the judges were all
left wondering
what BLMM
meant

BLMM Bridges

CE 383S: Prestressed Concrete Bridges

Final Design Project
May 04, 2006

Kimberly Grau
Catherine Hovell
Carrie Marr
Matt O'Callaghan
Peter Range
Daniel Williams

There were certainly a number of positives in your proposal - The Kite Soaring Bridge was original, ambitious, had a very efficient cross section, and obviously was something you wanted to do

However there were a number of glaring deficiencies in report

your cost treatment was very hit and miss - a real hodge podge - you had 900 feet and used 710' in many without including costs of fill and retaining walls

Some included railings - others didn't

Most seriously you did not put in anything for cost of temporary support of Kite Soaring deck during construction. Allowing a 1.5 factor on concrete for pylon was a step in right direction but hardly scratched surface

I was quite bothered by your decision waiting to support the cable stay
It looked unconsidered
solution -- if not unconsidered it was very incomplete

I am quite concerned over stability (and lack of a check of same) on the pylon - $\frac{kl}{r} \to 100$

your drawings of final solution were very faint, small and incomplete, How are stays attached for example - a big problem in real life and not clearly shown.

I was disappointed that with all of the talent in your group, the report had so many rough edges.

The non-technical part of writeup was pretty good but there were just too many technical details left hanging to be a top level report

B

ORAL GROUP B

2 Judges picked 1st or tied for 1st

1 Judge picked 3rd

1 Judge picked 4th

Overall place was 3rd but just a little out of 2nd

Oral Grade A

②

Critiques **CE 383S** **Final Project**

Group B: Carrie Marr
Peter Range
Daniel Williams
Kim Grau
Matt O'Callaghan
Catherine Hovell

Judge: Mark Bloschock

		Points	
		Maximum	**Actual**
1.	Apparent Structural Adequacy	25	21
2.	Consideration of Cost and Constructability	15	~~12~~ 11
3.	Quality of Presentation	15	13
4.	Consideration of Aesthetics	10	10
5.	Consideration of Durability and Maintenance	10	7
6.	Consideration of Environment	8	7
7.	Maintenance of Barton Springs Road Traffic	7	~~5~~ 7
8.	Originality	10	9
	Total	100	85

Comments: what is a "BLMM" bridge?

- Good selection criteria mix
- Good "Keep Austin Weird" theme
- no such thing as "transparent aesthetic railings"
- "won't go into detail due to time constraints" – good comment!
- "units in inches" - good note on slide
- 3-D rendering was very good
- Good points for temporary shoring and traffic control

Critiques CE 383S Final Project

Group B: Carrie Marr
Peter Range
Daniel Williams
Kim Grau
Matt O'Callaghan
Catherine Hovell

Judge: John Breen

		Points Maximum	Points Actual	
1. Apparent Structural Adequacy	SAP Model - Hollow Pylon V good Large abutments - Detail of anchors	25	20	
2. Consideration of Cost and Constructability	Did not include temp steel costs why not precast arch	15	10	
3. Quality of Presentation		15	13	Hi
4. Consideration of Aesthetics		10	10	Very good Nice proportion Nice sketches
5. Consideration of Durability and Maintenance		10	9	
6. Consideration of Environment	V Good	8	8	Very good
7. Maintenance of Barton Springs Road Traffic	In Constructability Negative is support during construction	7	5	
8. Originality		10	10	
Total		100	85	

Comments:

5 alternates			
	Arch	600 K	
	Tree bridge	1.6 M	
	Kite swing	520 K	More maintenance → up to 900 K
	U Box	680	Higher Depth
	I Box	507	Higher Depth

Very intriguing cross section -- very efficient
Pylon very congested steel
Excellent final renderings - Pylon not intrusive on park +
change in cost from prelim to final makes cable stay very expensive
In addition full impact of need to support all
sections of roadway not fully reflected

Critiques **CE 383S** **Final Project**

Group B: Carrie Marr
Peter Range
Daniel Williams
Kim Grau
Matt O'Callaghan
Catherine Hovell

Judge: Alan Matejowsky

		Points	
		Maximum	**Actual**
1.	Apparent Structural Adequacy	25	16
2.	Consideration of Cost and Constructability	15	10.
3.	Quality of Presentation — Did not show complete cross section	15	12.
4.	Consideration of Aesthetics	10	8
5.	Consideration of Durability and Maintenance	10	7
6.	Consideration of Environment	8	6
7.	Maintenance of Barton Springs Road Traffic	7	4
8.	Originality	10	8
	Total	100	71

Comments:

⊕ Site visit - productive
Utility lines noted

Aesthetics discussion

Selection matrix
Aesth 35 %
Cost 30
Construct 20
Durability 15
Good discussion

Self cleaning concrete

Good rendering

Arch multi $600K
Tree bridge - long arch $1.6 M
Single pylon cable stay 575K → 900K
U-Beam 680K
I-Beam 500K

SAP model
⊖ Hollow pylon why hollow? High steel ?
Back stay - expendable
Grouted soil anchors

Stay anchor is problematic ⊖

Conc in compression

⊖ thin members - constructability

Pylon forming - difficult & $
Erect super on falsework - I-beams

Critiques **CE 383S** **Final Project**

Group B: Carrie Marr
Peter Range
Daniel Williams
Kim Grau
Matt O'Callaghan
Catherine Hovell

Judge: Mary Lou Ralls-Newman

	Points **Maximum**	**Actual**
1. Apparent Structural Adequacy	25	15
2. Consideration of Cost and Constructability	15	8
3. Quality of Presentation	15	11
4. Consideration of Aesthetics	10	10
5. Consideration of Durability and Maintenance	10	8
6. Consideration of Environment	8	7
7. Maintenance of Barton Springs Road Traffic	7	3
8. Originality	10	10
Total	100	72

Comments:

- Good slides – outline; plan view of entire location; few words per slide
- Considered power lines, limited ROW due to Nature Center, tree removal, moon tower
- Also good consideration of aesthetics
- Decision matrix for superstructure selection
  - 35% aesthetics – high
  - Argument for selected type (kite swing) was relatively weak
- Good consideration of durability
- Pedestrian traffic not included
- Impact of shoring of superstructure on traffic & costs not included
- Good 3-D superimposed visuals
- Presentation skills – talking to screen

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

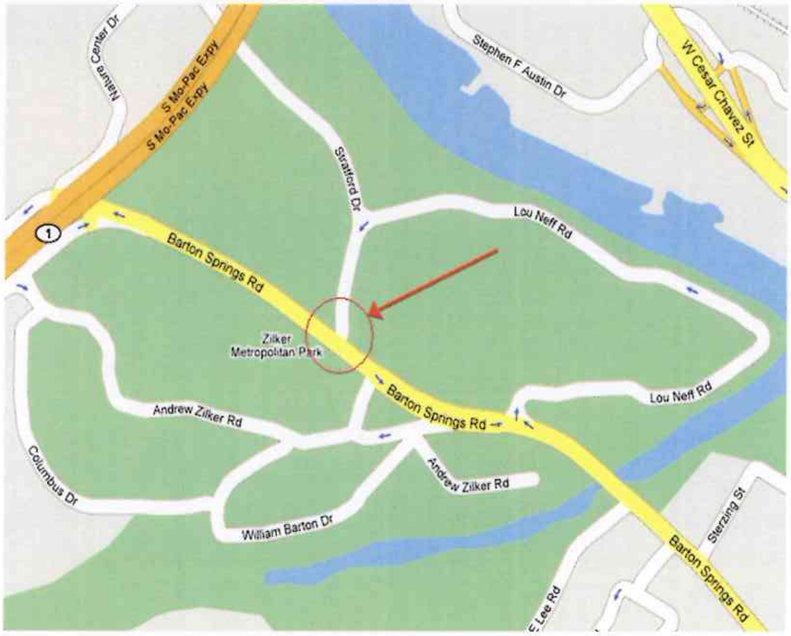
PROJECT SCOPE

Just southwest of downtown Austin lies one of its finest public parks. Zilker Park has hike and bike trails, a public pool, and sports fields that are constantly in use. Every fall, the park is filled with fresh music at the Austin City Limits festival; at Christmas, the park is home to Austin's Trail of Lights and the Zilker Park Christmas Tree; and every spring, one day is spent celebrating the art of kite-making and flying. The park is a place to exercise, to relax, to step away from the hot heat of paved roads.

