Arch 314 – Structures I

Bridge Project

2024

Criteria
Preliminary Report
Testing
Final Report

Examples
Dr. Frame Analysis

Bridge Criteria

(scaled to 1:64)

AASHTO

Lane Load = 640 lbs/ft of lane

2 lanes = 1280 lbs/ft bridge

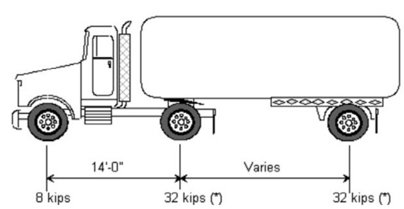
160 x 1280 = 204 800 lbs total

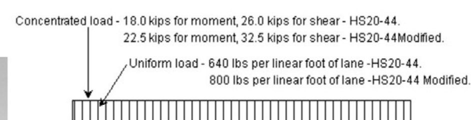
÷ 64^2

scaled load = 50 lbs total

HS20-44 Truck Loading

The HS20-44 truck is defined below as one 8 kip axle load and two 32 kip axle loads spaced as shown.





Design Lane Loading

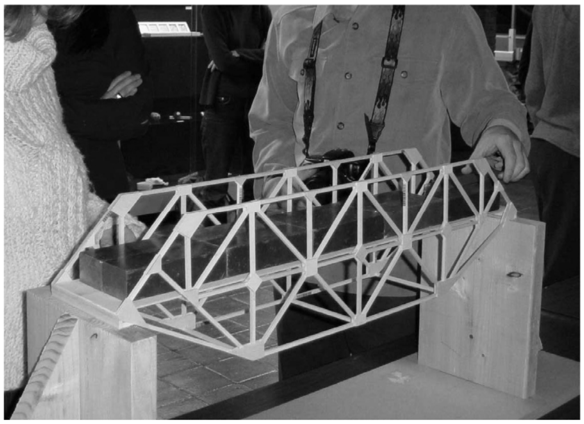
Span=160 ft (scaled = 30 in)
Max. Depth = 53 ft (10 in)
Max. Deck = 8 in (1/8 in thick)

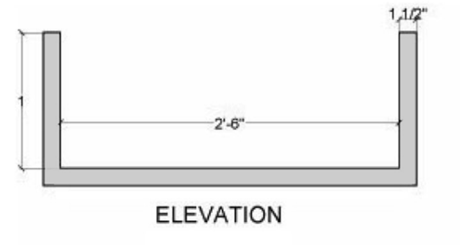
Max Weight = 68k (4 oz)
Material = wood + glue

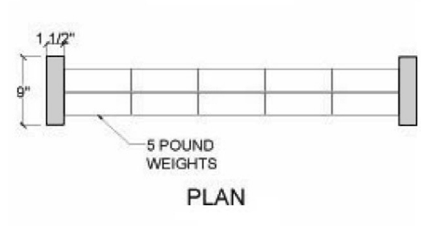
Test Setup

Frame: 30" x 9" x max depth of 10"

Weights: 1.5" x 2" x 5.875"







Requirements

Criteria

- dimensions – 30" span
- loading – 50 lbs min.
- Materials – wood + glue

Efficiency score

- weight limit – 4 oz. (minimize)
- load capacity – 50 lb (maximize)
- (4/weight)x50 + (load/50)x9

Submission

- preliminary report
- model testing
- final report

Truss Bridge Project

Description
This project gives students the chance to apply concepts learned in truss analysis to the design of a small road bridge. The project also introduces techniques for design and testing of structural models. Work is to be conducted in groups of up to four people. The project is divided into three parts: 1) initial conceptual design and analysis, 2) design development and testing, 3) post analysis and documentation.

Objectives
- to explore the geometric design parameters of a structural truss through bridge design.
- to perform quantitative analysis as a means of testing and evaluating a design.
- to test a design concept using a 1:64 (3/16" = 1') scale structural model.
- to document the results in a clear, well organized report.

Procedure
1) Develop a structural concept for a 2-lane vehicular bridge meeting the following criteria:
   - Function: accommodate a flat roadway to carry 2-lane traffic (10ft lane width)
   - Loads: each lane to carry 640 PLF (HS20 truck loading)
   - Geometry: 160 ft span, 52 ft maximum depth (below supports), unlimited height
   - Materials: wood, glue (no strength modifying of wood, i.e., coating in glue or other material)
   - Efficiency: maximize the load capacity to bridge weight ratio.
2) Analyze the design concept using either manual calculations or computer software:
   - Determine the magnitude and sign (tension or compression) of the force within each truss member.
   - Determine the cross-sectional sizing for each member based on the force calculations and the allowable material stress (**F = P/A** or **A = P/F**). See attached table for material properties of basswood.
3) Document initial design concept and quantitative analysis in a preliminary report.
4) Construct a structural test model (scale: 3/16" = 1'-0"). The model will be tested in class to determine its maximum load capacity. Load is applied with 5 lb. steel bars measuring 1 ½" x 2" x 5 7/8".
5) Produce a final report (see scoring rubric for more details) to include:
   - Explanation of the structural concept
   - Design and analysis with drawings
   - Test documentation and results
   - Discussion of results and possible improvements

Model Criteria
- Models are to be made entirely of basswood and glue. Additional basswood gusset plates at member connections are allowed. No steel pins or fasteners are allowed for the joining of members.
- Trusses must be constructed of individual members. That is, you may not laser cut a truss from a flat sheet of basswood. Based on the grain of wood, this would be counterproductive anyway.
- Maximum member cross-sectional dimension = ¼". If two pieces of wood are laminated together, the maximum thickness may not exceed ¼".
- Strength modifying of basswood (coating in glue or other material) is not allowed.
- Models must span a 30" gap (an exactly 30" long bridge will fall through), hang no further than 10" below the supports, and have a 1/8" maximum deck thickness.
- Models may bear only on the top surfaces of the support frame.
- Models must have a **FLAT,** continuous deck with a minimum of 4" width. It cannot be perforated.
- The models will be loaded on the roadway deck using 1 ½" x 2" x 5 7/8" steel bars.
- Bridge decks must be loadable, and able to accommodate the placement of steel weights.
- Models (wood + glue) may not weigh more than **4 ounces.**
- Models must carry a **minimum load of 50 lbs**. (10 steel bars)
- Ranking score is based on the ratio of load capacity to the weight of the bridge.
- Some points will be awarded based on class ranking of load-to-weight ratio.

