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## ***Introduction***

Infrastructure development is widely regarded as a key driver of societal progress, offering benefits such as improved connectivity, economic growth, and enhanced security. The Federal Highway Act of 1956, which established the Interstate Highway System, significantly transformed the urban landscape of the United States. It addressed issues like traffic congestion, improved the flow of goods, and created jobs in construction and manufacturing. However, the implementation of this large-scale project came with severe consequences for certain communities, particularly African Americans and other marginalized groups. Urban highways often cut through minority neighborhoods, displacing families, lowering property values, and creating physical and social divides. These disruptions not only fractured communities but also established long-standing racial and economic inequalities. Additionally, the environmental impacts, such as air pollution from heavy traffic near these neighborhoods, further degraded the quality of life. While the highway system brought benefits, its negative effects on underrepresented communities highlight the need for more equitable and inclusive approaches to infrastructure development.

## ***Federal Highway Act Research***

The Interstate Highway System was introduced as a solution to several problems the country was facing. Congestion was a big issue, causing massive losses in time and productivity because of “detours and traffic jams” and even leading to “civil lawsuits” that bogged down the courts (Karas 10). Poorly designed roads also slowed the delivery of goods and contributed to alarmingly high rates of accidents and fatalities. There were also concerns about the country's readiness for warfare. President Eisenhower believed that his proposal for a nationwide highway system would tackle these issues and "change the face of America" (Karas 10). He saw it as a way to boost the economy by creating jobs in manufacturing and construction while also opening up rural areas in ways that would be transformative and hard to measure.

While the Interstate Highway System was funded 90% federally, the states had significant control over where the highways were built (Karas 10). Unfortunately, this power was often used in ways that prioritized economic development and suburban communities at the expense of minority neighborhoods. Many African-American families were displaced under the pretense of urbanization, with their communities being targeted for highway routes (Karas 11). State agencies frequently held public hearings but failed to properly notify the people who would be affected, leaving them without a voice in the process (Karas 12). In some cases, the highways were even used to deliberately enforce racial segregation by creating physical barriers between white and minority neighborhoods, reinforcing the discriminatory practices of the time.

The history of the Interstate Highway System clearly shows that it had a profound and often devastating impact on minority communities in urban areas, particularly African Americans. Highways often targeted black neighborhoods, destroying homes, dividing communities, and forcing the removal of what were referred to as "emerging ghettos" (Karas 14). A striking example of this is in Miami, where construction consumed a vast area, displacing thousands of homes and wiping out one of the state’s most prominent black communities (Karas 13). Similarly, in Detroit and other cities, property values dropped significantly as highway construction was announced long before it began, leaving communities in decline (Karas 13). African Americans faced not only the challenge of opposing these destructive plans but also struggled to find safe and sanitary housing after being displaced. The combined effects of these actions left lasting scars on urban minority populations.

First, many of the highway routing plans were connected to the fear of slums that was growing in many American cities at the time. Highways were often used as a way to clear these areas, but this came at a big cost to underrepresented minority communities. These communities were already dealing with issues like lack of investment, poor schools, and rundown properties, and the highways made things worse by creating physical separations that isolated them even more. The freeways became both physical and symbolic barriers, cutting off residents from opportunities and restricting their mobility. On top of that, pollution from cars lowered air quality and caused health problems like asthma, especially for people living near the highways. The drop in land values, lack of investment, and rise in crime in these neighborhoods made it almost impossible for them to recover, leaving many trapped in poverty for decades.

In recent years, cities across the United States have begun exploring "capping" interstate highways to address these historic harms. These caps, which create parks or mixed-use developments over freeways sections, aim to reconnect divided neighborhoods, improve air quality, and increase green space. Dallas led the way in capping highways with its Klyde Warren Park, constructed over a section of Woodall Rodgers Freeway. Completed in 2012, this project has been celebrated as a model for how capping can transform urban spaces, providing green space and bringing economic activity to the area while restoring a sense of connectivity between previously separated communities (Our Story). The Stitch, an ambitious proposal to cap the downtown Connector freeway, is designed to reconnect downtown Atlanta with Midtown. The Stitch aims to add parks, affordable housing, and commercial spaces to areas long divided by the freeway (Simmons). If completed, it would significantly improve pedestrian access, green space, and residential options for nearby communities. The Park 101 project is an ongoing initiative to cap a section of the 101 Freeway, which has long divided neighborhoods in downtown Los Angeles. This project is envisioned to include parks, recreational areas, and pedestrian-friendly spaces, which would bring economic benefits and reconnect historically marginalized areas with the city center (Fulton). Park 101 aims to restore urban cohesion while reducing environmental and social impacts of the highway.