Good opening

However, much of the beauty of the park is not fully enjoyed by those who use it most often: one of the busiest east-west commuter roads between downtown and MoPac/Loop-1 cuts straight through the park. Barton Springs Road experiences heavy traffic every day of the week, but on a sunny weekend, when the full park adds to the number of cars on the road, merging into traffic can be downright impossible.

Off Barton Springs, between the open playing fields and the botanical gardens lies Stratford Drive, a two-lane road that cuts to the north, accessing the tennis courts and the back soccer fields. A map of intersection of Barton Springs and Stratford Drive is shown in Figure 1.



Good

Figure 1: Intersection of Barton Springs Road and Stratford in Zilker Park (maps.google.com)

INTERSECTION REQUIREMENTS

In an effort to alleviate congestion from left-turning traffic off Stratford Drive onto Barton Springs Road, an overpass is to be built. The off-ramp from Stratford Drive will exit to the right approximately three hundred feet before the existing intersection. The ramp back on to Barton Springs will merge from the right, approximately four hundred feet after the existing intersection. Traffic will travel a curve nearing ninety degrees, from southbound to eastbound. ✓

The ramp needs to accommodate one lane of traffic, adequate shoulders, and a pedestrian walkway. Barton Springs Road, as it passes below, has a height restriction of at least eighteen feet of vertical clearance for all driving lanes. The right-turn lane from Stratford Drive to Barton Springs Road should stay in approximately the same location and also carries the same vertical clearance restrictions as Barton Springs Road. ✓

DESIGN GOALS

A satisfactory design for this location will achieve a variety of goals. Foremost, the bridge must have adequate access for vehicular and pedestrian traffic, thus reducing the congestion problem currently resulting from left-turning vehicles off of Stratford Drive.

Secondly, the design should be attractive and well-suited for the location. Zilker Park is in an environmentally sensitive area, with high visibility to Austin locals and tourists alike. A reasonably higher cost, as compared to a standard Texas Department of Transportation (TxDOT) bridge, is justified by the need for an aesthetically appealing bridge. An increase in cost of between five and ten percent is considered reasonable and acceptable.

this is certainly reasonable and in that site might be increased to 15-20% However much more would be very controversial

In any bridge design, there are standard details that must be regarded. For instance, the impact of the structure on the location, in terms of size, height, and bulk of the girders and piers. Related to that, one must consider the transparency of the structure, or how easily the bridge can disappear into its surroundings.

Fritz Leonhardt, bridge designer and aestheticist, stressed the importance of a high slenderness ratio, or, the span-to-depth ratio of the beams of a bridge. Considering the low height of this bridge, it is important that the beams not be incredibly deep, lest the bridge appear heavy and clumsy. The slenderness ratio should be around twenty. ✓

Therefore the final bridge design sought should be thin, light, and open in order to rest delicately in the large, popular park. The bridge should also compliment the city's character, as it will become a point of interest amidst the many city-wide activities that occur there. ✓

Good

PRELIMINARY DESIGNS

Several preliminary design possibilities were considered and are described here. Basic calculations were made to approximate sizing; this work can be found in Appendix C. Each design is described below and its strengths and weaknesses evaluated in terms of cost, aesthetics, constructability, and maintenance.

TxDOT I-BEAM BRIDGE

The I-Beam Bridge design was inspired by traditional TxDOT bridge design. This design is known for being economical and easy to construct, but relatively unattractive when compared with other bridges.

Preliminary Design

This preliminary design is based on standard TxDOT designs from their bridge division website ("Bridge Standards"). Using the Thirty Foot Roadway Width design guidelines, the foundations would be three three-foot diameter drilled shafts per bent.

One pier sits atop each of the drilled shafts. The columns tie together with a standard bent cap, dimensioned at 3'6"by 3'3" by 30'.

Four AASHTO Type IV girders per span rest on each bent cap. Each span excluding the central one would be one hundred feet long. The main span would be one hundred ten feet to accommodate the height and curvature requirements at the site. The deck would be a ten inch thick deck with barriers on the sides, as well as between the pedestrian and traffic lanes.

Since these are standard TxDOT sections, very little further analysis was done to check all loading conditions. It was assumed that these standard sections would support any and all loads that in-use prestressed I-beam bridges are currently supporting.

Design Considerations

Aesthetics

This bridge was not designed to be the most appealing bridge among all the styles of bridges that were investigated. There would be little to no consideration for aesthetics, as cost is the driving factor behind this design.

Cost

To achieve the lowest cost, the TxDOT I-Beam Bridge uses prefabricated elements, which reduces on-site labor and material costs. Precast I-beams can be manufactured in mass production, using standard forms, concrete mixes, and rebar cages.

Labor expenses are a substantial portion of any construction job, so minimizing this is crucial in limiting total cost. Using very few cast-in-place members means less on-site forming, which decreases the amount of labor needed.

The total preliminary estimate of cost for this bridge is $515,351. The details of the cost estimate calculation are in Table 1, and are based off the standard costs provided.

Table 1: Cost estimates for the I-Beam Bridge

Design Detail	Composition	Cost
Type IV Girders	576 cy Prestressed Concrete	$172,764
Columns	72 cy Reinforced CIP Concrete	$24,887
Slab	561 cy Reinforced CIP Concrete	$210,370
Bent Caps	78 cy Reinforced Concrete	$28,440
Foundations	156 cy Drilled Shafts	$59,887
Abutments	40 cy, Reinforced CIP Concrete	$19,003
Total		**$515,351**

Railing Cost?

✓ $515,351 / 900 × 32 ≃ $18/sf

Constructability

Since the TxDOT I-Beam Bridge is designed from TxDOT standards, most local contractors have experience in building similar bridges. As such, most already own the correct equipment necessary for the project, and are familiar with the quality expected. Familiarity with the design should also allow the project to move at a faster pace, minimizing disruption to the park and the costs of the workers and contractors. ✓

Maintenance

The TxDOT I-Beam Bridge should require very little maintenance. Regular inspections should occur to check for cracking, so that corrosion does not deteriorate the condition of the bridge. The wearing surface will eventually have to be replaced, but this is true of all bridges considered. ✓

Advantages and Disadvantages

The advantages of using a standard TxDOT bridge focus on familiarity with the structure: it is easier and cheaper to build a bridge in the same form as hundreds that have come before. This standard bridge would be cheaper and easier to build than one with a unique design. ✓

The low final cost estimate of the TxDOT I-Beam Bridge is due mainly to the use of standard precast segments, which are comparatively cheap to construct at a precasting yard, and reduce the on-site time and work required. A shorter construction period impacts the surrounding traffic and community less. ✓

A simple bridge like this also has the advantage of low maintenance demands. Unlike many steel or cable-stayed bridge designs, the frequency of inspection in low. Considering the cost of the inspections, this will reduce the long-term upkeep prices of this bridge. ✓

However, the drawback of this design is the appearance. There are multiple columns at each bent, giving the idea from some angles of a wall of columns underneath the bridge.

I Bm can be done with single piece bent cap

There is no figure with this bridge in text?

Additionally, the girders are plain and the bridge would look like the majority of other overpasses across the state of Texas.

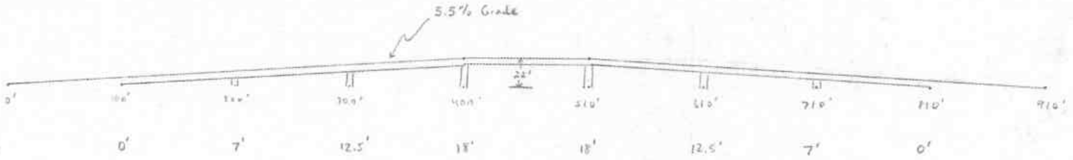
Since this bridge is in a visible area the aesthetic value of the bridge is very important. While the cost of the TxDOT I-Beam Bridge may be low, some of the other designs that were investigated can greatly improve the aesthetics of the bridge without increasing the cost beyond a reasonable amount.

TXDOT U-BEAM BRIDGE

This design consists of a standard U-beam bridge with some aesthetic enhancements. The additions are based on local themes such as the Zilker Park Kite Festival and the expansive soccer fields next to the roadway.

Preliminary Design

The TxDOT U-Beam Bridge is divided into six spans of one hundred feet each and one span of one hundred ten feet, as shown in Figure 2. Each span consists of three TxDOT U40 beams. The maximum height at the center span is twenty-two feet, resulting in a maximum grade of 5%.