Part	Due Dates	points
Preliminary Report	10.04.24	40
Model Testing	11.04.24	60
Final Report	11.25.24	150

Preliminary Report

Explanation

concept
truss type

Analysis

member forces (Dr Frame)
member sizing
selfweight
capacity

Presentation

letter size report

Due Date

4 October 2024

Truss Bridge Project – Preliminary Report

Pre-Test Design Proposal Requirements:

Explanation – Describe the structural design logic that led to the development of your design. How have the principals of truss analysis influenced your design decisions? This may include comparisons to an existing truss or bridge design, but you should also reflect on structural principles you have learned in class.

Illustration – Include diagrams and drawings so that your structure can be understood in its entirety. At least one transverse cross section, one elevation, and one three dimensional view (axon or perspective) of your bridge are required. Orthographic drawings must be dimensioned, and the member sizes labeled in a clear way that corresponds to your calculations. Also be sure to consider the way in which your bridge rests on the supports. A drawing of this detail may be beneficial. All drawings must be digitally produced to scale; free hand sketches are not permissible as illustrations of your bridge design, nor are screen shots or print-to-file images of Rhino models.

Analysis – Calculations* should include the following:

- **internal axial forces** (including sign – T or C) for each truss member. This analysis can be conducted manually (method of joints or sections), or using computer software (Dr. Frame, etc.). Loading should be considered as a distributed load over the length of the bridge, however, this load will be transferred to the joints of the truss by the deck. Thus, in analysis, only apply loading as point loads to joints directly beneath the bridge deck.
- **cross-sectional sizing** for each member in your design (based on $F = P/A$ or $A = P/F$). This step involves deriving the required cross-sectional area based upon the axial loads applied to a member.
- **weight estimate** of entire bridge – break down should include each member and take into consideration the weight of connections (i.e. about 10% for glue) – total should be under 4 oz. *(See properties of basswood for unit weight.)*
- **load capacity** - predict the ultimate capacity in lbs. that the bridge can support. Choose a critical member (for instance, a member that carries the largest axial load, or the member with the largest internal stress) and determine the load level that will cause this member to fail.

* If an excel spreadsheet is used to make calculations for any portion of the analysis, make sure to provide the equations being used for each column in the table.

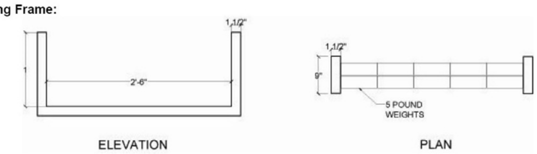
The Pre-Test Design Proposal is worth 40 points of the total score for this project. **SUBMIT ONLY ON 8½ X 11 PAPER.** NO 11X17 PAPER SUBMISSIONS WILL BE ACCEPTED. Once returned to you graded, **save the original copy** of the Preliminary Report for submission together with the Final Report.

Remember that the report is to be a professional document. Writing should be clear, grammatically correct, and language should be appropriate and professional. *(See Report Guidelines for more details)*

Properties of Basswood (approximate):

Unit Density	24 lb/ft^3	Compression ⊥ to grain	370 psi (bearing)
E	1,460,000 psi (for deflection)	Compression ∥ to grain	4730 psi
E_{min}	460,000 psi (for buckling)	Tension ∥ to grain	4500 psi (estimate)
G	25,000 psi (shear modulus)	Shear ∥ to grain	990 psi

Testing Frame:



Final Report

Documentation

see tally sheet for detail
development of prelim
revised analysis
final design
test results
post-test analysis

Report Guidelines

1. **No calculations are to be hand written**. Microsoft Word has a function for typing very legible and professional-looking equations. In Word, go to Insert and select Equation. In just a few minutes you should be able to become proficient in producing equations. It's pretty simple to use. If not using Word, there are other alternatives available on the web to effectively and clearly type equations.
2. **No screenshots of digital models**. All drawings should be digitally generated as polished line-drawings from programs such as Illustrator, AutoCAD, or similar to produce dimensioned drawings of your models. You can for example use the Make2D function in Rhino. Photographs of your final model before and/or after testing will be required in addition to drawings.
3. **Submit reports on 8-1/2" x 11" paper only.** Reports on 11x17 paper are not acceptable.
4. **Failure to produce a clean, polished, and professional report will result in up to 10% off of your final report points.** Write clearly, legibly, and with good grammar. Proofread your reports before turning them in. Use appropriate professional language in your report. The mark of a good report is one that is easy to understand by someone not familiar with the project.
5. **Turn in the ORIGINAL graded copy of your Preliminary Report with your Final Report.**
6. In the Pre-Analysis section of the Final Report, do all of the listed calculations for your model, as tested. That is, you should re-analyzing the model that you actually built and tested. We expect that certain changes were made during your development of a final design, based on the feedback given on your preliminary report which then require this re-analysis.
7. Throughout your analysis, verify that calculated values are reasonable. For instance, if your calculations produce a predicted load capacity of 70 kips, you have probably done something wrong, and should work to correct this before submitting your report.