## ***Preliminary Truss Design***

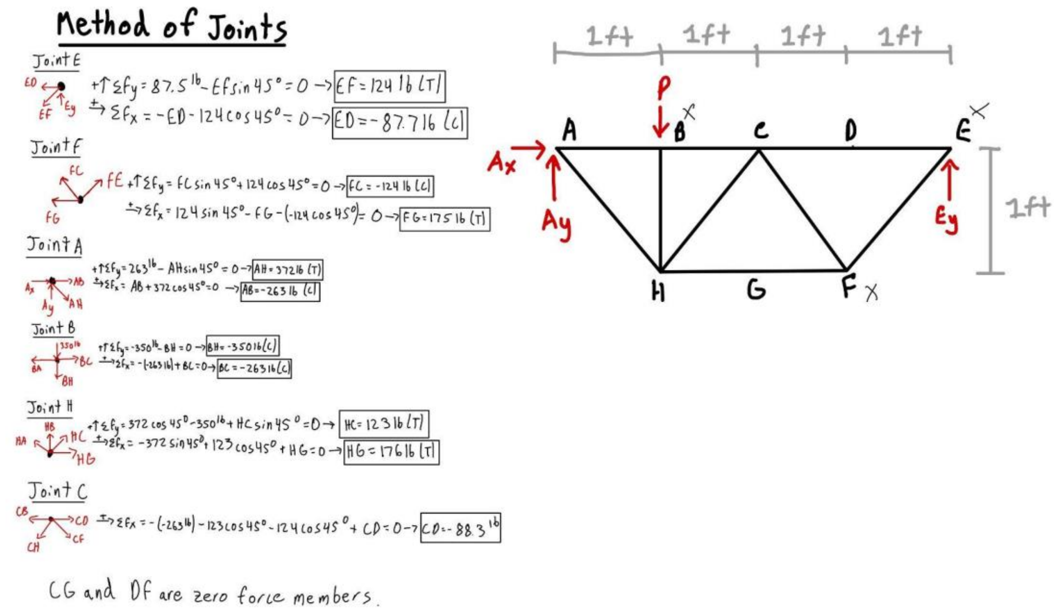


*Figure 1: Methods of Joints Shown Work Towards Preliminary Truss Design*

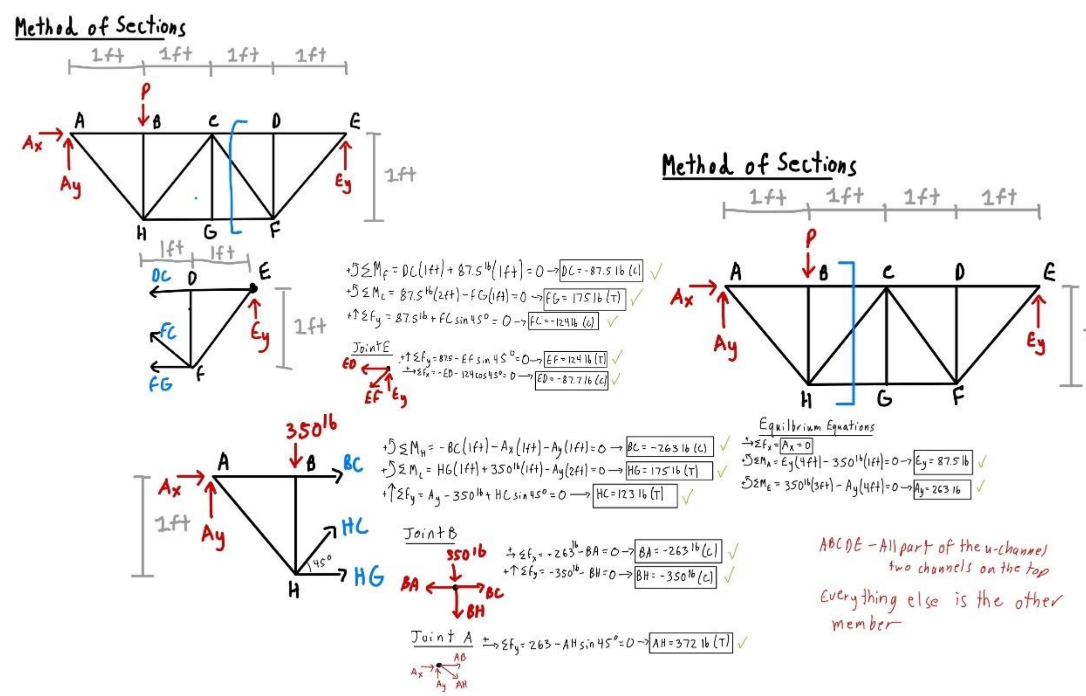


*Figure 2: Methods of Joints Shown Work Towards Preliminary Truss Design*

## ***Building the Truss Prototype***

*Figures 3-8: Tap and fillet welds, T and bolt Joints, and Truss Assembly.*

The slender members are joined with the channel members on the top of the truss through a slot connection with another plate as well as being welded. The plate that has the slot is joined to the channel through a pin joint. The pin, however, goes through another plate that is welded onto the channel. The lengths of the members for the truss are much shorter than the lengths of the theoretical model. The joint layout for the practical truss is much different than the model itself as well. During testing, none of the members yielded; however, one member failed in buckling when the load (P) reached 667 lbs. The load was applied at node D on the opposite side of the truss, but this does not affect the calculations as the truss is symmetrical. Member CH failed first under buckling.

## ***Calculating for Failure***

1) The maximum load (P) that could be applied to the truss at node B before a member failed due to compression was determined to be 355 lbs. The variables influencing the critical load ($N_{critical}$) were compiled in Excel and used in the calculation. Members subjected to compressive forces were assessed for buckling, with six members identified as being in compression based on **figures 1 and 2**. The primary factors affecting the compressive performance of these members included their lengths, cross-sectional areas, and moments of inertia. The lowest $N_{critical}$, as shown in **figure 9**, was 177.89 lbs, indicating that member CF would fail in compression if its load exceeded this value. To maintain a conservative estimate, the value was rounded down to 177 lbs, recognizing that failure would occur before reaching 178 lbs if rounded up. However, when put into the John Hopkins truss simulator in **figure 14**, member BH fails under buckling before the member CF since its $N_{critical}$ value of 355 lbs was reached before CF was 177 lbs in compression. BH reaches its $N_{critical}$ value when a load (P) of 355 lbs is applied at node B as shown in figure 14. The $N_{critical}$ value of BH was rounded down as well to 355 lbs. Member CF doesn't fail under buckling until the load value (P) applied at Node B is 500 lbs.