400' ~ 300' bridge plus 100' approach fill — where is this in your costs

Figure 2: TxDOT U-Beam Bridge span layout

If you cut bridge length to 700' OK but you need another 200' fill – at face and causes problems w/other lanes would need retaining walls etc

Each bent cap is supported by one column. The columns have a diameter of five feet and range in height from four to fifteen feet. A typical pier with beams is sketched in Figure 3. The base of each column is covered with rugged mosaic tiles depicting local popular park events, such as the Kite Festival.

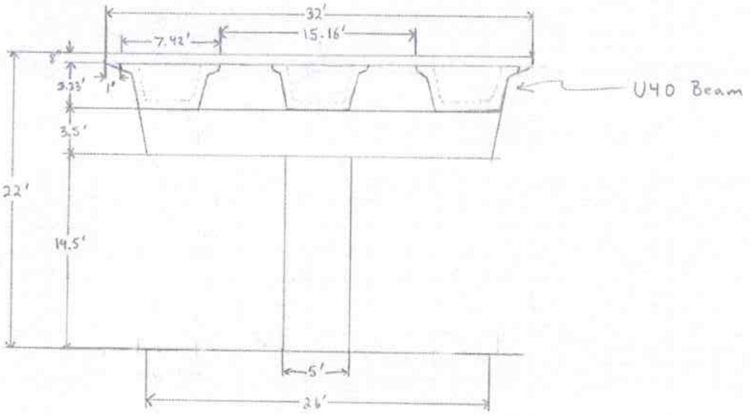


Figure 3: Pier and beam geometry of the TxDOT U-Beam Bridge

The railing also has aesthetic enhancements depicting local themes. This design is very economical, constructible, and durable, due to use of common structural elements.

Design Considerations

Aesthetics

As illustrated in Figure 4, the base of each column is covered with rugged mosaic tiles depicting local popular park events such as the kite festival. In addition, the railing also has aesthetic enhancements depicting local themes. Lighting would be utilized to make the columns visible at night.

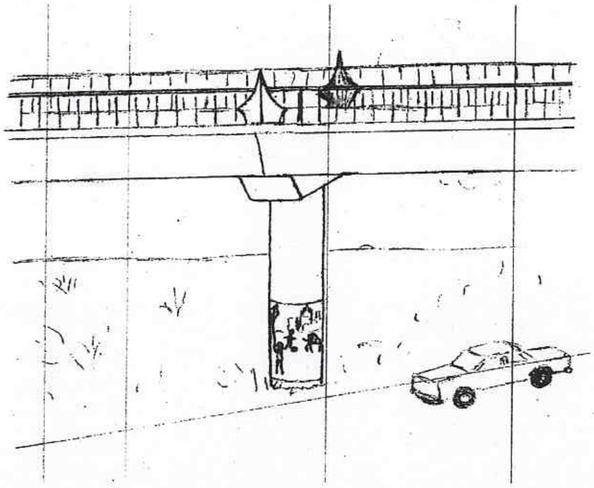


Figure 4: Piers of U-Beam bridge, with mosaic tiling on the columns

Interesting concept

Cost

The design is very economical with its use of very common structural elements and simple construction. The division of costs is presented in Table 2. These costs do not include the mosaic tile, lighting, or the use of aesthetic aggregates. The preliminary cost of the TxDOT U-Beam Bridge is $473,800.

Table 2: Division of costs for TxDOT U-Beam Bridge

Design Detail	Composition	Cost
Columns	54.5 cy, Reinforced Concrete	$20,400
U40 Beams	536.9 cy, Prestressed Concrete (GR 8)	$161,100
Slab	719 cy, Combination Reinforced Concrete and Prestressed Concrete	$242,700
Abutments	272 cy, Reinforced CIP Concrete	$10,200
Bents	105 cy Reinforced CIP Concrete	$39,400
Total		**$473,800**

$\frac{473{,}800}{900 \times 32} = 16.45$

Railing cost?
Foundation cost

Cost of mosaic tiling?

Constructability

The construction would be straight-forward, as each span is simply supported. The construction of the main span would be the most difficult, but could be done in one night, which would minimize disruption to disruption. Using prestressed sections will reduce

Included in Table

the amount of on-site construction time necessary and using standard shapes removes the need for specially designed and built formwork.

Maintenance

The rugged tile mosaics would require limited maintenance and use of lighting would help to prevent vandalism and subsequent clean-up. With no exposed structural steel, the U-Beam Bridge would be very durable. With an adequate drainage system, the concrete should stay free from major staining, although dirt and animal debris will accumulate. The basic maintenance level of cleaning debris will be similar for all bridges.

If designed correctly, considering for typical load cases and long-term stress-change effects, the prestressed U-Beams should keep their strength and require little repair. As a precaution, post-tensioning ducts could be installed, but the tendons not fully stressed, so as to leave a way to re-stress the girders without destruction of the bridge, if a problem were to occur in the future.

Advantages and Disadvantages

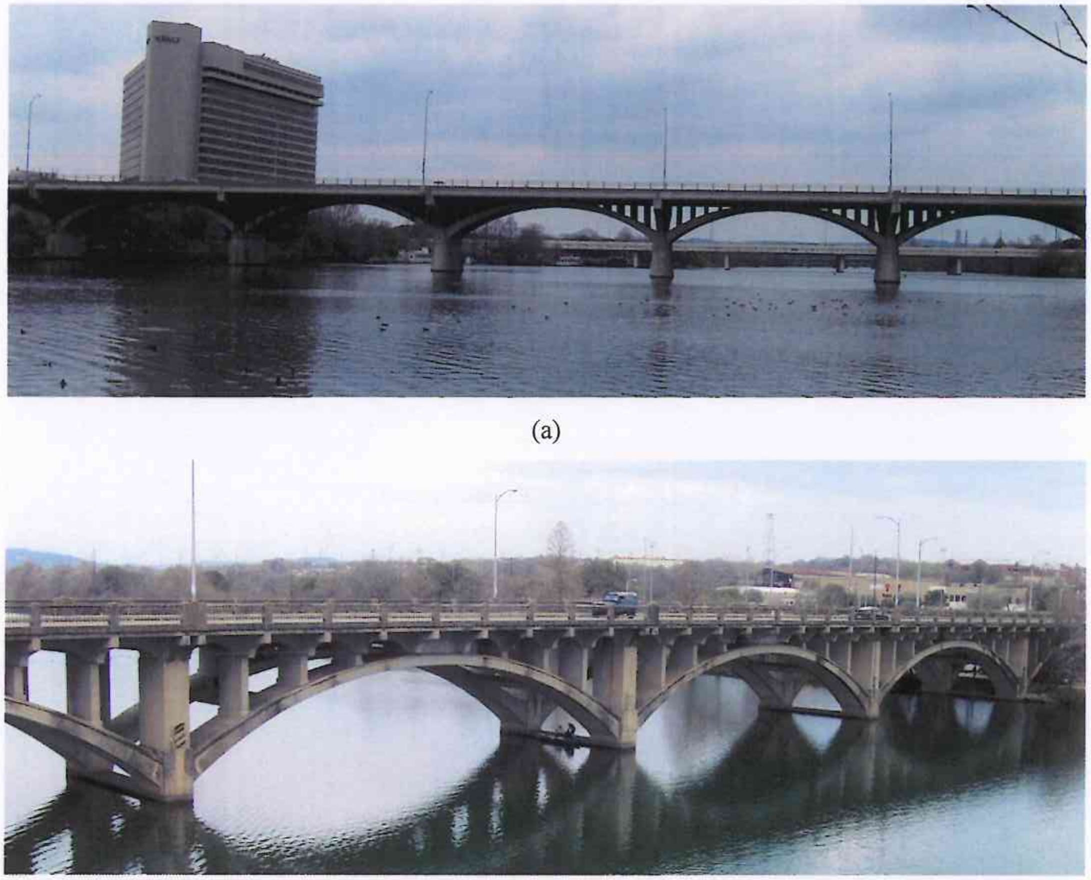
The advantages of this design are the very low cost per square foot due to the use of U40 beams and cast-in-place columns. Construction would also be comparatively easy, as each span is simply supported. The main span could be constructed quickly, with very little disruption of traffic.