Score Tally

Three Parts
- prelim report 40
- testing 60
- final report 150

Architecture 314
Structures I

Truss Bridge Project Tally Sheet

Peter von Buelow
Fall 2024

Group____________________

PRELIMINARY REPORT (re-submit original)	**40**	
Explanation	5	
Illustrations: section (5), elevation (5), 3d view (5)	15	
Analysis: forces (5), sizing (5), weight estimate (5), load capacity (5)	20	
TESTING	**60**	
Bridge < 4 oz is 8 pts and holds at least 50 lbs is 8 pts (else pts scaled down)	16	
Correct materials – wood and glue – solid deck (no holes)	14	
Points awarded (out of 30) based on class rank using formula: [(4/weight OZ)*50 + (load in LBS/50)*9]	30	
FINAL REPORT REQUIREMENTS	**150**	
Preliminary Design Development	**20**	
How initial (preliminary) bridge design was developed	4	
How initial (preliminary) member sizes were chosen	4	
Why bridge design was or was not adjusted from preliminary design	4	
Why member sizes were or were not adjusted from preliminary design	4	
Discussion of how pre-analysis of initial bridge impacted the final design	4	
Revised Bridge Design Analysis	**50**	
Internal axial force calculations/modeling (with proper design loading indicated) (Dr. Frame acceptable)	10	
Derivation of member cross-sectional areas from axial forces	10	
Member size selection from available stock	4	
Est. weight calculation of bridge - including members, glue & fasteners	6	
Method of joints/sections calculation for at least 1 joint (@ reaction is usually easiest based on truss geometry, but could be done elsewhere)	10	
Member crushing calculations/check (show work) using $F'_c=P/A$	4	
Prediction of capacity of bridge and mode of failure	6	
Illustration of Tested (Revised from Preliminary) Design	**20**	
Cross-section of bridge	4	
Elevation(s) of bridge	4	
Dimensions and units labeled in elevation and cross-section	4	
Member sizes labeled (with dimensions)	4	
Member stresses labeled (with units)	4	
Testing Results	**30**	
Weight and height of bridge	5	
Capacity of bridge	5	
Observations of testing	6	
Description of mode of failure	5	
Images of failure	5	
Following the guidelines	4	
Post-Testing Analysis	**30**	
Comparison of testing with predicted capacity and modes of failure	10	
Discussion of discrepancies between results	10	
Suggested improvements for future designs with reasoning discussed	10	
FINAL GRADE	**250**	

Up to 20 pts may be withheld for a lack of clarity or professional quality. **8.5"x11" PAPER ONLY!**

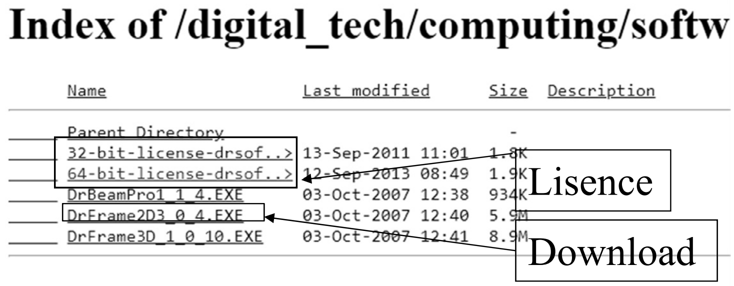
2022 Test

Running Dr. Frame

Dr. Frame can be found on most PC's in the TCAUP system.

or

Download the software here:
https://internal.tcaup.umich.edu/digital_tech/computing/software/DrSoftware/



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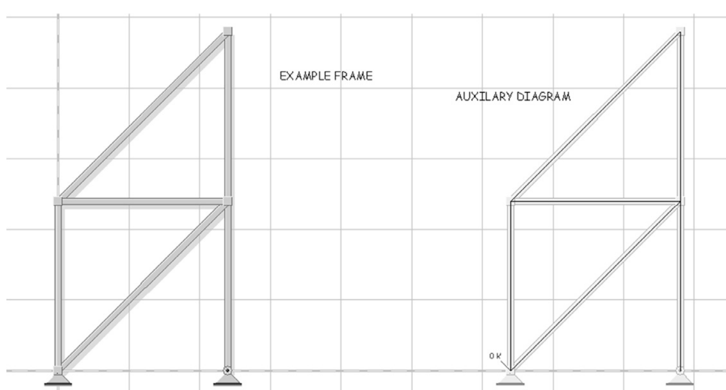
"RegName"="TCAUP„
"RegOrg"="University of Michigan„
"HomeDir"="C:¥¥Documents and Settings¥¥Administrator„

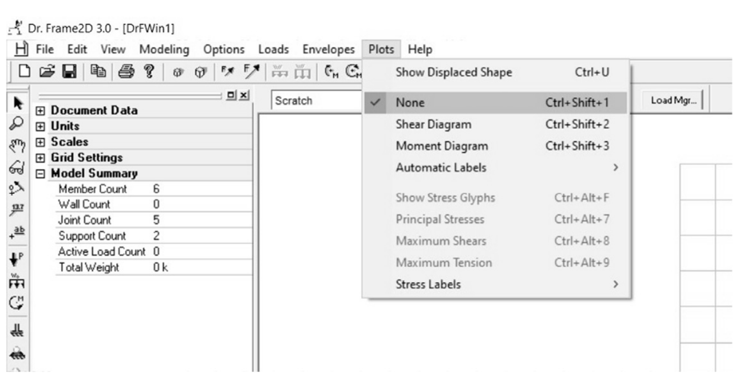
Turn off Auxiliary Diagram

The default setup starts with a simple frame on the screen and an auxiliary diagram to the right for viewing graphic plots of forces.

