\right) + y_{cg}(z) \cdot \left(\sin\left(\phi_f(z)\right) - \sin\left(\phi_i(z)\right)\right)\right) + \frac{Ro_S(z)^2 - Ri_S(z)^2}{2} \cdot x_{cg}(z) \cdot y_{cg}(z) \cdot \left(2 \cdot \pi + \phi_i(z) - \phi_f(z)\right)$$

$Ixy(0) = 0.000\ in^4$ $Ixy(z_{cut}) = 0.000\ in^4$ $Ixy(L_{total}) = 0.000\ in^4$ Shaft Product of Inertia:

Shaft Area Moment of Inertia w.r.t. the z-Axis: (*Approximation for Polar Moment of Inertia*)

$Izz(z) := Ixx(z) + Iyy(z)$ $Izz(0) = 13.940\ in^4$ $Izz(z_{cut}) = 13.940\ in^4$ $Izz(L_{total}) = 2.827\ in^4$

$rxx(z) := \sqrt{\frac{Ixx(z)}{A(z)}}$ Radius of Gyration w.r.t. the x-Axis: $rxx(0) = 1.714\ in$

$rxx(z_{cut}) = 1.714\ in$

$rxx(L_{total}) = 1.007\ in$

$ryy(z) := \sqrt{\frac{Iyy(z)}{A(z)}}$ Radius of Gyration w.r.t. the y-Axis: $ryy(0) = 1.714\ in$

$ryy(z_{cut}) = 1.714\ in$

$ryy(L_{total}) = 1.007\ in$

Elastic Section Moduli w.r.t. the x-Axis:

$$Sxx_U(z) := \frac{Ixx(z)}{Ro_S(z) - y_{cg}(z)}$$

Elastic Section Moduli Above Centroidal x-Axis:

$Sxx_U(0) = 2.788\ in^3$ $Sxx_U(z_{cut}) = 2.788\ in^3$ $Sxx_U(L_{total}) = 0.942\ in^3$

$$Sxx_L(z) := \frac{Ixx(z)}{Ro_S(z) + y_{cg}(z)}$$

Elastic Section Moduli Below Centroidal x-Axis:

$Sxx_L(0) = 2.788\ in^3$ $Sxx_L(z_{cut}) = 2.788\ in^3$ $Sxx_L(L_{total}) = 0.942\ in^3$

$Sxx_{max}(z) := \max(Sxx_U(z), Sxx_L(z))$ Maximum Elastic Section Modulus w.r.t. the x-Axis

Elastic Section Moduli w.r.t. the y-Axis:

$$Syy_U(z) := \frac{Iyy(z)}{Ro_S(z) - x_{cg}(z)}$$

Elastic Section Moduli Above Centroidal y-Axis:

$Syy_U(0) = 2.788\ in^3$ $Syy_U(z_{cut}) = 2.788\ in^3$ $Syy_U(L_{total}) = 0.942\ in^3$

$$Syy_L(z) := \frac{Iyy(z)}{Ro_S(z) + x_{cg}(z)}$$

Elastic Section Moduli Below Centroidal y-Axis:

$Syy_L(0) = 2.788\ in^3$ $Syy_L(z_{cut}) = 2.788\ in^3$ $Syy_L(L_{total}) = 0.942\ in^3$

$Syy_{max}(z) := \max(Syy_U(z), Syy_L(z))$ Maximum Elastic Section Modulus w.r.t. the y-Axis

$\phi_{xi.i}(z) := \operatorname{asin}\left(\frac{y_{cg}(z)}{Ri_S(z)}\right)$ $\phi_{xi.i}(z_{cut}) = 0.000\ deg$ Angle from Geometric Center to Inner Radius on Centroidal (+)x-Axis:

$\phi_{xo.i}(z) := \operatorname{asin}\left(\frac{y_{cg}(z)}{Ro_S(z)}\right)$ $\phi_{xo.i}(z_{cut}) = 0.000\ deg$ Angle from Geometric Center to Outer Radius on Centroidal (+)x-Axis:

$\phi_{xi.f}(z) := \pi - \operatorname{asin}\left(\frac{y_{cg}(z)}{Ri_S(z)}\right)$ $\phi_{xi.f}(z_{cut}) = 180.000\ deg$ Angle from Geometric Center to Inner Radius on Centroidal (-)x-Axis:

$\phi_{xo.f}(z) := \pi - \operatorname{asin}\left(\frac{y_{cg}(z)}{Ro_S(z)}\right)$ $\phi_{xo.f}(z_{cut}) = 180.000\ deg$ Angle from Geometric Center to Outer Radius on Centroidal (-)x-Axis:

$\phi_{yi.i}(z) := \frac{\pi}{2} - \operatorname{asin}\left(\frac{x_{cg}(z)}{Ri_S(z)}\right)$ $\phi_{yi.i}(z_{cut}) = 90.000\ deg$ Angle from Geometric Center to Inner Radius on Centroidal (+)y-Axis:

$\phi_{yo.i}(z) := \frac{\pi}{2} - \operatorname{asin}\left(\frac{x_{cg}(z)}{Ro_S(z)}\right)$ $\phi_{yo.i}(z_{cut}) = 90.000\ deg$ Angle from Geometric Center to Outer Radius on Centroidal (+)y-Axis:

$\phi_{yi.f}(z) := \frac{3 \cdot \pi}{2} + \operatorname{asin}\left(\frac{x_{cg}(z)}{Ri_S(z)}\right)$ $\phi_{yi.f}(z_{cut}) = 270.000\ deg$ Angle from Geometric Center to Inner Radius of Centroidal (-)y-Axis:

$\phi_{yo.f}(z) := \frac{3 \cdot \pi}{2} + \operatorname{asin}\left(\frac{x_{cg}(z)}{Ro_S(z)}\right)$ $\phi_{yo.f}(z_{cut}) = 270.000\ deg$ Angle from Geometric Center to Outer Radius on Centroidal (-)y-Axis:

$$f\phi_c(\phi_l, \phi_u, \phi_c) := \begin{cases} \text{if } \phi_c \le \phi_l \\ \quad \phi_l \\ \text{else if } \phi_c \ge \phi_u \\ \quad \phi_u \\ \text{else} \\ \quad \phi_c \end{cases}$$

Function to Find Angle Limits of Cutout w.r.t. Centroidal Axes:

$\phi_{cxi.i}(z) := f\phi_c(\phi_{xi.i}(z), \phi_{xi.f}(z), \phi_i(z))$ — $\phi_{cxi.i}(z_{cut}) = 180.000\ deg$ — Initial Inner Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$\phi_{cxo.i}(z) := f\phi_c(\phi_{xo.i}(z), \phi_{xo.f}(z), \phi_i(z))$ — $\phi_{cxo.i}(z_{cut}) = 180.000\ deg$ — Initial Outer Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$\phi_{cxi.f}(z) := f\phi_c(\phi_{xi.i}(z), \phi_{xi.f}(z), \phi_f(z))$ — $\phi_{cxi.f}(z_{cut}) = 180.000\ deg$ — Final Inner Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$\phi_{cxo.f}(z) := f\phi_c(\phi_{xo.i}(z), \phi_{xo.f}(z), \phi_f(z))$ — $\phi_{cxo.f}(z_{cut}) = 180.000\ deg$ — Final Outer Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$\phi_{cyi.i}(z) := f\phi_c(\phi_{yi.i}(z), \phi_{yi.f}(z), \phi_i(z))$ — $\phi_{cyi.i}(z_{cut}) = 270.000\ deg$ — Initial Inner Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$\phi_{cyo.i}(z) := f\phi_c(\phi_{yo.i}(z), \phi_{yo.f}(z), \phi_i(z))$ — $\phi_{cyo.i}(z_{cut}) = 270.000\ deg$ — Initial Outer Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$\phi_{cyi.f}(z) := f\phi_c(\phi_{yi.i}(z), \phi_{yi.f}(z), \phi_f(z))$ — $\phi_{cyi.f}(z_{cut}) = 270.000\ deg$ — Final Inner Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$\phi_{cyo.f}(z) := f\phi_c(\phi_{yo.i}(z), \phi_{yo.f}(z), \phi_f(z))$ — $\phi_{cyo.f}(z_{cut}) = 270.000\ deg$ — Final Outer Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$$Qxx(z) := \frac{Ro_S(z)^3}{3} \cdot (\cos(\phi_{xo.i}(z)) - \cos(\phi_{xo.f}(z)) + \cos(\phi_{cxo.f}(z)) - \cos(\phi_{cxo.i}(z))) + \frac{Ri_S(z)^3}{3} \cdot (\cos(\phi_{cxi.i}(z)) - \cos(\phi_{cxi.f}(z)) + \cos(\phi_{xi.f}(z)) - \cos(\phi_{xi.i}(z))) + \frac{y_{cg}(z)}{2} \cdot \left(Ro_S(z)^2 \cdot (\phi_{cxo.f}(z) - \phi_{cxo.i}(z) + \phi_{xo.i}(z) - \phi_{xo.f}(z)) + Ri_S(z)^2 \cdot (\phi_{xi.f}(z) - \phi_{xi.i}(z) + \phi_{cxi.i}(z) - \phi_{cxi.f}(z))\right)$$

$Qxx(0) = 1.831\ in^3$ — $Qxx(z_{cut}) = 1.831\ in^3$ — $Qxx(L_{total}) = 0.632\ in^3$ — First Moment of Area w.r.t. Centroidal x-Axis:

$$Qyy(z) := \frac{Ro_S(z)^3}{3} \cdot (\sin(\phi_{yo.f}(z)) - \sin(\phi_{yo.i}(z)) + \sin(\phi_{cyo.i}(z)) - \sin(\phi_{cyo.f}(z))) + \frac{Ri_S(z)^3}{3} \cdot (\sin(\phi_{cyo.f}(z)) - \sin(\phi_{cyo.i}(z)) + \sin(\phi_{yo.i}(z)) - \sin(\phi_{yo.f}(z))) + \frac{x_{cg}(z)}{2} \cdot \left(Ro_S(z)^2 \cdot (\phi_{cyo.f}(z) - \phi_{cyo.i}(z) + \phi_{yo.i}(z) - \phi_{yo.f}(z)) + Ri_S(z)^2 \cdot (\phi_{yi.f}(z) - \phi_{yi.i}(z) + \phi_{cyi.i}(z) - \phi_{cyi.f}(z))\right)$$

$Qyy(0) = 1.831\ in^3$ — $Qyy(z_{cut}) = 1.831\ in^3$ — $Qyy(L_{total}) = 0.632\ in^3$ — First Moment of Area w.r.t. Centroidal y-Axis:

$Zxx(z) := 2 \cdot Qxx(z)$ Plastic Section Modulus w.r.t. Centroidal x-Axis:

$Zxx(0) = 3.662\ in^3$ $Zxx(z_{cut}) = 3.662\ in^3$ $Zxx(L_{total}) = 1.263\ in^3$

$Zyy(z) := 2 \cdot Qyy(z)$ Plastic Section Modulus w.r.t. Centroidal y-Axis:

$Zyy(0) = 3.662\ in^3$ $Zyy(z_{cut}) = 3.662\ in^3$ $Zyy(L_{total}) = 1.263\ in^3$

Shaft Wind Loads:

$$C_h(z) := 2.01 \cdot \left(\frac{\max(16.4 \cdot ft, z + H_{Pier})}{z_g} \right)^{\frac{2}{\alpha}}$$

Coefficient of Height:
(*Ref. Section 3.2.3 of NAAMM FP 1001-07*)

$C_h(0) = 0.865$ $C_h(L_{total}) = 0.937$

$$C_d(d) := \begin{cases} 1.10 & \text{if } U_D \cdot d \le 39 \cdot mph \cdot ft \\ \dfrac{129}{\left(\dfrac{U_D \cdot d}{mph \cdot ft}\right)^{1.3}} & \text{else if } 39 \cdot mph \cdot ft < U_D \cdot d < 78 \cdot mph \cdot ft \\ 0.45 & \text{else} \end{cases}$$

Drag Coefficient:
(*Ref. Table 3.2.4 of NAAMM FP 1001-07*)

$C_d(D(0)) = 1.100$

$C_d(D(L_{total})) = 1.100$

$$P_z(z) := 0.00256 \cdot \left(\frac{U_D}{mph}\right)^2 \cdot C_h(z) \cdot G_{eff} \cdot psf$$

Design Wind Pressure:
(*Ref. Section 3.2.1 of NAAMM FP 1001-07*)

$P_z(0) = 20.447\ psf$ $P_z(L_{total}) = 22.154\ psf$

$$V_{Shaft}(z) := \int_z^{L_{total}} P_z(z) \cdot C_d(D(z)) \cdot D(z)\, dz$$

Function for Wind Shear on Pole Shaft:
(*Function of Height*)

$$M_{Shaft}(z) := \int_z^{L_{total}} (\varepsilon - z) \cdot P_z(\varepsilon) \cdot C_d(D(\varepsilon)) \cdot D(\varepsilon)\, d\varepsilon$$

Function for Wind Moment on Pole Shaft:
(*Function of Height*)

$$V_{Flag}(z, i) := \begin{cases} \gamma_{F_i} \cdot \left(\dfrac{U_D}{mph}\right)^2 \cdot \sqrt{\dfrac{V_{F_i} \cdot H_{F_i}}{ft^2}} \cdot C_h(z) \cdot G_{eff} & \text{if } z \le z_{F_i} \\ 0 \cdot lbf & \text{else} \end{cases}$$

Function for Wind Shear of *ith* Flag:

$$V_{EPA}(z, i) := \begin{cases} EPA_i \cdot P_z(zEPA_i) & \text{if } z \le zEPA_i \\ 0 \cdot lbf & \text{else} \end{cases}$$

Function for Wind Shear of *ith* Attachment:

Function for Wind Shear of Gaff:

$$V_{Gaff}(z) := \begin{cases} \text{if } z \le z_{GA} \\ \quad P_z\left(z_{GA} + \frac{L_{GA}}{2} \cdot \cos(\theta_{GA})\right) \cdot C_d(D_{GA}) \cdot D_{GA} \cdot L_{GA} \\ \text{else} \\ \quad 0 \cdot lbf \end{cases}$$

Function for Wind Shear of Gaff Flag:

$$V_{F.Gaff}(z) := \begin{cases} \text{if } z \le z_{GA} \\ \quad z_0 \leftarrow L_{GA} \cdot \cos(\theta_{GA}) \\ \quad \gamma_{F.GA} \cdot \left(\frac{U_D}{mph}\right)^2 \cdot \sqrt{\frac{V_{F.GA} \cdot H_{F.GA}}{ft^2}} \cdot C_h(z_{GA} + z_0) \cdot G_{eff} \\ \text{else} \\ \quad 0 \cdot lbf \end{cases}$$

Function for Wind Shear of Yard Arm:

$$V_{Yard}(z) := \begin{cases} \text{if } z \le z_{YA} \\ \quad P_z(z_{YA}) \cdot C_d(D_{YA}) \cdot D_{YA} \cdot L_{YA} \\ \text{else} \\ \quad 0 \cdot lbf \end{cases}$$

Function for Wind Shear of Single Yard Arm Flag:

$$V_{F.Yard}(z) := \begin{cases} \text{if } z \le z_{YA} \\ \quad \gamma_{F.YA} \cdot \left(\frac{U_D}{mph}\right)^2 \cdot \sqrt{\frac{V_{F.YA} \cdot H_{F.YA}}{ft^2}} \cdot C_h(z_{YA}) \cdot G_{eff} \\ \text{else} \\ \quad 0 \cdot lbf \end{cases}$$

$$\Sigma Vw_{Flags}(z) := V_{F.Gaff}(z) + 2 \cdot V_{F.Yard}(z) + \sum_{i=1}^{\text{length}(V_F)} V_{Flag}(z, i)$$

Total Wind Shear from Flags: (*Unfactored*)

$$\Sigma Vw_{Attachments}(z) := V_{Gaff}(z) + V_{Yard}(z) + \sum_{i=1}^{\text{length}(EPA)} V_{EPA}(z, i)$$

Total Wind Shear from Attachments: (*Unfactored*)

$$\Sigma V_{Wind}(z) := \gamma_W \cdot \left(V_{Shaft}(z) + \Sigma Vw_{Flags}(z) + \Sigma Vw_{Attachments}(z)\right)$$

Total Wind Shear: (*Factored*)

$$\Sigma V_{Wind}(0 \cdot in) = 296.116\ lbf$$

Total Wind Moment from Flags: (*Unfactored*)

$$\Sigma Mw_{Flags}(z) := 0.95 \cdot V_{F.Gaff}(z) \cdot (z_{GA} - z) + 1.90 \cdot V_{F.Yard}(z) \cdot (z_{YA} - z) + \sum_{i=1}^{\text{length}(V_F)} V_{Flag}(z, i) \cdot \left(z_{F_i} - z\right)$$

Total Wind Moment from Attachments: (*Unfactored*)

$$\Sigma Mw_{Attachments}(z) := V_{Gaff}(z) \cdot (z_{GA} - z) + V_{Yard}(z) \cdot (z_{YA} - z) + \sum_{i=1}^{\text{length}(EPA)} V_{EPA}(z, i) \cdot \left(zEPA_i - z\right)$$

$$\Sigma M_{Wind}(z) := \gamma_W \cdot \left(M_{Shaft}(z) + \Sigma Mw_{Flags}(z) + \Sigma Mw_{Attachments}(z)\right)$$

Total Wind Moment: (*Factored*)

$$\Sigma M_{Wind}(0) = 4077.125\ ft \cdot lbf$$

$\Sigma Tw_{Flags} := 0.95 \cdot V_{Gaff}(0) \cdot L_{GA} \cdot \sin(\theta_{GA})$ Total Wind Torsion from Flags: (*Unfactored*)

$\Sigma Tw_{Attachments} := \frac{1}{2} \cdot V_{Gaff}(0) \cdot L_{GA} \cdot \sin(\theta_{GA}) + \sum_{i=1}^{\text{length}(EPA)} V_{EPA}(0,i) \cdot xEPA_i$ Total Wind Torsion from Attachments: (*Unfactored*)

$\Sigma T_{Wind} := \gamma_W \cdot (\Sigma Tw_{Flags} + \Sigma Tw_{Attachments})$ Total Wind Torsion: (*Factored*) $\Sigma T_{Wind} = 0.000 \; ft \cdot lbf$

Shaft Dead Loads:

$\rho_{Shaft} := 1.125$ Weight Factor:
Note: This weight factor helps to account for the weight of miscellaneous parts associated with a flag pole. It is applied directly to the calculated shaft weight.