The simple design of the TxDOT U-Beam Bridge integrated well with the park by not rising too high or overshadowing the surrounding areas. The mosaics on the columns give a more human scale to their appearance, and would require little maintenance.

The downside of the U-Beam Bridge design is in its lack of attractiveness or uniqueness. Despite the aesthetic touches, the overall design is close to a standard TxDOT prestressed U-beam bridge. Additionally, the bridge does not display a very high level of complexity or originality.

ARCH BRIDGE

The Arch Bridge design is inspired by the graceful appearances of the Lamar Street and Congress Avenue arch bridges, as shown in Figure 5. While both bridges pictured appear light and have relatively high levels of transparency, the arch style of the Lamar Street Bridge was selected for its lower profile, which seemed more appropriate for a park setting. Basing the bridge design on an existing Austin bridge was thought to provide continuity by tying the bridge design to distinctive architectural styles of the city.


(a)

(b)

Figure 5: (a) Congress Avenue Bridge, (b) Lamar Street Bridge

✓

2(100 + 150) + 200 = 700' of bridge

Preliminary Design

The Arch Bridge design is laid out with the goals of forming an open, well-proportioned structure. The chosen design uses five symmetric arches, increasing from one hundred feet long and twelve and one half feet high at the smallest, outside arches to one hundred and fifty feet long and eighteen and three quarters feet high, to two hundred feet long and twenty-five feet high for the center span. The spandrels are evenly spaced at twenty-five feet: with each shorter span, one spandrel is removed on either side of the center of the arch. A sketch of the bridge is shown in Figure 6. ✓ ✓ ✓

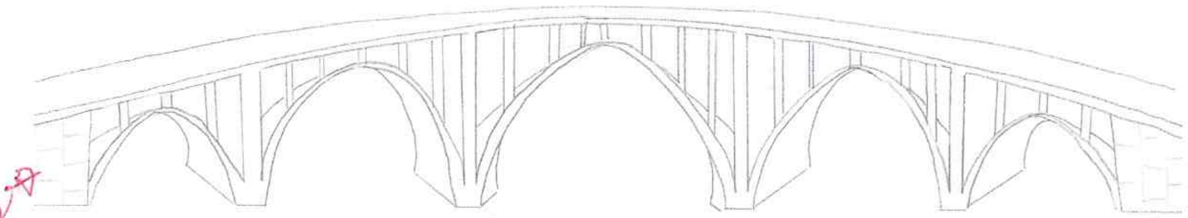

✓

Figure 6: Arch Bridge preliminary sketch

where is cost of this 100' of fill and retaining wall

Arches are tricky to build on a horizontal curve - this is a negative factor

Hard to understand why if a 110' span worked for [illegible] it has to go to 200' for each - this is what drives up cost

In an attempt to avoid a sea of columns beneath the arch, and to allow for a sturdy appearance, the supporting piers and spandrels were designed as solid walls, rather than traditional columns. The depth of these support walls would be twenty-eight feet, leaving a two foot overhang of the deck on either side of the superstructure. The width of the spandrels would be one foot, and the piers two feet. By bringing adjacent arches down into one single foundation, the majority of the shear forces balance each other and the resultant force would be small and easily carried by anchor bolts.

The arch itself follows the funicular shape for a distributed load in order to be in compression at all locations and thus avoid putting the concrete into tension. As the arch nears the center point, it narrows, both because there is less load on it at that point, and to create a slimmer appearance of the roadway-and-arch juncture that would occur.

The excellent limestone rock base available at the location and the efficient design of the superstructure make for a simple foundation design. Beneath the four main pier-walls are spread footings, extending two feet beyond the footprint of the wall in all directions. The foundation sits at least one foot below the finished grade, and extends two feet in depth. Shear forces are resisted with anchor bolts drilled and epoxied into the bedrock.

The outside ends of the two smallest arches land in solid abutments at the front of the approaches. The sides of the approach ramps use textured precast panels and reinforced earth. The weight of the earth and the roadway above provide the resistance needed from the outward push of the arch.

The railing is designed to be open and light, and to match the arches below. A solid, heavy railing would clash with the light- and openness of the structure, and would reduce the apparent span-to-depth ratio.

Design Consideration

Aesthetics

As mentioned previously, the main inspiration for this bridge design is its attractive appearance. Since the bridge under consideration is to be constructed in a popular and highly used public parkland, an attractive bridge with wide appeal is desired. In the preliminary design, a constant span-to-depth ratio is used for all of the arches to give continuity to the bridge across all five spans.

Cost

Due to the open spandrel design and utilization of the compressive strength of concrete, the arch design offers a competitive cost for construction. Using estimated concrete volumes and the cost data provided (reproduced in Appendix E), the Arch Bridge superstructure would cost approximately $600,000. With the finalization of plans and addition of substructure and abutment details, the cost would increase. Preliminary total estimates put the project price at just over $831,000. The cost breakdown is presented in Table 3.

Much less than 59k in Table 1! Arch would seem to need more. Probably way too low for a cip arch because you do not consider falsework costs

Table 3: Cost estimates for the Arch Bridge

Design Detail	Composition	Cost
Columns and Deck	1600 cy Reinforced CIP Concrete	$600,000
Foundations	450 lb Steel Anchor Bolts 45 cy Reinforced CIP Concrete	$19,125
Abutments	15 cy Precast Reinforced Concrete	$5,850
Railing	2750 ft	$206,300
Total		**$831,275**

you have 200' of approaches to bring in fill and retaining walls

Containing abutments in end span for arch would cost more 99k in Table 1!

I note that no railing cost included in previous 2 bridges

Constructability

Due to the cast-in-place construction required by this design, this bridge would require more concrete work in the field than the typical TxDOT bridge, which uses precast beams and deck panels. A more detailed design could explore using precast segments to construct the arches, piers, and deck panels, which would decrease on-site construction time, but perhaps increase the cost.

wo

Usually precasting will decrease costs as well because of drastic reduction in formwork costs that account for 30-40% of all r.c. costs

For the cast-in-place design, the necessary manual labor was reduced by repeating shapes, such as the uniform spandrels and scaled arches. This repetition allows the reuse of formwork throughout the project.

The main construction concern would be in disruption of traffic on Barton Springs Road and the right turn lane of Stratford Lane during overhead construction.

For how long? I imagine quite long

Maintenance

Durability requirements are not deemed to be particularly high for a bridge in a park in Central Texas. There is no sea spray present, deicing salts are rarely used, and there are no significant freeze-thaw cycles. Maintenance focuses largely on the removal of graffiti. Wide walls of smooth concrete could prove too great a temptation for graffiti artists. Adding a textured surface, through the use of form liners, could reduce the likelihood of graffiti. Alternatively, a paint of titanium dioxide could be applied to the concrete, essentially making the material self-cleaning. The titanium dioxide acts as a catalyst in the presence of ultraviolet rays in sunlight to break down organic compounds so that they wash away easily.

Advantages and Disadvantages

An arch bridge uses concrete quite efficiently, as the material is almost entirely in compression. Using an open-spandrel bridge reduces the amount of concrete needed, and lightens the entire structure in appearance and load.

But greatly lengthening spans is not very efficient – making a 130' span into a 200' span greatly increases costs

The pier-walls are solid, however, a detail which results in a structure that is not necessarily very transparent. Especially from close to the side of the bridge, the bridge would look entirely solid, not light and graceful as it appears from the circle it is forming.

By using a constant-width columns and span-to-depth ratio of the arches, this design has maximized the reuse of forms. Considering that the bridge would be mainly cast-in-place concrete, this will save time and manpower during construction.

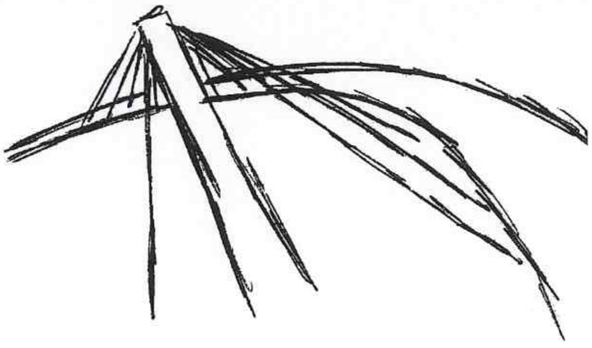
The nature of cast-in-place concrete design requires much higher manpower on-site, and a longer and more disruptive construction schedule than a design using precast girders or segmental sections. Specifically, crossing Barton Springs Road could take significant amounts of time, requiring the closing of the roadway for possibly more than just a few nights. Considering the heavy traffic volume, this is not a favorable scenario.