In the truss analysis this "aux" diagram can be initially shut off :

Plots → None

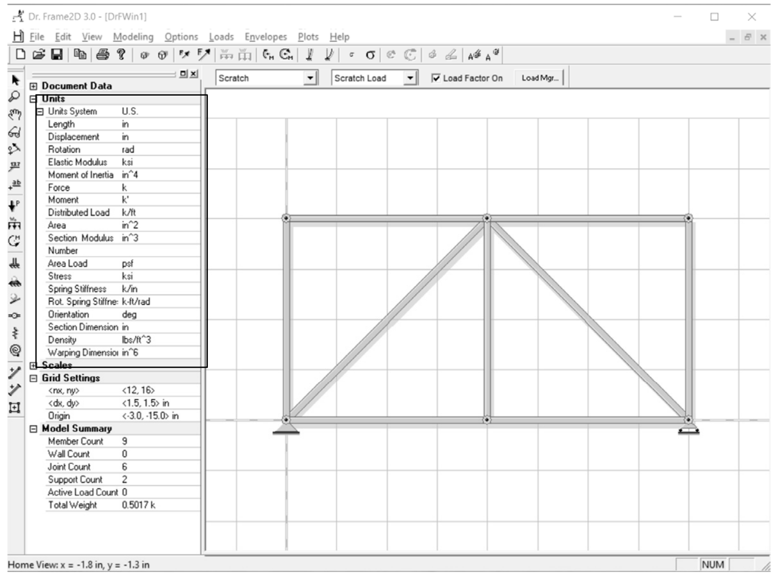




Unit

To select the proper unit you need for your design.

U.S.

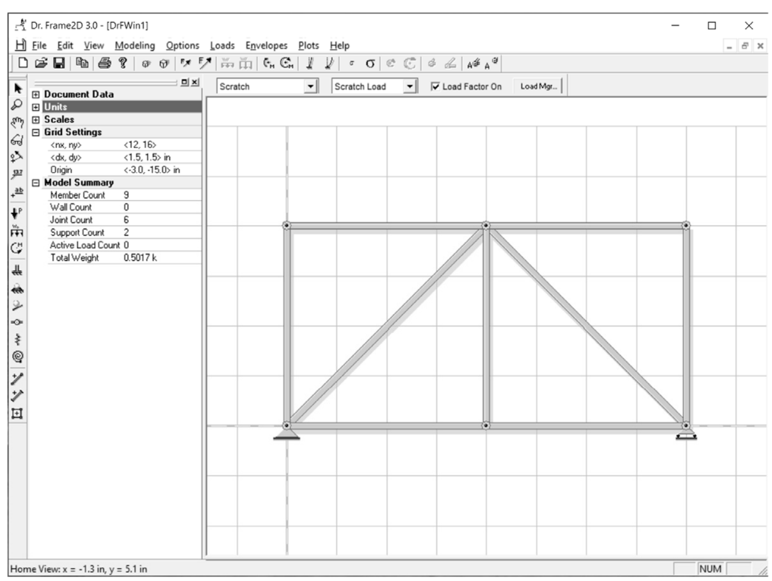


Setting the Grid Parameters

The default setup starts with a grid with 1.5 in increments<dx,dy>. The grid is12 increments by 16 increments<nx,ny> (Totaling 18 in wide by 24 in high).

To adjust the grid size and scale to fit your truss:

Click on the grid to bring up side bar menu



Zooming and Panning

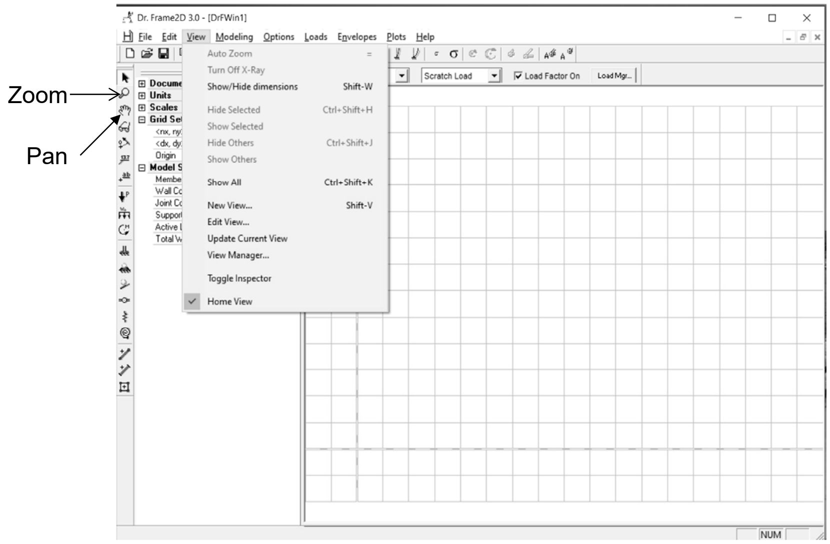
There are several ways to zoom in or out in.

In Dr. Frame you can also zoom by clicking on the zoom icon and clicking on the area of the screen you want to zoom in on. To zoom out, hold down the shift key. You will see you cursor change to a "-" and click on the area to zoom out from.

You can also zoom by selecting the zoom icon and clicking on the screen and drawing a rectangle around the area you wish to zoom in on. (Much like Autocad).