2) The maximum load (P) that could be applied to the truss at node B before a member failed due to yielding was calculated in **figure 10** as 4449 lbs. Members typically fail in tension before compression when considering yielding, as most materials plastically deform at lower stress levels under tensile forces than compressive forces. The maximum tensile load for failure in each member was determined by multiplying the material's yield stress by the cross-sectional area. Since all members are assumed to be made of structural A-36 steel alloy, the yield stress is consistent across members, but the cross-sectional areas vary. Specifically, there are two distinct cross-sectional areas: one for the slender rectangular members and another for the top four truss members. **In figure 10**, the smallest yielding load calculated was 4719 lbs for the slender members with the smaller cross-sectional area. To determine the maximum load (P) that could be applied at Node B before any member failed, P was incrementally increased in the John Hopkins truss simulator until a tensile force of 4719 lbs was observed in one of the members. Member AH will fail under yielding if more than 4719 lbs is applied at node B since the member is approximately 4449 lbs in tension in the simulator, as shown in **figure 13.**

3) The controlling load (P) is determined by the buckling value calculated in (1), as buckling causes failure first. The smallest buckling load is compared to the loads that would cause other members in compression to fail. Among the six $N_{critical}$ values, two are lower than both the yielding loads, while the remaining four are higher. This indicates that a member of the truss will fail due to buckling before any other members in tension reach failure. Specifically, member BH buckles at 335 lbs, which occurs when P = 355 lbs.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yielding Section | | | | Buckling Section | | | | | | |
| | Internal Stress (σ | $\sigma_y$ (what you get from the model) | | | $C < N_{critical}$ | $N_{cr = (pi)^\wedge 2EI / (kl)^\wedge 2}$ | | | | | |
| | T/A = σ | 36300 psi | | | | | | | | | |
| Members | σ: | Tension Values (lb): | Area (in$^2$) | Members | E (lb/in$^2$) | I (lbf.in) | k | L (in) | Area (in$^2$) | Compression Values (lb | $N_{cr}$ |
| CD | 304.48 | 88.3 | 0.29 | ED | 29,000,000 | 0.0157 | 1 | 12 | 0.29 | 87.7 | 31205.77 |
| HC | 946.15 | 123 | 0.13 | FC | | 0.000179 | | 17 | 0.13 | 124 | 177.892765 |
| EF | 953.85 | 124 | 0.13 | AB | | 0.0157 | | 12 | 0.29 | 263 | 31205.77 |
| FG | 1346.15 | 175 | 0.13 | BC | | 0.0157 | | 12 | 0.29 | 263 | 31205.77 |
| HG | 1353.85 | 176 | 0.13 | BH | | 0.000179 | | 12 | 0.13 | 350 | 355.785531 |
| AH | 2861.54 | 372 | 0.13 | CD | | 0.0157 | | 12 | 0.29 | 88.3 | 31205.77 |
| | | Theoretical Length Values | | | | | | | | | |

*Figure 9: Yielding and Buckling Data with Calculations for Theoretical Model*

## Failing Under Tension

$\sigma_y = 36300psi$ $\quad A = 0.13\,in^2$ ↑ Slender Members

$\frac{T}{A} = \sigma_y$

$T = \sigma_y A$

$T = (36300)(0.13) = 4719\ lb$

for the four top members:

$\sigma_y = 36300\ psi \quad A = 0.29\,in^2$

$T = \sigma_y A$

$T = (36300)(0.29) = 10527\ lb$

*Figure 10: Yielding Values for Two Different Member Shapes*

For triangle $A_4$,

$I_{x'} = \frac{bh^3}{36}$

$b = 0.2575 - 0.145$

$\boxed{b = 0.1125}$

$h = 0.50 - 0.13$

$\boxed{h = 0.37}$

$A = \frac{bh}{2}$

$\boxed{A = 0.02081}$

$d_x = 0.50 - \frac{h}{3}$

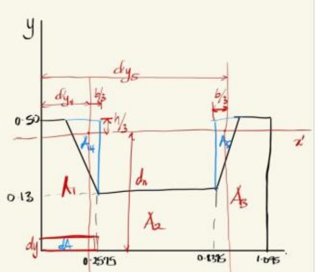
$\boxed{d_x = 0.3767}$

$I_{x'} = 0.0001583$

$I_x = I_{x'} + Ad_x^2$

$I_x = 0.0001583 + (0.02081)(0.3767)^2$

$\boxed{I_x = 0.003111}$




$I_{y'} = \frac{hb^3}{36}$

$I_{y'} = 0.00001463$

$I_y = I_{y'} + Ad_y^2$

$d_{y_4} = 0.2575 - \frac{b}{3}$

$d_{y_4} = 0.22$

$\Rightarrow I_y = 0.00001463 + (0.02081)(0.22)^2$

$\boxed{I_y = 0.001022}$

For triangle $A_5$,

$I_{x'}$ of $A_4$ = $I_{x'}$ of $A_5$

$d_x$ of $A_4$ = $d_x$ of $A_5$

$\Rightarrow I_x$ of $A_4$ = $I_x$ of $A_5$

$\boxed{I_x = 0.003111}$

$I_{y'}$ of $A_4$ = $I_{y'}$ of $A_5$

$\Rightarrow I_{y'} = 0.00001463$

$d_{y_5} = 0.8375 + \frac{b}{3} = 0.875$

$I_y = 0.00001463 + (0.02081)(0.875)^2$

$\boxed{I_y = 0.01595}$

$\Sigma I_x = 0.02188 - 0.00311 - 0.0311$

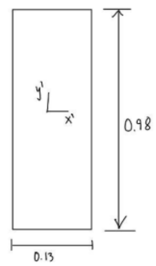
$= 0.01566$

$\Sigma I_y = 0.1485 - 0.001022 - 0.01595$

$= 0.1315$

Since $I_x < I_y$, $I = I_x = 0.01566$

*Figure 11: Calculated Inertia for First Shape Member*

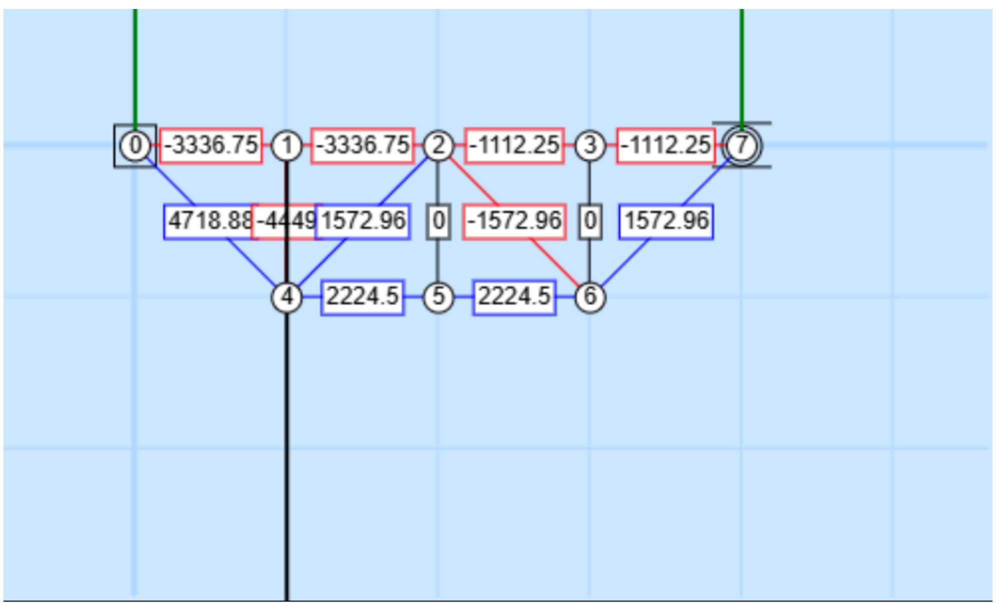



$$I_x = \frac{bh^3}{12} = \frac{0.13(0.98)^3}{12} = 1.02 \times 10^{-2}\ \text{lb}\cdot\text{ft}$$

$$I_y = \frac{b^3h}{12} = \frac{(0.13)^3(0.98)}{12} = 1.79 \times 10^{-4}\ \text{lb}\cdot\text{ft}$$

$$\boxed{\text{Smaller Initia} = I_y = 1.79 \times 10^{-4}\ \text{lb}\cdot\text{ft}}$$

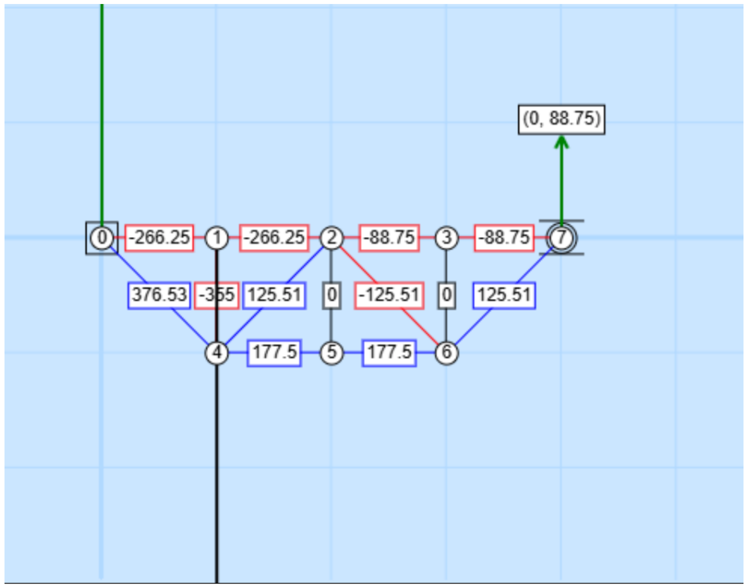
*Figure 12: Calculated Inertia for Second Shape Member*




**External Forces**

| Node | Fx [N] | Fy [N] |
|---|---|---|
| 1 | 0 | -4449 |
| 0* | 0 | 3336.75 |
| 7* | 0 | 1112.25 |
| *Reaction forces at a support | | |