This design not only blends easily with the surrounding park, staying below the tree lines and allowing for pedestrian, bike, and vehicular traffic on, around, and below it, but also matches other bridges in the city. Specifically, the design was based off the nearby Lamar Street and Congress Avenue bridges, which are both open-spandrel arch designs. This connection ties this bridge back to the local downtown and the associated personality of the city.

KITE BRIDGE

General Description

The goal of the Kite Swing Bridge is to remove traditional column bridge supports to make the bridge appear thin and light. A reinforced concrete pylon uses cable stays to fully support precast concrete superstructure segments. This configuration will provide a sleek, slender bridge that will also introduce a unique "signature bridge" to the frequently-visited Zilker Park. A sketch of this bridge is shown in Figure 7.



Very sketchy but catchy

Figure 7: Sketch of the Kite Swing Bridge

Preliminary Design

The centerline of the bridge will follow the geometry shown in Figure 8. A single two-hundred foot tall reinforced concrete pylon is located at the northeast corner of the Barton Springs and Stratford Lane intersection. This one pylon will be located close to the horizontal radius of curvature of the superstructure. The pylon will be angled at 21.8 degrees to the vertical, away from the superstructure, and tied to the ground using a vertical back stay.

wow! that's a 20 story building!

Total length is 200+200+295 = 695'

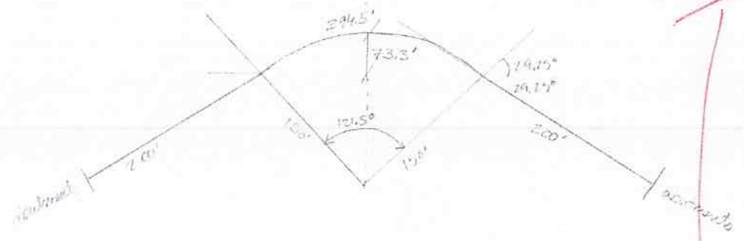


Figure 8: Kite Bridge geometry

Need much heavier live weights and ~~the~~ more lengthe facts

They pylon and cables will provide the entire vertical support for the bridge, and the angle of the pylon and the presence of the back stay will minimize the live load moment that will otherwise exist in the pylon. The large horizontal force components will be transferred through the horizontal arch created by the superstructure in plan view to the abutments. Sketches of the preliminary structural design can be seen in Figure 9 and Figure 10.

Pier sketch is far too small to show travel clearance geometry

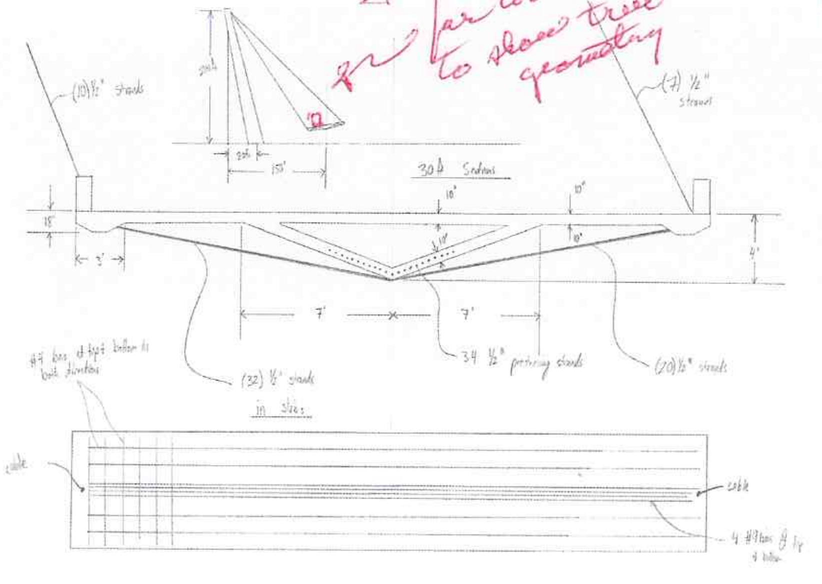


Figure 9: Kite Swing Bridge preliminary superstructure geometry design

With around 120' across needed at min vert clearance how do you get 18' + 4' = 22' up in $\frac{(695-120)}{2} \approx 288'$

That's over an 8% grade

You do not have any costs for approach fills, retaining walls, etc.

way too small and faint

can't read dimensions here

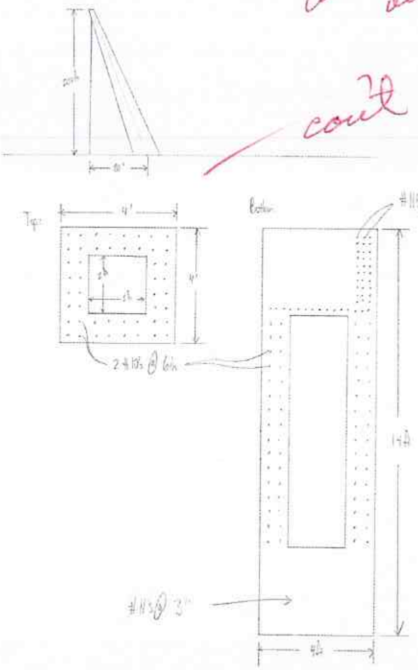


Figure 10: Kite Swing Bridge preliminary pylon design

✓

Costs for temporary supports

The preliminary total cost of the pylon, cables, and substructure is $587,126. A breakdown of this estimate can be seen in Table 4.

Table 4: Cost estimates for the Kite Swing Bridge

Design Detail	Composition	Cost
Superstructure	25 – 47.5 cy Precast Prestressed Concrete Sections	$356,400
Cables	83,287 lb	$125,000
Pylon	175.5 cy Reinforced Concrete	$98,726
Columns	19 cy Reinforced Concrete	$7,000
Total		**$587,126**

Foundations
abutments
Railings
Earth work
Not included

Railing?

Design Considerations

Aesthetics

Special attention was devoted to the aesthetic qualities of this design. In order to provide a sleek, slender bridge, all columns were removed and the vertical forces are carried entirely by the cable stays and the pylon. In addition, the cross-section of the prefabricated superstructure elements is designed as a truss to efficiently use materials. This cross-section reduces the real and apparent depth of the superstructure. The results is a design that is sleek and slender, while maintaining the goal of "keeping Austin weird."

These cost estimates in tables are too uneven to give any reasonable basis for cost comparisons

Cost

As mentioned, the structural system of the Kite Swing Bridge is very efficient. Almost all concrete members are in compression, and all members in tension utilize steel cables. Thus, material costs have been minimized.

The estimated total cost of the bridge was found using suggested standard values. However, these estimates were based simply on the gross per unit material costs. Because the pylon proposed for this bridge is very inclined (21.8 degrees to the vertical), the unit costs were increased by 50%, rather than the 25% suggested in the guidelines. ✓ good

Constructability

The complex structural configuration of the Kite Swing Bridge design requires a complex construction sequence, as the vertical support provided by the cable stays is directly dependent on the ability of the superstructure to redirect the horizontal stay forces through the horizontal arch. Therefore, the superstructure sections cannot be hung from the pylons unless the full arch created by the superstructure is in place. ✓

Because the bridge is relatively short for a cable stay bridge, the hanging of the superstructure will be completed most cheaply and efficiently in one stage. I-beams and other temporary falsework will need to be constructed across Barton Springs and along the entire length of the bridge. The precast superstructure segments will be supported on the falsework while the cables are suspended. Once all cables are in place, the formwork would be systematically removed to transfer the horizontal forces from the cable stays to the arch of the superstructure. The vertical component of the cable stays will bend the decks back up, but the initial downward stressing will help to minimize cracking. ✓ costs ?? ✓

Maintenance

The Kite Swing Bridge will have the advantage that almost all the concrete members will be in compression, which reduces cracking and helps prevent reinforcing bar corrosion. As with any cable stay bridge, however, increased attention will need to be placed on maintaining the cable stays. The cables will need to be inspected and replaced periodically. In addition, the stress levels in the concrete superstructure will need to be checked regularly to ensure against cracking. Post-tensioning may be required over time to help prevent cracking, and the precast superstructure should be constructed with additional post-tensioning ducts to allow for supplementary cables. ✓ Good ✓