The command Auto Zoom will return you to the default view, showing your structure at the original scale:

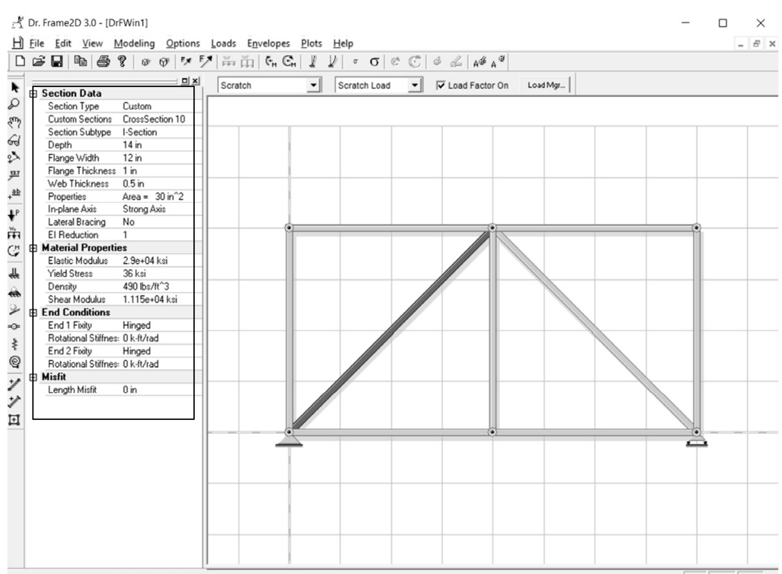
View
  → *Auto Zoom "="*



Selecting Members and Modifying Properties

To select a member in Dr. Frame, first select the Select Tool.

Then click on any item within your structure. You can select any item including a member, a support, a or a load. Once you have selected an item, it will become highlighted on the screen. You can change any property under the section data window.



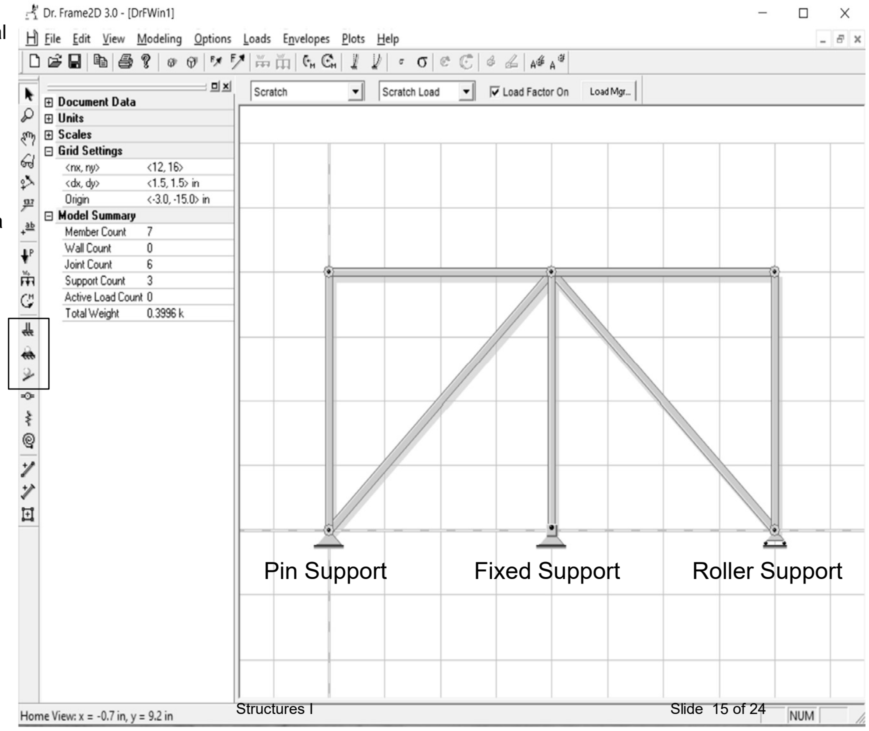
Support Types

There are support tools available in Dr. Frame.

The Pin Support provides a vertical and a horizontal restraint.

The Fixed Support provides a rotational restraint in addition to a vertical and horizontal restraint.

The Roller Support provides only a vertical restraint.



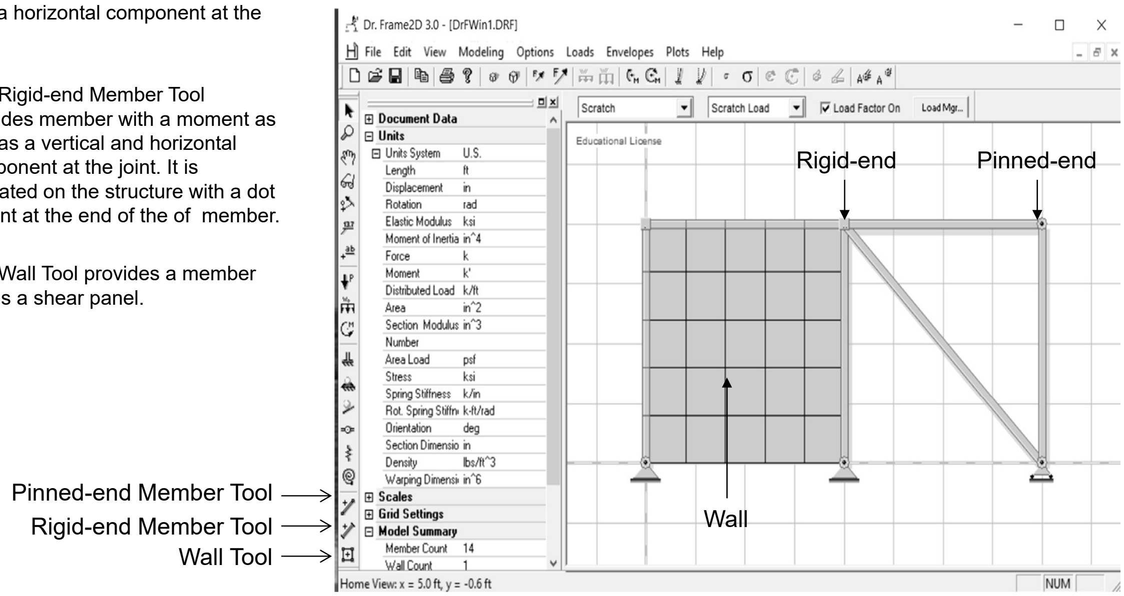
Member Types

There are three member types available in Dr. Frame.