*Figure 13: Maximum Load (P) Applied at Node B Before Failure Under Yielding for Theoretical Model*




| External Forces | | |
|---|---|---|
| Node | Fx [N] | Fy [N] |
| 1 | 0 | -355 |
| 0* | 0 | 266.25 |
| 7* | 0 | 88.75 |
| *Reaction forces at a support | | |

*Figure 14: Maximum Load (P) Applied at Node B Before Failure Under Buckling for Theoretical Model*

## ***Comparing Calculations with Lab Results***

The buckling values differ between the practical truss constructed for the experiment and the theoretical diagram used for calculations. This discrepancy arises because the measured lengths of the practical truss members differ significantly from those in the theoretical diagram, affecting their $N_{critical}$ values but not their yielding values. **Figure 15** illustrates the positioning of the top and bottom members. Since the practical truss members are shorter than those in the theoretical model (**Figures 1 and 2**), their $N_{critical}$ values are higher, for $N_{critical}$ is inversely proportional to $L^2$. The N critical value calculated was 286 lbs, attributed to member CF. However, member BH fails in compression before CF. Based on calculations seen in figure, member BH is expected to fail under buckling when P reaches approximately 499 lbs. Member CF would fail if the load (P) applied was 815 lbs.

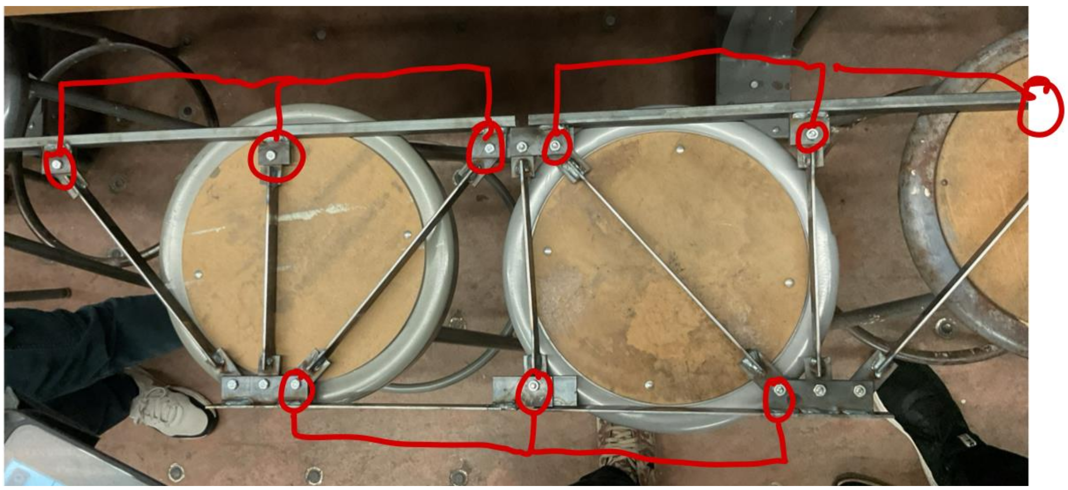


*Figure 15: Decided Layout of the Truss Members*

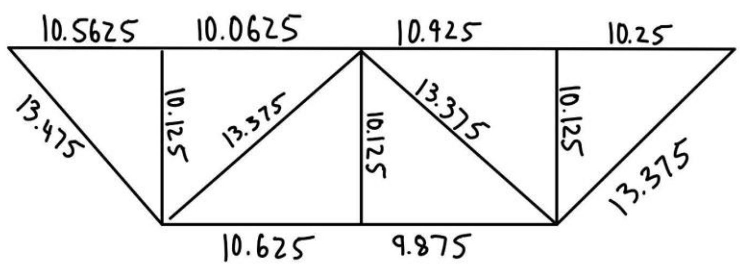
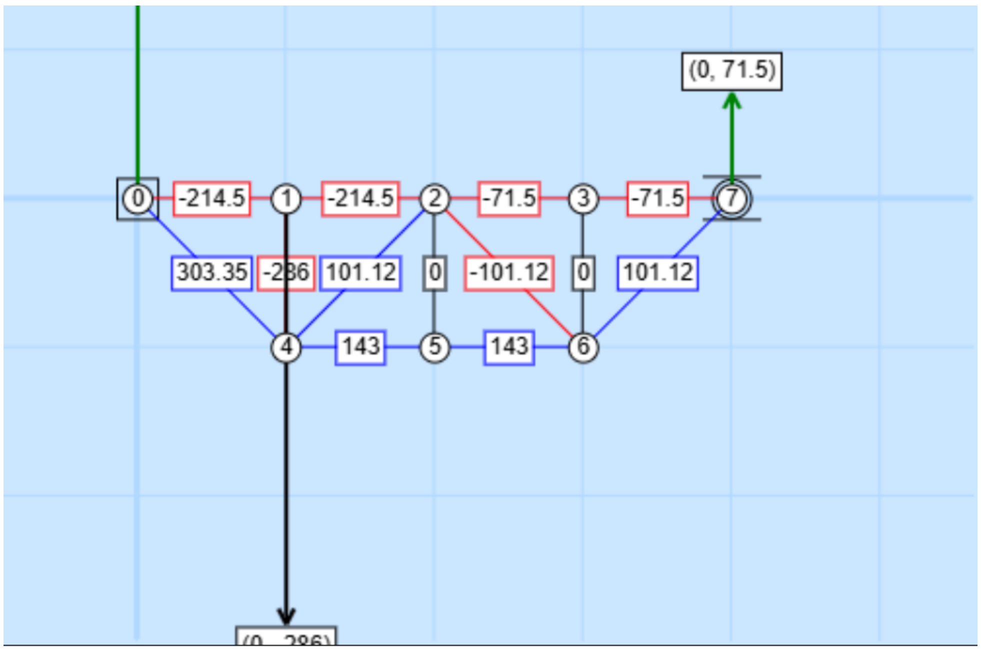



