PGSuper Flexural Design Algorithm Modifications

Second Cut, February 20, 2007

Background

The flexural design algorithm in PGSuper is being modified so that it will be flexible enough to handle both TxDOT and WSDOT design requirements. The algorithm will also be modified to incorporate debond design as well as harped strand design. Note that shear design is not addressed in this document.

This document describes the user input and design algorithms required to make this change happen. Note that other changes have already been incorporated into the program to make this possible. One example is the new strand input UI/implementation.

Organization of This Document

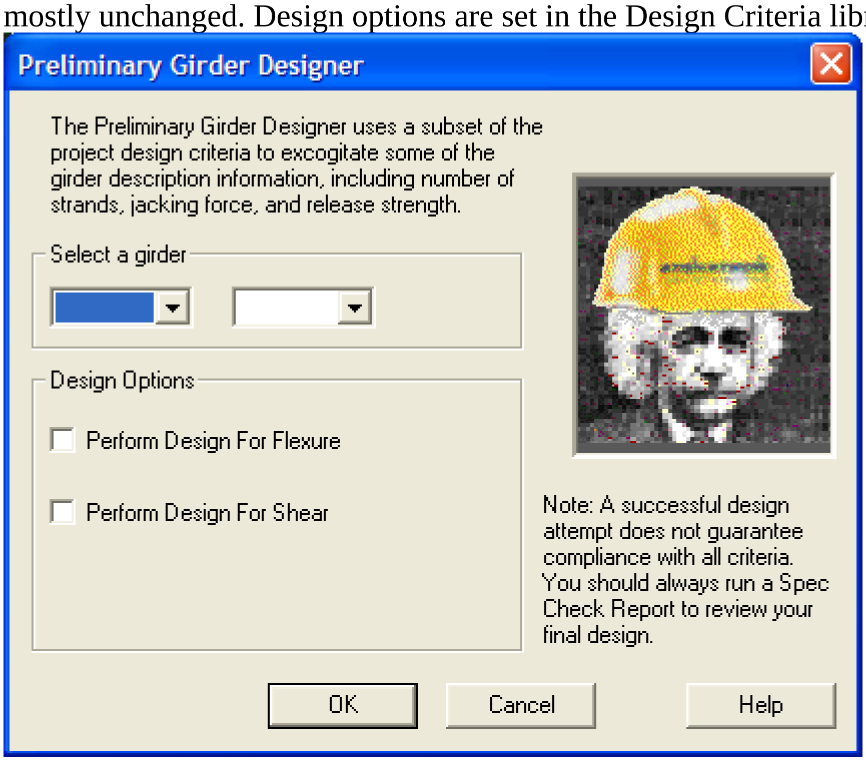
The initial paragraphs of this document are meant to give the user an understanding of the background information for this project, and how the design algorithm will fit into the PGSuper program. However, the “meat” of the information is contained in the detailed flow charts contained in the Appendices.The flowcharts must be reviewed carefully to avoid major problems in the implementation. Sorry for the difficult reading, but in software development, the Devil hides in the details. Also note that there is a Glossary of terms in Appendix D.

User Interface Changes

The following is a discussion of various user interface widgets that directly affect the design algorithm.

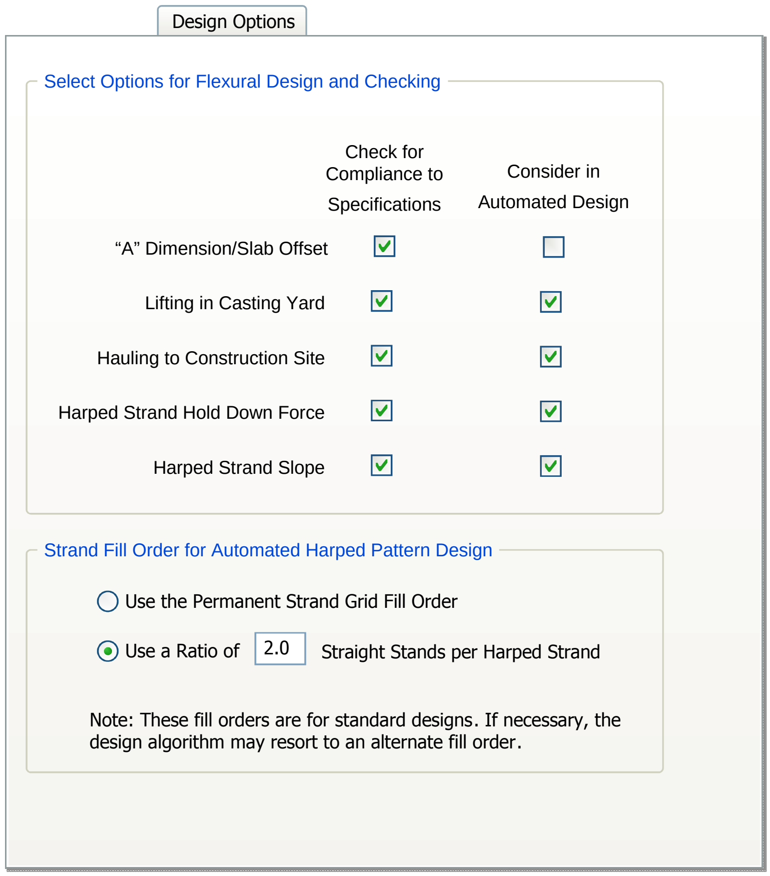
Girder Designer Dialog

The Preliminary Girder Designer dialog (shown below) will remain mostly unchanged. Design options are set in the Design Criteria library



Design Criteria Dialog

Primary control of the design algorithm, and compliance checking is contained in a new tab to be added to the Design Criteria library entry. User’s wanting flexural design can now specify whether the algorithm will include the design of the “A” Dimension, Lifting, Hauling, Strand Slope, and Hold Down Force. Note that design cannot be turned on for an item unless compliance checking is also turned on.



“A” Dimension Design

The “A” dimension is the vertical distance between the top of the slab and the top of the girder at the bearing line. If enabled, the “A” Dimension design will attempt to find a distance that will minimize “A” while keeping the girder from impinging into the slab at the highest camber location.

If “A” dimension design is disabled, the program will use the current project value.

Lifting Design

The lifting design algorithm will attempt to optimize values of lifting loop location, concrete strength, number of harped strands, and number of temporary strands so the girder can be safely lifted in the casting yard.

Hauling Design

The hauling design algorithm will attempt to optimize values of support locations, concrete strength, and number of temporary strands so the girder can be safely trucked from the casting yard to the construction site.

Strand Slope Design

Limiting max strand slope is a manufacturability requirement. If enabled, the algorithm will check to make sure the slope of harped strands is below the limit and will attempt to lower the harped pattern at the girder ends if it is.

Note that this option is only applicable to harped girder design.

Hold Down Force Design

Limiting max hold down force is a manufacturability requirement. If enabled, the algorithm will check to make sure the hold down force is below the limit and will lower the harped pattern at the girder ends if it is.

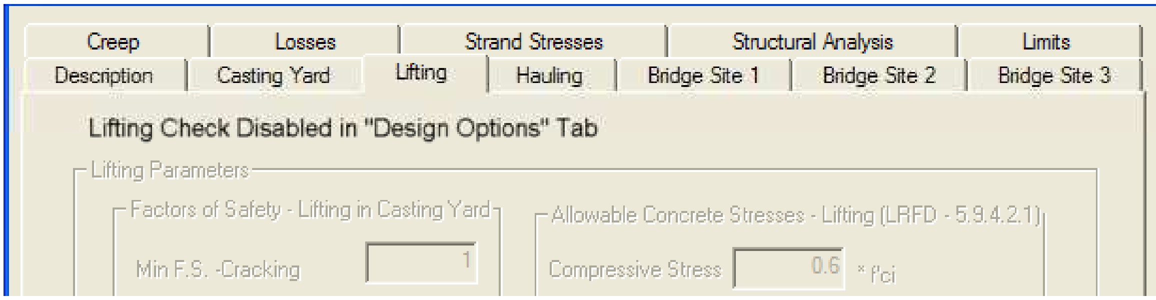
Note that this option is only applicable to harped girder design.

Fill Order for Harped and Straight Strand Design

This option tells the designer to either fill strands using the global strand order defined in the girder library entry, or to use a target proportion of straight to harped strands.

Changes to Other Design Criteria Tabs

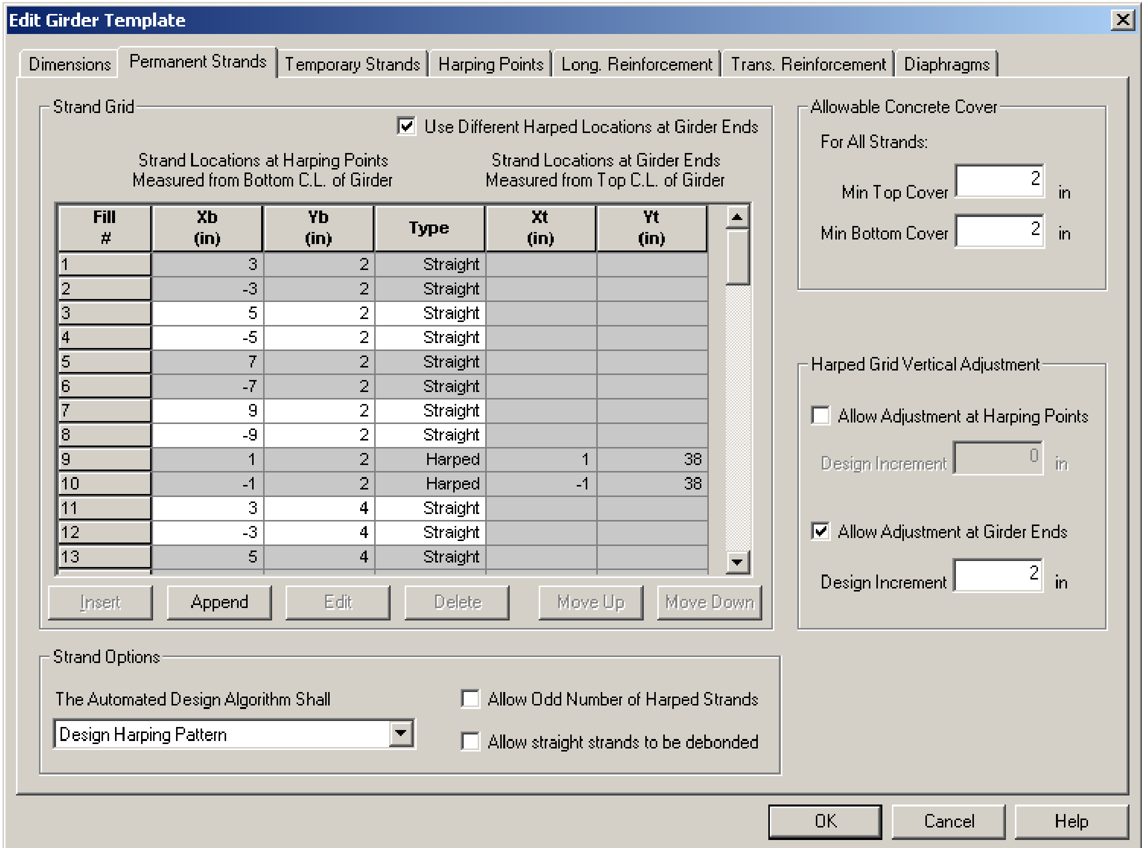
Additional changes must also be made to the “Lifting”, “Hauling”, and “Casting Yard” tabs. When a criterion Check is disabled, all parameters will be disabled and, an informational message will be displayed to tell the user that the pertinent option has been turned off in the Design Options tab. As an example, the Lifting tab is shown below:



Other criterion will be treated similarly in their respective locations.

Girder Library Entry Dialog

The “Permanent Strands” tab in the Girder entry dialog shown below contains several parameters that directly affect the design algorithm.



Strand Fill Order

The design algorithm fills strands using the strand order(s) defined on this tab. Straight and harped strands are filled independently if “Select Number of Strands Using Number of Harped and Number of Straight” is selected in the Girder Editor dialog (discussed later).

Strand Pattern Design

The user can select whether Debonding or Harping is used to control top tensile stress at the girder end-zones. If “Design Debond Pattern” is selected and “Allow Straight Strands to be Debonded” is disabled, the algorithm will attempt to design using fully-bonded straight strands only.

Vertical Adjustment of Harped Strands

If “Design Harping Pattern” is selected, the user can chose whether or not to allow the user, or the design algorithm, to vertically adjust the harped strand grids at the girder ends or harping points. Strand locations must be within the specified top and bottom cover.

Note that the design algorithm uses the design increment to move that strands. If the design increment is zero, the algorithm will not adjust the strands. However, users can manually adjust the strands in the Girder Editing dialog.

Questions/Open Issues

1. If vertical harped grid adjustment is allowed and the increment value is zero, should the design algorithm use the user-input value for offset?

2. For debond design, the algorithm defines “Mid-Zone” of girder to be region between “maximum debond length”. However, max debond length is not an input parameter to PGSuper – It probably should be? Do we need a max debond length? What about the length between debond zones – is 3’ a fixed rule?

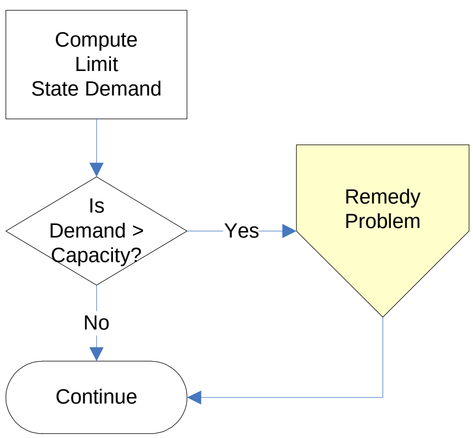
Description of the Appendices

The design algorithm flowcharts are in the following Appendices:

Appendix A – Main Flexural Design Flowcharts
Appendix B –Harped Strand Remedy Strategy
Appendix C – Debond Strand Remedy Strategy
Appendix D – Glossary of Terms

How to Read the Flow Charts

Right now, you might be asking yourself – why three groups of flowcharts for one design algorithm? For brevity, the flow chart was broken into two logical sections: 1) the logic that determines the primary constraints and limit states for the design, and 2) the strategies that remedy those limit states for a particular type of girder. The following flowchart gives a rough outline of this approach:



Note that the yellow off-page reference references the method that represents the **strategy** to remedy the problem for a particular girder type.

To read the flowcharts; pair Appendix A with B or C depending on the type of girder to be designed. For example, when you want to read the flow charts for Harped design; Read Appendix A and follow its references (yellow symbols) into Appendix B.