$P_{Shaft}(z) := \rho_{Shaft} \cdot \rho_{6063} \cdot \int_z^{L_{total}} A(z) \, dz$ Function for Shaft Weight: $P_{Shaft}(0) = 69.624 \; lbf$

Function for Yard Arm Weight:

$$P_{Yard}(z) := \begin{cases} \pi \cdot t_{YA} \cdot (D_{YA} - t_{YA}) \cdot L_{YA} \cdot \rho_{6063} & \text{if } z \le z_{YA} \\ 0 \cdot lbf & \text{else} \end{cases}$$

Function for Gaff Weight:

$$P_{Gaff}(z) := \begin{cases} \pi \cdot t_{GA} \cdot (D_{GA} - t_{GA}) \cdot L_{GA} \cdot \rho_{6063} & \text{if } z \le z_{GA} \\ 0 \cdot lbf & \text{else} \end{cases}$$

Function for Weight of *ith* Attachment:

$$P_{EPA}(z,i) := \begin{cases} wEPA_i & \text{if } z \le zEPA_i \\ 0 \cdot lbf & \text{else} \end{cases}$$

$\Sigma P(z) := \gamma_D \cdot \left(P_{Shaft}(z) + P_{Gaff}(z) + P_{Yard}(z) + \sum_{i=1}^{\text{length}(EPA)} P_{EPA}(z,i)\right)$ Total Weight: (*Factored*) $\Sigma P(0) = 69.624 \; lbf$

$\Sigma M_{Dead}(z) := \gamma_D \cdot \left(\frac{1}{2} \cdot P_{Gaff}(z) \cdot L_{GA} \cdot \sin(\theta_{GA}) + \sum_{i=1}^{\text{length}(EPA)} P_{EPA}(z,i) \cdot xCG_i\right)$ Total Dead Load Moment: (*Factored*) $\Sigma M_{Dead}(0) = 0.000 \; ft \cdot lbf$

Shaft Combined Loads:

$V_x(z) := 0 \cdot lbf$ Total Shear in x-Direction: $V_x(0) = 0.000 \; lbf$

$V_y(z) := \Sigma V_{Wind}(z)$ Total Shear in y-Direction: $V_y(0) = 296.116 \; lbf$

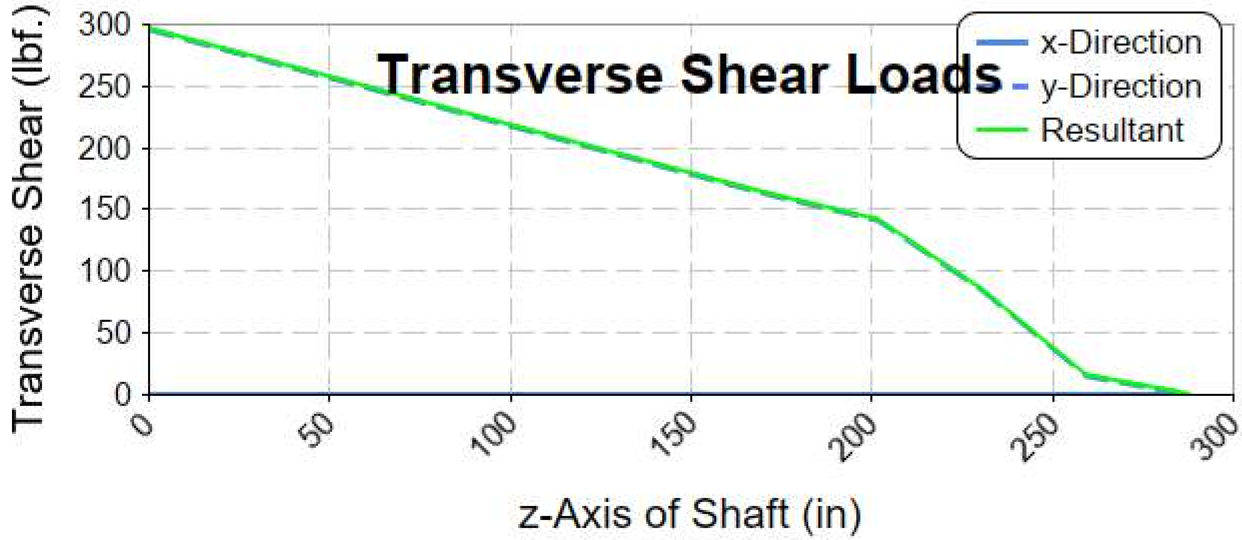
$V_c(z) := \sqrt{V_x(z)^2 + V_y(z)^2}$ Total Resultant Shear: $V_c(0) = 296.116 \; lbf$

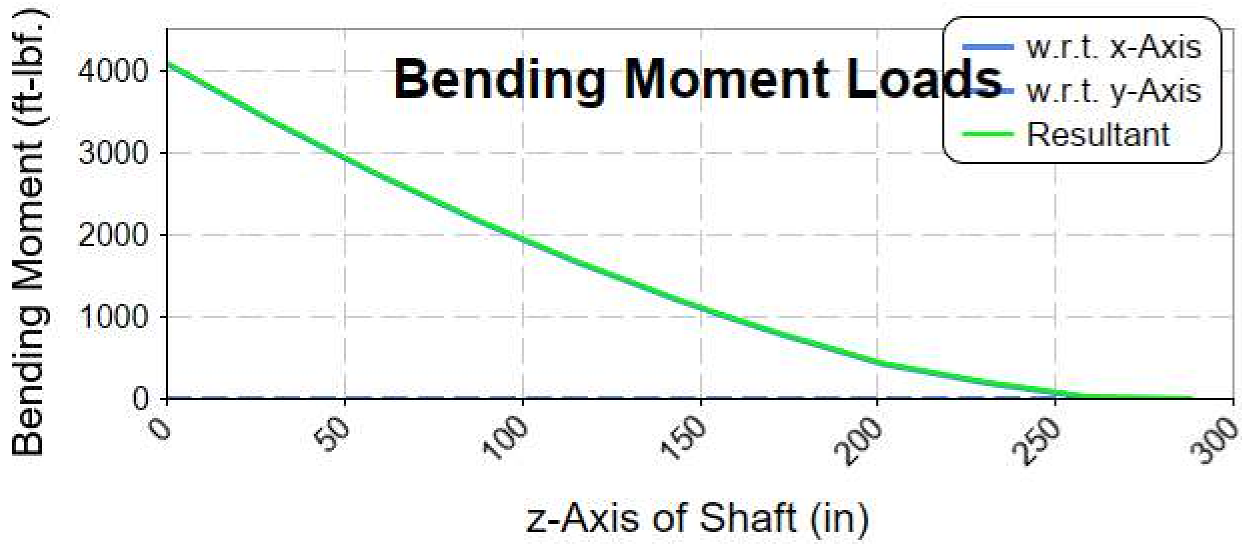
$M_{xx}(z) := \Sigma M_{Wind}(z)$ Total Moment w.r.t. x-Axis: $M_{xx}(0) = 4077.125 \; ft \cdot lbf$

$M_{yy}(z) := \Sigma M_{Dead}(z)$ Total Moment w.r.t. y-Axis: $M_{yy}(0) = 0.000 \; ft \cdot lbf$

$M_c(z) := \sqrt{M_{xx}(z)^2 + M_{yy}(z)^2}$ Total Resultant Moment: $M_c(0) = 4077.125 \; ft \cdot lbf$

$T_c := \Sigma T_{Wind}$ Total Torsion: $T_c = 0.000 \; ft \cdot lbf$





Shaft Stresses:

Axial Stresses:

$$fa(z) := \frac{\Sigma P(z)}{A(z)}$$

Axial Stress Function:

$fa(0) = 0.029\ ksi$

Bending Stresses:

$$fb_{xx}(z) := \frac{M_{xx}(z) \cdot Iyy(z) - M_{yy}(z) \cdot Ixy(z)}{Ixx(z) \cdot Iyy(z) - Ixy(z)^2} \cdot \max\left(Ro_S(z) - y_{cg}(z), Ro_S(z) + y_{cg}(z)\right)$$

Bending Stress w.r.t. x-Axis: $fb_{xx}(0) = 17.548\ ksi$ $fb_{xx}(L_{total}) = 0.000\ ksi$

$$fb_{yy}(z) := \frac{M_{yy}(z) \cdot Ixx(z) - M_{xx}(z) \cdot Ixy(z)}{Ixx(z) \cdot Iyy(z) - Ixy(z)^2} \cdot \max\left(Ro_S(z) - x_{cg}(z), Ro_S(z) + x_{cg}(z)\right)$$

Bending Stress w.r.t. y-Axis: $fb_{yy}(0) = 0.000\ ksi$ $fb_{yy}(L_{total}) = 0.000\ ksi$

Shear Stresses:

$$fs(z) := \sqrt{\left(\frac{V_x(z) \cdot Qxx(z)}{2 \cdot Ixx(z) \cdot t_w}\right)^2 + \left(\frac{V_y(z) \cdot Qyy(z)}{2 \cdot Iyy(z) \cdot t_w}\right)^2} + \frac{|T_c| \cdot \left(Ro_S(z) + \sqrt{x_{cg}(z)^2 + y_{cg}(z)^2}\right)}{Izz(z)}$$

Total Shear Stress: $fs(0) = 0.249\ ksi$ $fs(L_{total}) = 0.000\ ksi$

Shaft Allowable Stresses:

$$Fa(z) := \left\| \begin{array}{l} \lambda \leftarrow \dfrac{k_{eff} \cdot z}{min\left(rxx\left(\frac{z}{2}\right), ryy\left(\frac{z}{2}\right)\right)} \\ \lambda_C \leftarrow \dfrac{\pi}{1.08} \cdot \sqrt{\dfrac{E_{6063}}{Fcy_{6063}}} \\ \text{if } \lambda \le \lambda_C \\ \quad \| \ 0.6 \cdot Fcy_{6063} \\ \text{else} \\ \quad \| \ \dfrac{\pi^2 \cdot E_{6063}}{1.95 \cdot \lambda^2} \end{array} \right.$$

Allowable Axial Stress:
(Ref. Section 6.7 of NAAMM FP 1001-07)

$Fa(0 \cdot in) = 15.000\ ksi$

$Fa(L_{total}) = 0.452\ ksi$

$$Fb(z) := \left\| \begin{array}{l} \lambda \leftarrow \dfrac{D(z) - t_w}{2 \cdot t_w} \\ F \leftarrow \text{if } \lambda \le 33 \\ \qquad \| \ 24 \cdot ksi \\ \qquad \text{else} \\ \qquad \| \ \left(27.7 - 1.70 \cdot \sqrt{\lambda}\right) \cdot ksi \\ F \end{array} \right.$$

Allowable Bending Stress:
(Ref. Section 6.8.2 of NAAMM FP 1001-07)

$Fb(0) = 24.000\ ksi$

$Fb(L_{total}) = 24.000\ ksi$

$Fs(z) := 11.330 \cdot ksi$

Allowable Shear Stress:
(Ref. Table 6.8.2 of NAAMM FP 1001-07)

$Fs(0) = 11.330\ ksi$

$Fs(L_{total}) = 11.330\ ksi$

Coefficient of Amplification: (Second Order Effects)

Refer to Section 6.6 of NAAMM FP 1001-07 for details on the coefficient of amplification.

$$Ca_{xx} := \left\| \begin{array}{l} \text{if } Fa\left(\dfrac{L_{total}}{2}\right) \le 0.26 \cdot Fcy_{6063} \\ \quad \left\| \ 1 - \dfrac{1}{0.52} \cdot \dfrac{\left(0.38 \cdot \Sigma P(0) + \Sigma P(L_{total}) \cdot \sqrt[3]{\dfrac{Ixx(0)}{Ixx(L_{total})}}\right) \cdot L_{total}^2}{2.46 \cdot E_{6063} \cdot Ixx(0)} \right. \\ \text{else} \\ \quad \left\| \ 1 - \dfrac{1}{0.52} \cdot \dfrac{0.38 \cdot \Sigma P(0) \cdot L_{total}^2}{2.46 \cdot E_{6063} \cdot Ixx(0)} \right. \end{array} \right.$$

Coefficient of Amplification
w.r.t. x-Axis:

$Ca_{xx} = 0.976$

$$Ca_{yy} := \begin{cases} 1 - \dfrac{1}{0.52} \cdot \dfrac{\left(0.38 \cdot \Sigma P(0) + \Sigma P(L_{total}) \cdot \sqrt[3]{\dfrac{Iyy(0)}{Iyy(L_{total})}}\right) \cdot L_{total}^{2}}{2.46 \cdot E_{6063} \cdot Iyy(0)} & \text{if } Fa\left(\dfrac{L_{total}}{2}\right) \le 0.26 \cdot Fcy_{6063} \\ 1 - \dfrac{1}{0.52} \cdot \dfrac{0.38 \cdot \Sigma P(0) \cdot L_{total}^{2}}{2.46 \cdot E_{6063} \cdot Iyy(0)} & \text{else} \end{cases}$$

Coefficient of Amplification w.r.t. y-Axis:

$Ca_{yy} = 0.976$

Combined Stress Ratio of Shaft:

Refer to Section 6.6 of NAAMM FP 1001-07 for details on the combined Stress Ratio.

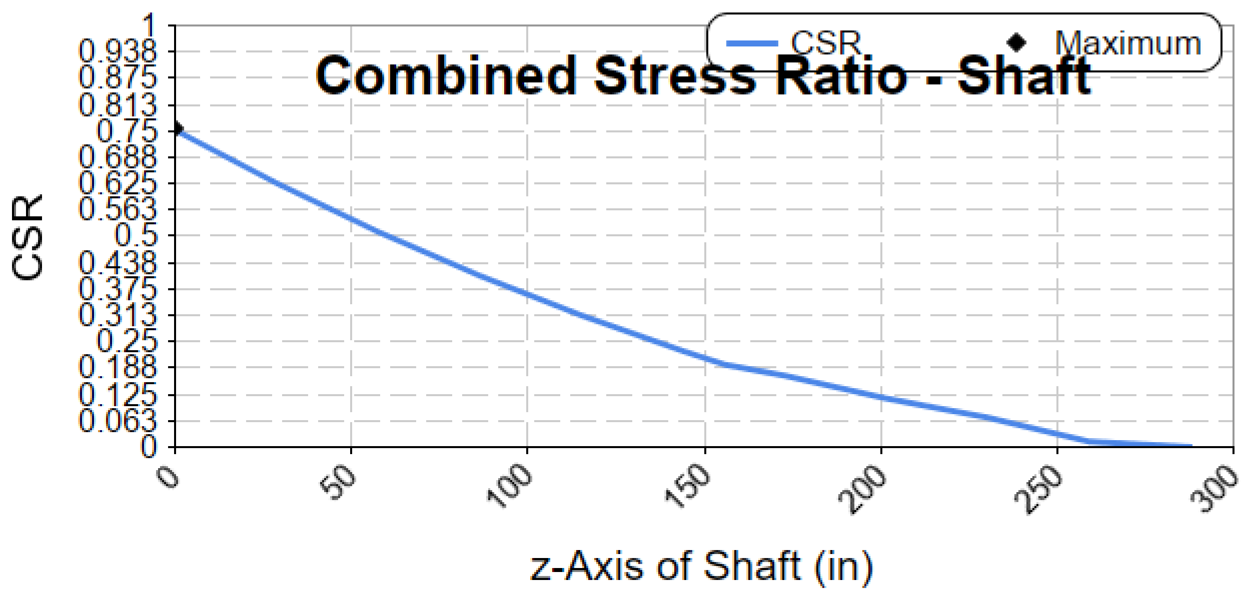
$$CSR(z) := \frac{fa(z)}{Fa(z)} + \frac{\sqrt{\left(\dfrac{fb_{xx}(z)}{Ca_{xx}}\right)^2 + \left(\dfrac{fb_{yy}(z)}{Ca_{yy}}\right)^2}}{Fb(z)} + \left(\frac{fs(z)}{Fs(z)}\right)^2$$

Maximum Pole Shaft CSR:

$Status_{Shaft} = \text{"Pass"}$

$CSR_{Max} = 0.752$ Maximum Pole Shaft CSR (*Must be less than or equal to 1*)

$CSR_{Location} = 0.000\ in$ Location of Maximum CSR (*Along z-Axis*)



Summary of Pole Design Calculations for Pole ESR25C51-SAT

Design Specification:

These calculations are based on *Guide Specifications For Design Of Metal Flagpoles, ANSI/NAAMM FP 1001-7*.