Advantages and Disadvantages

The slender lines of the pylon, cables, and bridge sections evolve into a light, modern, non-traditional structure. Thus, the bridge will be aesthetically beautiful and unique, helping to "keep Austin weird." The precast superstructure elements and hollow pylon efficiently use materials and structural shapes to reduce material costs. The nature of the design keeps the concrete sections in compression, minimizing cracking and reinforcing bar corrosion. ✓ Good ✓

certainly not true of pylon in case something happens to back stay

Although this bridge is beautiful and efficient, it has its flaws. For one, although its cost is comparable with more basic designs, the Kite Swing Bridge is more expensive than a standard TxDOT prestressed concrete bridge. As mentioned above, special attention will

you never show a really good view to judge aesthetics

Something substantial should have been added to your selection cost matrix

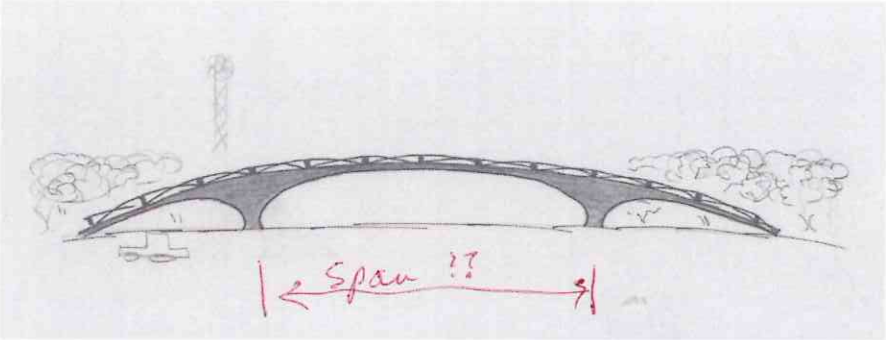
But you need get these into your selection decision making

have to be given to the construction sequence of the bridge, which will likely add time and cost to the construction. The decks in each superstructure section will need post-tensioning downward prior to hanging the section to reduce the bending moments in the deck from the vertical force components in the cable stays. Because of the dependence on the compressive strength of the superstructure, the entire horizontal arch will likely have to be supported temporarily and then hung at the same time.

Additionally, this bridge will require more frequent inspections to ensure the integrity of the stays and the post-tensioning in the segments.

TREE BRIDGE

Zilker Park and much of Austin is filled with live oak trees that are low with twisted and curved trunks. These live oaks are the inspiration for the Tree Bridge. Two large, curvilinear trunk-like columns are the primary supports that grow into the bridge, as shown in Figure 11. The bridge is playful, a with decorative railing and a bark-like surface texture. ✓



✓

Figure 11: Sketch of the Tree Bridge, from the northeast

Preliminary Design

The bridge design has three simply supported spans with varying cross-sections. Detailed preliminary calculations and sketches are shown in Appendix C. Because of the unique geometry, three sections were studied for bending and torsion: the column centerline, the midspan, and the quarter point, which was assumed critical in torsion.

The bridge geometry is the same as for the Kite Swing Bridge, and is shown in Figure 8, where the column centerlines are located two hundred feet from each abutment wall. Clearance over Barton Springs Road is eighteen feet.

Design Considerations

Aesthetics

Aesthetic considerations weigh heavily on the design. The bridge is intended to have a thin slab on heavy columns so it appears anchored and stable. Its organic curves follow the shape of the bending forces for efficient use of concrete. Balance is suggested by symmetry from the view of the soccer fields.

wow

Cost

The preliminary cost estimate is $1.6 million. This estimate is based entirely from the volume of cast-in-place reinforced concrete that will be required in the columns, deck, and foundations, totaling over four thousand cubic yards.

The cost is high because of the large volume of concrete necessary and the time and money demands of cast-in-place structures. A more open design would lessen the former problem; more repetition in the design would lessen the latter.

Constructability

The bridge would be entirely cast-in-place because of its unique geometry. This would make construction labor-intensive, as formwork construction and rebar placement take large amounts of time.

The most difficult section to construct crosses Barton Springs Road. Overhead work would require temporary road closures, as the formwork requires significant shoring during casting and until concrete is cured. It would be worthwhile to spend extra time designing formwork and rebar cages that could be assembled elsewhere in the construction site and then simply lifted into place across the road, ready to pour concrete.

Maintenance

Minimal maintenance is required; primarily visual inspection and deck surface re-sealing. The large expanses of concrete may encourage graffiti artists to leave their mark, requiring removal and leaving unattractive staining. Significant lighting in the area could deter would-be vandals, but might detract from the natural atmosphere in the park.

Advantages and Disadvantages

The Tree Bridge is aesthetically pleasing because of its unique shape, graceful curves, and light railing. Clean lines stay within the tree line of the park, leaving an open sky. The simplicity of the bridge is ideal for a park as it does not distract or interfere with the natural surroundings.

The high preliminary cost estimate is a result of the large volume of concrete and steel required for bending. This design does not use concrete efficiently, with many sections in tension. Unique bridge geometry requires labor intensive design and construction, affecting the overall cost and leaving room for construction errors.

SELECTION PROCESS

The preliminary designs were compiled and evaluated by the individual team members using a decision matrix based on the major criteria of aesthetics, cost, constructability, and durability. Explanations of the importance factoring for each category are given below.

SELECTION CRITERIA

Aesthetics

The aesthetics criteria considers the proportions, order, texture, color, complexity, artistic shaping, harmony with the environment, and character of the bridge. Thought was first given to scoring each category individually, but the group decided it was better to provide one score with all the subcategories in mind. Providing one overall score better represented how well the designer had incorporated and melded together all of the aesthetics aspects into one cohesive design. ✓

Due to the sensitive location, aesthetics were given the highest percentage weight, 35% of the total score.

Cost

The preliminary costs were calculated using the estimates given in the project statement and reproduced in Appendix E. Thought was given to how each structural component was manufactured and constructed to most accurately predict final construction costs. Ranking was based on the bridge costs relative to the standard TxDOT I-Beam Bridge.

Cost was weighted on a scale of $500,000 to $2,000,000 with a rating of ten applied to the low end and one for the high end. Preliminary costs were proportionally rated on that scale.

too low

As the bridge is a publicly funded project, cost was determined to have the next highest weight at 30% of the total score.

Constructability

For constructability, the primary focus was on reducing the impact to the surrounding park and roadways while keeping the costs low. Bridges which required more in-place formwork scored lower on constructability, as the work will impact the park and roadways the most. Standard sections and segmental designs scored higher as they would have less of an impact. The standard designs also scored high due to their very simple construction requiring the least amount of skilled labor.

Due to the impact on cost and time, constructability was weighted at 20%.

Durability

The main factors influencing durability were the amount of exposed steel, the type of post tensioning system, if any, and the detailing. The bridges with no exposed steel and only prestressed or mild steel scored well, as little long-term maintenance would be required for the structure. The use of mosaics or extremely detailed features decreased the overall durability.

Considering that most of the bridges have similar maintenance and inspection requirements, durability was given the lowest percent weight, at 15%.

SELECTION CRITERIA DECISION MATRIX

The decision matrix for the various preliminary designs is presented in Table 5. Each of the individual votes are tabulated, averaged, and multiplied by the weight percentage. The cost estimates do not include substructure, abutment, and railing costs, as these would be comparable on each bridge. Too high

Too low

Not realistic these are very constructable

Table 5: Selection criteria decision matrix

Type	Cost Est.		Aesthetics	Cost Rating	Construct.	Durability	Total	Final Rank
		Weight	35%	30%	20%	15%	100%	
TxDOT I-Beam	$507k	Votes	4,3,2,2,3,2	9	8,6,10,10,9,10	8,6,9,9,7,7		4
		Vote Avg.	2.667	9.000	8.833	7.667		
		Weighted Avg.	0.933	2.700	1.767	1.150	6.550	
TxDOT U-Beam	$470k	Votes	5,3,5,5,4,6	9	8,5,9,10,9,10	7,6,7,9,7,8		2
		Vote Avg.	4.667	9.000	8.500	7.333		
		Weighted Avg.	1.633	2.700	1.700	1.100	7.133	
Arch	$600k	Votes	7,8,4,5,9,8	8	5,7,7,6,7,5	6,5,9,9,8,7		3
		Vote Avg.	6.833	8.000	6.167	7.333		
		Weighted Avg.	2.392	2.400	1.233	1.100	7.125	
Tree	$1.6mil	Votes	7,7,6,9,7,8	3	5,7,5,6,6,6	5,5,9,7,6,7		5
		Vote Avg.	7.333	3.000	5.833	6.500		
		Weighted Avg.	2.567	0.900	1.167	0.975	5.608	
Kite Swing	$570k	Votes	10,8,9,9,9,10	8	9,7,8,8,7,7	4,6,5,7,7,6		1
		Vote Avg.	9.167	8.000	7.667	5.833		
		Weighted Avg.	3.208	2.400	1.533	0.875	8.016	

515 on pt w/o railing and 200' of approaches w/o railing foundation approaches

$900k pc-8 says

$831k p12 says

much too high

Not realistic - this is extremely complex to build

The decision matrix resulted in the Kite Swing Bridge being the best option, followed by the TxDOT U-Beam and the Arch Bridges. The TxDOT I-Beam and Tree Bridges fell far behind.