Appendix A – Main Flexural Design Flowcharts

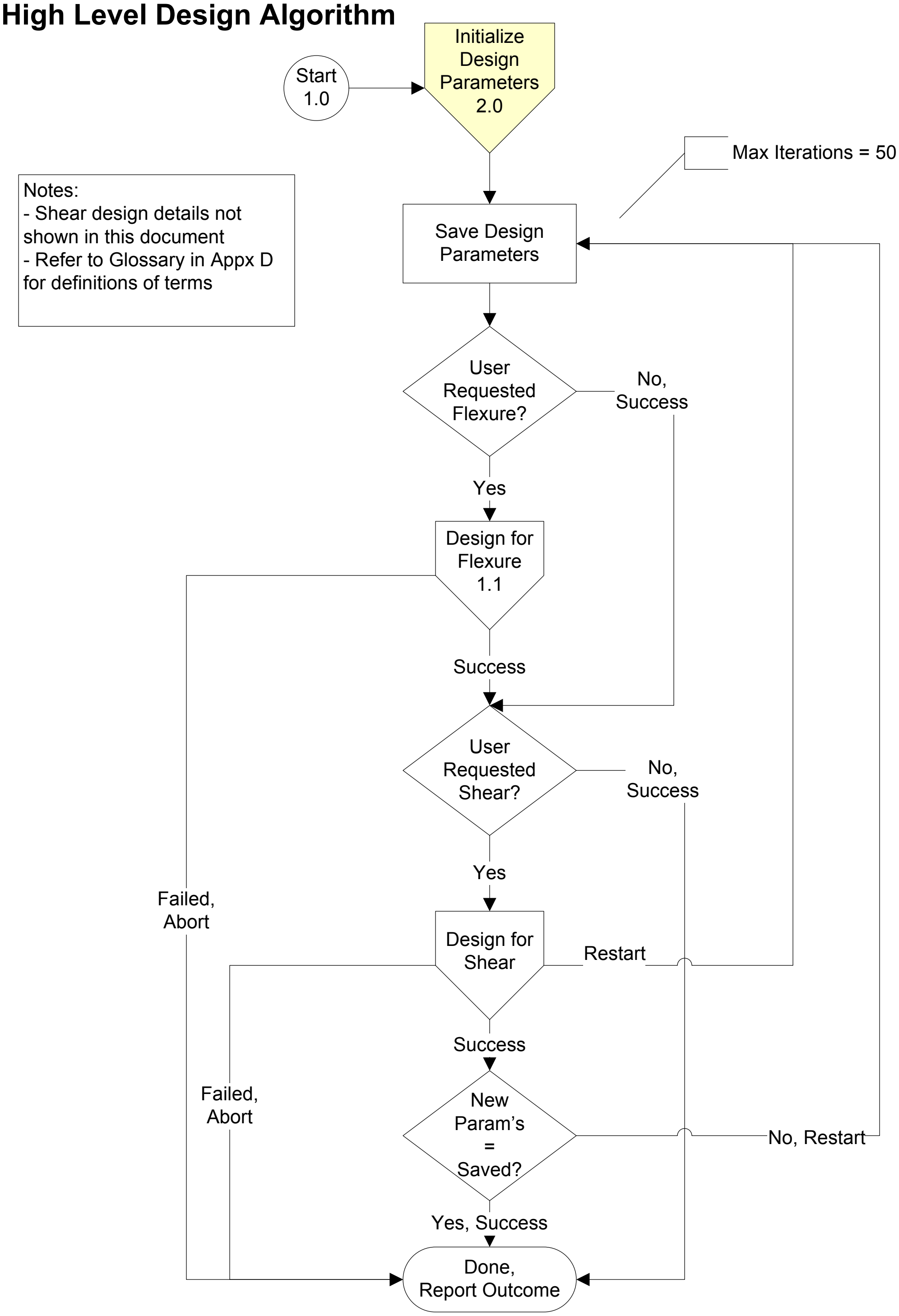
Appendix B –Harped Strand Remedy Strategy