Loading Parameters:

Design Wind Speed: $U_D = 90.000\ mph$

Height Above Grade: $H_{Pier} = 0.000\ ft$

Gust Effect Factor: $G_{eff} = 1.140$

Size and Material Type of Flags:

$$V_F = \begin{bmatrix} 5.000 \\ 4.000 \\ 0.000 \end{bmatrix} ft \qquad H_F = \begin{bmatrix} 8.000 \\ 6.000 \\ 0.000 \end{bmatrix} ft$$

$$\gamma_F = \begin{bmatrix} 0.001 \\ 0.001 \\ 0.001 \end{bmatrix} lbf \qquad z_F = \begin{bmatrix} 21.500 \\ 17.000 \\ 0.000 \end{bmatrix} ft$$

Yard Arm Properties:

Flag Vertical: $V_{F.YA} = 0.000\ ft$

Flag Horizontal: $H_{F.YA} = 0.000\ ft$

Material Factor: $\gamma_{F.YA} = 0.001\ lbf$

Arm Length: $L_{YA} = 0.000\ ft$

Arm Diameter: $D_{YA} = 0.000\ in$

Mount Location: $z_{YA} = 0.000\ ft$

Gaff Properties:

Flag Vertical: $V_{F.GA} = 0.000\ ft$

Flag Horizontal: $H_{F.GA} = 0.000\ ft$

Material Factor: $\gamma_{F.GA} = 0.001\ lbf$

Arm Length: $L_{GA} = 0.000\ ft$

Arm Diameter: $D_{GA} = 0.000\ in$

Arm Angle: $\theta_{GA} = 0.000\ deg$

Mount Location: $z_{GA} = 0.000\ ft$

EPA, Weight, and Location of Attachments:

$$EPA = \begin{bmatrix} 0.000 \\ 0.000 \end{bmatrix} ft^2 \qquad wEPA = \begin{bmatrix} 0.000 \\ 0.000 \end{bmatrix} lbf$$

$$xEPA = \begin{bmatrix} 0.000 \\ 0.000 \end{bmatrix} ft \qquad xCG = \begin{bmatrix} 0.000 \\ 0.000 \end{bmatrix} ft$$

$$zEPA = \begin{bmatrix} 0.000 \\ 0.000 \end{bmatrix} ft$$

Design Parameters:

Bottom Diameter: $D_B = 5.000\ in$

Top Diameter: $D_T = 3.000\ in$

Wall Thickness: $t_w = 0.156\ in$

Bottom Straight: $L_{botst} = 13.000\ ft$

Taper Length: $L_{taper} = 11.000\ ft$

Top Straight: $L_{topst} = 0.000\ ft$

Total Length: $L_{total} = 24.000\ ft$

Taper Exponent: $n_{taper} = 1.000$

Shaft Tensile Strength: $Ftu_{6063} = 30.000\ ksi$

Shaft Yield Strength: $Fty_{6063} = 25.000\ ksi$

Pole Base Reactions:

Axial: $\Sigma P(0) = 69.624\ lbf$

Moment: $M_c(0) = 4077.125\ ft \cdot lbf$

Shear: $V_c(0) = 296.116\ lbf$

Design Checks:

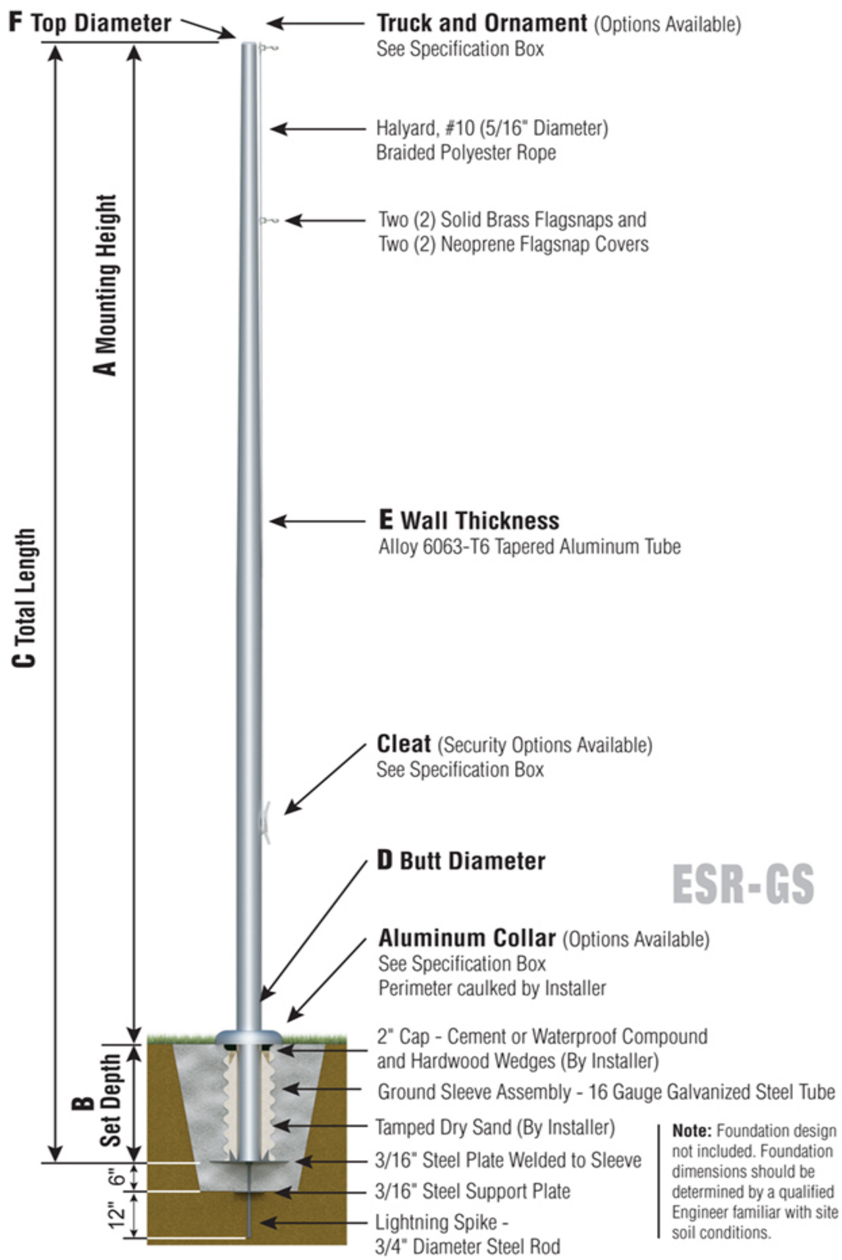
Shaft:

$Status_{Shaft} = \text{"Pass"}$ $\qquad CSR_{Max} = 75.187\%$

Continental Series

ESR - External Single Revolving
Rope Halyard
Ground Set Installation

ESR25C51 - SAT

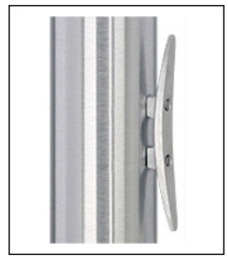


TRK-9610

In-Line Truck
Single Revolving

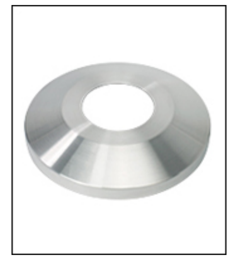
BAL-0512-GLD-ES

HD Gold Anodized
Aluminum Ball



CLA-9090-SAT | 7' from bottom

Cleat Only



COL1-A05S

FC-11 Spun Alum
1-Piece

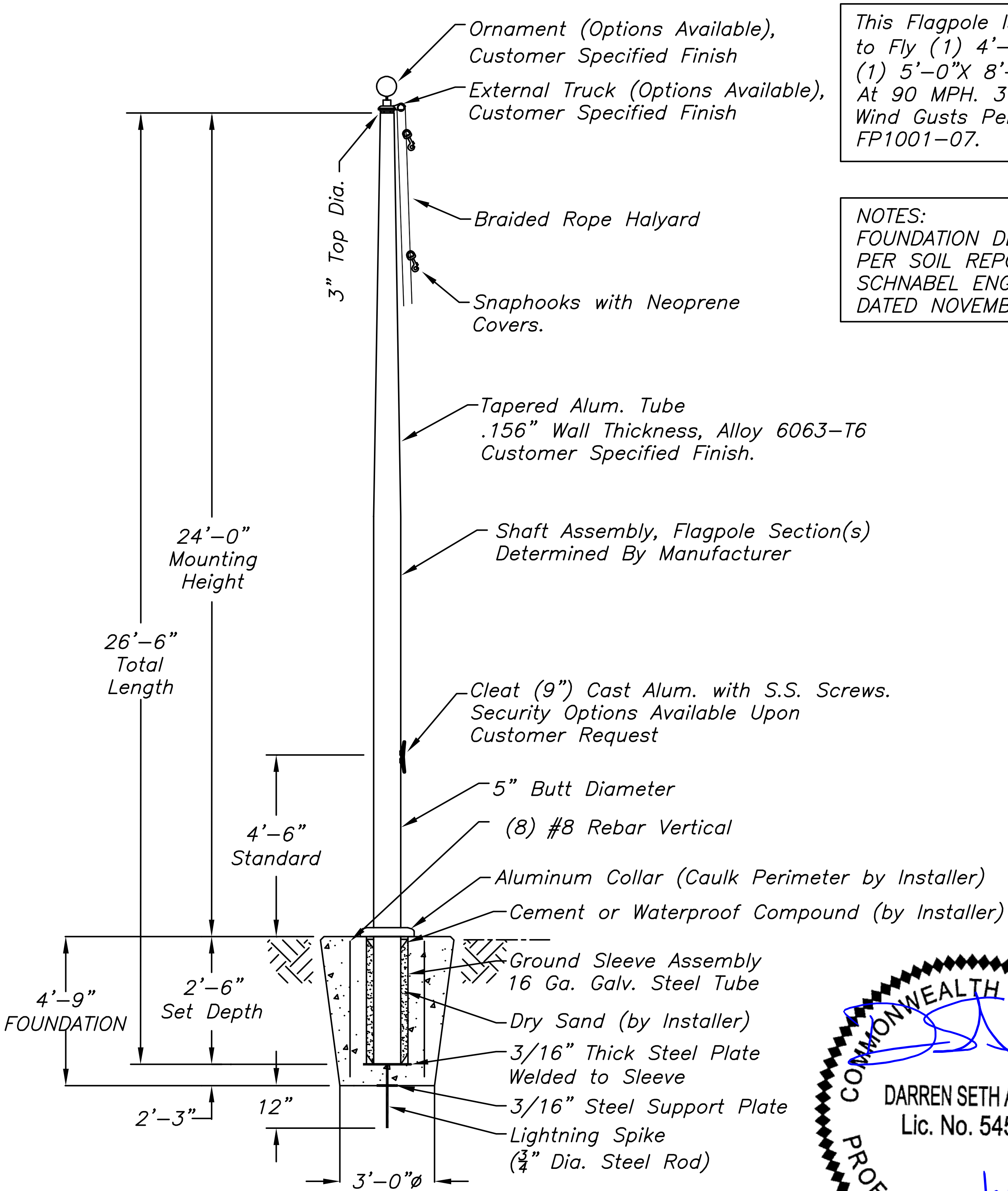
SAT

Satin Finish

NOMINAL EXPOSED HEIGHT: Total Shaft Length of 25' flagpoles is 26'-6" with a Set Depth of 2'-6". With the Truck and Ornament attached, the nominal Mounting Height is 25'.

Customer Name:		
Dealer: Gates Flag & Banner		Qty: 1
Project: Exit 54 Roundabout Flagpoles	Location: Colonial Height, VA 23834	
Notes: EPT95377		

Specifications
A. Mounting Height: 24'
B. Set Depth: 2'-6"
C. Total Length: 26'-6"
D. Butt Diameter: 5"
E. Wall Thickness: .156"
F. Top Diameter: 3"
Flagpole Sections: 1
Shaft Weight: 87 lbs.
Hardware Weight: 9 lbs.
Ground Sleeve Weight: 26 lbs.
* Rated Flag Size: (1) 5' x 8' & (1) 4' x 6'
* Rated Wind Speed w/Nylon Flag: 90 mph
* Wind Speed Specifications from ANSI/NAAMM FP 1001-07



This Flagpole Is Designed to Fly (1) 4'–0" X6'–0", (1) 5'–0"X 8'–0" Flag(s), At 90 MPH. 3 Second Wind Gusts Per NAAMM FP1001–07.

NOTES:
FOUNDATION DESIGNED PER SOIL REPORTS BY SCHNABEL ENGINEERING DATED NOVEMBER 6, 2024

NO.	REVISIONS	DATE

CONCORD AMERICAN FLAGPOLE
Abingdon, Va.

TITLE: External Halyard Flagpole
PROJECT: EXIT 54 ROUNDABOUT
LOCATION: COLONIAL HEIGHTS, VA
CUSTOMER OR REP.:
DATE: 04.03.25 | SCALE: NTS | DWG #: ESR25C51–SAT
PT#: EPT–95377

MBI Companies Inc.
299 North Weisgarber Road
Knoxville, TN 37919
Phone: (865) 584-0999
Fax: (865) 584-5213

www.sign-engineer.com

Project	**Exit 54 Roundabout**		
Client	**Concord Industries**		
Location	**Colonial Heights, VA**		
Comm. No.	**240209-078-02**		
Designed by	**Concord Industries**	Date	**4/3/2025**
Reviewed by	**DSA**	Date	**4/3/2025**

DESIGN CALCULATIONS FOR:

Concord Industries

Exit 54 Roundabout

Colonial Heights, VA

24' Flagpole

Analysis	**Concord Industries**
Reviewed by:	**Darren S. Antle, P.E.**
Comm#:	**240209-078-02**

MBI Companies Inc.
299 North Weisgarber Road
Knoxville, TN 37919
Phone: (865) 584-0999

April 3, 2025

Round Pole Design Calculations & Loading Analysis

CAFP Pole Design: *ESR25C51-SAT*
Calculation Date: *09/17/2024*
Calculations Prepared By: *Jonathan Pinchback, Product Design Engineer*

These calculations are based on the *Guide Specifications For Design Of Metal Flagpoles, ANSI/NAAMM FP 1001-7.*

AASHTO LTS-6 AND VDOT SP700-000180-03

Wind Loading Criteria:

$U_D := 90 \cdot mph$ Design Wind Speed (*3-Second Gust*)
$G_{eff} := 1.14$ Gust Effect Factor
$\alpha := 9.5$ Height Exponent (*Exposure Cat. C*)
$z_g := 900 \cdot ft$ Boundary Layer Height (*Exposure Cat. C*)
$H_{Pier} := 0 \cdot ft + 0 \cdot in$ Pier Height (*Above Grade*)

Load & Safety Factors:

$\gamma_D := 1.00$ Dead Load Factor
$\gamma_W := 1.00$ Wind Load Factor

Shaft Dimensional Parameters:

$D_B := 5 \cdot in$ Bottom Diameter
$D_T := 3 \cdot in$ Top Diameter
$t_w := 0.156 \cdot in$ Nominal Wall Thickness
$L_{botst} := 13 \cdot ft + 0 \cdot in$ Bottom Straight Length
$L_{taper} := 11 \cdot ft + 0 \cdot in$ Tapered Length
$L_{topst} := 0 \cdot ft + 0 \cdot in$ Top Straight Length
$L_{total} := L_{botst} + L_{taper} + L_{topst}$

$L_{total} = 24.000\ ft$ Total Shaft Length

$n_{taper} := 1$ Taper Exponent
$k_{eff} := 2.00$ Effective Length Factor

Shaft Material Properties:

The pole shaft is made of 6063-T6 aluminum.

$E_{6063} := 10100 \cdot ksi$ Modulus of Elasticity (*6063 Al.*)
$\rho_{6063} := 0.1 \cdot pci$ Material Density (*6063 Al.*)
$Ftu_{6063} := 30 \cdot ksi$ Ultimate Tensile Strength (*6063-T6*)
$Fty_{6063} := 25 \cdot ksi$ Tensile Yield Strength (*6063-T6*)
$Fcy_{6063} := 25 \cdot ksi$ Compressive Yield Strength (*6063-T6*)
$Fsu_{6063} := 18 \cdot ksi$ Ultimate Shear Strength (*6063-T6*)
$Fsy_{6063} := 15 \cdot ksi$ Yield Shear Strength (*6063-T6*)
$kt_{6063} := 1.00$ Tension Coefficient (*6063-T6*)

Unreinforced Handhole Parameters:

$z_{cut} := 0 \cdot ft + 0 \cdot in$ Height to Center of Cutout
$\theta_{cut} := 0 \cdot deg$ Angle to Cutout (*CCW from front*)
$w_{cut} := 0 \cdot in$ Cutout Width
$l_{cut} := 0 \cdot in$ Cutout Length

Loading Inputs:

The loading inputs shown below have been either provided to CAFP or assumed. If any loads appear to be incorrect, unaccounted for, or have changed since these calculations were produced, please contact CAFP Engineering for revised calculations.

Flag 1:

$V_{F_1} := 5 \cdot ft$	Flag Vertical Dimension
$H_{F_1} := 8 \cdot ft$	Flag Horizontal Dimension
$\gamma_{F_1} := 0.0010 \cdot lbf$	Flag Material Load Factor
$z_{F_1} := 21 \cdot ft + 6 \cdot in$	z Coordinate of Flag

Flag 2:

$V_{F_2} := 4 \cdot ft$	Flag Vertical Dimension
$H_{F_2} := 6 \cdot ft$	Flag Horizontal Dimension
$\gamma_{F_2} := 0.0010 \cdot lbf$	Flag Material Load Factor
$z_{F_2} := 17 \cdot ft + 0 \cdot in$	z Coordinate of Flag

Flag 3:

$V_{F_3} := 0 \cdot ft$	Flag Vertical Dimension
$H_{F_3} := 0 \cdot ft$	Flag Horizontal Dimension
$\gamma_{F_3} := 0.0010 \cdot lbf$	Flag Material Load Factor
$z_{F_3} := 0 \cdot ft + 0 \cdot in$	z Coordinate of Flag

Yard Arm:

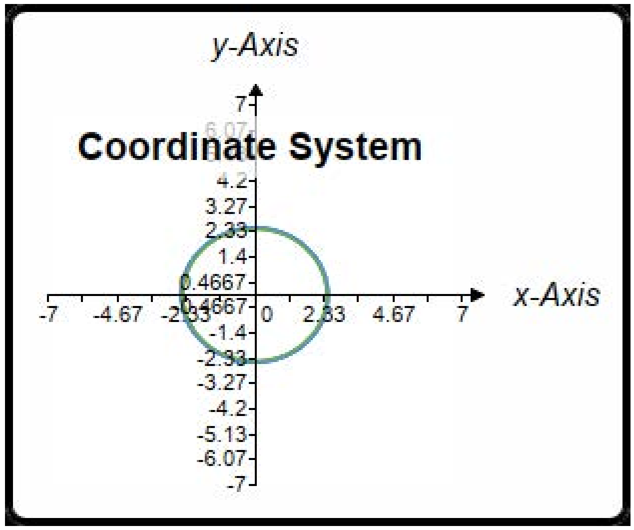
$D_{YA} := 0 \cdot in$	Diameter of Yard Arm
$L_{YA} := 0 \cdot ft + 0 \cdot in$	Length of Yard Arm
$t_{YA} := 0 \cdot in$	Thickness of Yard Arm
$z_{YA} := 0 \cdot ft + 0 \cdot in$	z Coordinate of Yard Arm
$V_{F.YA} := 0 \cdot ft$	Yard Arm Flag Vertical Dimension
$H_{F.YA} := 0 \cdot ft$	Yard Arm Flag Horizontal Dimension
$\gamma_{F.YA} := 0.0010 \cdot lbf$	Yard Arm Flag Material Load Factor

Gaff:

$D_{GA} := 0 \cdot in$	Diameter of Gaff
$L_{GA} := 0 \cdot ft + 0 \cdot in$	Length of Gaff
$t_{GA} := 0 \cdot in$	Thickness of Gaff
$\theta_{GA} := 0 \cdot deg$	Angle of Gaff
$z_{GA} := 0 \cdot ft + 0 \cdot in$	z Coordinate of Gaff
$V_{F.GA} := 0 \cdot ft$	Gaff Flag Vertical Dimension
$H_{F.GA} := 0 \cdot ft$	Gaff Flag Horizontal Dimension
$\gamma_{F.GA} := 0.0010 \cdot lbf$	Gaff Flag Material Load Factor

Coordinate System Information:

In this analysis, a standard x,y,z coordinate system is used. The coordinate system is placed at the base of the pole shaft, with the z-axis moving positive along the pole's longitudinal axis. The x-axis will move left(-) to right(+), and the y-axis will move backwards(-) and forwards(+) from the pole's diametric center.