The Pinned-end Member Tool provides a member with a vertical and a horizontal component at the joint.

The Rigid-end Member Tool provides member with a moment as well as a vertical and horizontal component at the joint. It is indicated on the structure with a dot at joint at the end of the of member.

The Wall Tool provides a member that is a shear panel.



Load Types

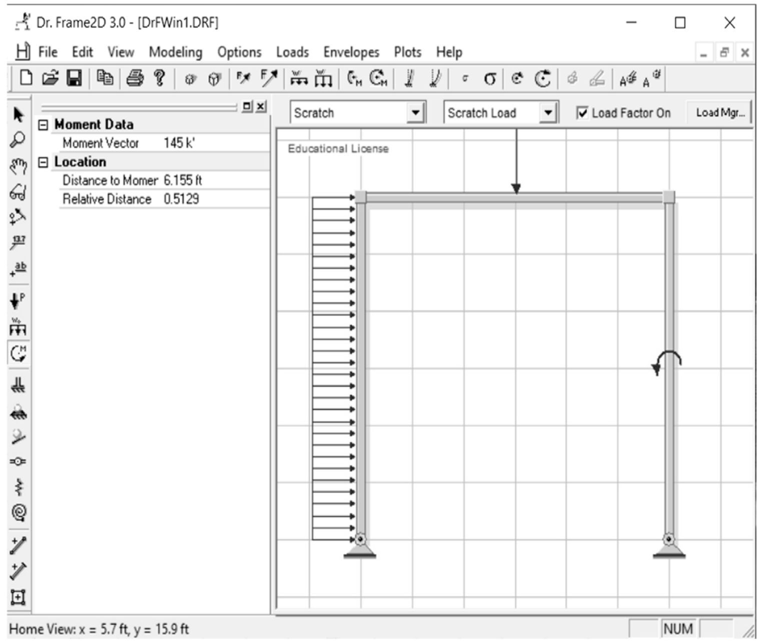
There are three load types available in Dr. Frame.

The Distributed Load Tool applies a uniform load to a member.

The Concentrated Load Tool applies a point load to a member.

The Concentrated Moment Tool applies a moment to a member.

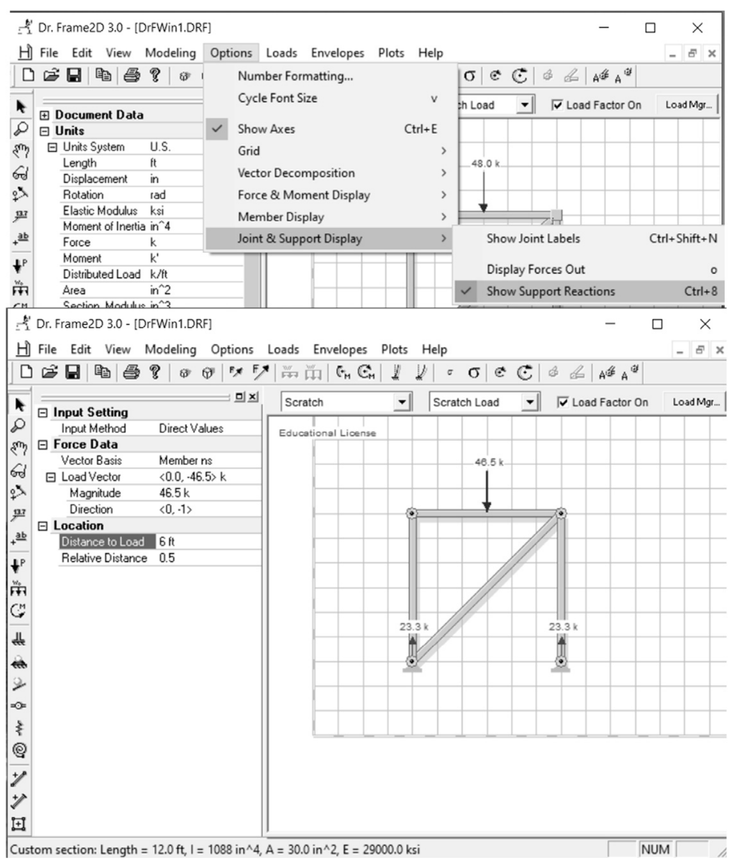
Concentrated Load Tool →
Distributed Load Tool →
Concentrated Moment Tool →



Display Analysis: Support Reactions

Dr. Frame will calculate the reaction for given loading conditions on your given structure.