Appendix C – Debond Strand Remedy Strategy

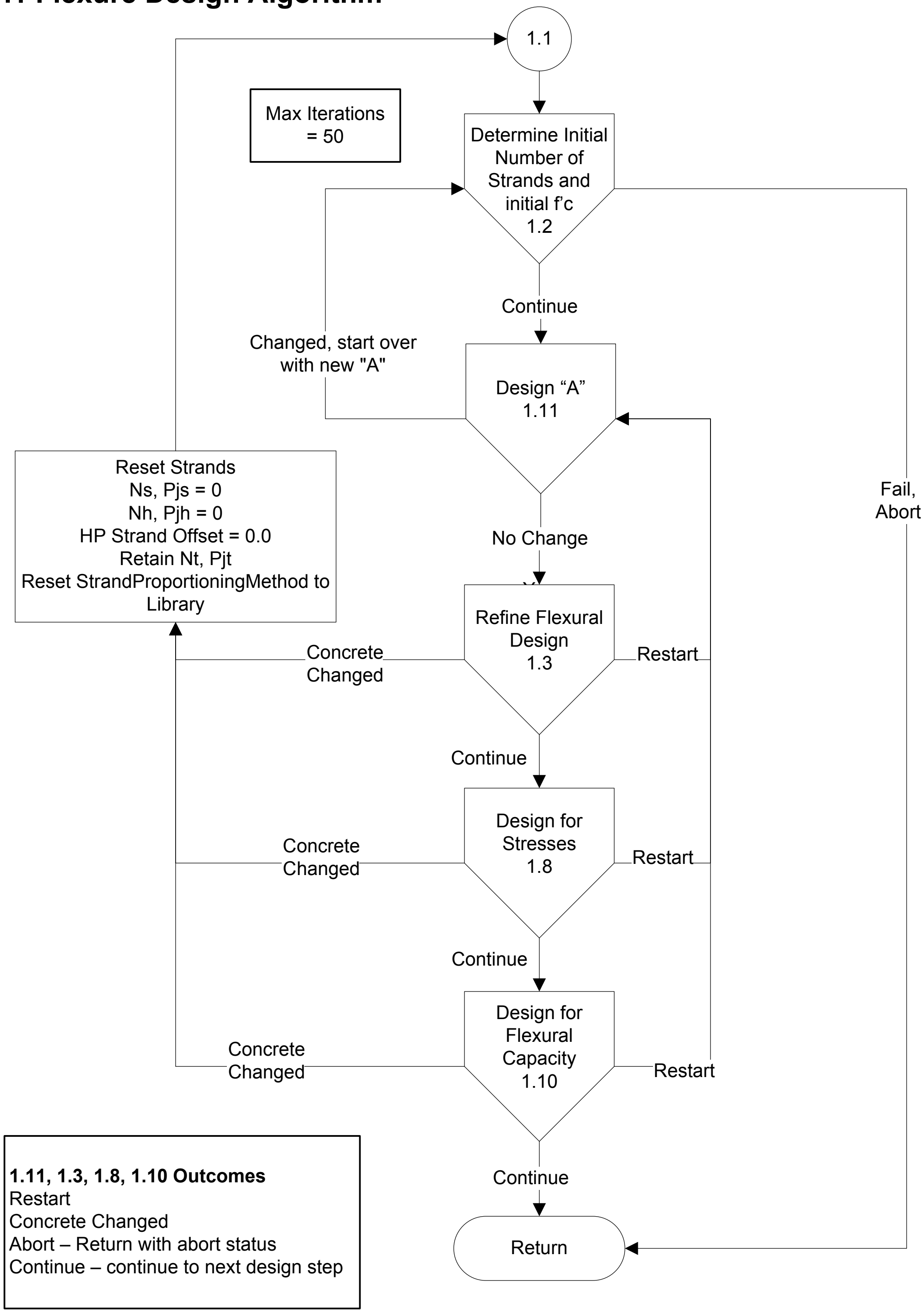
TBD

Appendix E – Glossary Of Terms

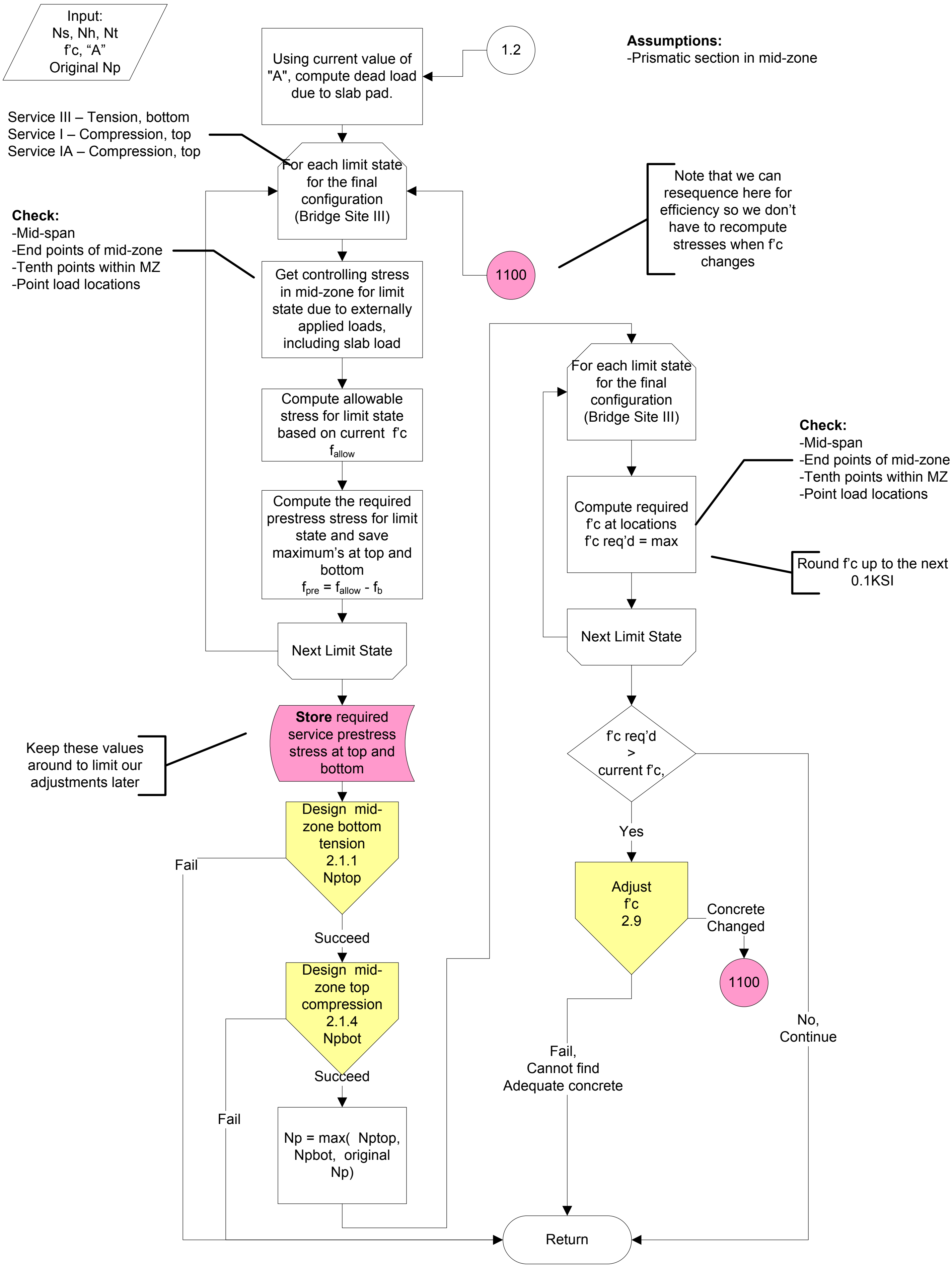
1.0 High Level Design Algorithm



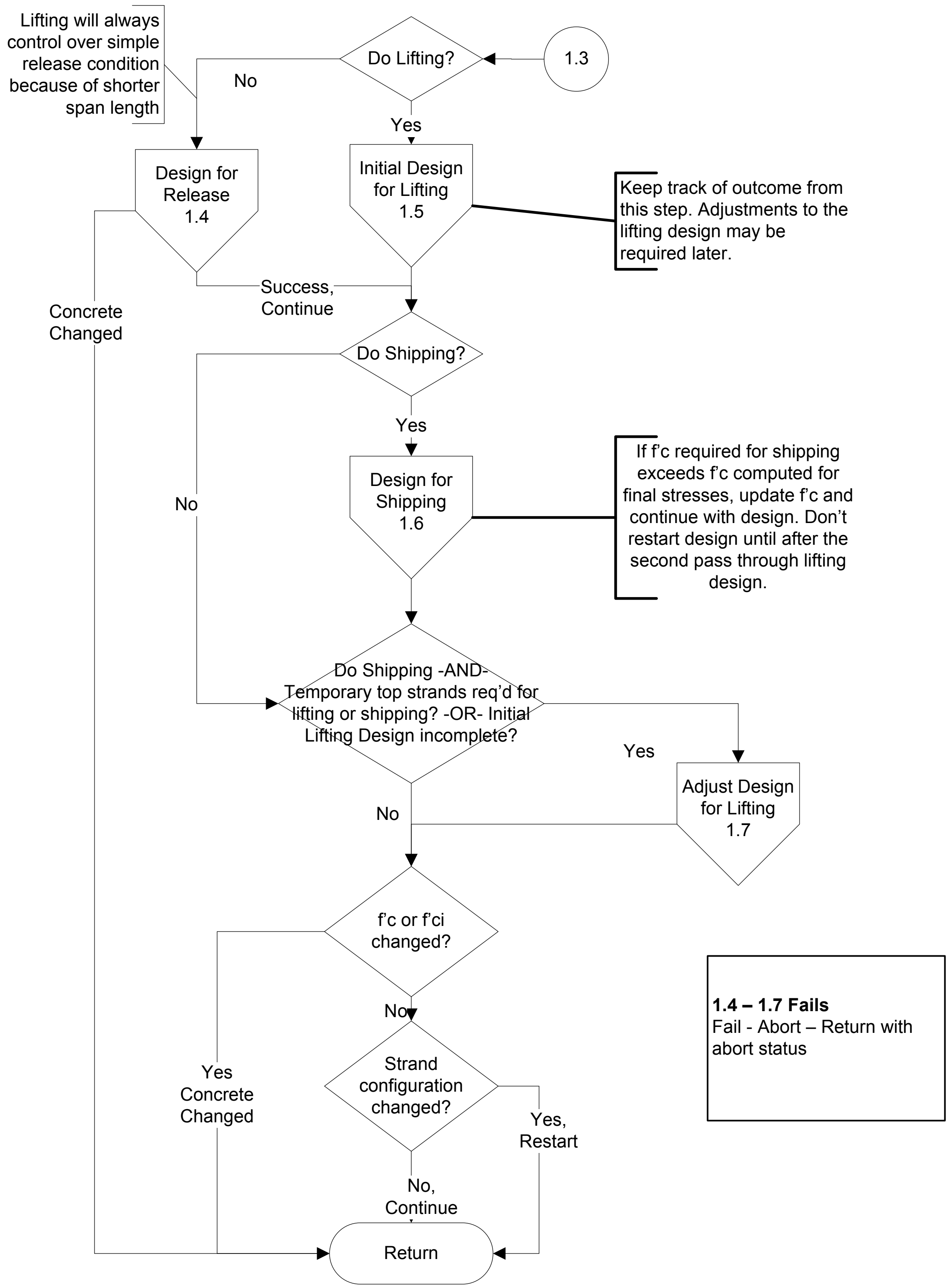
1.1 Flexure Design Algorithm



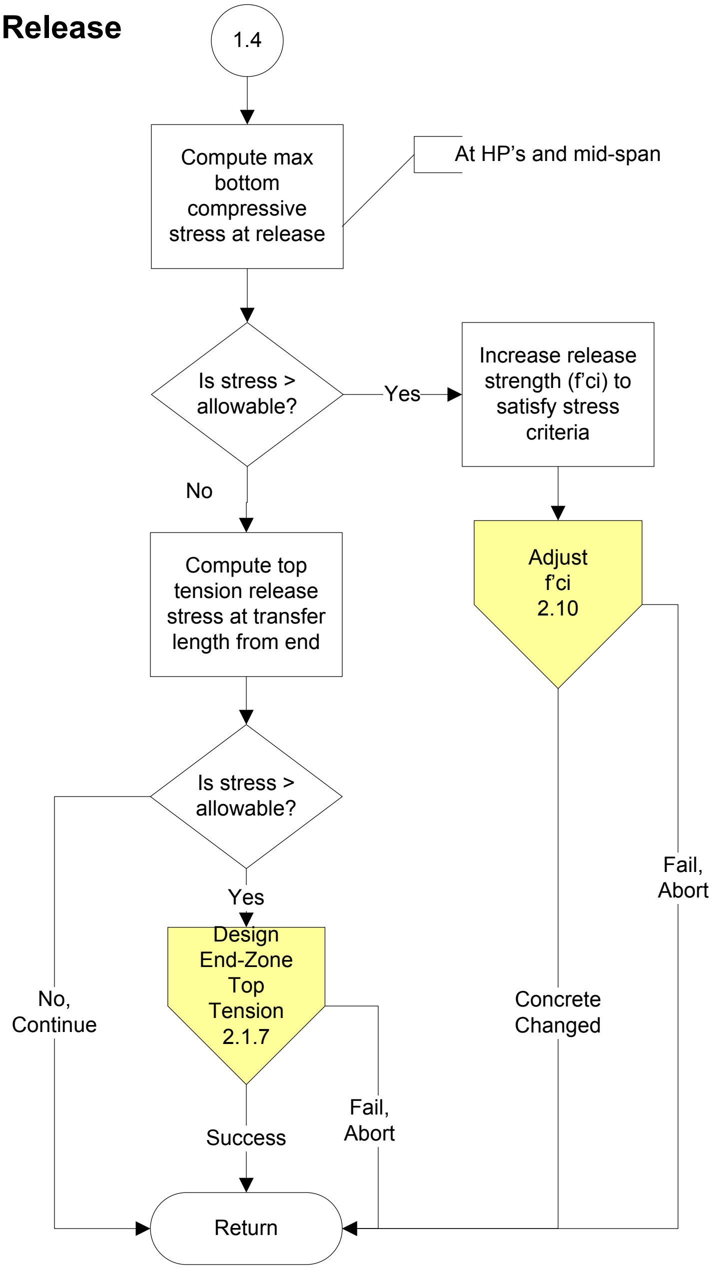
1.2 Determine Initial Number Of Strands and initial f'c



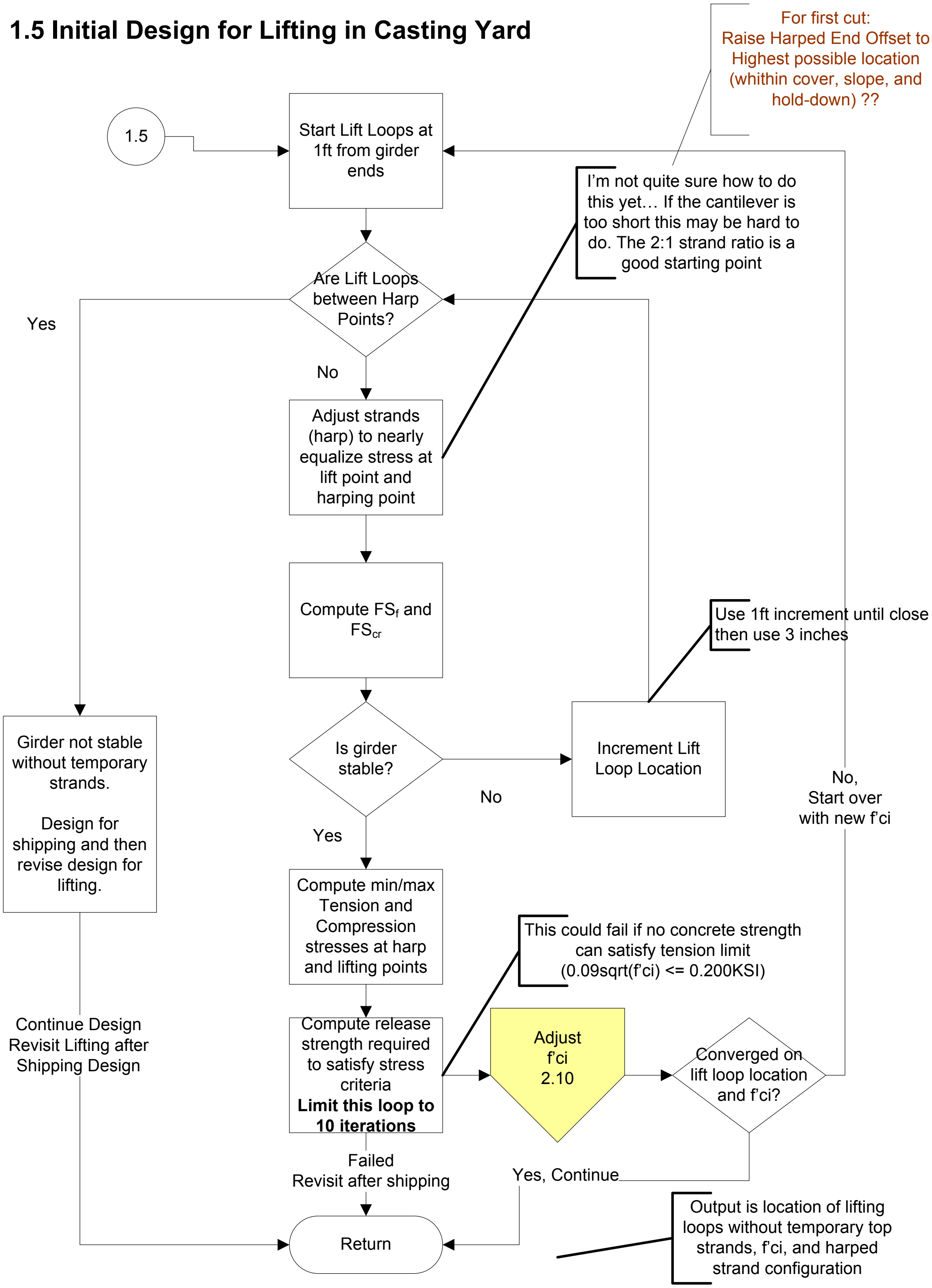
1.3 Refine Flexural Design



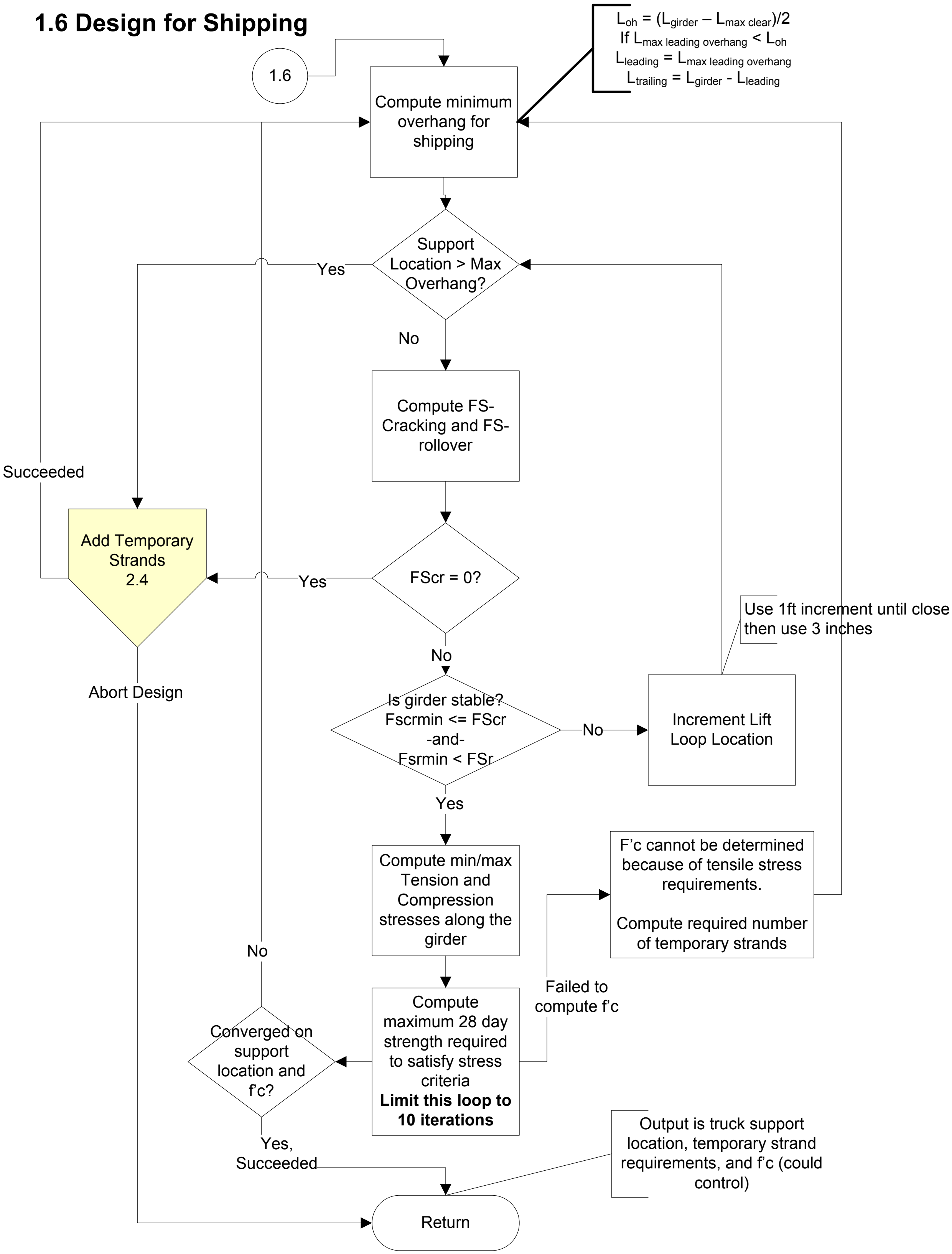
1.4 Design For Release



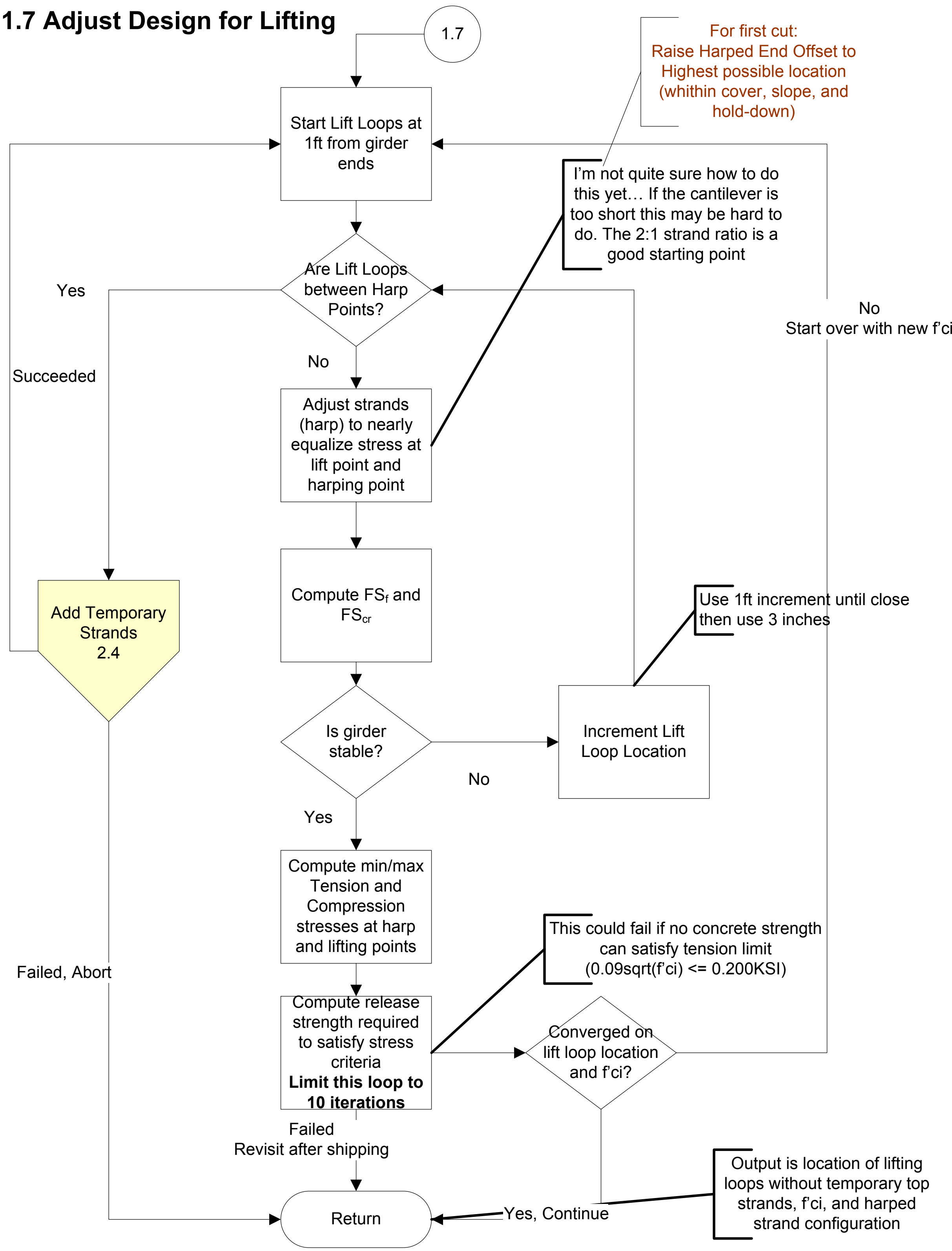
1.5 Initial Design for Lifting in Casting Yard