Flag Material Load Factor:

Refer to Section 4.1 of NAAMM FP 1001-07 for information regarding Flag Wind Loads. Flags made of nylon and/or cotton will have a load factor of $\gamma_{Nylon} := 0.0010 \cdot lbf$ in accordance with Equation 4. Flags made of polyester will have a load factor of $\gamma_{Poly} := 0.0014 \cdot lbf$ in accordance with Equation 5.

Attachment 1: XXXXXX

$EPA_1 := 0 \cdot ft^2$	Effective Projected Area
$xEPA_1 := 0 \cdot ft + 0 \cdot in$	x Coordinate of EPA
$xCG_1 := 0 \cdot ft + 0 \cdot in$	x Coordinate of Weight
$zEPA_1 := 0 \cdot ft + 0 \cdot in$	z Coordinate of Attachment
$wEPA_1 := 0 \cdot lbf$	Weight of Attachment

Attachment 2: XXXXXX

$EPA_2 := 0 \cdot ft^2$	Effective Projected Area
$xEPA_2 := 0 \cdot ft + 0 \cdot in$	x Coordinate of EPA
$xCG_2 := 0 \cdot ft + 0 \cdot in$	x Coordinate of Weight
$zEPA_2 := 0 \cdot ft + 0 \cdot in$	z Coordinate of Attachment
$wEPA_2 := 0 \cdot lbf$	Weight of Attachment

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Shaft Calculations:

Shaft Geometry:

$$D(z) := \begin{cases} D_B & \text{if } z \le L_{botst} \\ D_T + (D_B - D_T) \cdot \left(\dfrac{L_{botst} + L_{taper} - z}{L_{taper}}\right)^{n_{taper}} & \text{else if } z < L_{botst} + L_{taper} \\ D_T & \text{else} \end{cases}$$

Shaft Diameter Function:

$D(0) = 5.000\ in$ Diameter at Bottom

$D\left(\frac{L_{total}}{2}\right) = 5.000\ in$ Diameter at Middle

$D(L_{total}) = 3.000\ in$ Diameter at Top

$$Ro_S(z) := \frac{D(z)}{2} \qquad Ri_S(z) := Ro_S(z) - t_w$$

Outer and Inner Shaft Radii Functions, Respectively

$$\phi_{cut}(z) := \begin{cases} 2 \cdot \operatorname{asin}\left(\dfrac{w_{cut}}{D(z)}\right) & \text{if } \dfrac{-l_{cut}}{2} < z - z_{cut} < \dfrac{l_{cut}}{2} \\ 0 \cdot deg & \text{else} \end{cases}$$

Function for Angle Swept by Cutout:

$\phi_{cut}(0) = 0.000\ deg$

$\phi_{cut}(z_{cut}) = 0.000\ deg$

$$\phi_i(z) := \begin{array}{l} \phi \leftarrow \theta_{cut} - \dfrac{\pi + \phi_{cut}(z)}{2} \\ \text{if } \phi \le 0 \cdot deg \\ \quad \phi \leftarrow \phi + 2 \cdot \pi \\ \phi \end{array}$$

Angle to Start of Cut from (+)x-Axis:

$\phi_i(0) = 270.000\ deg$

$\phi_i(z_{cut}) = 270.000\ deg$

$$\phi_f(z) := \phi_i(z) + \phi_{cut}(z)$$

Angle to End of Cut from (+)x-Axis:

$\phi_f(0) = 270.000\ deg$ $\phi_f(z_{cut}) = 270.000\ deg$

$$A(z) := \left(\pi - \frac{\phi_{cut}(z)}{2}\right) \cdot \left(Ro_S(z)^2 - Ri_S(z)^2\right)$$

Shaft Cross-Sectional Area Function:

$A(0) = 2.374\ in^2$ $A(z_{cut}) = 2.374\ in^2$ $A(L_{total}) = 1.394\ in^2$

$$x_{cg}(z) := \frac{Ro_S(z)^3 - Ri_S(z)^3}{3 \cdot A(z)} \cdot (\sin(\phi_i(z)) - \sin(\phi_f(z)))$$

x-Coordinate of Cross-Section Centroid:

$x_{cg}(0) = 0.000\ in$ $x_{cg}(z_{cut}) = 0.000\ in$ $x_{cg}(L_{total}) = 0.000\ in$

$$y_{cg}(z) := \frac{Ro_S(z)^3 - Ri_S(z)^3}{3 \cdot A(z)} \cdot (\cos(\phi_f(z)) - \cos(\phi_i(z)))$$

y-Coordinate of Cross-Section Centroid:

$y_{cg}(0) = 0.000\ in$ $y_{cg}(z_{cut}) = 0.000\ in$ $y_{cg}(L_{total}) = 0.000\ in$

$$Ixx(z) := \frac{Ro_S(z)^4 - Ri_S(z)^4}{4} \cdot \left(\pi - \frac{\phi_f(z) - \phi_i(z)}{2} + \frac{1}{4} \cdot \left(\sin\left(2 \cdot \phi_f(z)\right) - \sin\left(2 \cdot \phi_i(z)\right)\right)\right) + \frac{2 \cdot \left(Ro_S(z)^3 - Ri_S(z)^3\right)}{3} \cdot y_{cg}(z) \cdot \left(\cos\left(\phi_i(z)\right) - \cos\left(\phi_f(z)\right)\right) + \frac{Ro_S(z)^2 - Ri_S(z)^2}{2} \cdot y_{cg}(z)^2 \cdot \left(2 \cdot \pi + \phi_i(z) - \phi_f(z)\right)$$

$Ixx(0) = 6.970\ in^4$ $Ixx(z_{cut}) = 6.970\ in^4$ $Ixx(L_{total}) = 1.413\ in^4$ Shaft Area Moment of Inertia w.r.t. the x-Axis:

$$Iyy(z) := \frac{Ro_S(z)^4 - Ri_S(z)^4}{4} \cdot \left(\pi - \frac{\phi_f(z) - \phi_i(z)}{2} - \frac{1}{4} \cdot \left(\sin\left(2 \cdot \phi_f(z)\right) - \sin\left(2 \cdot \phi_i(z)\right)\right)\right) + \frac{2 \cdot \left(Ro_S(z)^3 - Ri_S(z)^3\right)}{3} \cdot x_{cg}(z) \cdot \left(\sin\left(\phi_f(z)\right) - \sin\left(\phi_i(z)\right)\right) + \frac{Ro_S(z)^2 - Ri_S(z)^2}{2} \cdot x_{cg}(z)^2 \cdot \left(2 \cdot \pi + \phi_i(z) - \phi_f(z)\right)$$

$Iyy(0) = 6.970\ in^4$ $Iyy(z_{cut}) = 6.970\ in^4$ $Iyy(L_{total}) = 1.413\ in^4$ Shaft Area Moment of Inertia w.r.t. the y-Axis:

$$Ixy(z) := \frac{Ro_S(z)^4 - Ri_S(z)^4}{8} \cdot \left(\cos\left(\phi_f(z)\right)^2 - \cos\left(\phi_i(z)\right)^2\right) + \frac{Ro_S(z)^3 - Ri_S(z)^3}{3} \cdot \left(x_{cg}(z) \cdot \left(\cos\left(\phi_i(z)\right) - \cos\left(\phi_f(z)\right)\right) + y_{cg}(z) \cdot \left(\sin\left(\phi_f(z)\right) - \sin\left(\phi_i(z)\right)\right)\right) + \frac{Ro_S(z)^2 - Ri_S(z)^2}{2} \cdot x_{cg}(z) \cdot y_{cg}(z) \cdot \left(2 \cdot \pi + \phi_i(z) - \phi_f(z)\right)$$

$Ixy(0) = 0.000\ in^4$ $Ixy(z_{cut}) = 0.000\ in^4$ $Ixy(L_{total}) = 0.000\ in^4$ Shaft Product of Inertia:

Shaft Area Moment of Inertia w.r.t. the z-Axis: (*Approximation for Polar Moment of Inertia*)

$Izz(z) := Ixx(z) + Iyy(z)$ $Izz(0) = 13.940\ in^4$ $Izz(z_{cut}) = 13.940\ in^4$ $Izz(L_{total}) = 2.827\ in^4$

$rxx(z) := \sqrt{\frac{Ixx(z)}{A(z)}}$ Radius of Gyration w.r.t. the x-Axis: $rxx(0) = 1.714\ in$

$rxx(z_{cut}) = 1.714\ in$

$rxx(L_{total}) = 1.007\ in$

$ryy(z) := \sqrt{\frac{Iyy(z)}{A(z)}}$ Radius of Gyration w.r.t. the y-Axis: $ryy(0) = 1.714\ in$

$ryy(z_{cut}) = 1.714\ in$

$ryy(L_{total}) = 1.007\ in$

Elastic Section Moduli w.r.t. the x-Axis:

$$Sxx_U(z) := \frac{Ixx(z)}{Ro_S(z) - y_{cg}(z)}$$

Elastic Section Moduli Above Centroidal x-Axis:

$Sxx_U(0) = 2.788\ in^3$ $Sxx_U(z_{cut}) = 2.788\ in^3$ $Sxx_U(L_{total}) = 0.942\ in^3$

$$Sxx_L(z) := \frac{Ixx(z)}{Ro_S(z) + y_{cg}(z)}$$

Elastic Section Moduli Below Centroidal x-Axis:

$Sxx_L(0) = 2.788\ in^3$ $Sxx_L(z_{cut}) = 2.788\ in^3$ $Sxx_L(L_{total}) = 0.942\ in^3$

$Sxx_{max}(z) := \max(Sxx_U(z), Sxx_L(z))$ Maximum Elastic Section Modulus w.r.t. the x-Axis

Elastic Section Moduli w.r.t. the y-Axis:

$$Syy_U(z) := \frac{Iyy(z)}{Ro_S(z) - x_{cg}(z)}$$

Elastic Section Moduli Above Centroidal y-Axis:

$Syy_U(0) = 2.788\ in^3$ $Syy_U(z_{cut}) = 2.788\ in^3$ $Syy_U(L_{total}) = 0.942\ in^3$

$$Syy_L(z) := \frac{Iyy(z)}{Ro_S(z) + x_{cg}(z)}$$

Elastic Section Moduli Below Centroidal y-Axis:

$Syy_L(0) = 2.788\ in^3$ $Syy_L(z_{cut}) = 2.788\ in^3$ $Syy_L(L_{total}) = 0.942\ in^3$

$Syy_{max}(z) := \max(Syy_U(z), Syy_L(z))$ Maximum Elastic Section Modulus w.r.t. the y-Axis

$\phi_{xi.i}(z) := \operatorname{asin}\left(\frac{y_{cg}(z)}{Ri_S(z)}\right)$ $\phi_{xi.i}(z_{cut}) = 0.000\ deg$ Angle from Geometric Center to Inner Radius on Centroidal (+)x-Axis:

$\phi_{xo.i}(z) := \operatorname{asin}\left(\frac{y_{cg}(z)}{Ro_S(z)}\right)$ $\phi_{xo.i}(z_{cut}) = 0.000\ deg$ Angle from Geometric Center to Outer Radius on Centroidal (+)x-Axis:

$\phi_{xi.f}(z) := \pi - \operatorname{asin}\left(\frac{y_{cg}(z)}{Ri_S(z)}\right)$ $\phi_{xi.f}(z_{cut}) = 180.000\ deg$ Angle from Geometric Center to Inner Radius on Centroidal (-)x-Axis:

$\phi_{xo.f}(z) := \pi - \operatorname{asin}\left(\frac{y_{cg}(z)}{Ro_S(z)}\right)$ $\phi_{xo.f}(z_{cut}) = 180.000\ deg$ Angle from Geometric Center to Outer Radius on Centroidal (-)x-Axis:

$\phi_{yi.i}(z) := \frac{\pi}{2} - \operatorname{asin}\left(\frac{x_{cg}(z)}{Ri_S(z)}\right)$ $\phi_{yi.i}(z_{cut}) = 90.000\ deg$ Angle from Geometric Center to Inner Radius on Centroidal (+)y-Axis:

$\phi_{yo.i}(z) := \frac{\pi}{2} - \operatorname{asin}\left(\frac{x_{cg}(z)}{Ro_S(z)}\right)$ $\phi_{yo.i}(z_{cut}) = 90.000\ deg$ Angle from Geometric Center to Outer Radius on Centroidal (+)y-Axis:

$\phi_{yi.f}(z) := \frac{3 \cdot \pi}{2} + \operatorname{asin}\left(\frac{x_{cg}(z)}{Ri_S(z)}\right)$ $\phi_{yi.f}(z_{cut}) = 270.000\ deg$ Angle from Geometric Center to Inner Radius of Centroidal (-)y-Axis:

$\phi_{yo.f}(z) := \frac{3 \cdot \pi}{2} + \operatorname{asin}\left(\frac{x_{cg}(z)}{Ro_S(z)}\right)$ $\phi_{yo.f}(z_{cut}) = 270.000\ deg$ Angle from Geometric Center to Outer Radius on Centroidal (-)y-Axis:

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$$f\phi_c(\phi_l,\phi_u,\phi_c):=\begin{array}{l}\text{if } \phi_c\le\phi_l\\ \quad \phi_l\\ \text{else if } \phi_c\ge\phi_u\\ \quad \phi_u\\ \text{else}\\ \quad \phi_c\end{array}$$

Function to Find Angle Limits of Cutout w.r.t. Centroidal Axes:

$\phi_{cxi.i}(z):=f\phi_c(\phi_{xi.i}(z),\phi_{xi.f}(z),\phi_i(z))$ — $\phi_{cxi.i}(z_{cut})=180.000\ deg$ — Initial Inner Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$\phi_{cxo.i}(z):=f\phi_c(\phi_{xo.i}(z),\phi_{xo.f}(z),\phi_i(z))$ — $\phi_{cxo.i}(z_{cut})=180.000\ deg$ — Initial Outer Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$\phi_{cxi.f}(z):=f\phi_c(\phi_{xi.i}(z),\phi_{xi.f}(z),\phi_f(z))$ — $\phi_{cxi.f}(z_{cut})=180.000\ deg$ — Final Inner Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$\phi_{cxo.f}(z):=f\phi_c(\phi_{xo.i}(z),\phi_{xo.f}(z),\phi_f(z))$ — $\phi_{cxo.f}(z_{cut})=180.000\ deg$ — Final Outer Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$\phi_{cyi.i}(z):=f\phi_c(\phi_{yi.i}(z),\phi_{yi.f}(z),\phi_i(z))$ — $\phi_{cyi.i}(z_{cut})=270.000\ deg$ — Initial Inner Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$\phi_{cyo.i}(z):=f\phi_c(\phi_{yo.i}(z),\phi_{yo.f}(z),\phi_i(z))$ — $\phi_{cyo.i}(z_{cut})=270.000\ deg$ — Initial Outer Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$\phi_{cyi.f}(z):=f\phi_c(\phi_{yi.i}(z),\phi_{yi.f}(z),\phi_f(z))$ — $\phi_{cyi.f}(z_{cut})=270.000\ deg$ — Final Inner Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$\phi_{cyo.f}(z):=f\phi_c(\phi_{yo.i}(z),\phi_{yo.f}(z),\phi_f(z))$ — $\phi_{cyo.f}(z_{cut})=270.000\ deg$ — Final Outer Cutout Angle Limit w.r.t. Centroidal (+)x-Axis:

$$Qxx(z):=\frac{Ro_S(z)^3}{3}\cdot(\cos(\phi_{xo.i}(z))-\cos(\phi_{xo.f}(z))+\cos(\phi_{cxo.f}(z))-\cos(\phi_{cxo.i}(z)))+\frac{Ri_S(z)^3}{3}\cdot(\cos(\phi_{cxi.i}(z))-\cos(\phi_{cxi.f}(z))+\cos(\phi_{xi.f}(z))-\cos(\phi_{xi.i}(z)))+\frac{y_{cg}(z)}{2}\cdot\left(Ro_S(z)^2\cdot(\phi_{cxo.f}(z)-\phi_{cxo.i}(z)+\phi_{xo.i}(z)-\phi_{xo.f}(z))+Ri_S(z)^2\cdot(\phi_{xi.f}(z)-\phi_{xi.i}(z)+\phi_{cxi.i}(z)-\phi_{cxi.f}(z))\right)$$

$Qxx(0)=1.831\ in^3$ — $Qxx(z_{cut})=1.831\ in^3$ — $Qxx(L_{total})=0.632\ in^3$ — First Moment of Area w.r.t. Centroidal x-Axis:

$$Qyy(z):=\frac{Ro_S(z)^3}{3}\cdot(\sin(\phi_{yo.f}(z))-\sin(\phi_{yo.i}(z))+\sin(\phi_{cyo.i}(z))-\sin(\phi_{cyo.f}(z)))+\frac{Ri_S(z)^3}{3}\cdot(\sin(\phi_{cyo.f}(z))-\sin(\phi_{cyo.i}(z))+\sin(\phi_{yo.i}(z))-\sin(\phi_{yo.f}(z)))+\frac{x_{cg}(z)}{2}\cdot\left(Ro_S(z)^2\cdot(\phi_{cyo.f}(z)-\phi_{cyo.i}(z)+\phi_{yo.i}(z)-\phi_{yo.f}(z))+Ri_S(z)^2\cdot(\phi_{yi.f}(z)-\phi_{yi.i}(z)+\phi_{cyi.i}(z)-\phi_{cyi.f}(z))\right)$$

$Qyy(0)=1.831\ in^3$ — $Qyy(z_{cut})=1.831\ in^3$ — $Qyy(L_{total})=0.632\ in^3$ — First Moment of Area w.r.t. Centroidal y-Axis:

$Zxx(z) := 2 \cdot Qxx(z)$ Plastic Section Modulus w.r.t. Centroidal x-Axis:

$Zxx(0) = 3.662\ in^3$ $Zxx(z_{cut}) = 3.662\ in^3$ $Zxx(L_{total}) = 1.263\ in^3$

$Zyy(z) := 2 \cdot Qyy(z)$ Plastic Section Modulus w.r.t. Centroidal y-Axis:

$Zyy(0) = 3.662\ in^3$ $Zyy(z_{cut}) = 3.662\ in^3$ $Zyy(L_{total}) = 1.263\ in^3$

Shaft Wind Loads:

$$C_h(z) := 2.01 \cdot \left(\frac{\max(16.4 \cdot ft, z + H_{Pier})}{z_g} \right)^{\frac{2}{\alpha}}$$

Coefficient of Height:
(*Ref. Section 3.2.3 of NAAMM FP 1001-07*)