*Figure 16: Measured Lengths of Members Before Testing*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | T/A = σ | 36300 psi | | | | | | | | | |
| Members | σ: | Tension Values (lb): | Area ($in^2$) | Members | E ($lb/in^2$) | I (lbf.in) | k | L (in) | Area ($in^2$) | Compression Values (lb | $N_{cr}$ |
| CD | 304.48 | 88.3 | 0.29 | ED | 29,000,000 | 0.0157 | 1 | 10.25 | 0.29 | 87.7 | 42771.0257 |
| HC | 946.15 | 123 | 0.13 | FC | | 0.000179 | | 13.375 | 0.13 | 124 | 286.393524 |
| EF | 953.85 | 124 | 0.13 | AB | | 0.0157 | | 10.5625 | 0.29 | 263 | 40277.6341 |
| FG | 1346.15 | 175 | 0.13 | BC | | 0.0157 | | 10.0625 | 0.29 | 263 | 44379.8274 |
| HG | 1353.85 | 176 | 0.13 | BH | | 0.000179 | | 10.125 | 0.13 | 350 | 499.7591 |
| AH | 2861.54 | 372 | 0.13 | CD | | 0.0157 | | 10.725 | 0.29 | 88.3 | 39066.3462 |
| | | Lab Length Values | | | | | | | | | |

*Figure 17: Yielding and Buckling Data with Calculations for Practical Model*




| External Forces | | |
|---|---|---|
| Node | Fx [N] | Fy [N] |
| 1 | 0 | -286 |
| 0* | 0 | 214.5 |
| 7* | 0 | 71.5 |
| *Reaction forces at a support | | |

*Figure 18: Maximum Load (P) Applied at Node B Before Failure Under Buckling for Practical Model*

During testing, none of the members yielded; however, one member failed in buckling when the load (P) reached 667 lbs. The load was applied at node D on the opposite side of the truss, but this does not affect the calculations as the truss is symmetrical. Member DF was not the first to fail; instead, member CH failed first. Notably, member CF was expected to fail at a load of 815 lbs applied at node D.

Several factors could explain the discrepancies between the theoretical and practical models. One key reason for member CH failing before DF is the joint configuration at node C. In the theoretical model, members CH, CG, and CF connect to node C at a single joint. However, in the practical truss, these members are connected through three separate joints, each consisting of three bolts. This configuration likely reduced joint strength, leading to weaker reaction forces. Additionally, the members were not directly bolted together but were welded to separate plates through T joints, and these plates were bolted together. This design could have contributed to CH failing earlier than predicted. Furthermore, the material used in the practical truss may differ from the assumed structural A-36 steel alloy. If the member were made of a material with a higher Young's modulus (E), the $N_{critical}$ values would be higher, as $N_{critical}$ is directly proportional to E. This would result in a higher controlling load (P), explaining why the truss handled a greater load than expected. Lastly, potential weaknesses in the welds, particularly at member CF, may have further weakened the joints at nodes C and H, reducing the reaction forces and contributing to the earlier failure of CH.

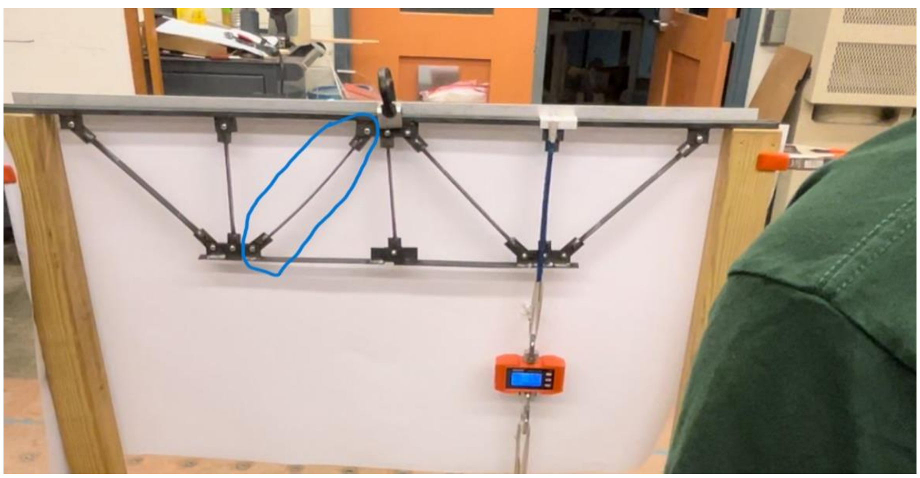


*Figure 19: Member CH Failing Under Buckling During Experiment*

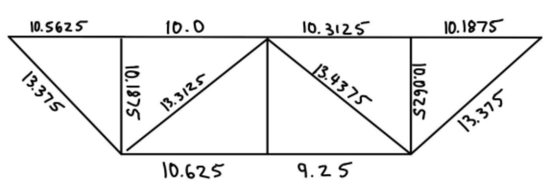
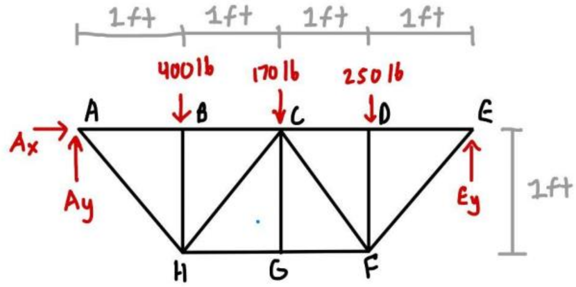