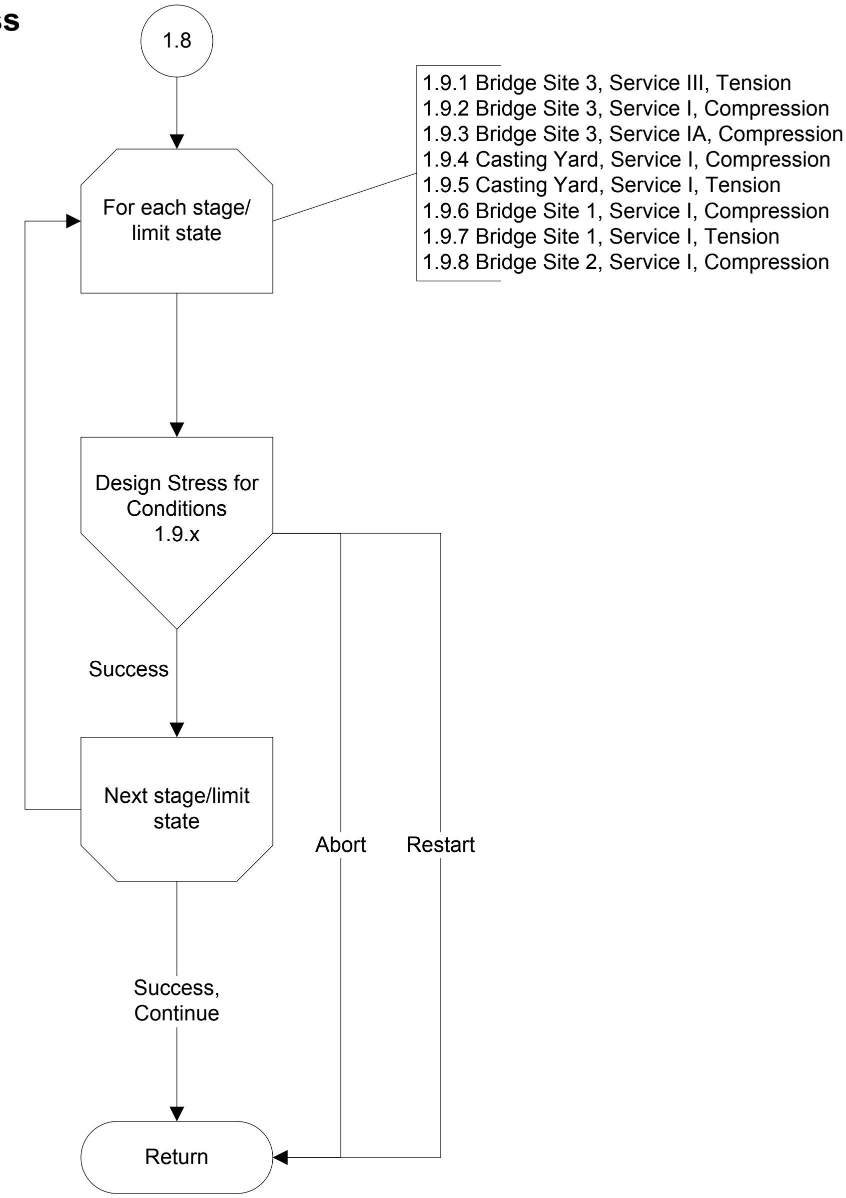
1.6 Design for Shipping



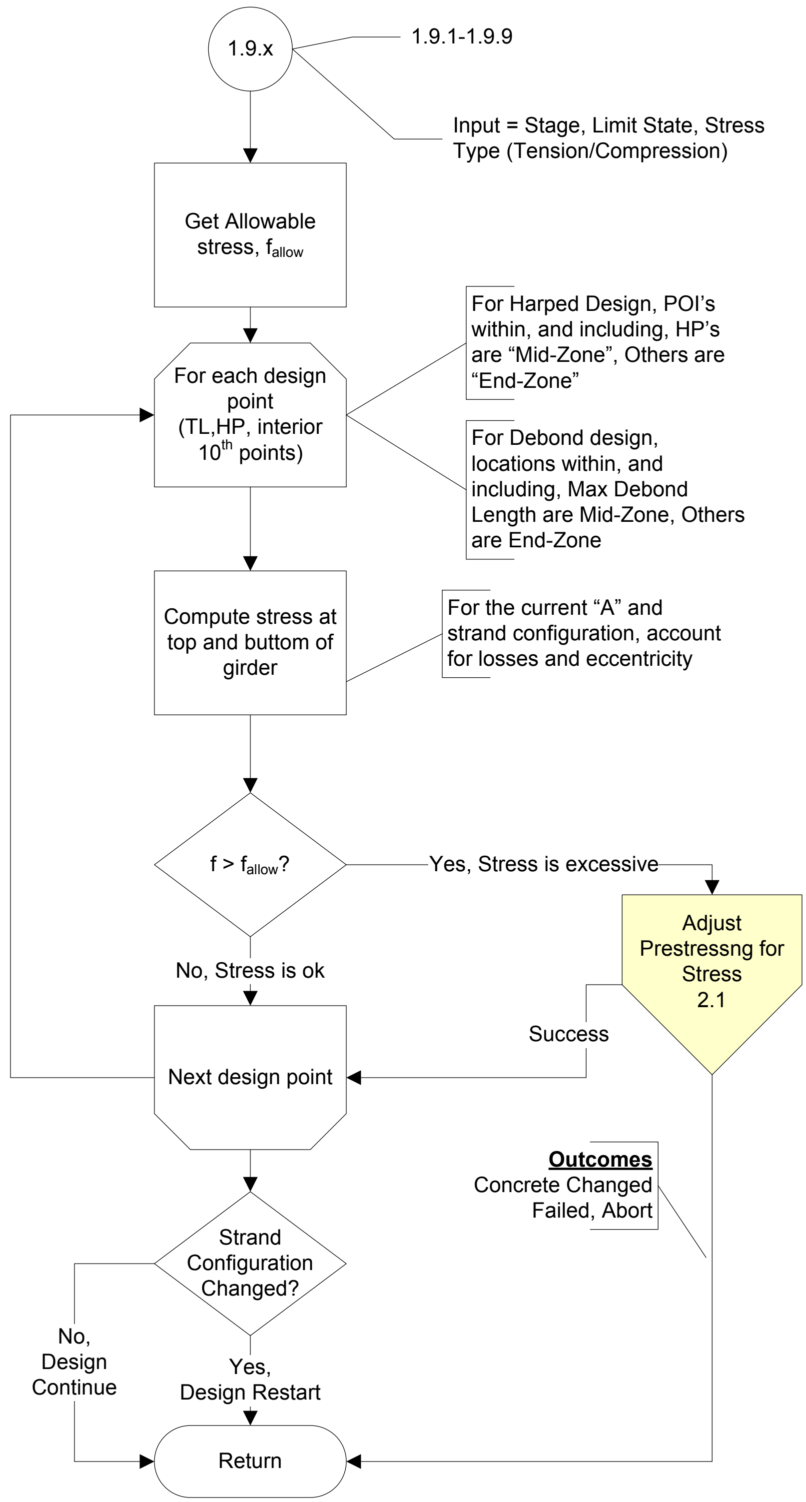
1.7 Adjust Design for Lifting



1.8 Design for Stress

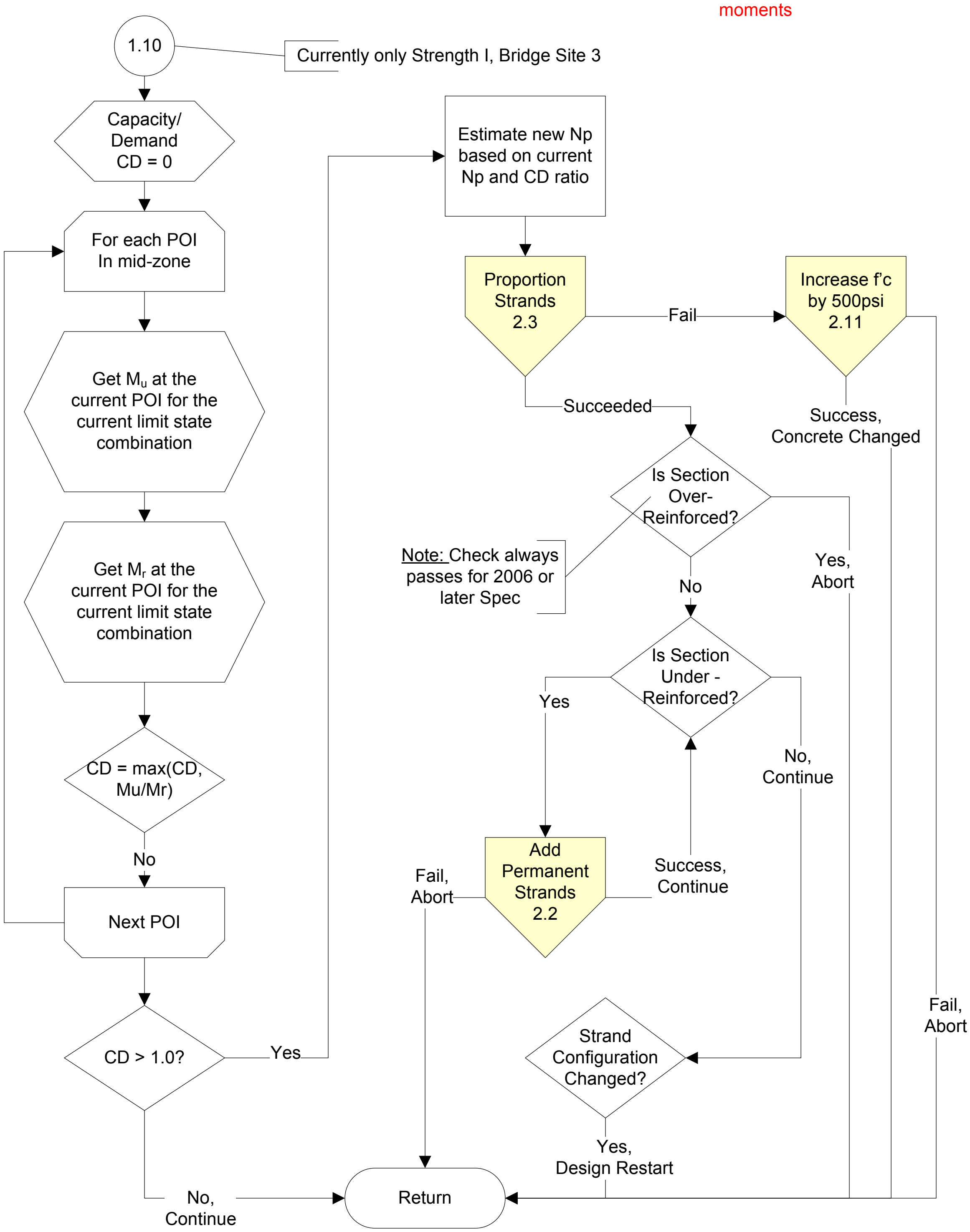


1.9 Design Stress For Condition

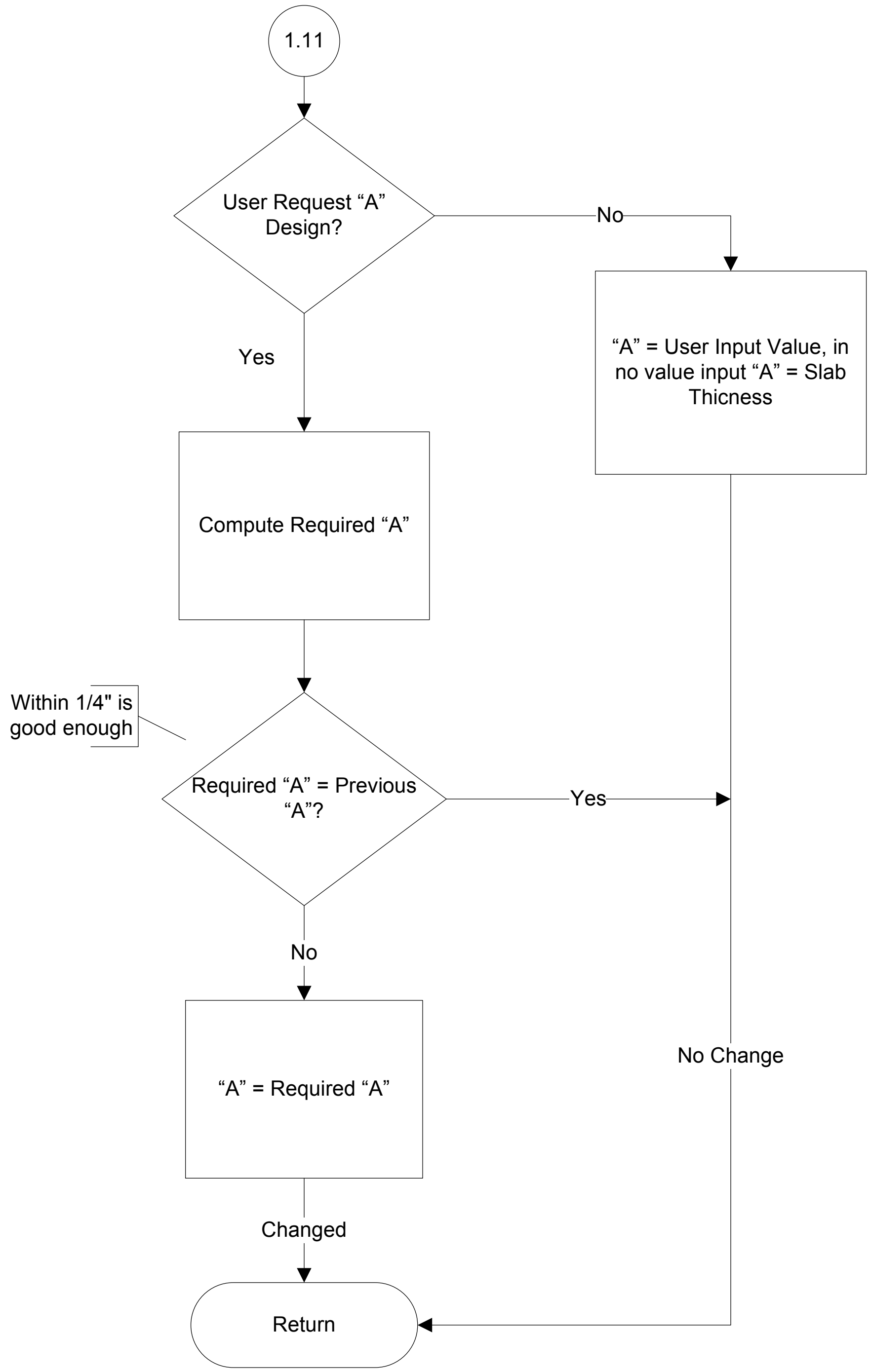


1.10 Design for Flexural Capacity

Assumes we are only designing for positive moments



1.11 Design “A”



1.11
User Request “A” Design?
No
“A” = User Input Value, in no value input “A” = Slab Thicness
Yes
Compute Required “A”
Within 1/4" is good enough
Required “A” = Previous “A”?
Yes
No
“A” = Required “A”
No Change
Changed
Return

Appendix D Glossary of Terms

General Terms

Design Parameters – Variables that affect design
f'c – Final concrete strength
f'ci – Concrete strength at release
Strand Offset – Distance harped strand pattern is moved vertically from original library position at HP or End. Up is positive.
Ns – Number of straight strands
Nh = Number of harped strands
Nt = Number of temporary strands
Np = Number of permanent strands (Ns + Nh)
Pjs, Pjh, Pjt, Pjp – Pjack of straight, harped, temp, permanent strands
TL – Length of prestress transfer
HP – Harping point
End-Zone – Portion of girder outside of Mid-Zone
Mid-Zone – Portion of girder between, and including; harping points, or max debond boundaries
StrandProportioningMethod – This value is defined in the Specification Library and represents how straight strands are proportioned relative to harped strands. Two methods are possible:

- -LibraryFill – Permanent strands are filled directly using library fill order
- -Straight2HarpedRatio – Strands are filled attempting to maintain an X:1 harped to straight ratio.