$C_h(0) = 0.865$ $C_h(L_{total}) = 0.937$

$$C_d(d) := \begin{cases} 1.10 & \text{if } U_D \cdot d \le 39 \cdot mph \cdot ft \\ \dfrac{129}{\left(\dfrac{U_D \cdot d}{mph \cdot ft}\right)^{1.3}} & \text{else if } 39 \cdot mph \cdot ft < U_D \cdot d < 78 \cdot mph \cdot ft \\ 0.45 & \text{else} \end{cases}$$

Drag Coefficient:
(*Ref. Table 3.2.4 of NAAMM FP 1001-07*)

$C_d(D(0)) = 1.100$

$C_d(D(L_{total})) = 1.100$

$$P_z(z) := 0.00256 \cdot \left(\frac{U_D}{mph}\right)^2 \cdot C_h(z) \cdot G_{eff} \cdot psf$$

Design Wind Pressure:
(*Ref. Section 3.2.1 of NAAMM FP 1001-07*)

$P_z(0) = 20.447\ psf$ $P_z(L_{total}) = 22.154\ psf$

$$V_{Shaft}(z) := \int_z^{L_{total}} P_z(z) \cdot C_d(D(z)) \cdot D(z)\, dz$$

Function for Wind Shear on Pole Shaft:
(*Function of Height*)

$$M_{Shaft}(z) := \int_z^{L_{total}} (\varepsilon - z) \cdot P_z(\varepsilon) \cdot C_d(D(\varepsilon)) \cdot D(\varepsilon)\, d\varepsilon$$

Function for Wind Moment on Pole Shaft:
(*Function of Height*)

$$V_{Flag}(z, i) := \begin{cases} \gamma_{F_i} \cdot \left(\dfrac{U_D}{mph}\right)^2 \cdot \sqrt{\dfrac{V_{F_i} \cdot H_{F_i}}{ft^2}} \cdot C_h(z) \cdot G_{eff} & \text{if } z \le z_{F_i} \\ 0 \cdot lbf & \text{else} \end{cases}$$

Function for Wind Shear of *ith* Flag:

$$V_{EPA}(z, i) := \begin{cases} EPA_i \cdot P_z(zEPA_i) & \text{if } z \le zEPA_i \\ 0 \cdot lbf & \text{else} \end{cases}$$

Function for Wind Shear of *ith* Attachment:

$$V_{Gaff}(z) := \begin{cases} P_z\left(z_{GA} + \frac{L_{GA}}{2} \cdot \cos(\theta_{GA})\right) \cdot C_d(D_{GA}) \cdot D_{GA} \cdot L_{GA} & \text{if } z \le z_{GA} \\ 0 \cdot lbf & \text{else} \end{cases}$$

Function for Wind Shear of Gaff:

$$V_{F.Gaff}(z) := \begin{cases} z_0 \leftarrow L_{GA} \cdot \cos(\theta_{GA}) \\ \gamma_{F.GA} \cdot \left(\frac{U_D}{mph}\right)^2 \cdot \sqrt{\frac{V_{F.GA} \cdot H_{F.GA}}{ft^2}} \cdot C_h(z_{GA} + z_0) \cdot G_{eff} & \text{if } z \le z_{GA} \\ 0 \cdot lbf & \text{else} \end{cases}$$

Function for Wind Shear of Gaff Flag:

$$V_{Yard}(z) := \begin{cases} P_z(z_{YA}) \cdot C_d(D_{YA}) \cdot D_{YA} \cdot L_{YA} & \text{if } z \le z_{YA} \\ 0 \cdot lbf & \text{else} \end{cases}$$

Function for Wind Shear of Yard Arm:

$$V_{F.Yard}(z) := \begin{cases} \gamma_{F.YA} \cdot \left(\frac{U_D}{mph}\right)^2 \cdot \sqrt{\frac{V_{F.YA} \cdot H_{F.YA}}{ft^2}} \cdot C_h(z_{YA}) \cdot G_{eff} & \text{if } z \le z_{YA} \\ 0 \cdot lbf & \text{else} \end{cases}$$

Function for Wind Shear of Single Yard Arm Flag:

$$\Sigma Vw_{Flags}(z) := V_{F.Gaff}(z) + 2 \cdot V_{F.Yard}(z) + \sum_{i=1}^{\text{length}(V_F)} V_{Flag}(z, i)$$

Total Wind Shear from Flags: (*Unfactored*)

$$\Sigma Vw_{Attachments}(z) := V_{Gaff}(z) + V_{Yard}(z) + \sum_{i=1}^{\text{length}(EPA)} V_{EPA}(z, i)$$

Total Wind Shear from Attachments: (*Unfactored*)

$$\Sigma V_{Wind}(z) := \gamma_W \cdot \left(V_{Shaft}(z) + \Sigma Vw_{Flags}(z) + \Sigma Vw_{Attachments}(z)\right)$$

Total Wind Shear: (*Factored*)

$$\Sigma V_{Wind}(0 \cdot in) = 296.116\ lbf$$

Total Wind Moment from Flags: (*Unfactored*)

$$\Sigma Mw_{Flags}(z) := 0.95 \cdot V_{F.Gaff}(z) \cdot (z_{GA} - z) + 1.90 \cdot V_{F.Yard}(z) \cdot (z_{YA} - z) + \sum_{i=1}^{\text{length}(V_F)} V_{Flag}(z, i) \cdot \left(z_{F_i} - z\right)$$

Total Wind Moment from Attachments: (*Unfactored*)

$$\Sigma Mw_{Attachments}(z) := V_{Gaff}(z) \cdot (z_{GA} - z) + V_{Yard}(z) \cdot (z_{YA} - z) + \sum_{i=1}^{\text{length}(EPA)} V_{EPA}(z, i) \cdot \left(zEPA_i - z\right)$$

$$\Sigma M_{Wind}(z) := \gamma_W \cdot \left(M_{Shaft}(z) + \Sigma Mw_{Flags}(z) + \Sigma Mw_{Attachments}(z)\right)$$

Total Wind Moment: (*Factored*)

$$\Sigma M_{Wind}(0) = 4077.125\ ft \cdot lbf$$

$\Sigma Tw_{Flags} := 0.95 \cdot V_{Gaff}(0) \cdot L_{GA} \cdot \sin(\theta_{GA})$ Total Wind Torsion from Flags: (*Unfactored*)

$\Sigma Tw_{Attachments} := \frac{1}{2} \cdot V_{Gaff}(0) \cdot L_{GA} \cdot \sin(\theta_{GA}) + \sum_{i=1}^{\text{length}(EPA)} V_{EPA}(0,i) \cdot xEPA_i$ Total Wind Torsion from Attachments: (*Unfactored*)

$\Sigma T_{Wind} := \gamma_W \cdot (\Sigma Tw_{Flags} + \Sigma Tw_{Attachments})$ Total Wind Torsion: (*Factored*) $\Sigma T_{Wind} = 0.000\ ft \cdot lbf$

Shaft Dead Loads:

$\rho_{Shaft} := 1.125$ Weight Factor:
Note: This weight factor helps to account for the weight of miscellaneous parts associated with a flag pole. It is applied directly to the calculated shaft weight.

$P_{Shaft}(z) := \rho_{Shaft} \cdot \rho_{6063} \cdot \int_{z}^{L_{total}} A(z)\,dz$ Function for Shaft Weight: $P_{Shaft}(0) = 69.624\ lbf$

Function for Yard Arm Weight:

$$P_{Yard}(z) := \begin{cases} \pi \cdot t_{YA} \cdot (D_{YA} - t_{YA}) \cdot L_{YA} \cdot \rho_{6063} & \text{if } z \le z_{YA} \\ 0 \cdot lbf & \text{else} \end{cases}$$

Function for Gaff Weight:

$$P_{Gaff}(z) := \begin{cases} \pi \cdot t_{GA} \cdot (D_{GA} - t_{GA}) \cdot L_{GA} \cdot \rho_{6063} & \text{if } z \le z_{GA} \\ 0 \cdot lbf & \text{else} \end{cases}$$

Function for Weight of *ith* Attachment:

$$P_{EPA}(z,i) := \begin{cases} wEPA_i & \text{if } z \le zEPA_i \\ 0 \cdot lbf & \text{else} \end{cases}$$

$\Sigma P(z) := \gamma_D \cdot \left(P_{Shaft}(z) + P_{Gaff}(z) + P_{Yard}(z) + \sum_{i=1}^{\text{length}(EPA)} P_{EPA}(z,i)\right)$ Total Weight: (*Factored*) $\Sigma P(0) = 69.624\ lbf$

$\Sigma M_{Dead}(z) := \gamma_D \cdot \left(\frac{1}{2} \cdot P_{Gaff}(z) \cdot L_{GA} \cdot \sin(\theta_{GA}) + \sum_{i=1}^{\text{length}(EPA)} P_{EPA}(z,i) \cdot xCG_i\right)$ Total Dead Load Moment: (*Factored*) $\Sigma M_{Dead}(0) = 0.000\ ft \cdot lbf$

Shaft Combined Loads:

$V_x(z) := 0 \cdot lbf$ Total Shear in x-Direction: $V_x(0) = 0.000\ lbf$

$V_y(z) := \Sigma V_{Wind}(z)$ Total Shear in y-Direction: $V_y(0) = 296.116\ lbf$

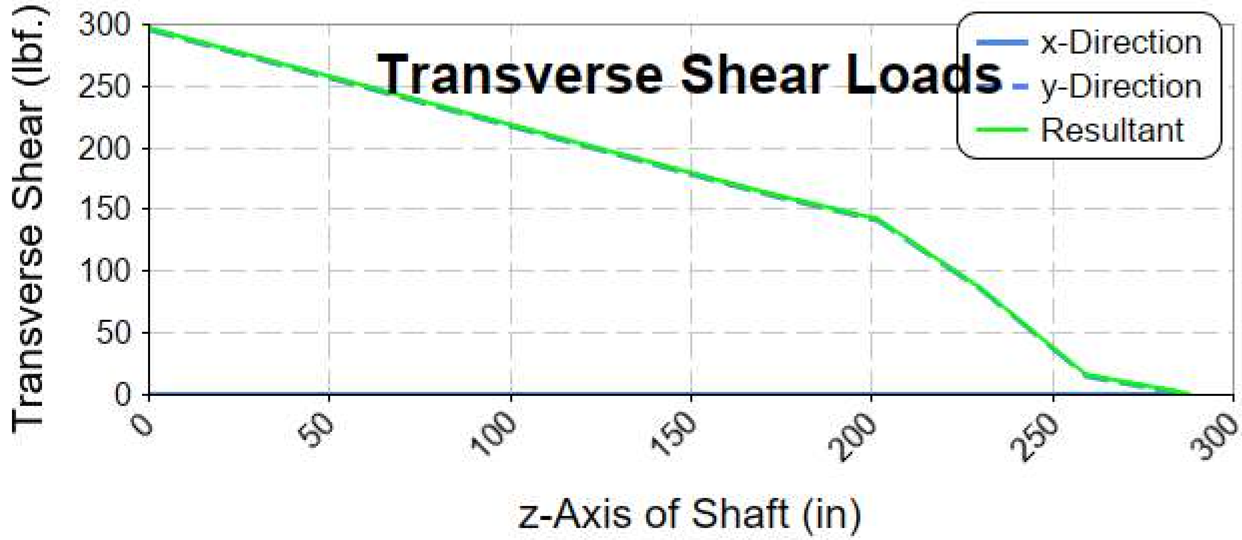
$V_c(z) := \sqrt{V_x(z)^2 + V_y(z)^2}$ Total Resultant Shear: $V_c(0) = 296.116\ lbf$

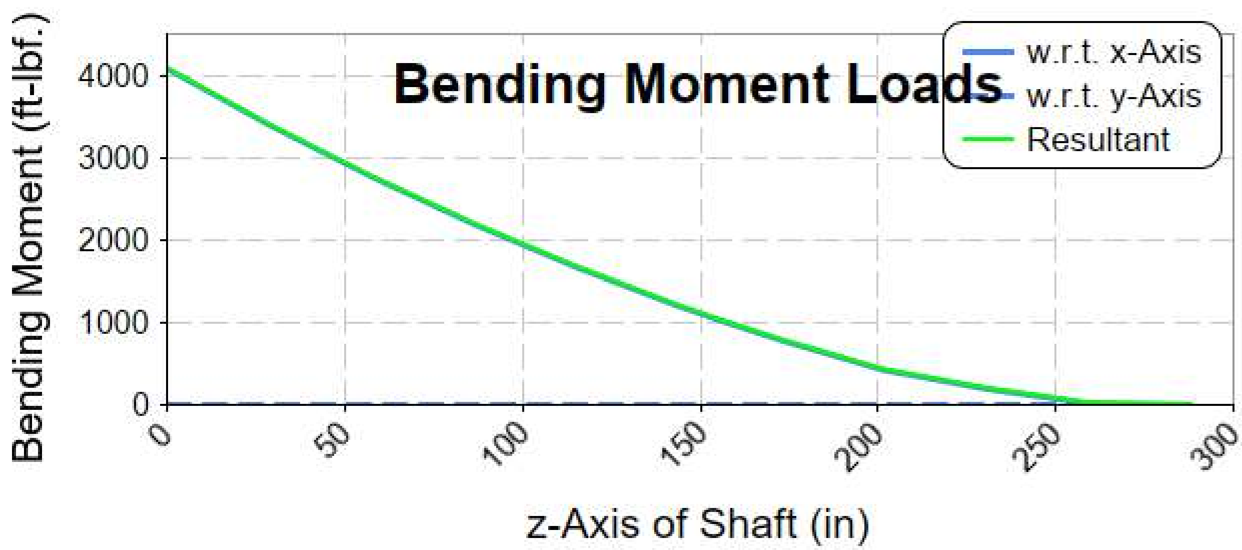
$M_{xx}(z) := \Sigma M_{Wind}(z)$ Total Moment w.r.t. x-Axis: $M_{xx}(0) = 4077.125\ ft \cdot lbf$

$M_{yy}(z) := \Sigma M_{Dead}(z)$ Total Moment w.r.t. y-Axis: $M_{yy}(0) = 0.000\ ft \cdot lbf$

$M_c(z) := \sqrt{M_{xx}(z)^2 + M_{yy}(z)^2}$ Total Resultant Moment: $M_c(0) = 4077.125\ ft \cdot lbf$

$T_c := \Sigma T_{Wind}$ Total Torsion: $T_c = 0.000\ ft \cdot lbf$





Shaft Stresses:

Axial Stresses:

$$fa(z) := \frac{\Sigma P(z)}{A(z)}$$

Axial Stress Function:

$fa(0) = 0.029\ \boldsymbol{ksi}$

Bending Stresses:

$$fb_{xx}(z) := \frac{M_{xx}(z) \cdot Iyy(z) - M_{yy}(z) \cdot Ixy(z)}{Ixx(z) \cdot Iyy(z) - Ixy(z)^2} \cdot \max\left(Ro_S(z) - y_{cg}(z), Ro_S(z) + y_{cg}(z)\right)$$

Bending Stress w.r.t. x-Axis: $fb_{xx}(0) = 17.548\ \boldsymbol{ksi}$ $fb_{xx}(L_{total}) = 0.000\ \boldsymbol{ksi}$

$$fb_{yy}(z) := \frac{M_{yy}(z) \cdot Ixx(z) - M_{xx}(z) \cdot Ixy(z)}{Ixx(z) \cdot Iyy(z) - Ixy(z)^2} \cdot \max\left(Ro_S(z) - x_{cg}(z), Ro_S(z) + x_{cg}(z)\right)$$

Bending Stress w.r.t. y-Axis: $fb_{yy}(0) = 0.000\ \boldsymbol{ksi}$ $fb_{yy}(L_{total}) = 0.000\ \boldsymbol{ksi}$

Shear Stresses:

$$fs(z) := \sqrt{\left(\frac{V_x(z) \cdot Qxx(z)}{2 \cdot Ixx(z) \cdot t_w}\right)^2 + \left(\frac{V_y(z) \cdot Qyy(z)}{2 \cdot Iyy(z) \cdot t_w}\right)^2} + \frac{|T_c| \cdot \left(Ro_S(z) + \sqrt{x_{cg}(z)^2 + y_{cg}(z)^2}\right)}{Izz(z)}$$

Total Shear Stress: $fs(0) = 0.249\ ksi$ $\quad fs(L_{total}) = 0.000\ ksi$

Shaft Allowable Stresses:

$$Fa(z) := \begin{array}{|l} \lambda \leftarrow \dfrac{k_{eff} \cdot z}{min\left(rxx\left(\frac{z}{2}\right), ryy\left(\frac{z}{2}\right)\right)} \\ \lambda_C \leftarrow \dfrac{\pi}{1.08} \cdot \sqrt{\dfrac{E_{6063}}{Fcy_{6063}}} \\ \text{if } \lambda \le \lambda_C \\ \quad \| \ 0.6 \cdot Fcy_{6063} \\ \text{else} \\ \quad \| \ \dfrac{\pi^2 \cdot E_{6063}}{1.95 \cdot \lambda^2} \end{array}$$

Allowable Axial Stress:
(Ref. Section 6.7 of NAAMM FP 1001-07)

$Fa(0 \cdot in) = 15.000\ ksi$

$Fa(L_{total}) = 0.452\ ksi$

$$Fb(z) := \begin{array}{|l} \lambda \leftarrow \dfrac{D(z) - t_w}{2 \cdot t_w} \\ F \leftarrow \text{if } \lambda \le 33 \\ \qquad \| \ 24 \cdot ksi \\ \qquad \text{else} \\ \qquad \| \ \left(27.7 - 1.70 \cdot \sqrt{\lambda}\right) \cdot ksi \\ F \end{array}$$

Allowable Bending Stress:
(Ref. Section 6.8.2 of NAAMM FP 1001-07)

$Fb(0) = 24.000\ ksi$

$Fb(L_{total}) = 24.000\ ksi$

$Fs(z) := 11.330 \cdot ksi$

Allowable Shear Stress:
(Ref. Table 6.8.2 of NAAMM FP 1001-07)

$Fs(0) = 11.330\ ksi$

$Fs(L_{total}) = 11.330\ ksi$

Coefficient of Amplification: (Second Order Effects)

Refer to Section 6.6 of NAAMM FP 1001-07 for details on the coefficient of amplification.

$$Ca_{xx} := \begin{array}{|l} \text{if } Fa\left(\dfrac{L_{total}}{2}\right) \le 0.26 \cdot Fcy_{6063} \\ \quad \| \ 1 - \dfrac{1}{0.52} \cdot \dfrac{\left(0.38 \cdot \Sigma P(0) + \Sigma P(L_{total}) \cdot \sqrt[3]{\dfrac{Ixx(0)}{Ixx(L_{total})}}\right) \cdot L_{total}^2}{2.46 \cdot E_{6063} \cdot Ixx(0)} \\ \text{else} \\ \quad \| \ 1 - \dfrac{1}{0.52} \cdot \dfrac{0.38 \cdot \Sigma P(0) \cdot L_{total}^2}{2.46 \cdot E_{6063} \cdot Ixx(0)} \end{array}$$

Coefficient of Amplification w.r.t. x-Axis:

$Ca_{xx} = 0.976$

$$Ca_{yy} := \begin{cases} \text{if } Fa\left(\frac{L_{total}}{2}\right) \le 0.26 \cdot Fcy_{6063} \\ \quad 1 - \frac{1}{0.52} \cdot \frac{\left(0.38 \cdot \Sigma P(0) + \Sigma P(L_{total}) \cdot \sqrt[3]{\frac{Iyy(0)}{Iyy(L_{total})}}\right) \cdot L_{total}^{2}}{2.46 \cdot E_{6063} \cdot Iyy(0)} \\ \text{else} \\ \quad 1 - \frac{1}{0.52} \cdot \frac{0.38 \cdot \Sigma P(0) \cdot L_{total}^{2}}{2.46 \cdot E_{6063} \cdot Iyy(0)} \end{cases}$$

Coefficient of Amplification w.r.t. y-Axis:

$Ca_{yy} = 0.976$

Combined Stress Ratio of Shaft:

Refer to Section 6.6 of NAAMM FP 1001-07 for details on the combined Stress Ratio.