There was short debate over the final selected design, whether the Kite Swing Bridge would be too much for the site. An informal oral survey of friends and park-users confirmed that the group consensus that it was a unique and interesting bridge, perhaps perfect for the city of Austin's personality, and the project moved forward with that design.

this is a pretty ridiculous figure even at this stage you knew from P18 that added cost was needed due to complexity but you have it in same range as I and U beam bridge - I find this upsetting

Selected Design

Using the criteria described above, the Kite Swing Bridge was selected for further development. Because this bridge is very slender and sleek, and because it provides a modern appearance, it has several desirable aesthetic traits that fit with the personality of Austin. Moreover, its efficient use of materials reduces costs lower than or competitive with all other options considered.

STRUCTURAL DETAILS

The final design varied little from the preliminary design described earlier. The most significant changes involved shortening the length of the suspended bridge and increasing the length of the approaches. This change decreased the estimated cost of the superstructure by reducing the number of prefabricated superstructure elements that will be needed.

An AutoCAD rendering of the bridge is shown in Figure 12, and further sketches of the design are in Appendix A.

Figure 12: AutoCAD rendering of the Kite Swing Bridge in Zilker Park

Superstructure

A single hollow pylon sits near the center of curvature of the superstructure. Cable stays carry the vertical loads from the superstructure back to the pylon. In order to decrease the live load moments in the pylon, it is angled at 21.8 degrees to the vertical. A back stay is provided for redundancy. The horizontal forces in the cable stays are redirected the compressive forces in the horizontal arch created by the superstructure sections. These compressive forces are then resisted by the abutments.

Design of abutments for these thrusts? I can't find any calcs, sketches or realistic costs

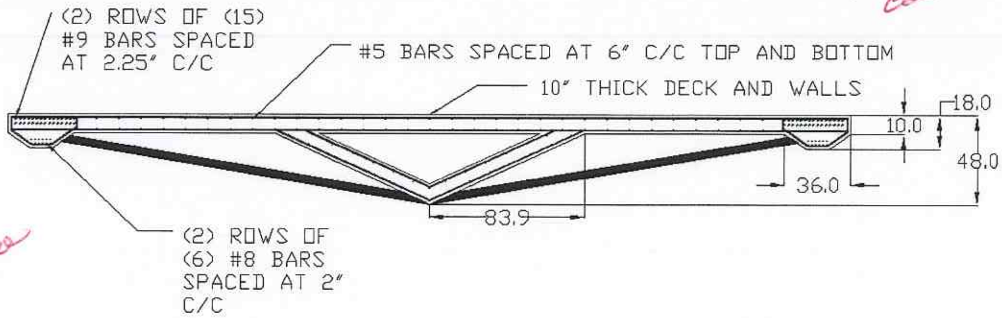
Each superstructure section is designed as a truss to minimize material weight and consumption. Only the portions of the superstructure that are under compression are constructed with concrete. The bottom chords of the truss utilize steel cables, as they are in tension. This minimizes the weight of each section by removing concrete that would

✓

crack and thus provide no stiffness. The cross-section of the superstructure elements can be seen in Figure 13.

How are cables attached?

How was this segment analyzed? where are the cables connected



what is nature of joint between segments

Figure 13: Superstructure standard segment cross-section

The concrete located horizontally between the cable stay connections requires significant steel reinforcement to resist the compressive forces in the top chord. This additional reinforcement and all structural details in the superstructure elements can be seen in Appendices A and B.

Not very many details

I could not find drawing of cable connection or cross section with pylons cables and deck to show clearance for trucks, etc so they don't come near cables

Load Cases

The Kite Swing Bridge is designed for AASHTO Strength I loading, tabulated in AASHTO LRFD Table 3.4.1-1 and below in Table 6. The table presents the load factors used for dead load, topping load, live (lane) loads, and dynamic loads (with impact factor).

Table 6: AASHTO Strength I load factors

Description	I.D.	Load Factor
Dead weight structural components	DW	1.25
Wearing Surfaces	DC	1.50
Live Load	LL	1.75
Dynamic Load Allowance	IM	1.33

The wind and seismic loads were not accounted for in this design, as Strength I is a basic load combination without wind and earthquake effects. While Strength I loading controlled the design of the Kite Swing Bridge, the bridge was also checked under Strength V (with wind) loading. This load combination was investigated using the same model as in Strength I. The load factors for this combination are shown in Table 7. ✓

Table 7: AASHTO Strength V load factors

Description	I.D.	Load Factor
Dead weight structural components	DW	1.25
Wearing Surfaces	DC	1.50
Live Load	LL	1.35
Dynamic Load Allowance	IM	1.33
Wind Load on Structure	WS	0.40
Wind Load on Vehicles	WL	1.00

No check of pylon stability
kl/r ≤ 100
WOW!

The bridge loads were modified using the Multiple Presence Factors in AASHTO LRFD Table 3.6.1.1.2-1 and in Table 8. While the intention is for the bridge to have only one loaded vehicular lane and one pedestrian lane, a multiple presence factor for three lanes was used, since the bridge is wide enough to accommodate two lanes of traffic and a pedestrian lane. It is also important to note that the lane of pedestrian traffic can use the same multiple presence factors even though the factors were developed for vehicular traffic. ✓ ✓

Table 8: AASHTO Multiple Presence Factors

Number of Loaded Lanes	Multiple Presence Factor
1	1.20
2	1.00
3	0.85

✓

The worst case found was under load from the HS20 Truck, Tandem, Lane Load, and dead loads while using the multiple presence factor for one lane of traffic. This factored loading gave the maximum loads shown in Table 9.

Table 9: Maximum calculated forces

Force Calculated	Maximum Value
Pylon Stay	5478^k
Moment in Pylon	$10{,}077^{k\text{-}ft}$
Shear in Pylon	266^k
Axial Force in Interior Stay Cables	320^k
Axial Force in Exterior Stay Cables	290^k
Axial Force in Segment Underside Cables	381^k
Compression in Segment Underside Pipes	109^k
Positive Moment in Edge Beams	$290^{k\text{-}ft}$
Negative Moment in Edge Beams	$357^{k\text{-}ft}$
Axial Force in Edge Beams	573^k (compression)

Pylon Axial force ?

18 fold increase

During the design, it was felt as though it would be important for a safe design to ensure that if the main pylon stay were cut the bridge would not suffer collapse. To determine this capability the model was reanalyzed without the cable and developed new loads on the pylon:

- Max Moment in Pylon – $179{,}987^{k\text{-}ft}$
- Maximum Shear in Pylon – 1018^k

Pylon Axial Force

✓

These numbers were obtained using a three-dimensional model in SAP. Some hand calculations were done to ensure that the data obtained from SAP was accurate. These hand calculations are included in Appendix B.

SAP model and sample output should be included to improve credibility

During design, all resistance factors were used with AASHTO definitions; for reinforced concrete, $\varphi = 0.90$; for prestressed concrete, $\varphi = 1.00$; for shear, $\varphi = 0.90$. The Kite Swing Bridge design meets all the above factored loads and resistance factors within the AASHTO LRFD 2005 Specifications.

This bridge is located in Austin, Texas, and seismic conditions for the area must be considered. The city lays in a Seismic Zone I region with acceleration coefficient of approximately 0.02. AASHTO LRFD Article 4.7.4.1 states that no analysis is required for a bridge in Seismic Zone I with regards to seismic loads, therefore no analysis was done for this case.