Max Debond Length – Furthest distance from end where debond can occur.

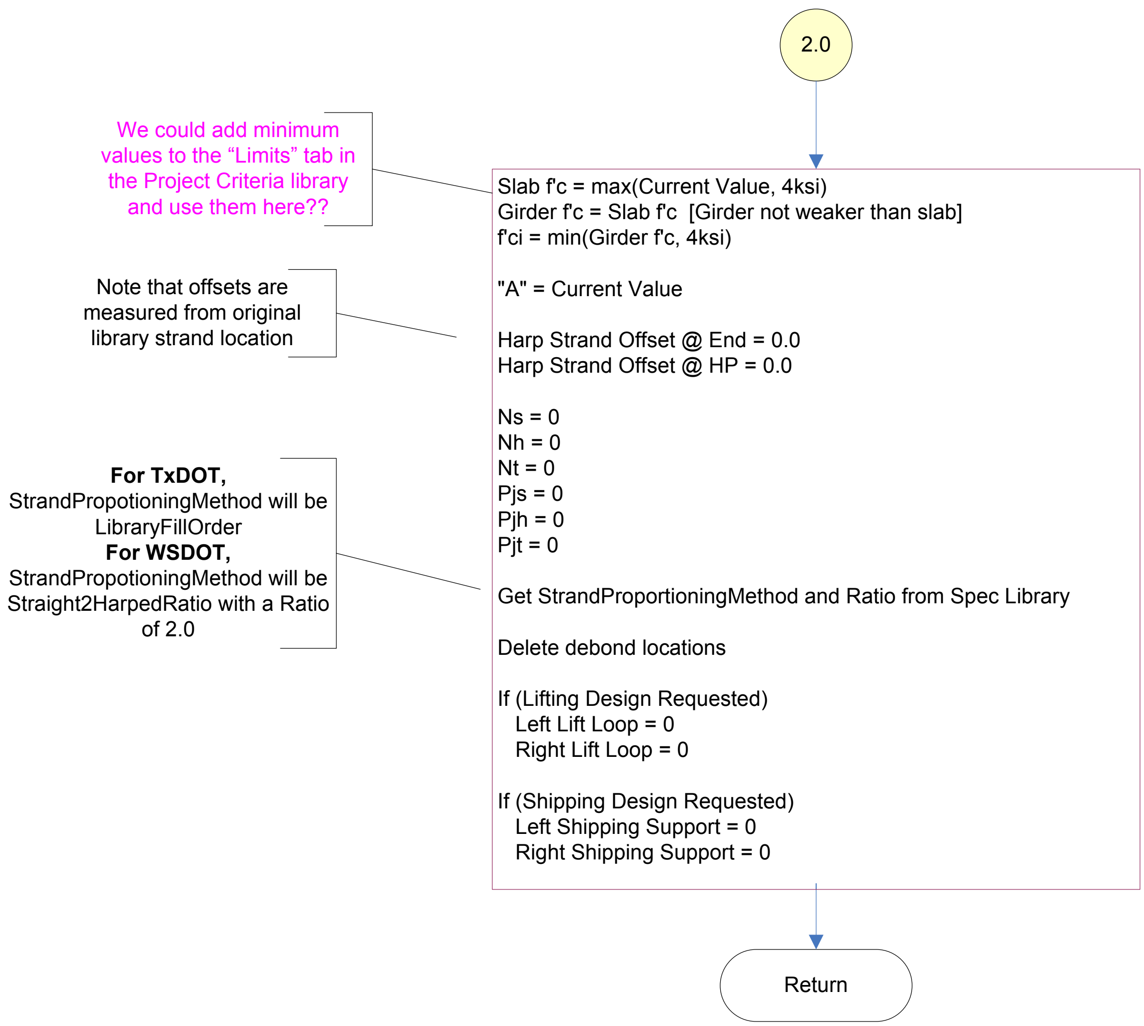
List of Design Parameters

"A" Dimension – Distance from top of slab to top of girder at bearing location
f'c - girder
f'c, - slab
f'ci, - girder initial strength
Harp Strand Offset – Girder Ends
Harp Strand Offset – Harping points
StrandProportioningMethod and Ratio, if req'd
Ns
Nh
Nt
Pjs
Pjh
Pjt
Lifting loop locations
Shipping support locations

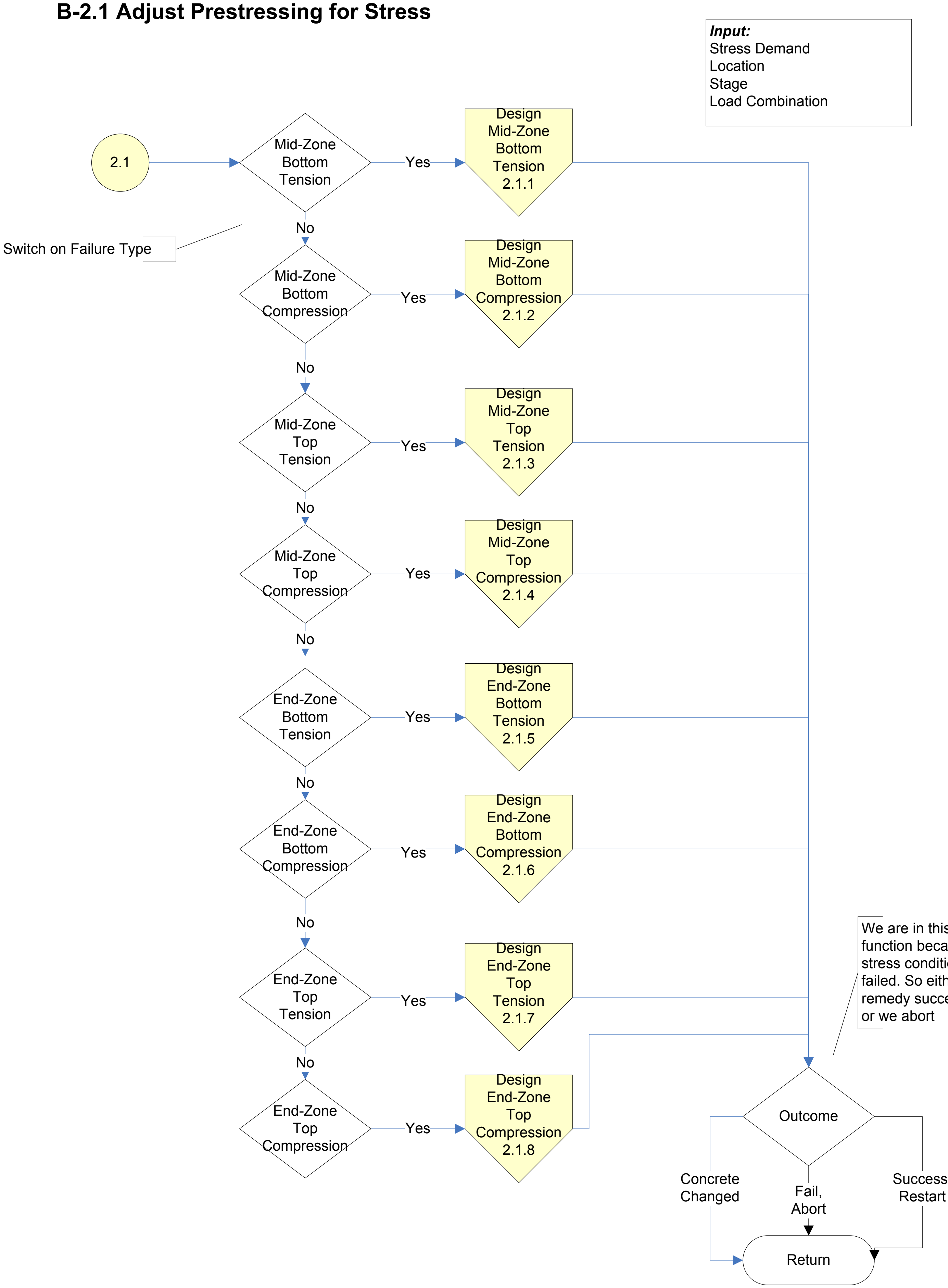
Design outcome return codes

Success – Design succeeded, continue to next limit state
Abort – Design failed, cannot continue
Concrete Changed – Restart design from beginning with new strength
Restart – Design succeeded, but adjustment was made to strands. Keep strand design and recheck all criteria.