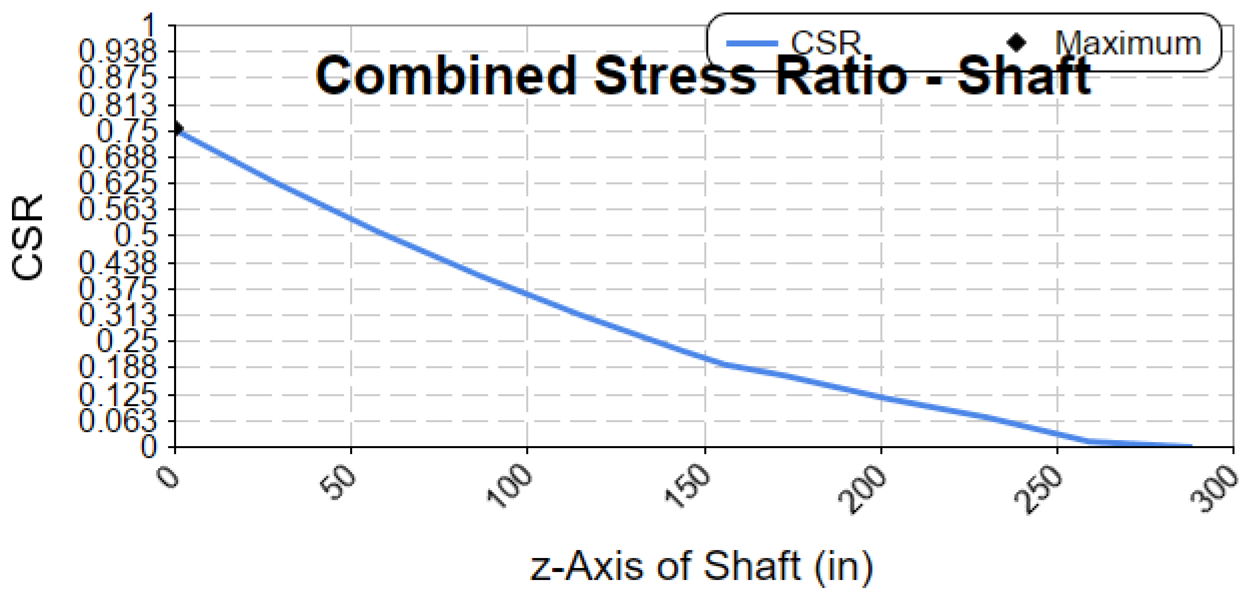
$$CSR(z) := \frac{fa(z)}{Fa(z)} + \frac{\sqrt{\left(\frac{fb_{xx}(z)}{Ca_{xx}}\right)^2 + \left(\frac{fb_{yy}(z)}{Ca_{yy}}\right)^2}}{Fb(z)} + \left(\frac{fs(z)}{Fs(z)}\right)^2$$

Maximum Pole Shaft CSR:

$Status_{Shaft} = \text{“Pass”}$

$CSR_{Max} = 0.752$ Maximum Pole Shaft CSR (*Must be less than or equal to 1*)

$CSR_{Location} = 0.000\ in$ Location of Maximum CSR (*Along z-Axis*)



Summary of Pole Design Calculations for Pole ESR25C51-SAT

Design Specification:

These calculations are based on *Guide Specifications For Design Of Metal Flagpoles, ANSI/NAAMM FP 1001-7*.

Loading Parameters:

Design Wind Speed: $U_D = 90.000\ mph$
Height Above Grade: $H_{Pier} = 0.000\ ft$
Gust Effect Factor: $G_{eff} = 1.140$

Size and Material Type of Flags:

$$V_F = \begin{bmatrix} 5.000 \\ 4.000 \\ 0.000 \end{bmatrix} ft \qquad H_F = \begin{bmatrix} 8.000 \\ 6.000 \\ 0.000 \end{bmatrix} ft$$

$$\gamma_F = \begin{bmatrix} 0.001 \\ 0.001 \\ 0.001 \end{bmatrix} lbf \qquad z_F = \begin{bmatrix} 21.500 \\ 17.000 \\ 0.000 \end{bmatrix} ft$$

Yard Arm Properties:

Flag Vertical: $V_{F.YA} = 0.000\ ft$
Flag Horizontal: $H_{F.YA} = 0.000\ ft$
Material Factor: $\gamma_{F.YA} = 0.001\ lbf$
Arm Length: $L_{YA} = 0.000\ ft$
Arm Diameter: $D_{YA} = 0.000\ in$
Mount Location: $z_{YA} = 0.000\ ft$

Gaff Properties:

Flag Vertical: $V_{F.GA} = 0.000\ ft$
Flag Horizontal: $H_{F.GA} = 0.000\ ft$
Material Factor: $\gamma_{F.GA} = 0.001\ lbf$
Arm Length: $L_{GA} = 0.000\ ft$
Arm Diameter: $D_{GA} = 0.000\ in$
Arm Angle: $\theta_{GA} = 0.000\ deg$
Mount Location: $z_{GA} = 0.000\ ft$

EPA, Weight, and Location of Attachments:

$$EPA = \begin{bmatrix} 0.000 \\ 0.000 \end{bmatrix} ft^2 \qquad wEPA = \begin{bmatrix} 0.000 \\ 0.000 \end{bmatrix} lbf$$

$$xEPA = \begin{bmatrix} 0.000 \\ 0.000 \end{bmatrix} ft \qquad xCG = \begin{bmatrix} 0.000 \\ 0.000 \end{bmatrix} ft$$

$$zEPA = \begin{bmatrix} 0.000 \\ 0.000 \end{bmatrix} ft$$

Design Parameters:

Bottom Diameter: $D_B = 5.000\ in$
Top Diameter: $D_T = 3.000\ in$
Wall Thickness: $t_w = 0.156\ in$
Bottom Straight: $L_{botst} = 13.000\ ft$
Taper Length: $L_{taper} = 11.000\ ft$
Top Straight: $L_{topst} = 0.000\ ft$
Total Length: $L_{total} = 24.000\ ft$
Taper Exponent: $n_{taper} = 1.000$
Shaft Tensile Strength: $Ftu_{6063} = 30.000\ ksi$
Shaft Yield Strength: $Fty_{6063} = 25.000\ ksi$

Pole Base Reactions:

Axial: $\Sigma P(0) = 69.624\ lbf$
Moment: $M_c(0) = 4077.125\ ft \cdot lbf$
Shear: $V_c(0) = 296.116\ lbf$

Design Checks:

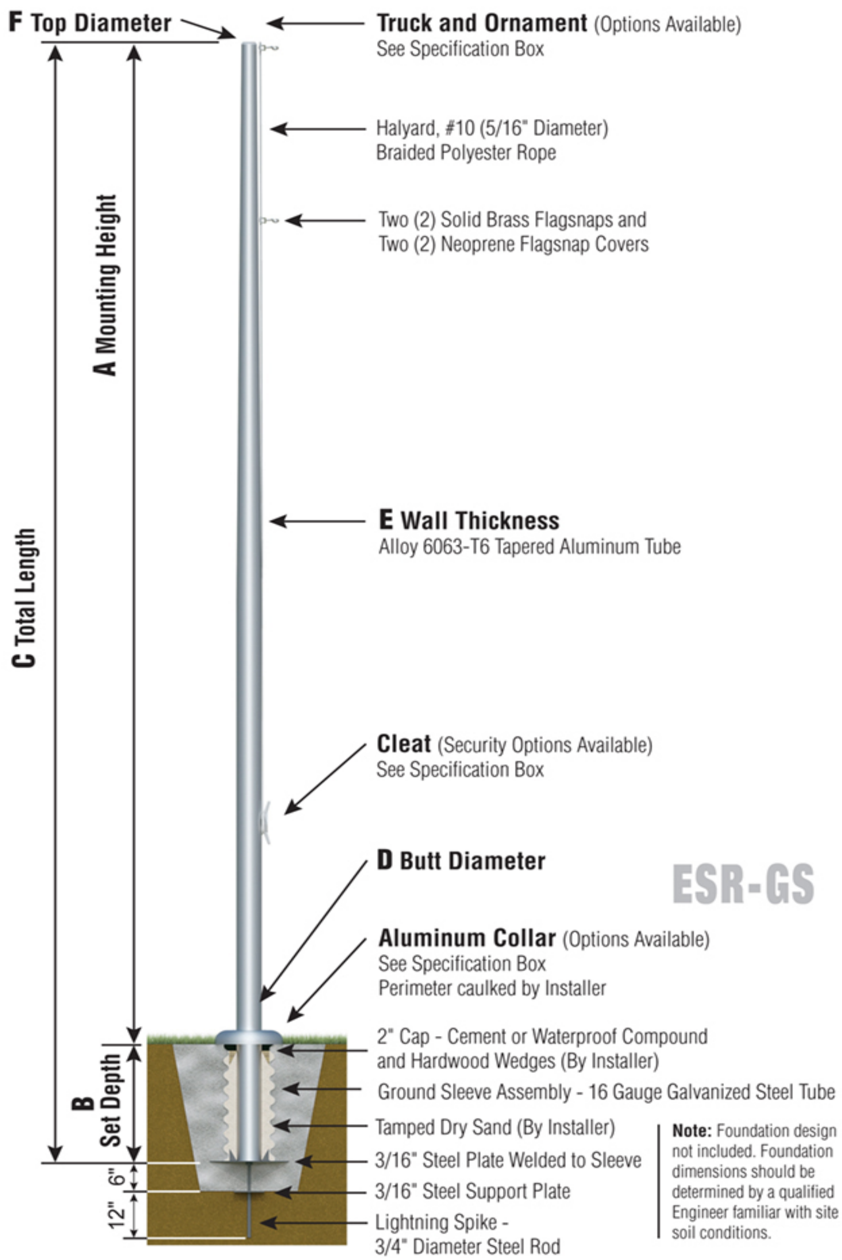
Shaft:

$Status_{Shaft} = \text{"Pass"}$ $\qquad CSR_{Max} = 75.187\%$

Continental Series

ESR - External Single Revolving
Rope Halyard
Ground Set Installation

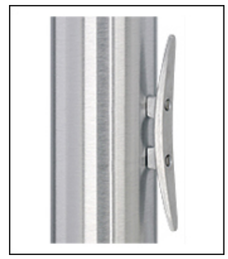
ESR25C51	-	SAT



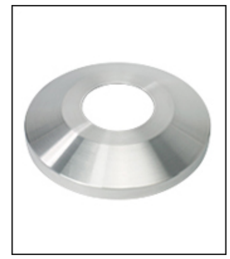
TRK-9610

In-Line Truck
Single Revolving

BAL-0512-GLD-ES
HD Gold Anodized
Aluminum Ball



CLA-9090-SAT | 7' from bottom
Cleat Only



COL1-A05S

FC-11 Spun Alum
1-Piece

SAT
Satin Finish

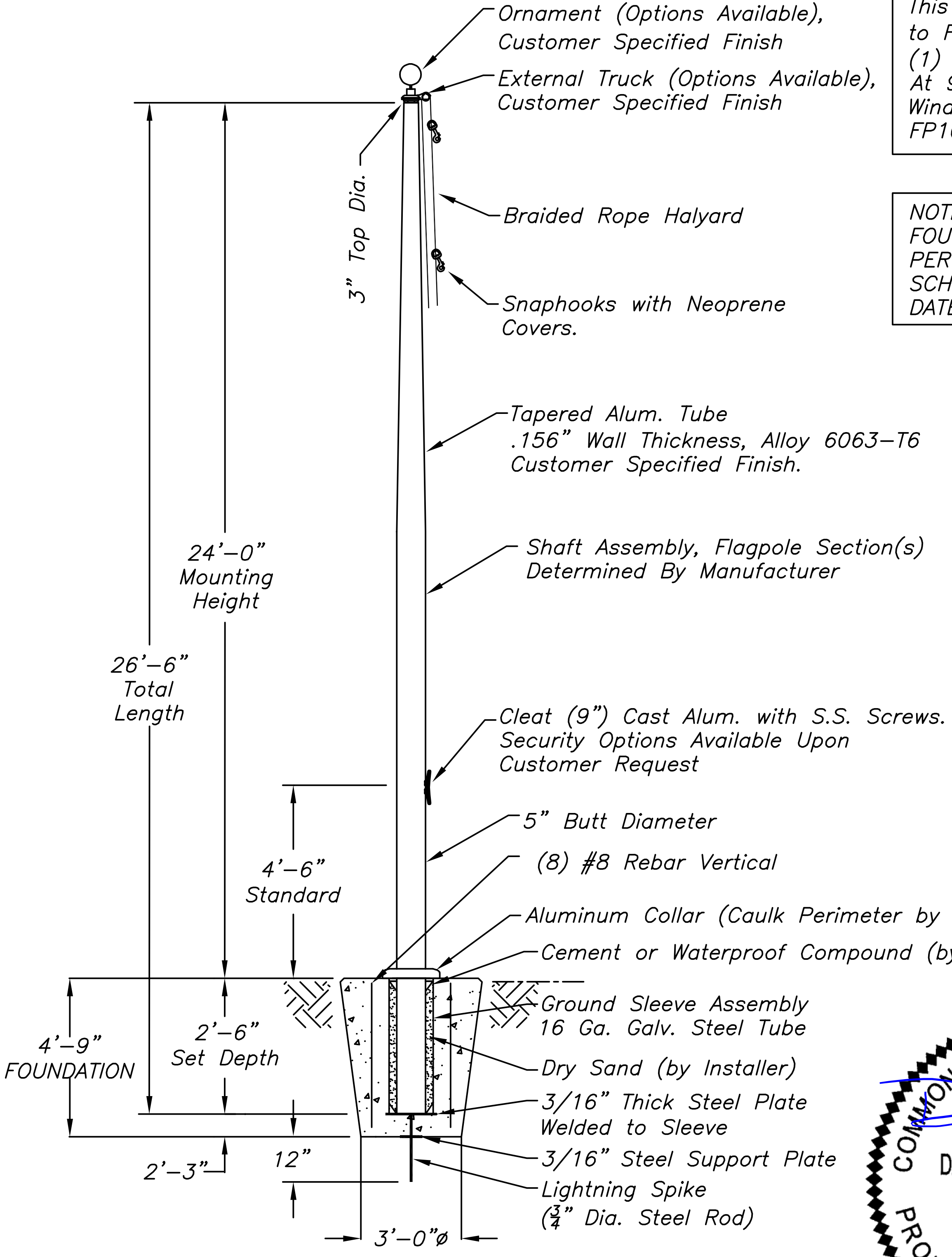
NOMINAL EXPOSED HEIGHT: Total Shaft Length of 25' flagpoles is 26'-6" with a Set Depth of 2'-6". With the Truck and Ornament attached, the nominal Mounting Height is 25'.

Specifications
A. Mounting Height: 24'
B. Set Depth: 2'-6"
C. Total Length: 26'-6"
D. Butt Diameter: 5"
E. Wall Thickness: .156"
F. Top Diameter: 3"
Flagpole Sections: 1
Shaft Weight: 87 lbs.
Hardware Weight: 9 lbs.
Ground Sleeve Weight: 26 lbs.
* Rated Flag Size: (1) 5' x 8' & (1) 4' x 6'
* Rated Wind Speed w/Nylon Flag: 90 mph
* Wind Speed Specifications from ANSI/NAAMM FP 1001-07

Customer Name:			
Dealer:	Gates Flag & Banner	Qty: 1	
Project:	Exit 54 Roundabout Flagpoles	Location: Colonial Height, VA 23834	
Notes: EPT95377			

This Flagpole Is Designed to Fly (1) 4'–0" X6'–0", (1) 5'–0"X 8'–0" Flag(s), At 90 MPH. 3 Second Wind Gusts Per NAAMM FP1001–07.

NOTES:
FOUNDATION DESIGNED PER SOIL REPORTS BY SCHNABEL ENGINEERING DATED NOVEMBER 6, 2024



NO.	REVISIONS	DATE

CONCORD AMERICAN FLAGPOLE

Abingdon, Va.

TITLE: External Halyard Flagpole
PROJECT: EXIT 54 ROUNDABOUT
LOCATION: COLONIAL HEIGHTS, VA
CUSTOMER OR REP.:
DATE: 04.03.25 SCALE: NTS DWG #: ESR25C51–SAT
PT#: EPT–95377

APPENDIX D

Transportation Management Plan Type "A":

CITY OF COLONIAL HEIGHTS
INCORPORATED 1948
VIRGINIA

Temple Avenue Flagpole Installation

Transportation Management Plan
(Type "A" Minimum Plan)

COMMONWEALTH OF VIRGINIA
RYAN W. MATTERN
No. 0402055220
PROFESSIONAL ENGINEER

Digitally signed by Ryan W. Mattern
DN: cn=Ryan W. Mattern, o=WALLACE MONTGOMERY AND ASSOCIATES LLP, email=rmattern@wallacemontgomery.com
Reason: I attest to the accuracy and integrity of this document
Date: 2025.12.19 13:47:57 -05'00'

Prepared By:

WALLACE MONTGOMERY
ENGINEERS I PLANNERS I SURVEYORS I CONSTRUCTION MANAGERS

December 2025

TRANSPORTATION MANAGEMENT PLAN

Project Description

The project is a Type A, Category I TMP in accordance with VDOT IIM-LD-241. This project involves the foundation design and maintenance of traffic control plans for the installation of three (3) total flag poles. Two (2) flag poles with a height of 24 feet and one (1) flagpole with a height of 30 feet.