Options
→ Joint & Support Display
→ Show Support Reactions



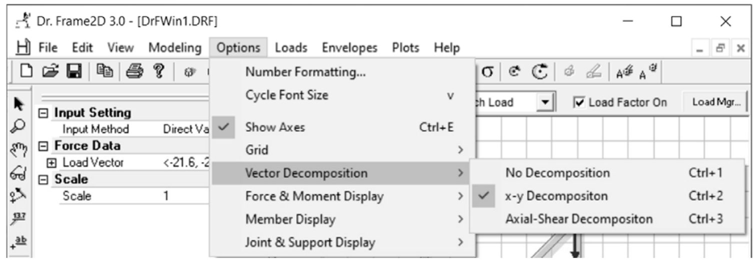
Display Analysis: Vector Decomposition

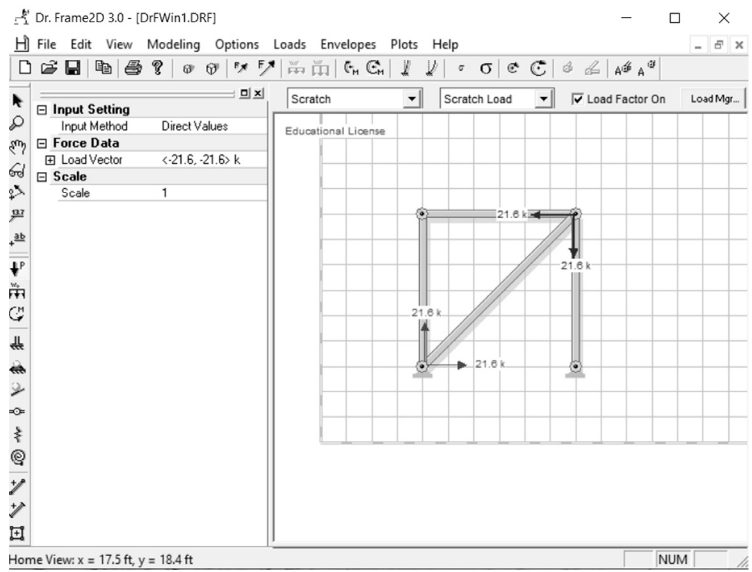
Dr. Frame can break a vector into its x and y components.

Options

→ Vector Decomposition

→ x-y Decomposition



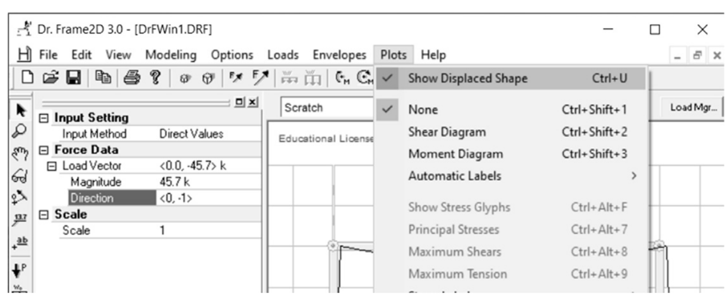


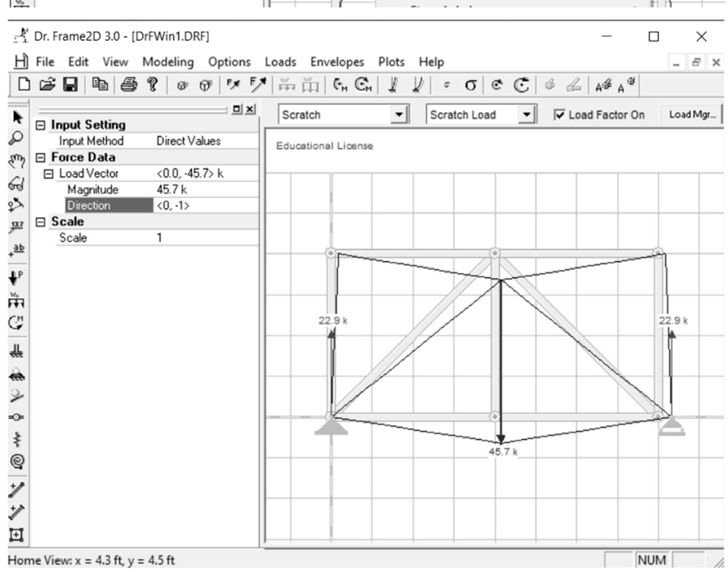
Display Analysis: Deflection

Dr. Frame can simulation the deflection of the structure based on the loading conditions.

Plots

→ Show Displaced Shape





Display Analysis: Member Display

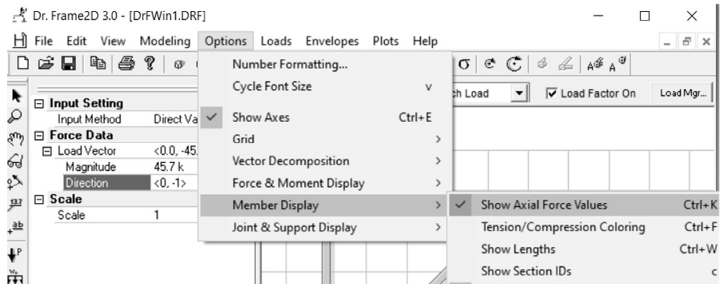
Dr. Frame can analyze a structure and its loading conditions to generated the axial forces within the members of your truss.