B-2.0 Initialize Design Parameters

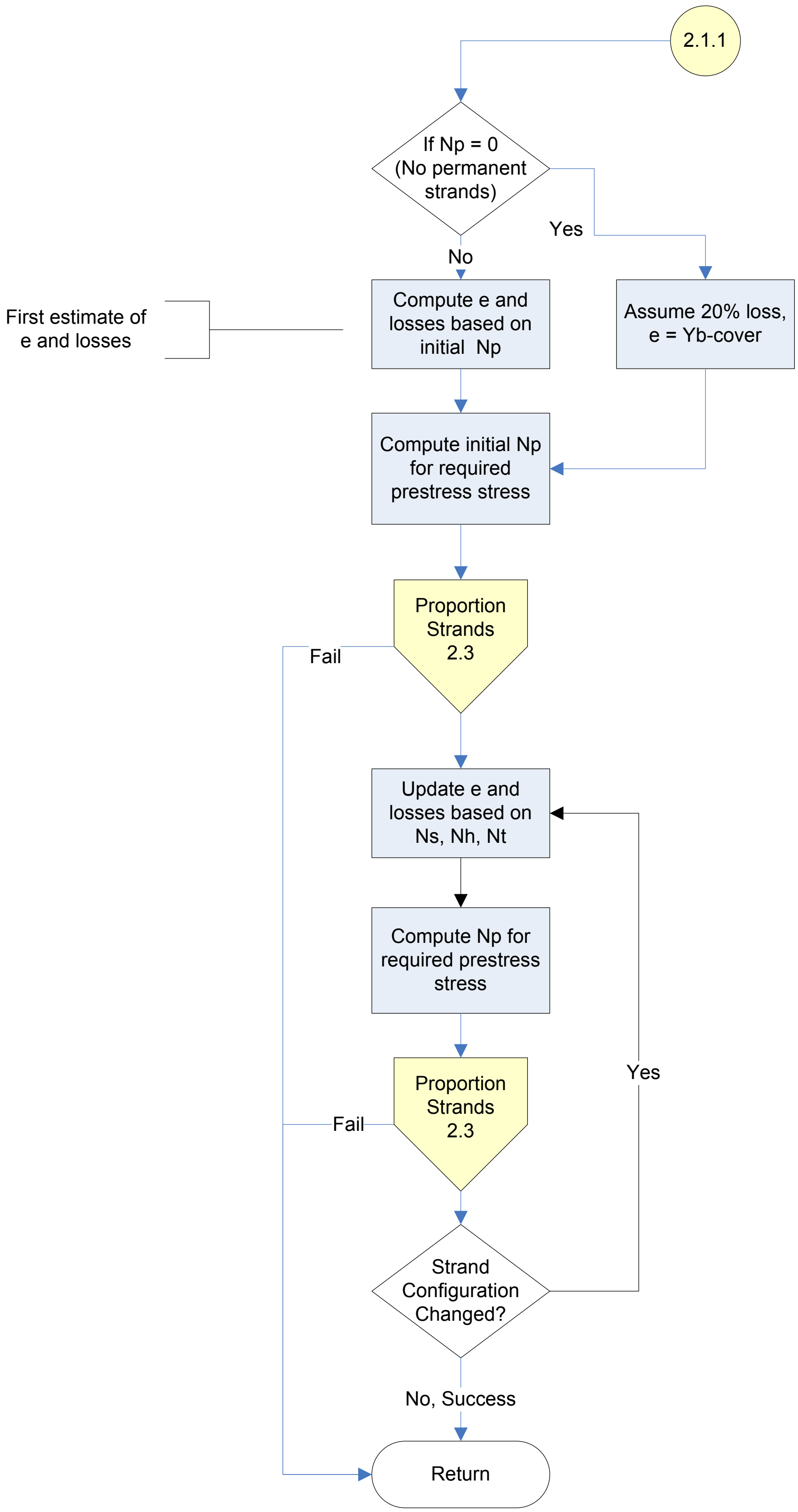


B-2.1 Adjust Prestressing for Stress

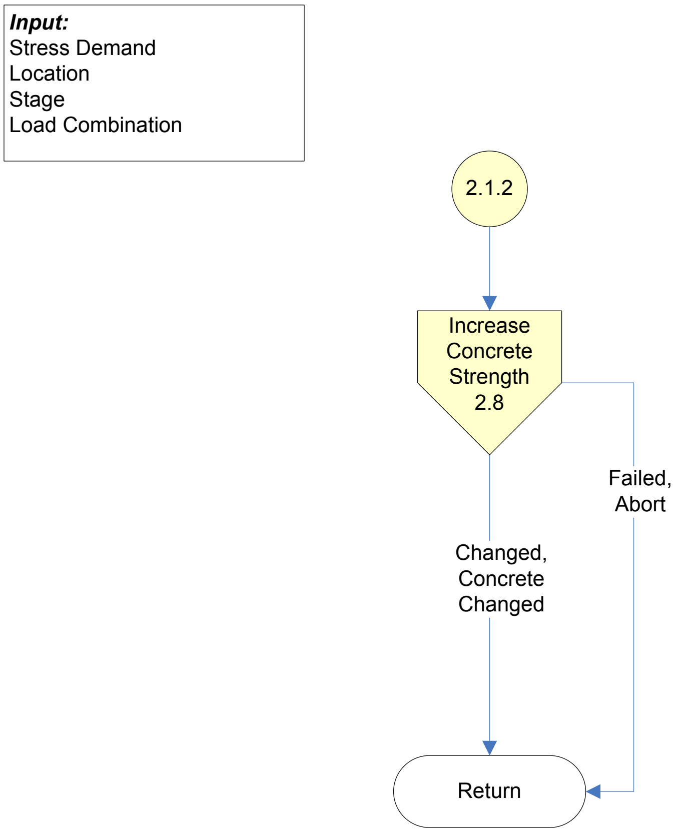


B-2.1.1 Design for Mid-Zone Bottom Tension

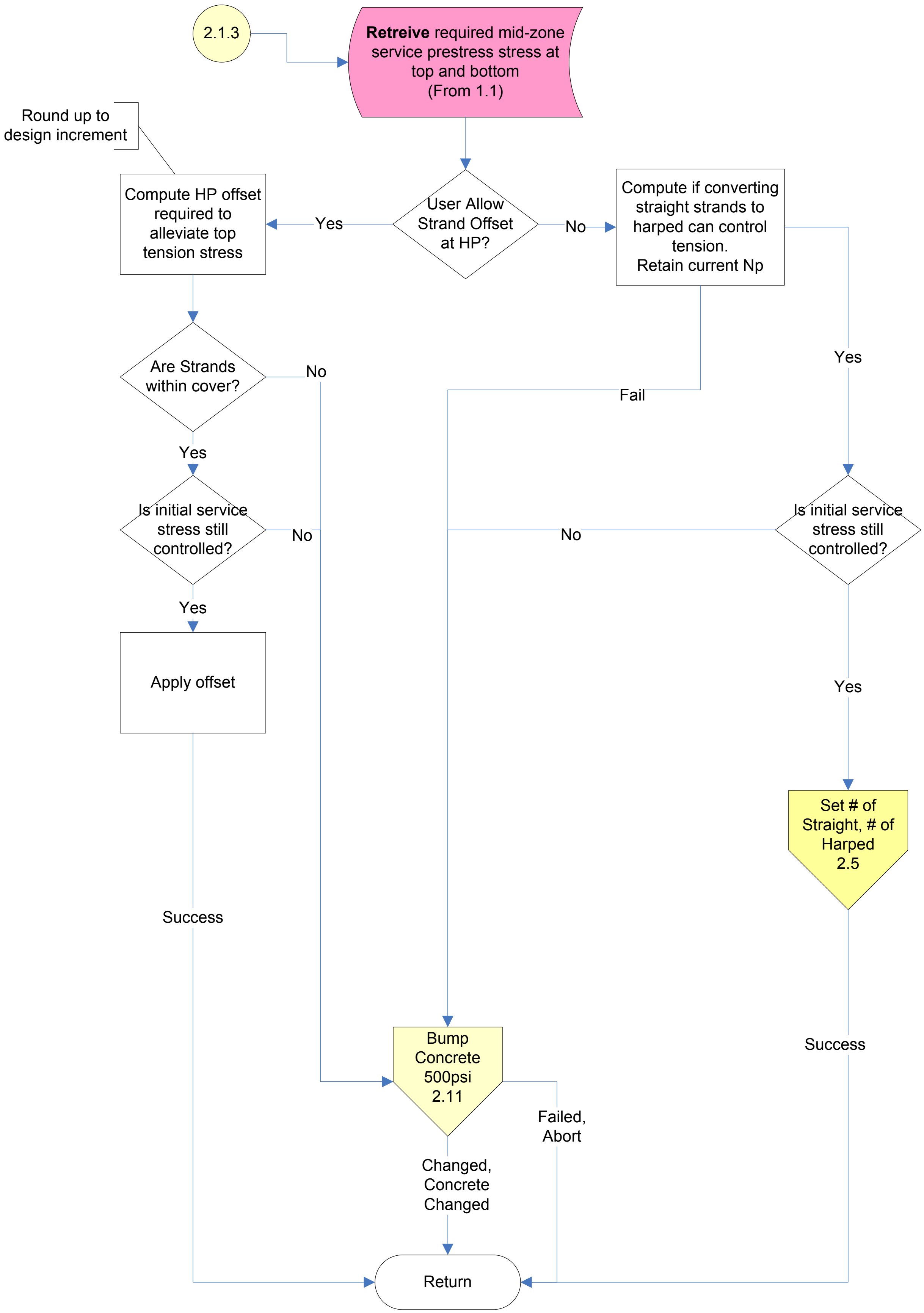
Prerequisites:
Np = current number of permanent strands
f_{reqd} = Stress to be remedied by strands



B-2.1.2 Design for Mid-Zone Bottom Compression

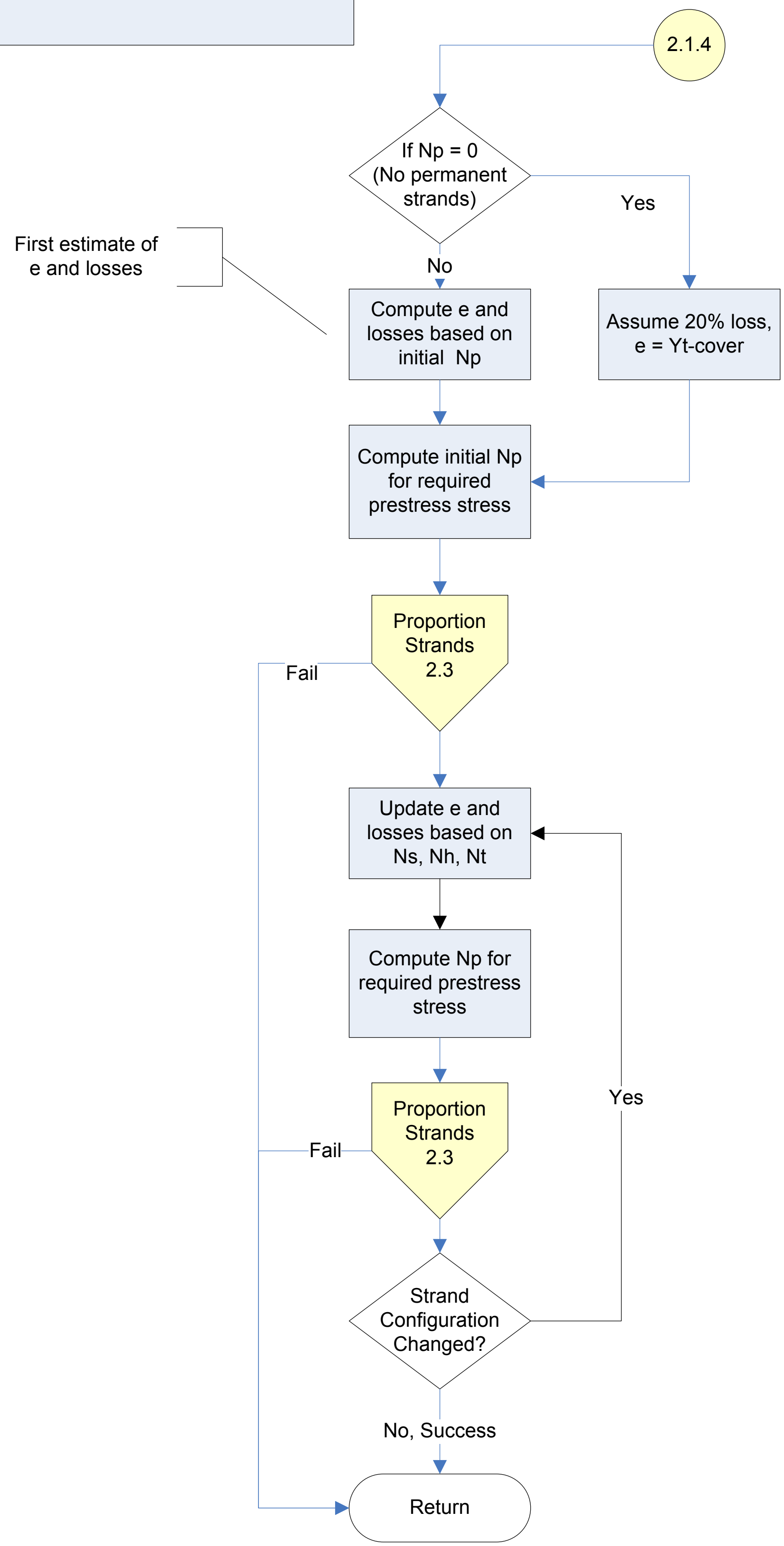


B-2.1.3 Design for Mid-Zone Top Tension



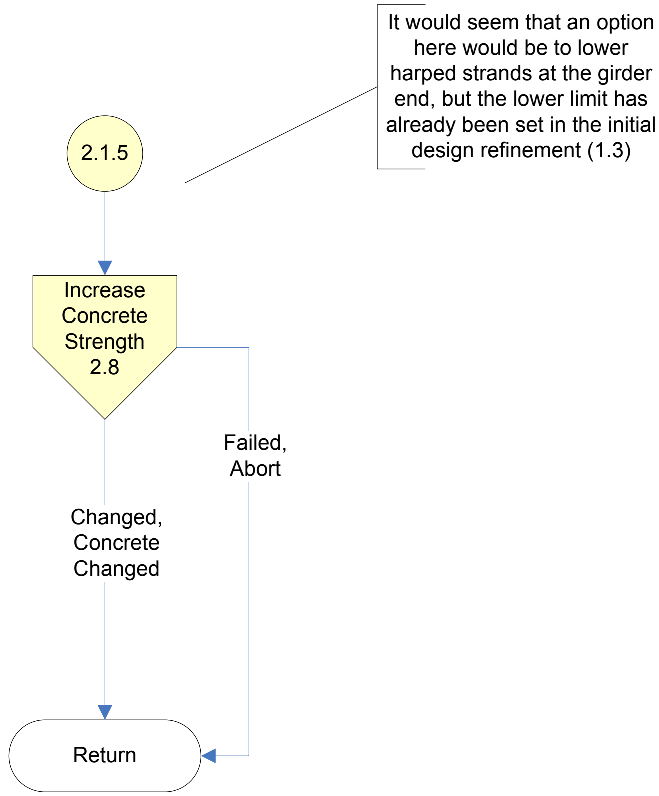
B-2.1.4 Design for Mid-Zone Top Compression

Prerequisites:
Np = current number of permant strands
f_{reqd} = Stress to be remedied by strands
As – Area of one strand
fpj – jacking stress

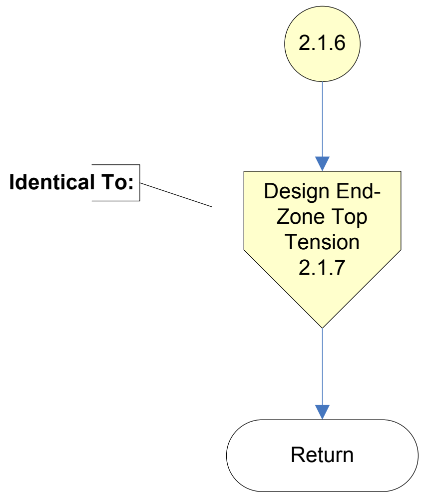


B-2.1.5 Design for End-Zone Bottom Tension

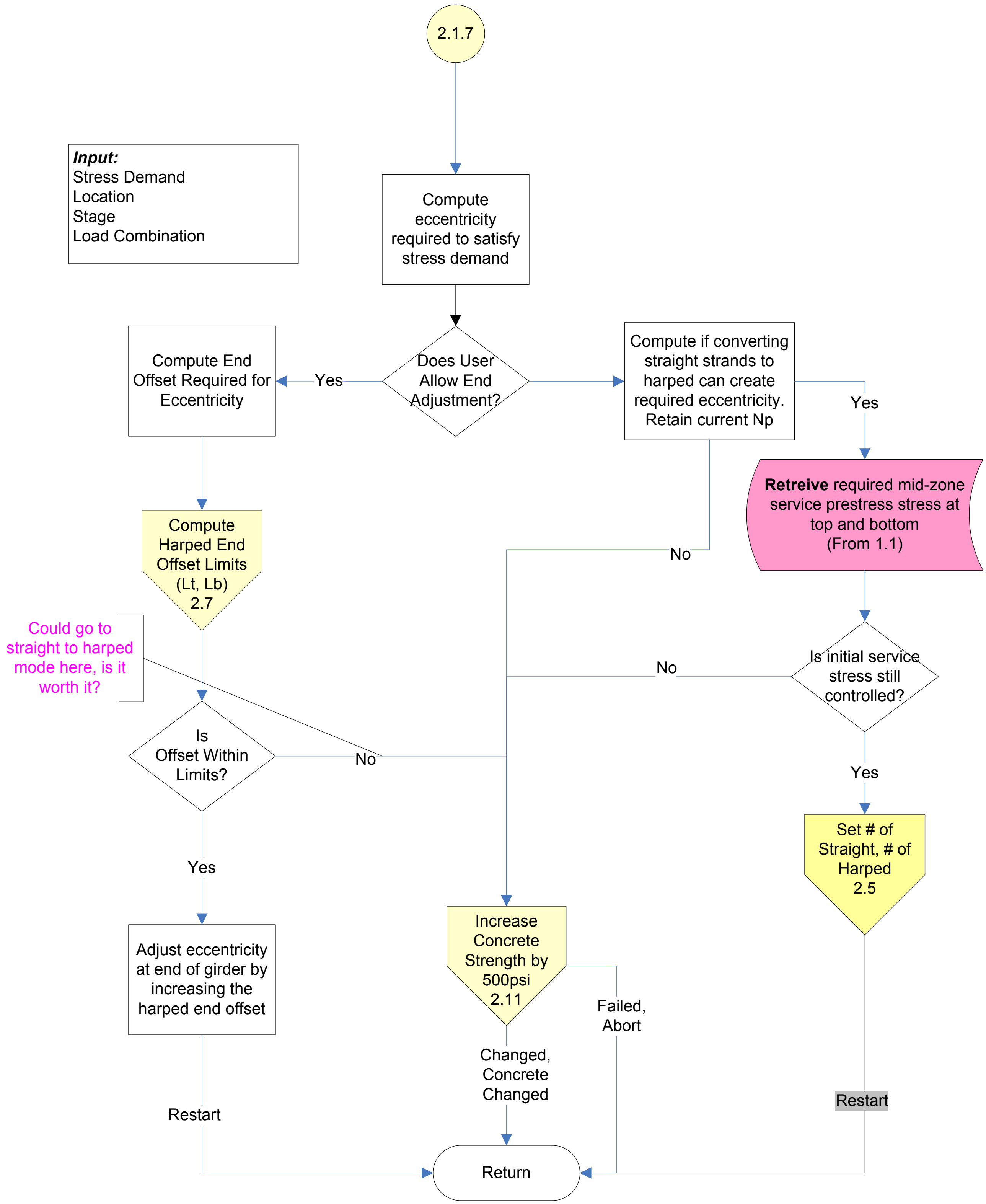
Input:
Stress Demand
Location
Stage
Load Combination