The project is within the roundabout at the Temple Avenue and the I-95 On-Ramp and Off-Ramp within the City of Colonial Heights.

The traffic volumes are heavy during peak periods with all types of traffic using this roadway and interchange. Types of traffic include trucks, school buses, commuters, and residents.

Construction

The Contractor shall obtain all necessary permits required for construction.

There are no identified areas within the right of way for the contractor to store equipment and materials.

The contractor shall restore any disturbed area of the grass buffer area between the back of curb and front of sidewalk to current conditions using topsoil and seed.

Work Hours/Lane Closures

All closures shall be in accordance with the lane closure hours listed in the table below. All travel lanes in both directions shall be open to traffic at the end of each workday. All shoulder and travel lanes shall be open to traffic during non-working hours unless approved or directed by the Engineer. Prior approval of the closure is required before work begins at the site.

No work shall be permitted on a holiday as defined by Section 108.02 of the 2020 VDOT Road and Bridge Specification or on Sundays except as is necessary to maintain traffic.

No lane closure signing or other disruptive work is to be initiated prior to the beginning closure time specified. The removal of all signs, equipment, and materials will be accomplished prior to the ending closure time specified.

It is the intent to minimize the impact to the traveling public. Lane closures or restrictions over segments of the project, in which no work is anticipated within a reasonable time frame, as determined by the Engineer, shall not be permitted.

Allowable Single-Lane Closures* or Shoulder		
ARTERIAL	**WEEKDAY**	
	Monday to Thursday	Friday
Temple Avenue (including Roundabout)	10:00AM to 3:00PM	9:00AM to 2:00PM
I-95 Ramps	10:00AM to 3:00PM	9:00AM to 2:00PM

**Single-lane closures only permitted for multiple-lane roadways.*

Minimum Lane Width

At a minimum, one lane traffic is to be maintained at all times in each direction, temporary lane widths should be no less than existing with desirable being 11' minimum, and detours are not needed.

Access Requirement

The Contractor shall provide and maintain safe and adequate access to all intersecting roadways and driveways at all times to the satisfaction of the Engineer. All cost for providing and maintaining access shall be included in the price bid for other items in the contract and no additional compensation will be allowed.

Pedestrian access shall be maintained to the maximum extent practicable to the satisfaction of the Engineer.

Special Details

There are no special details for this project that are not addressed within the TMP document and the Virginia Work Area Protection Manual.

Public Communications Plan

A complete Public Communication Plan is not applicable to this project. The process for notifying the Project Manager, Residency Engineer, or Administrator of scheduled work plans and traffic delays is as follows: The Contractor submits planned lane closures to the City Project Manager, who enters them into LCAMS and VA-Traffic. The Traffic Operations Center reviews the schedule and either approves it or identifies conflicts, which must be resolved before confirmation. The Contractor confirms their intent to proceed with approved closures in advance, and the City Project Manager coordinates notifications and updates with relevant parties throughout the lane closure period. Coordination and approval with VDOT shall be required as needed.

Transportation Operation Plan

A complete Transportation Operations Plan is not applicable to this project. The City Project Manager or Designee shall provide a notification of construction start/end dates and work zone information to the VA-Traffic operator to enter it into the Virginia Traffic system.

The contractor shall be responsible for contacting emergency agencies, implementing procedures to respond to traffic incidents that may occur in the work zone, notifying the Project Maintenance of Traffic Coordinator and all responsible parties of any incidents and expected traffic operations and the review process to modify any TTCP to reduce frequency and severity of incidents.

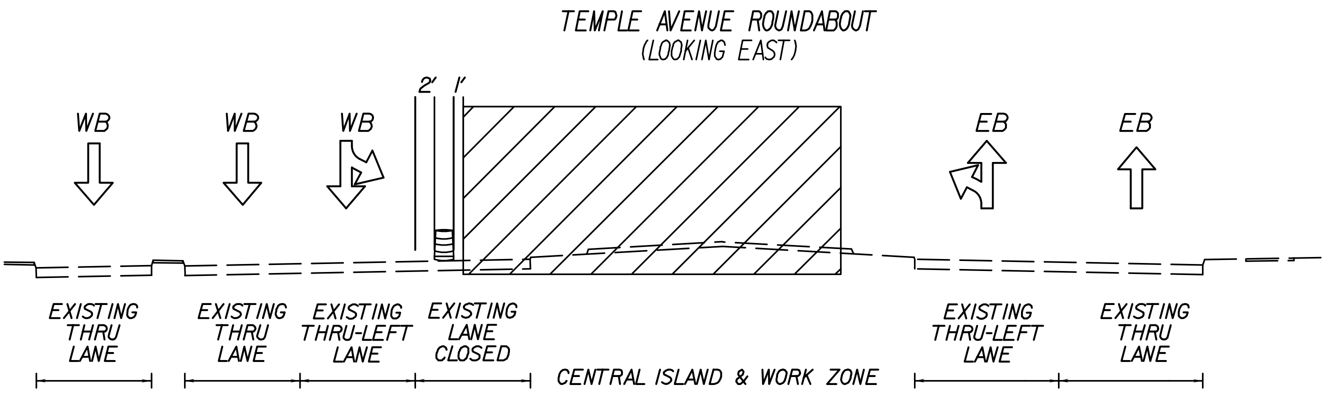
Temporary Traffic Control

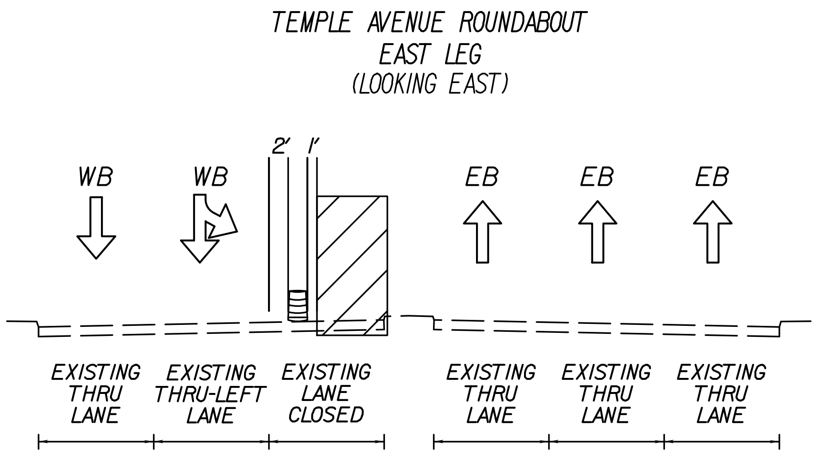
All temporary traffic control work and devices shall be in accordance with Section 512 of the 2020 Virginia Road and Bridge Specifications, 2011 Virginia Work Area Protection Manual (VWAPM) Revision 2.1, and as amended by contract provisions.

It is not the intent of this transportation management plan to enumerate every detail which must be considered in the construction of this project, but only to show the general handling of traffic.

The following a typical Section and basic Temporary Traffic Control Plan (TTCP) are based on the Virginia Work Area Protection Manual TTC-29.2, "Turn Lane Closure Operation", TTC-32.2, "Inside lane closure of roundabout" and TTC-53.0 (Signing for Project Limits) is to occur during allowable lane closure hours as noted.

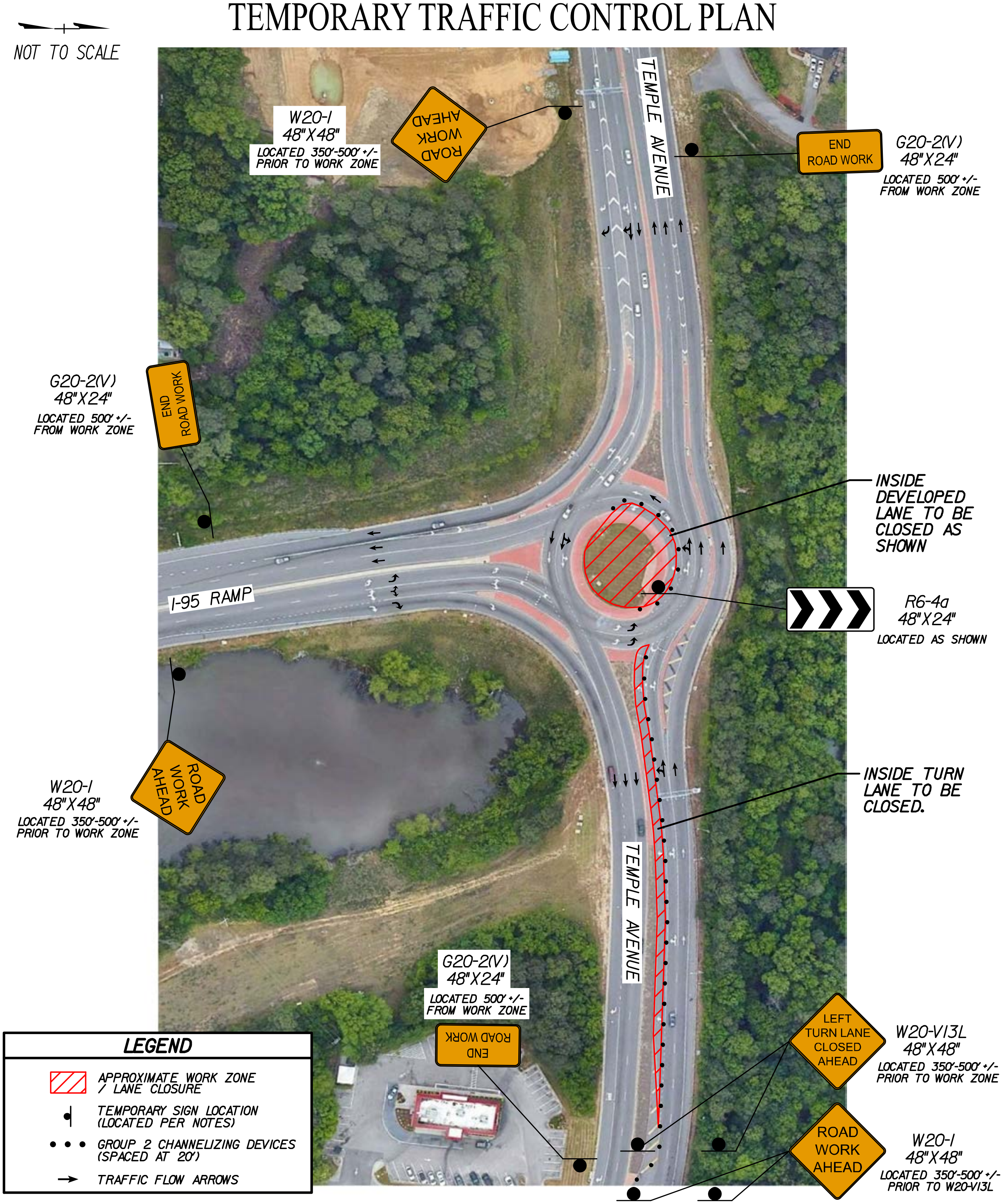
TEMPORARY TYPICAL SECTION





NOT TO SCALE

TEMPORARY TRAFFIC CONTROL PLAN



TEMPLE AVENUE FLAGPOLE INSTALLATION
TEMPORARY TRAFFIC CONTROL PLAN
CITY OF COLONIAL HEIGHTS

APPENDIX E

Flagpole and Light Details:

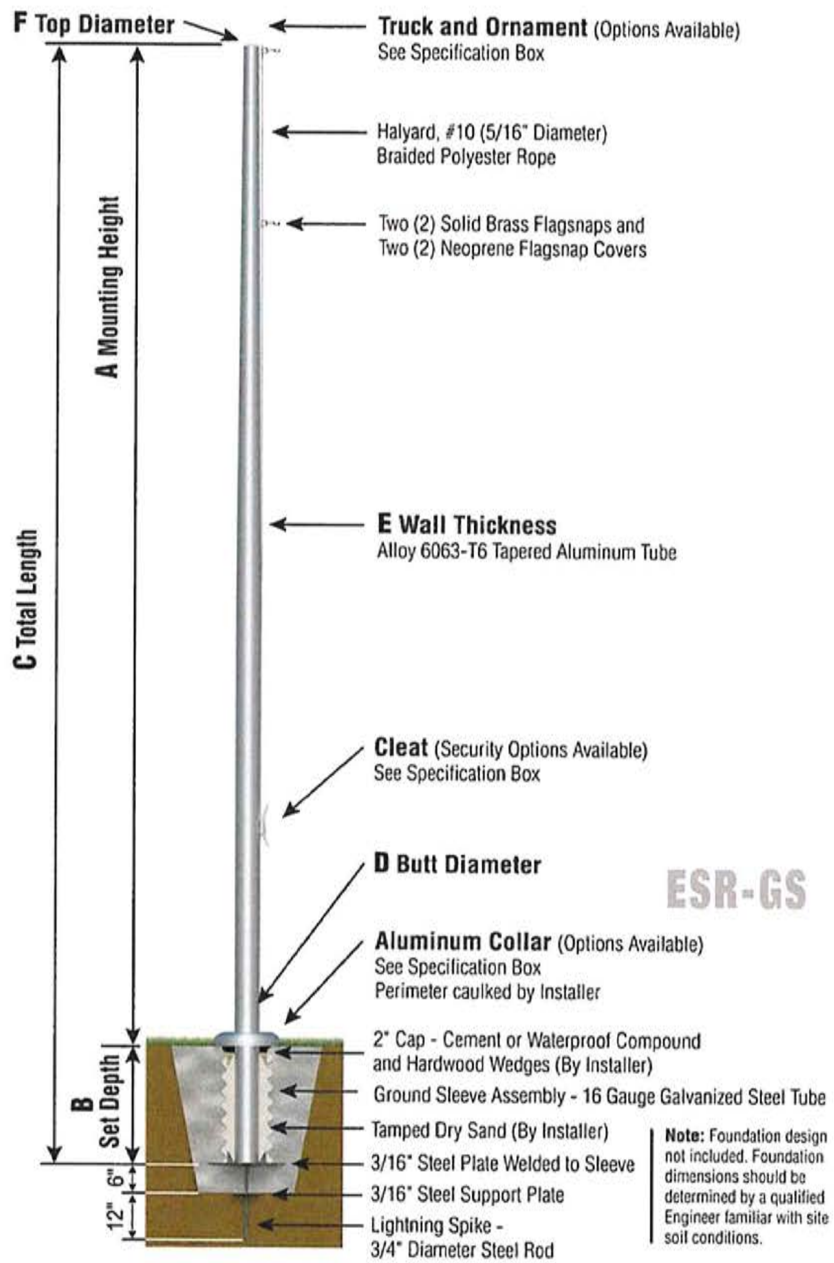
*AS SPECIFIED OR APPROVED EQUAL

CONCORD AMERICAN FLAGPOLE
Pride. Quality. Tradition.

Continental Series

ESR - External Single Revolving
Rope Halyard
Ground Set Installation

ESR30C61 - SAT



TRK-9610

In-Line Truck
Single Revolving

BAL-0612-GLD-ES
HD Gold Anodized
Aluminum Ball

CLA-9090-SAT | 7.5' from bottom
Cleat Only

COL1-A06S

FC-11 Spun Alum
1-Piece

SAT
Satin Finish

Specifications
A. Mounting Height: 30'
B. Set Depth: 3'-0"
C. Total Length: 33'-0"
D. Butt Diameter: 6"
E. Wall Thickness: .156"
F. Top Diameter: 3.5"
Flagpole Sections: 1
Shaft Weight: 135 lbs.
Hardware Weight: 10 lbs.
Ground Sleeve Weight: 36 lbs.
* Rated Flag Size: (1) 6' x 10' & (1) 5' x 8'
* Rated Wind Speed w/Nylon Flag: 90 mph
* Wind Speed Specifications from ANSI/NAAMM FP 1001-07

Customer Name:			
Dealer: Gates Flag & Banner		Qty: 1	
Project: Exit 54 Roundabout Flagpoles		Location: Colonial Heights, VA 23834	
Notes: EPT95377			

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*AS SPECIFIED OR APPROVED EQUAL

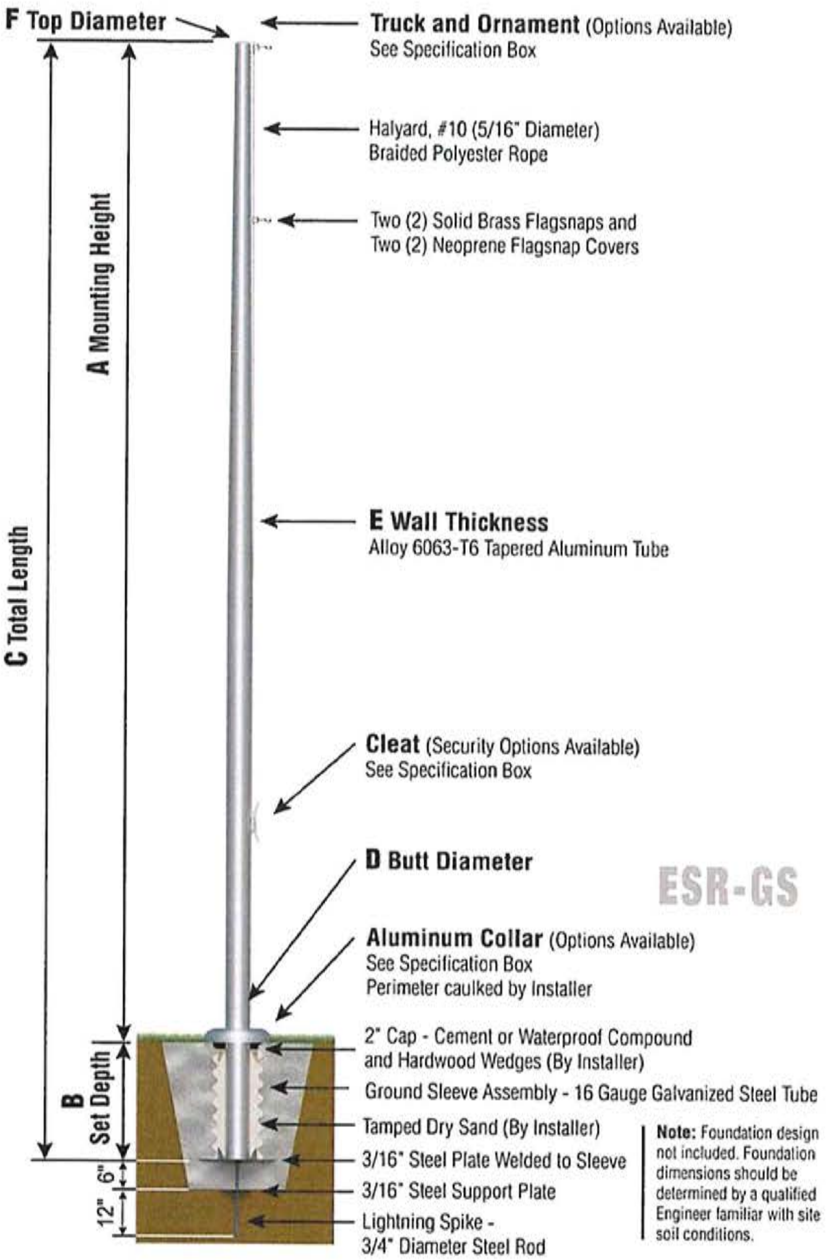
CONCORD AMERICAN FLAGPOLE

Pride. Quality. Tradition.