*Figure 20: Measured Lengths of Members After Testing*

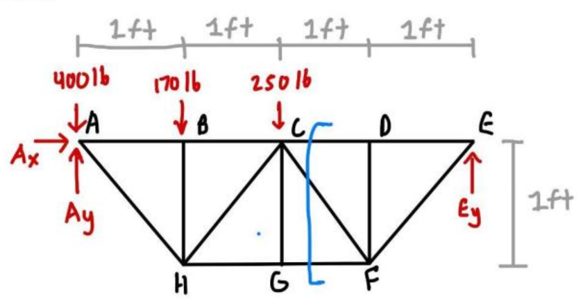
***Designing the Community Bridge***

Combination 1:



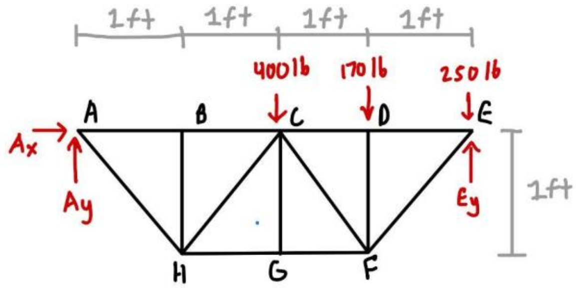

AB = 448 lb (C)
BC = 448 lb (C)
CD = 373 lb (C)
DE = 373 lb (C)
AH = 633 lb (T)
BH = 400 lb (C)
HC = 67.2 lb (C)
HG = 495 lb (T)
CG = zero force member
CF = 173 lb (C)
GF = 495 lb (T)
FE = 527 lb (T)
DF = 250 lb (C)

Combination 2:



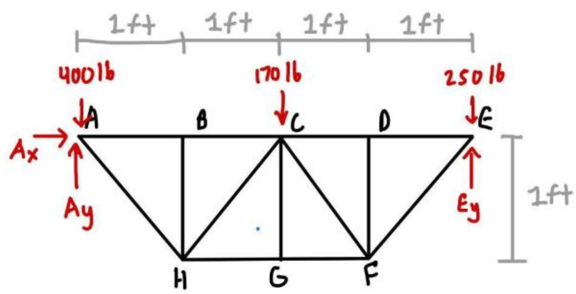

AB = 253 lb (C)
BC = 253 lb (C)
CD = 168 lb (C)
DE = 168 lb (C)
AH = 357 lb (T)
BH = 170 lb (C)
HC = 117 lb (C)
HG = 335 lb (T)
CG = zero force member
CF = 237 lb (C)
GF = 335 lb (T)
FE = 168 lb (C)
DF = zero force member

## Combination 3

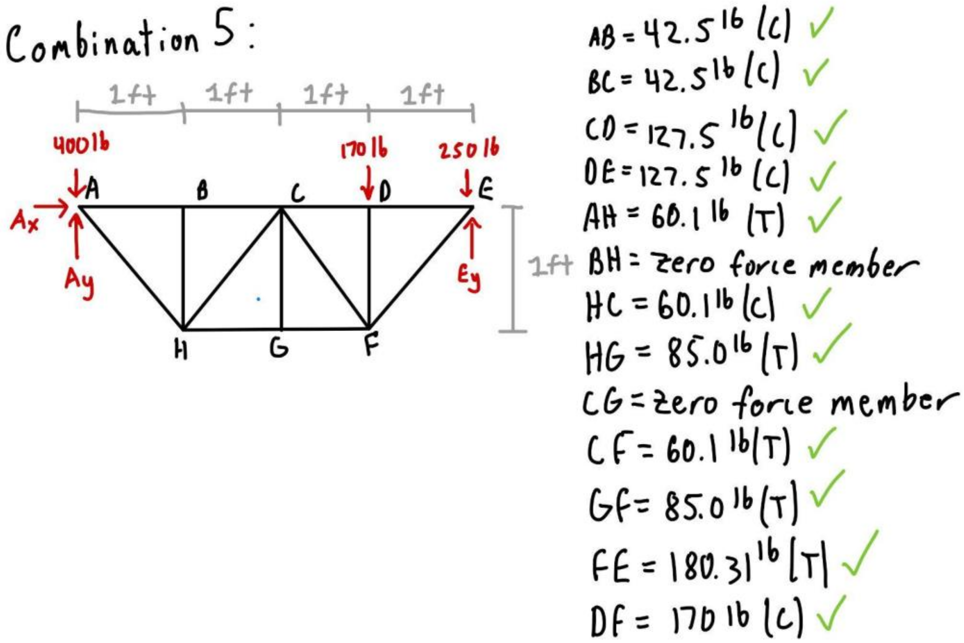



AB = 243 lb (C) ✓
BC = 243 lb (C) ✓
CD = 328 lb (C) ✓
DE = 328 lb (C) ✓
AH = 343 lb (T) ✓
BH = zero force member
HC = 343 lb (C) ✗
HG = 485 lb (T) ✓
CG = zero force member
CF = 223 lb (C) ✗
GF = 485 lb (T) ✓
FE = 463 lb (T) ✓
DF = 170 lb (C) ✓