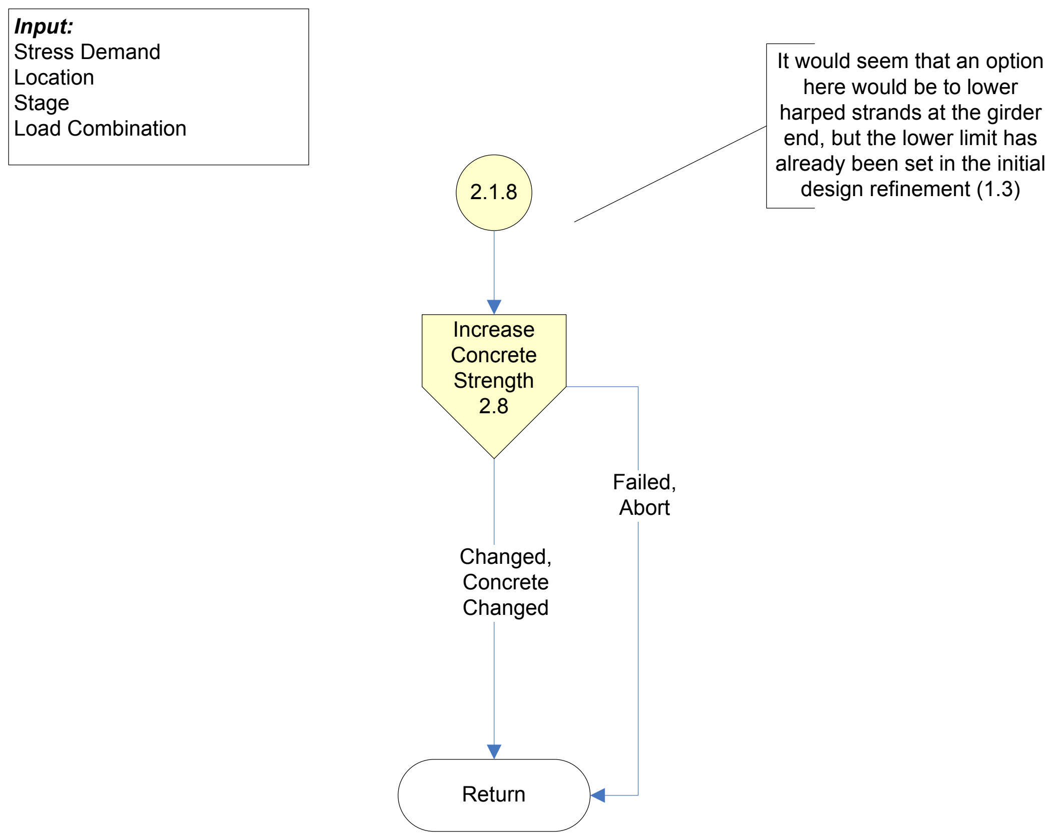
B-2.1.6 Design for End-Zone Bottom Compression



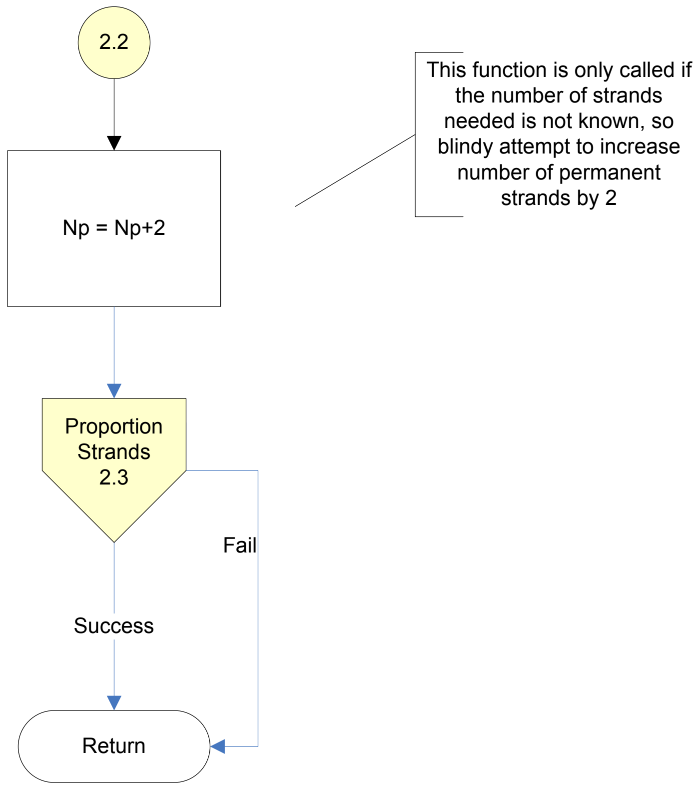
B-2.1.7 Design for End-Zone Top Tension



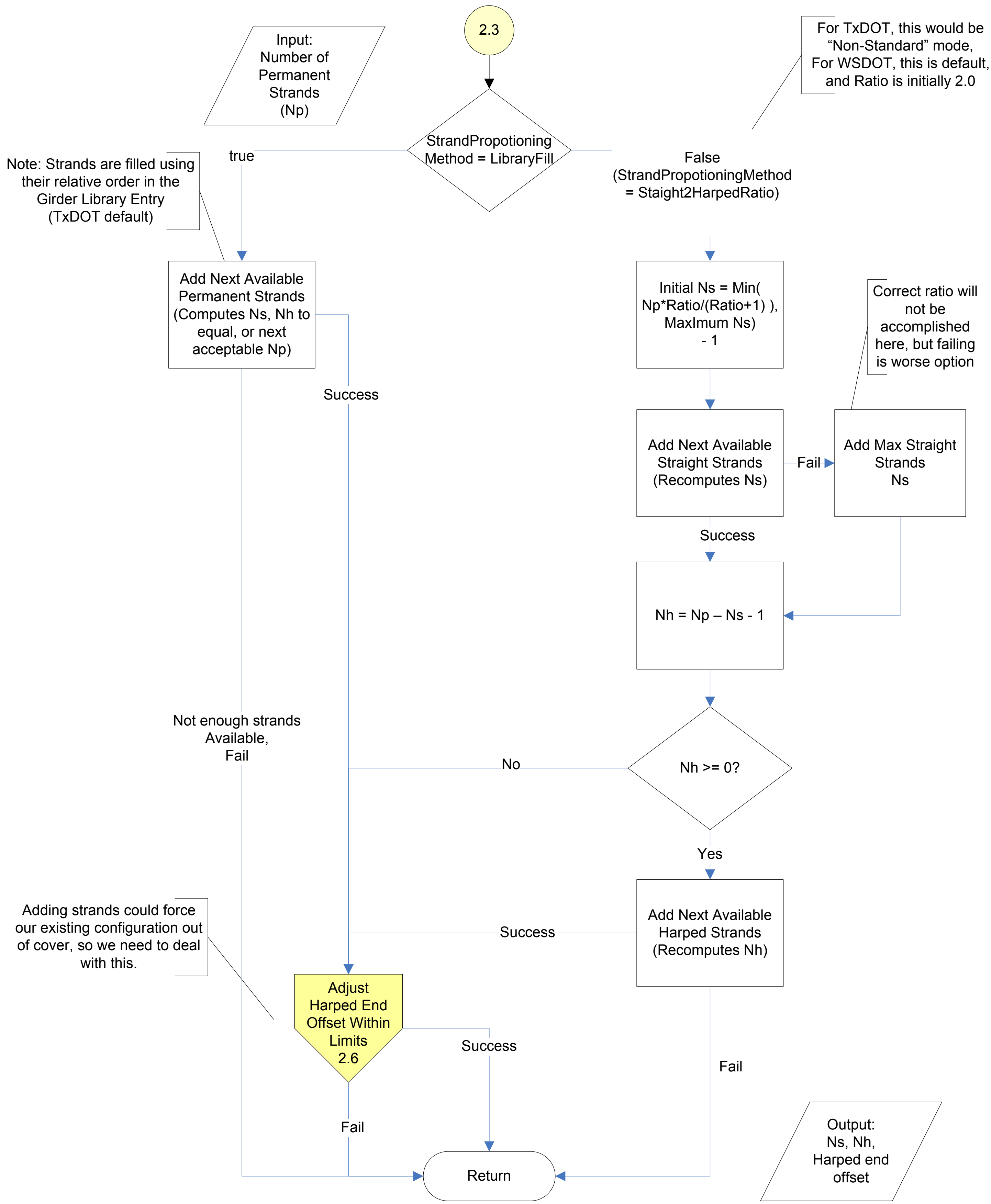
B-2.1.8 Design for End-Zone Top Compression