Continental Series

ESR - External Single Revolving
Rope Halyard
Ground Set Installation

ESR25C51 - SAT



TRK-9610

In-Line Truck
Single Revolving

BAL-0512-GLD-ES
HD Gold Anodized
Aluminum Ball

CLA-9090-SAT | 7' from bottom
Cleat Only

COL1-A05S

FC-11 Spun Alum
1-Piece

SAT
Satin Finish

NOMINAL EXPOSED HEIGHT: Total Shaft Length of 25' flagpoles is 26'-6" with a Set Depth of 2'-6". With the Truck and Ornament attached, the nominal Mounting Height is 25'.

Specifications
A. Mounting Height: 24'
B. Set Depth: 2'-6"
C. Total Length: 26'-6"
D. Butt Diameter: 5"
E. Wall Thickness: .156"
F. Top Diameter: 3"
Flagpole Sections: 1
Shaft Weight: 87 lbs.
Hardware Weight: 9 lbs.
Ground Sleeve Weight: 26 lbs.
* Rated Flag Size: (1) 5' x 8' & (1) 4' x 6'
* Rated Wind Speed w/Nylon Flag: 90 mph
* Wind Speed Specifications from ANSI/NAAMM FP 1001-07

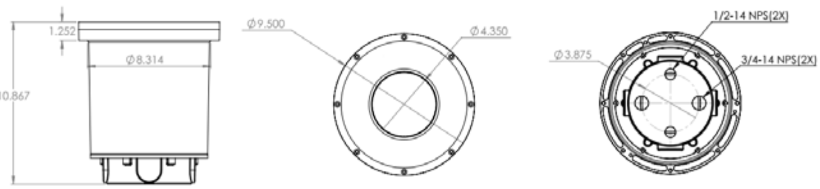
Customer Name:		
Dealer: Gates Flag & Banner		Qty: 2
Project: Exit 54 Roundabout Flagpoles	Location: Colonial Height, VA 23834	
Notes: EPT95377		

*As Specified or Approved Equal

STARBEAM SPECIFICATIONS

LED DIRECT BURIAL INGROUND LIGHT

Eagle Mountain Flag & Flagpole



FEATURES & SPECIFICATIONS

APPLICATION — The TDBX line of LED Lanscape Burial Lights are the most versatile LED fixtures on the market today. Various beam spreads and color temperatures allow for a customized finish to any property. The high end commercial grade system was designed for 120V or 208~277V operation commercial applcations.

CONSTRUCTION — The rough-in housing is made of black 25% glass filled polyester composite that will not flake, peel or corrode. The LED light source is housed within an 88% copper bronze alloy heat sink module for maximum heat dissipation. Internal cabling features anti-siphon wiring to prevent water intrusion as well as IP68 quick connects for quick change out and ease of installation. Silicone O-rings work with the CNC precision machined components to insure proper sealing. All fasteners provided are stainless steel. Trim plate made of 88% copper bronze alloy.

OPTICAL SYSTEM — A molded polycarbonate 82mm compact reflector is optimized for use with the LED light source allowing the fixture to be compact while using high density modern COB LEDs (80 CRI standard). The reflector smooths out and removes any unwanted color-over-angle artifacts from the beam. A 15mm low-iron tempered glass lens protects the light source. An aiming adjustment screw allows the optical assembly to be tilted up to 15° in any direction and locked into place.

ELECTRICAL SYSTEM — Fixture operates at 120V-277V. System is compatible with the use of a standard 0-10V dimmer. 10kV internal surge protection provided standard.

MOUNTING — Fixtures are designed to be in-ground burial lights and should be installed according to the installation instructions made available by Techlight. Proper drainage and substrate must be provided around the fixture. Two ¾" and two ½" conduit entries are supplied on the underside of the housing. ½" conduit side entries availabe upon request. Conrete pour kits available (see Accessories). Rough-in housing may be pre-shipped[1] at customer's expense.

LISTINGS — ETL suitable for wet locations. IP68 2M rated to 2 meters. Meets US and Canadian safety standards. -40°C to 40°C ambient operation. RoHS Compliant.

PRODUCT INFORMATION

NOMINAL DISTRIBUTION	NOMINAL OUTPUT	COLOR TEMP	VOLTAGE	TRIM FINISH
15DO = 15° Optic	5L = 5000 Lumens, 48W 6L = 6000 Lumens, 56W	CW = Cool White 5000K	D = Multi-Volt[1]	BLANK = No Paint Finish (Bronze)[2]

DELIVERED LUMEN CHART

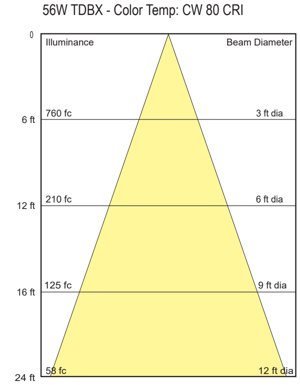
	5L (1200mA, 48W)		6L (1400mA, 57W)	
	CW		CW	
15DO = 15° Optic	4680		5441	

ILLUMINANCE CONE DIAGRAMS

TDBX15D6LCW

15 Degree Optic

56W TDBX - Color Temp: CW 80 CRI



ACCESSORIES (Order as separate line items)

TDBXPK TDBX Concrete Pour Frame (Stainless Steel)

The TDBXPK Concrete Pour Kit is a high grade rolled stainless steel mounting ring that is used with the TDBX RIH Rough-In Housing to provide simple and consistent installation into concrete. A cover is provided with the rough-in housing to keep debris and concrete out of the fixture housing.

NOTES

1 = Multi-Volt is an auto ranging power supply from 120V to 277V input.

2 = Bronze finish consists of a polyester powder coat applied to the exposed areas of the cast lens frame only. The lens frame will be provided as natural cast bronze.

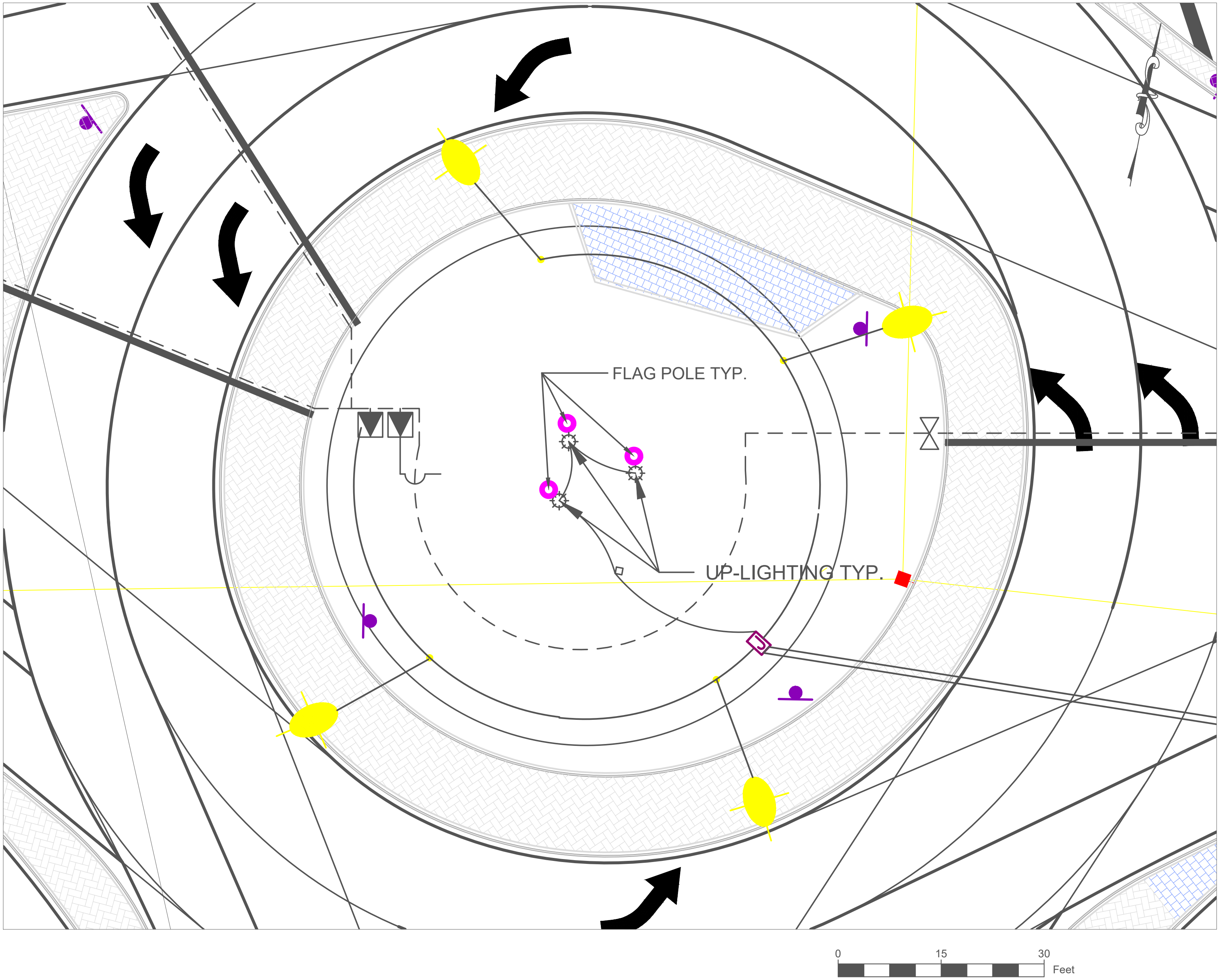
IP68 2M

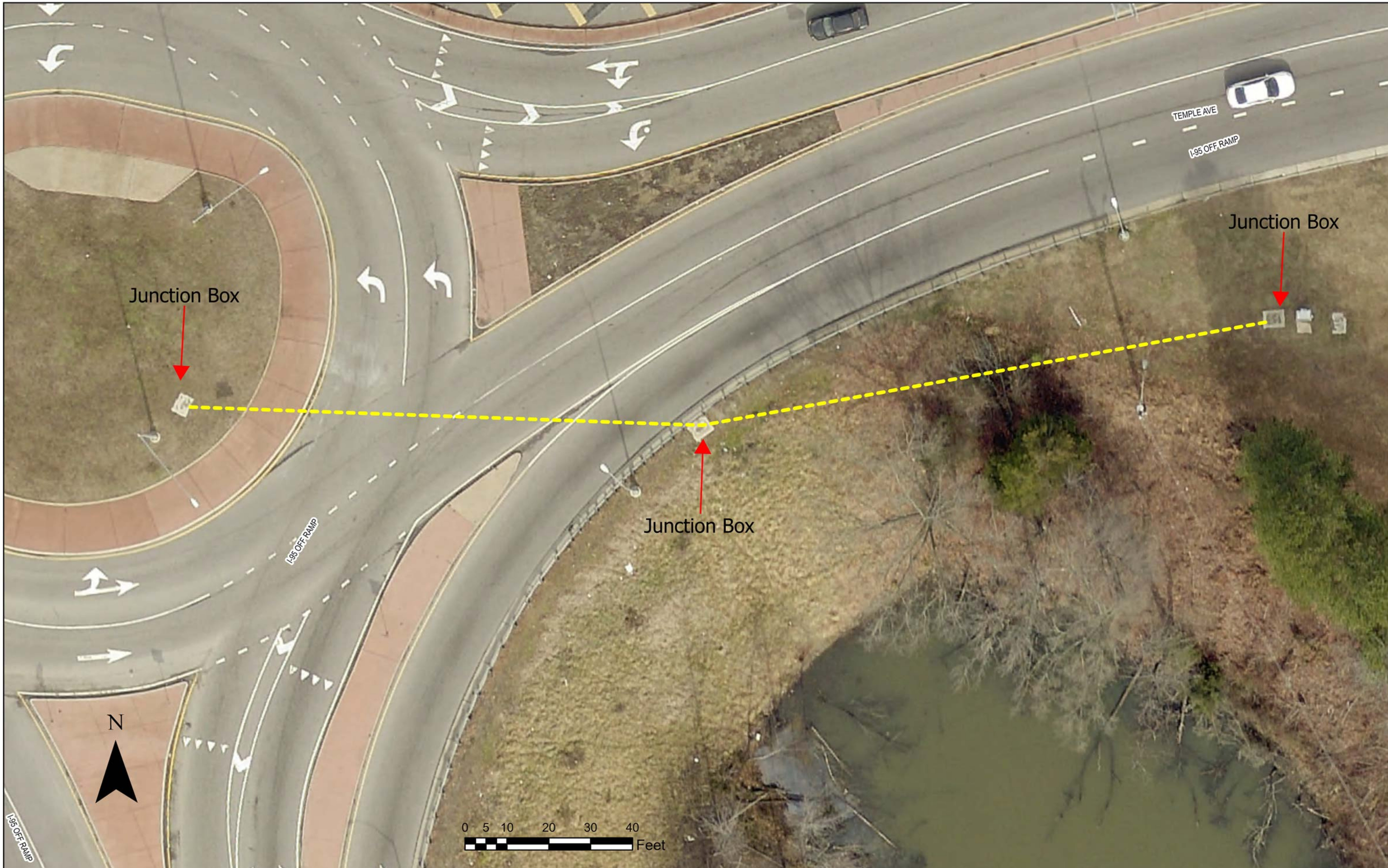
All dimensions and specifications are subject to change without notice.

APPENDIX F

Flagpole Installation Project Area:

***Flagpole locations to be confirmed at the Pre-Constion Meeting.**





TEMPLE AVE
I-95 OFF RAMP
Junction Box
Junction Box
Junction Box
I-95 OFF RAMP
I-95 OFF RAMP
N
0 5 10 20 30 40
Feet

APPENDIX G

Land Use Permit:

Commonwealth Of Virginia

Department Of Transportation

Land Use Permit

Permit No 426-57839

Status APPROVED

This permit only grants permission to use whatever rights the Commonwealth Transportation Board and the Department of Transportation have in the right of way and no more, and it is the obligation of the permittee to secure any other releases or permission that may be needed in order to perform the work.

Effective Date Oct 15, 2025 **Expiration Date** Oct 15, 2026 **Reinstatement Date**

Anticipated Start Date

Permitee Information	Your Job# 20 - Rt. 144 Temple Avenue - Roundabout - LIMITED ACCESS	Surety & Account Receivable Information
Owner & Address City of Colonial Heights 201 James Avenue Colonial Heights Virginia 23834	**Agent**	**Name** City of Colonial Heights **Surety Account** Suntrust Bank Chk# 857579, Part **Surety Type** Cash/Check **Amount** 1,500.00 **Obligation Amount** 1,500.00 **Surety Holder** CUSTOMER
Contact Matt Parker **Phone#** 804-520-9334 **Fax#** **24 Hr#**	**Contact** **Phone#** **Fax#** **24 Hr#**	

AUTHORIZATION: In compliance with your application, permission is hereby given insofar as the Commonwealth Transportation Board has the right, power, and authority under sections 33.2 - 210;33.2 - 240;33.2 - 241 of the Code of Virginia as amended, to grant by Special Agreement and/or by Land Use Permit for you to perform the work and or activity(s) described below:

Location

County/City/Town	City of Colonial Heights	Highway Route(s)	144 - Temple Avenue
From Route Number	1	From Route Name	US - 1
To Route Number	95	To Route Name	Richmond Petersburg Turnpike

Work Description The permittee/agent must contact the VDOT Customer Service Center at 1-800-367-7623 a minimum of 48 hours prior to initiating any excavation within 1,000 feet of a signalized intersection and/or VDOT ITS infrastructure.

The City of Colonial Heights to install (3) Flagpoles and uplighting in the Rt. 144 Temple Avenue roundabout. Work per approved plans shall be performed in accordance with all applicable sections of VDOT's Road & Bridge Specifications/Standards (current edition). Traffic shall not be blocked/re-routed (detoured) without written permission from the district administrator's designee. Lane closure hours: 10:00AM-3:00PM (Monday-Thursday) & 9:00AM-2:00PM (Friday) via Lane Closure Request Form required 48 hours prior. Temporary rumble strips for applicable TTC's required/will be strictly enforced. Failure to implement them per VWAMP Rev. 2019, will result in removal from the road. Please contact James Zimmerman at 804-894-2613 for preconstruction meeting.

Payment Reference	Payment Date	Payment Type	Payment Amount
Suntrust Bank Chk# 857579, Part	10/15/2025	Check	$160.00

Applicant has compiled with VA Code Section 56-265.15 Affidavit is attached.

TERMS: Applicable as stated in the VDOT Land Use Permit Regulations (current edition) and/or as per approved plans, and/or regulatory instructions, including but not limited to the LUP-SPG and/or agreement(s) attached hereto.

COMMONWEALTH TRANSPORTATION BOARD

By: [signature] *Oct 15, 2025*

Shannon Burks

C Call before you dig

A Allow the required time for marking

R Respect and protect the marks/flags

E Excavate carefully

va811.com Dig With CARE

[ ] When checkbox is marked, by approving this permit, the issuing official certifies that the entrance was designed in accordance with Appendix F of the Road Design Manual

FINAL INSPECTION & SURETY REQUIREMENTS: Upon completion of the work or activity(s) authorized under this Land Use Permit, the permittee shall contact the following office in writing or by electronic communication to request final inspection and release of the surety obligation for this permit.

Chesterfield Residency
3301 Speeks Drive Shannon.Burks@VDOT.Virginia.gov
Midlothian, VA VA 23112