## Combination 4:




AB = 85 lb (C) ✓
BC = 85 lb (C) ✓
CD = 85 lb (C) ✓
DE = 85 lb (C) ✓
AH = 120 lb (T) ✓
BH = zero force member
HC = 120 lb (C) ✓
HG = 170 lb (T) ✓
CG = zero force member
CF = 120 lb (T) ✓
GF = zero force member
FE = 120 lb (T) ✓
DF = zero force member




*Figures 21-25: Combinations for Applied Loads to Community Truss*

2) Combinations 1, 2, and 3 failed due to compression. In the combination diagrams, a check mark indicates that a specific member did not fail in compression or tension, while a red "X" signifies that the member failed.

3) Combinations 4 and 5 are recommended due to their suitability for the neighborhood layout and their structural integrity, as neither fails under compression or tension. These layouts prioritize accessibility by positioning the building at a support, allowing parking directly in front of the building. This arrangement also ensures easy access to the playground behind the community center and the nearby landscaping area. The primary difference between combinations 4 and 5 is the playground's distance to the community center. In combination 5, the playground is directly behind the community center, eliminating additional walking distance. This makes combination 5 the preferred option, as it allows kids to stay closer to the community center, enabling easier supervision and more convenient access.

## ***Letter to the Community***

Dear Community Members,

I hope this letter finds you well. I would like to share with you an important project aimed at improving our community – capping the interstate.

As it is taught in this community, the construction of the interstate divided our community both physically and socially posing challenges for connectivity and accessibility. The noise pollution, and the invisible barrier created by the highway have worsened our quality of life, thus inhibiting the social and economic growth of our area. Therefore, capping the interstate is more than just a project to me; it is a way of reconnecting our neighborhood and restoring our lost sense of community.

The benefits of capping the interstate are numerous. With the creation of playgrounds, community buildings and landscapes, we envision a vibrant environment for both current residents, and future residents to come. It will not only enhance recreational activities for us, but also promote biodiversity as plants could strive into the area once dominated by concrete. Furthermore, the improved air quality would also significantly elevate the quality of life.

Onto the main reason for this letter – our plan to develop the cap. After collaborating with urban planners and environmental engineers, we concluded that the best step was to create a bridge and, on the bridge, we would build the community building, playground and a landscape. We developed a prototype and took into consideration the weight of each of these and came up with what we think is the best arrangement for the community. We have given a blueprint of our possible combinations to the community elders, and we decided on combination five.

First, we used the fact that we want our playground between the community building and the landscape as we want it as close to the community building as possible, and we also want the children protected from the outside environment thus leading to our plan consisting of five combinations.  Our first three combinations were eliminated as a part of the bridge could fail thus putting the lives of our citizens in danger. Combinations four and five are recommended due to their suitability for the neighborhood layout and their structural integrity, as neither fails. These layouts prioritize accessibility by positioning the building at a support, allowing parking directly in front of the building. This arrangement also ensures easy access to the playground behind the community center and the nearby landscaping area. The primary difference between combinations four and five is the playground's distance to the community center. In combination five, the playground is directly behind the community center, eliminating additional walking distance. This makes combination five the preferred option, as it allows kids to stay closer to the community center, enabling easier supervision and more convenient access.

As expected, construction could initially present some inconveniences such as traffic delays and noises, but we believe the long-term benefits would far outweigh these temporary challenges. In terms of design, the cap would feature mainly natural elements and sustainable materials for seamless blending into our existing landscape. In conclusion, this report outlines our commitment to this project and to this community. We believe this initiative would bring about a positive transformation and deepen our connection as a community. For these reasons, I recommend moving forward with this project collectively, embracing the positive changes it will bring to our home. Thank you so much for your continued support. Together, let us build our brighter future.

Sincerely,
Akinfoluhan and Parker
VU Engineering Students

## ***Conclusion***

In conclusion, this project has shed light on the deep and often overlooked consequences of the Federal-Aid Highway Act of 1956, particularly its impact on underrepresented communities. As a result, we have learned a great deal about how infrastructure may reinforce social injustices.
The design and construction of a steel truss bridge prototype not only served as a practical application of structural engineering principles but also as a humbling reminder of our responsibility as engineers to advocate for inclusive solutions. By applying structural analysis and engaging in hands-on building techniques, we successfully combined theory and practice, while also identifying potential failure mechanisms thus ensuring safety and reliability—a crucial aspect of engineering.

Our efforts to reach out to the affected community highlighted the importance of communication and collaboration with those who are directly impacted by infrastructural decisions. The feedback we received reinforced the necessity for engineers to approach projects with empathy and social awareness, recognizing that our work does not occur in a vacuum and reminding us that we exist for the people's needs. This experience has equipped us with the skills and perspectives needed to promote ethical engineering practices in the future. As we move forward, we will ensure that our contributions reflect the values of inclusivity and resilience. Through the lessons learned in this project, we can aspire to be not just engineers, but advocates for a more connected and just society.

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