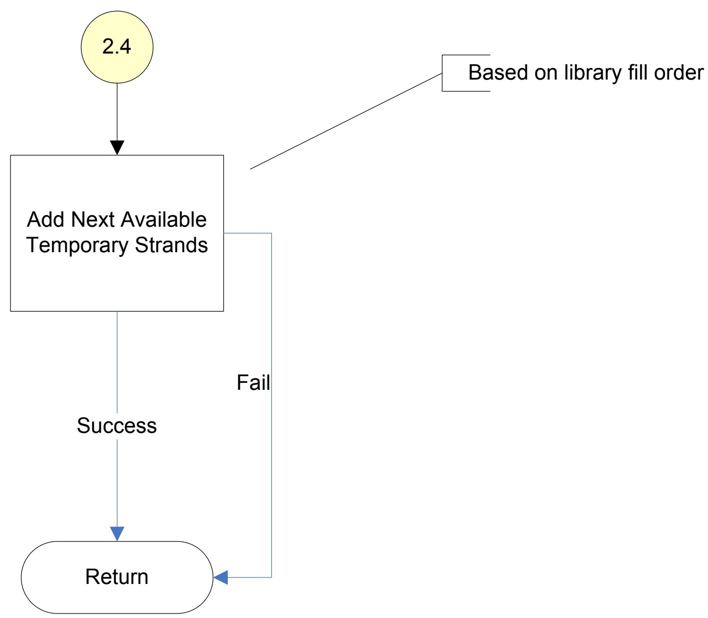
B-2.2 Add Permanent Strands to Girder



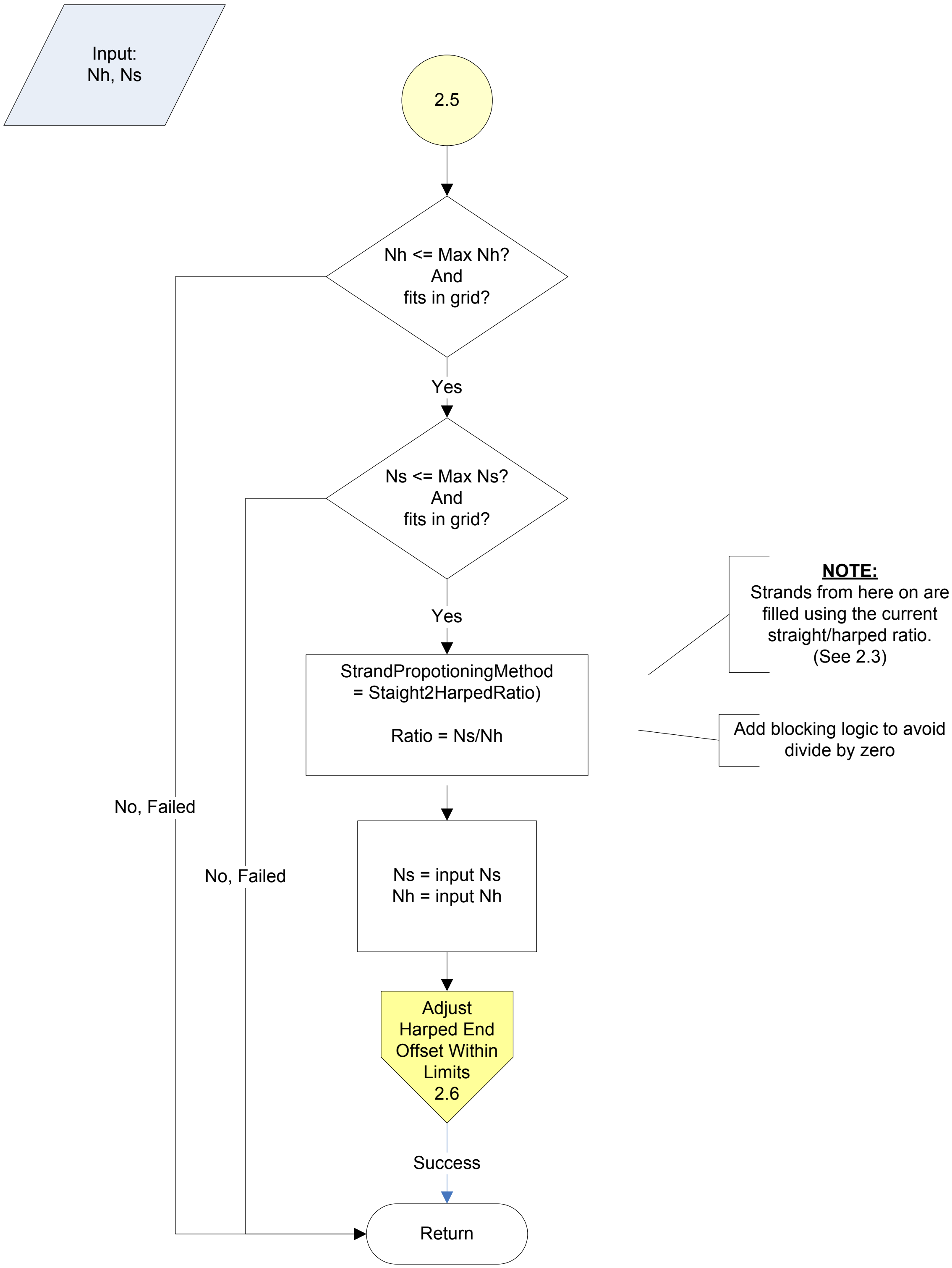
B-2.3 Proportion Strands



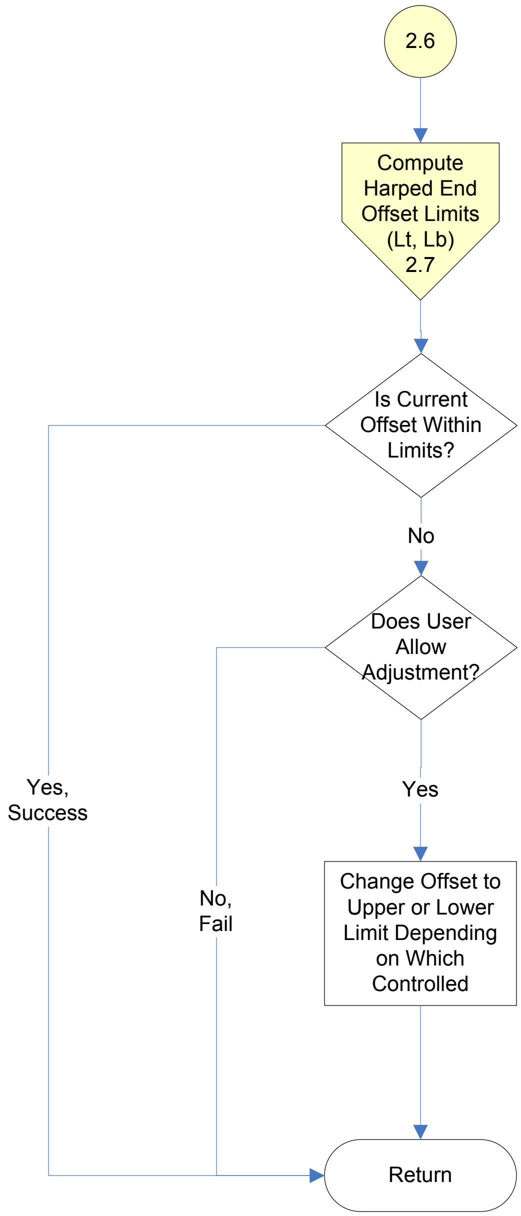
B-2.4 Add Temporary Strands to Girder



B-2.5 Set Number of Harped and Number of Straight Strands

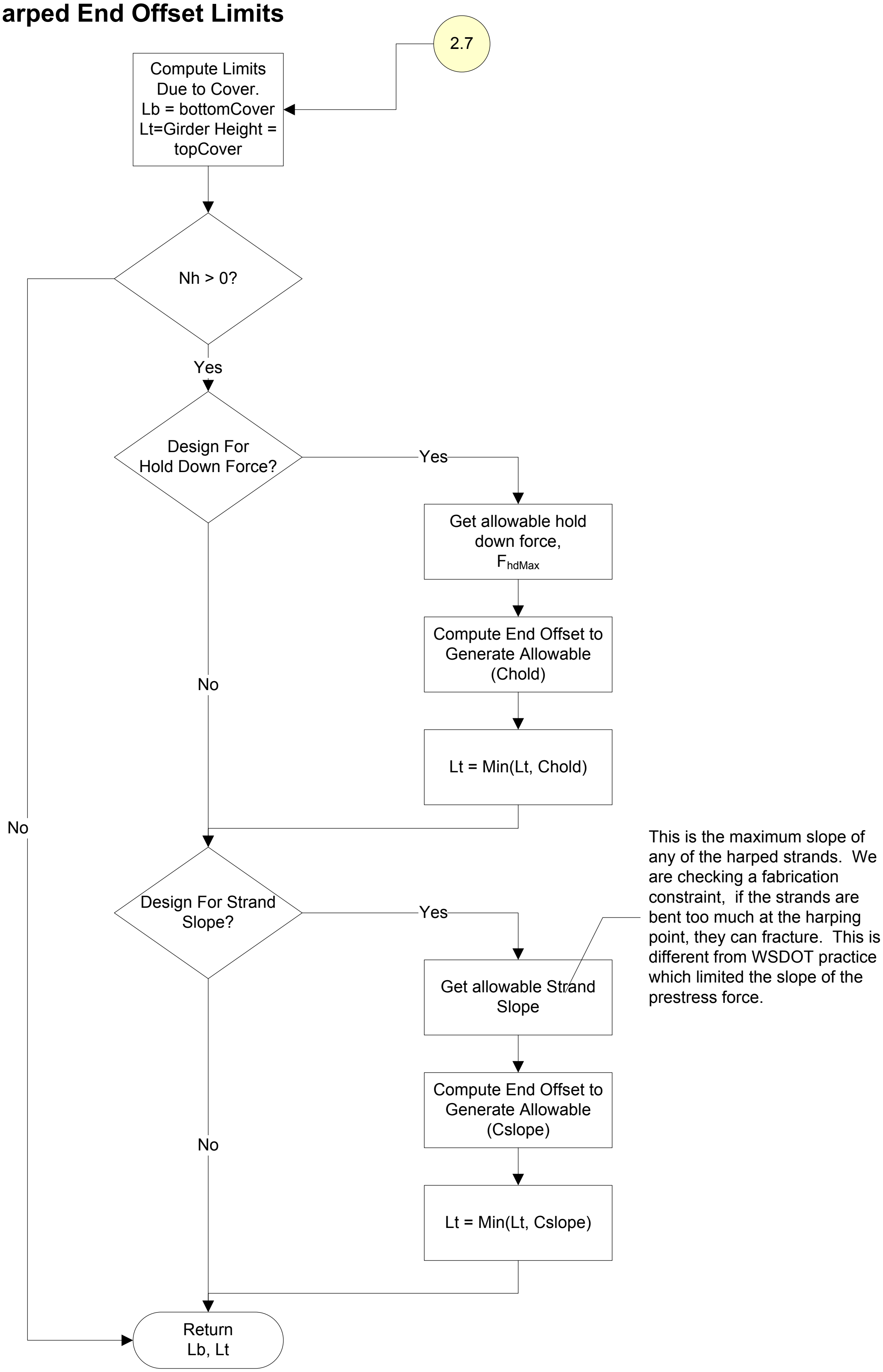


B-2.6 Adjust Harped End Offset Within Limits



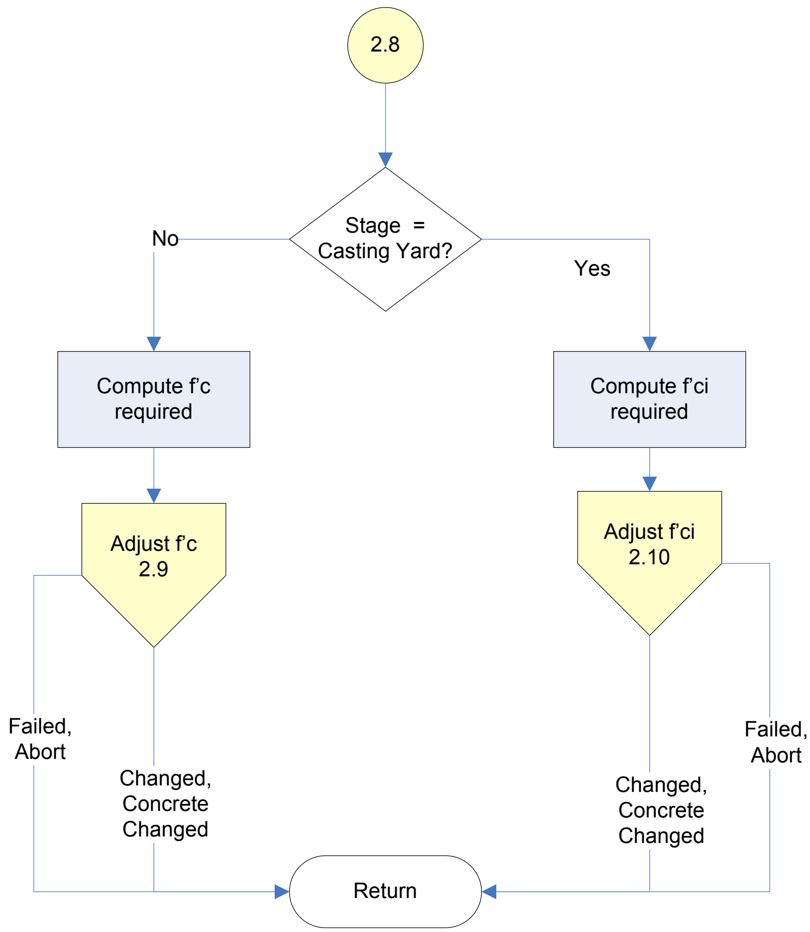
Assumes that harping is symmetric, so we don't need to compute at both ends

B-2.7 Compute Harped End Offset Limits

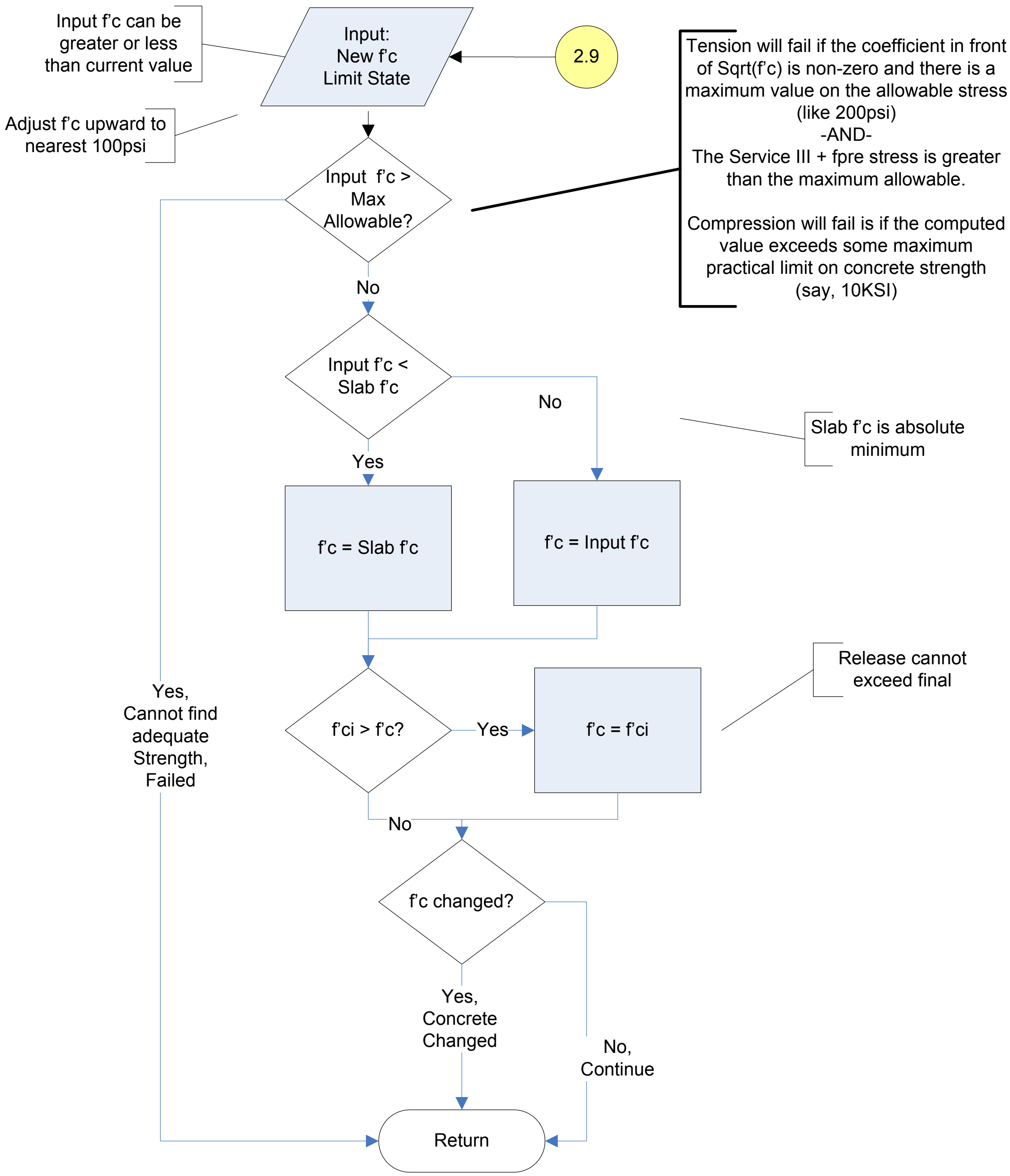


B-2.8 Increase Concrete Strength

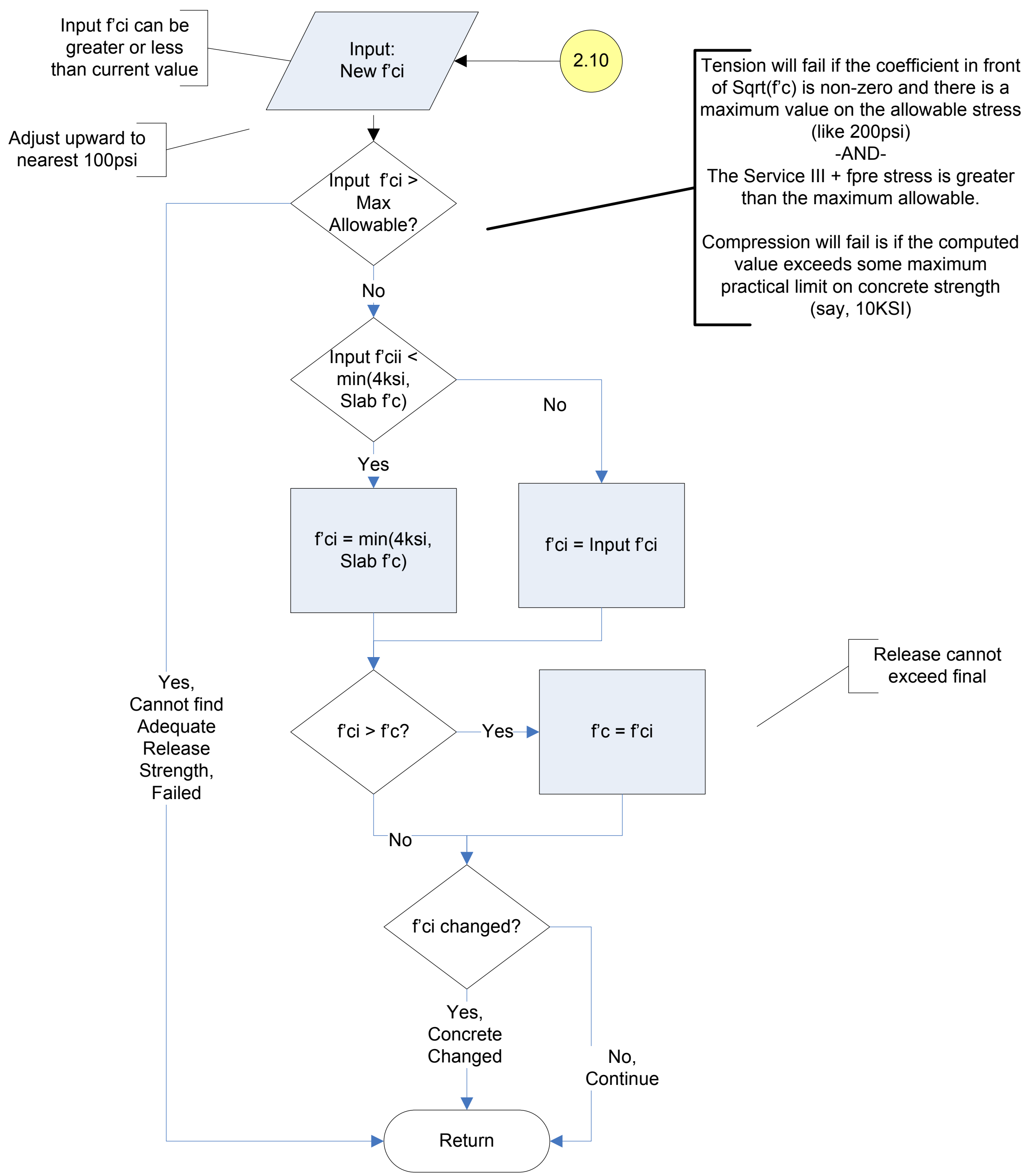
Input:
Stress Demand (tension or compression)
Stage
Load Combination



B-2.9 Adjust Girder Final Strength, f'c



B-2.10 Adjust Girder Release Strength, f'ci



B-2.11 Bump 500 – Increase Concrete Strength By 500 psi