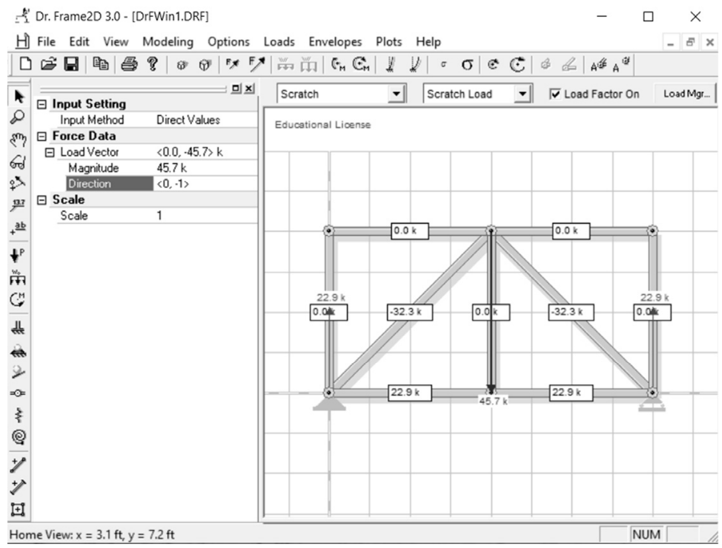
Options

→ Member Display

→ Show Axial Force Value

Dr. Frame illustrates members in compression with a positive stress and members in tension with a negative stress.





Display Analysis: Member Display

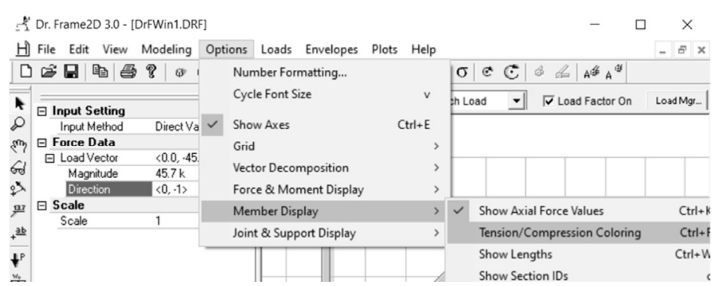
Dr. Frame can analyze a structure and its loading conditions to generated the axial forces within the members of your truss.

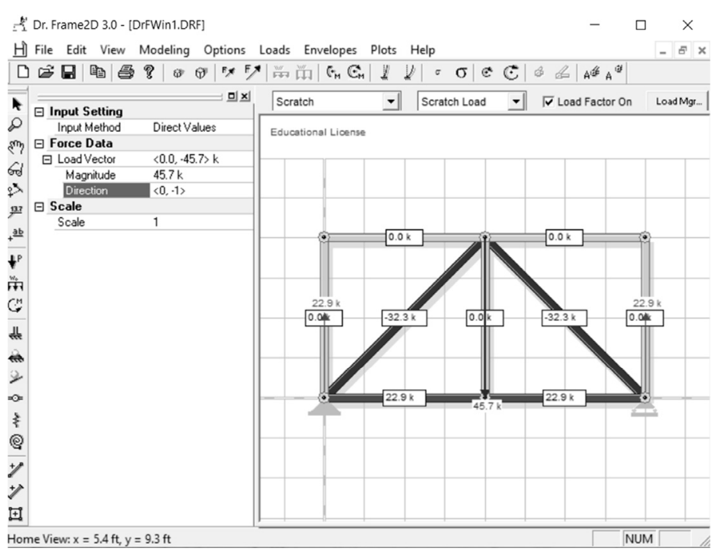
Options

→ Member Display

→ Show Tension/Compression Coloring

Dr. Frame illustrates members in compression in red and members in tension in blue.



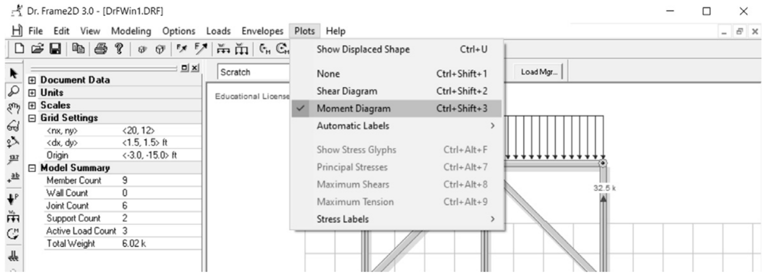


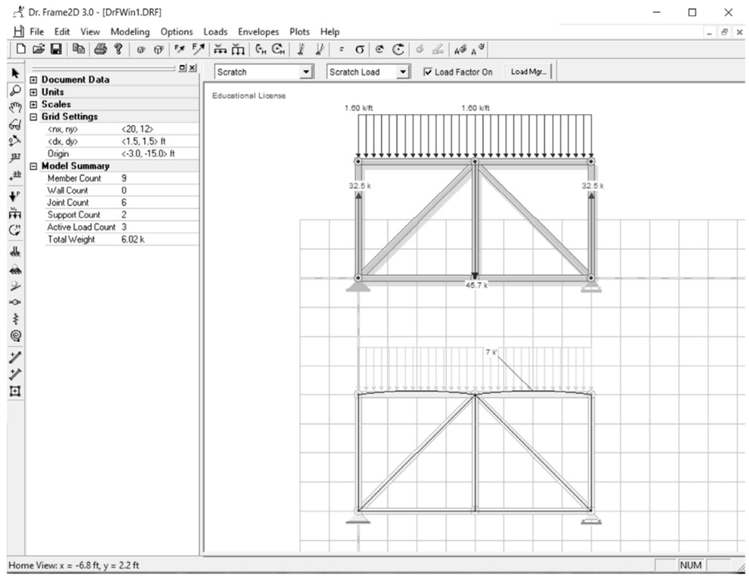
Display Analysis:
Auxiliary Diagrams

Dr. Frame can generate the moment diagram of a structure and its loading conditions.

Plots

→ *Moment Diagram*





Display Analysis:
Auxiliary Diagrams

Dr. Frame can label maximum or minimum points on its auxiliary diagrams.

Options

→ *Automatic Labels*

→ *Label All Maxima*

→ *Label All Maxima & Minima*