Foundations

Two foundation options were studied for the pylon and stay. The pylon foundation required axial and moment capacity for structural redundancy while the stay anchor required uplift resistance from the high tensile force. Drilled shafts were considered because of the construction limitations posed by high quality limestone. Grouted steel plate anchors were also preliminarily studied based on the drilled shaft designs. Basic calculations are shown in Appendix B.

Geotechnical data reported high quality limestone two-feet below the existing grade with a unit compressive strength of 18,000 psi. Comparing the compressive strengths of the limestone with typical concrete (4000 to 5000 psi), the limestone has three times the strength of concrete, deeming extensive foundation work unnecessary. Limestone, however, is a heterogeneous rock with unknown discontinuities leading to extremely conservative assumptions which are:

- End bearing pressure is 70% of the unit compressive strength,
- Uplift frictional resistance is 70% of the drilled shaft skin friction,
- Modulus of elasticity of limestone ranges from 100,000 to 800,000 tons/ft^2,
- Unit weight of limestone is 120-pcf,
- Two feet of soil does not contribute to foundation capacity,
- Water table 30 to 40-feet below grade,
- Factor of safety of 3, and
- Bond between grout and limestone only 80% efficient.

From preliminary calculations drilled shafts were deemed unnecessary as high compressive strength limestone would be replaced with lower compressive strength concrete. Additionally the time and equipment required for drilled shaft construction are costly. Steel plates anchored to the limestone by grouted rods are recommended foundation solutions as they require two-feet of excavation and up to 20-feet of coring.

A two-foot square, four-inch thick steel plate bolted to the limestone by eight two-inch diameter steel rods grouted 10-feet is sufficient to resist the tensile force of the stay. The pylon requires two 4-foot square, 6-inch thick steel plates on each end of the rectangular base. Fifteen four-inch diameter steel rods per plate grouted 20-feet in limestone carries the pylon moment that results without the stay.

Approaches

To simplify the design and reduce costs, the approaches used take advantage of TxDOT standards for abutment design. The approaches are flanked by sloped, vegetated areas with built-in concrete planters, which will reduce the visual impact of the solid structure. The side view of one approach can be seen in Figure 14. The shaded section represents the concrete required for shear resistance of the relatively high axial loads imparted on the abutments by the bridge superstructure.

Costs?
capacity calcs for
these are not clearly shown anywhere

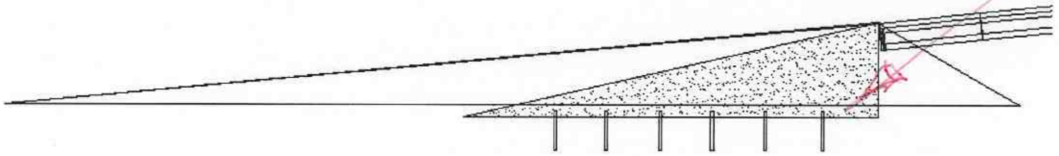


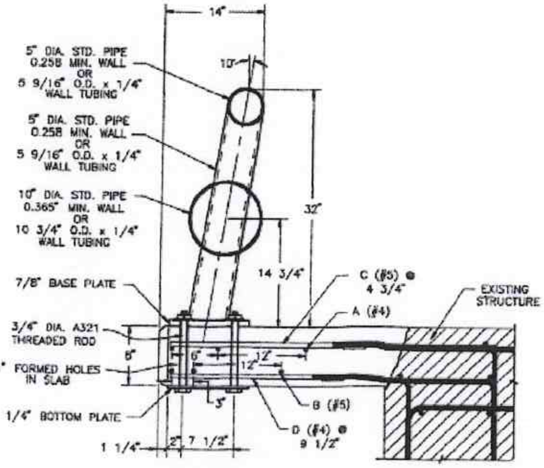
Figure 14: Typical abutment section

The other portions of the abutment have W-shape foundations that will be bolted to the underlying limestone with grouted anchors. The design varies from the TxDOT standard in the bearing pad, which is modified to accommodate the unique concrete sections.

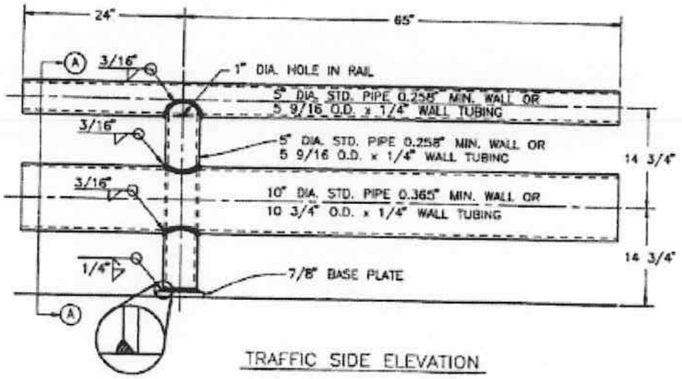
The materials in the abutment are normal weight reinforced concrete and Grade 60 uncoated steel. The abutment is designed for factored dead and live loads.

Railings

The railings for the Kite Swing Bridge were chosen to enhance the visually apparent slenderness of the bridge while still providing adequate vehicular, bicycle, and pedestrian safety. A Texas Type 421 Aesthetic Rail was chosen for the outside vehicular railing. From Figure 15, it is apparent that this is a very transparent railing with a total height of only thirty-two inches and wide openings between the two tubes of the rail.



(a)



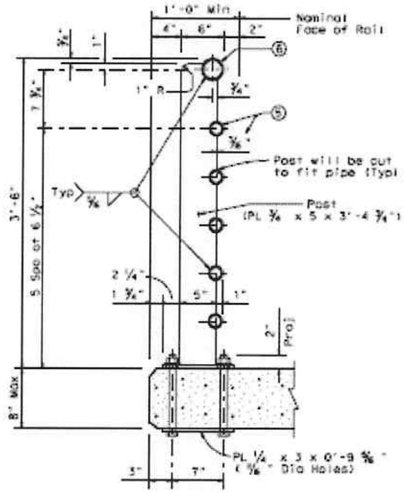
(b)

Figure 15: (a) T421 rail cross-section, (b) T421 rail profile (TxDOT)

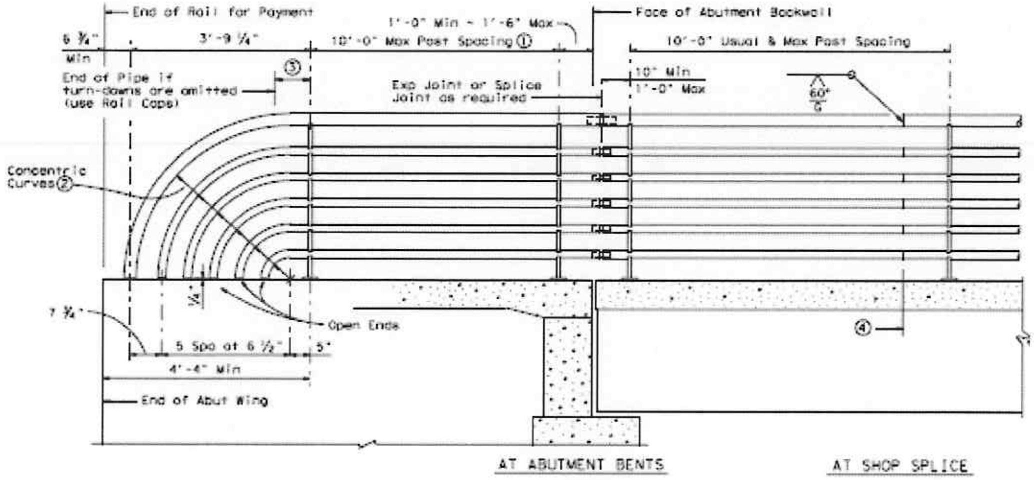
The other outside railing had to be designed to provide adequate safety for bicyclists and pedestrians. It was determined that a fifty-four inch high railing should be used due to the following characteristics of the bicycle/pedestrian path:

- Bicyclist may fall over railing into the path of oncoming traffic
- Bridge has a drop-off of two feet or greater
- A shared use path where large volume of users could cause a bicyclist to take evasive action and collide with railing at a sharp angle
- A shared use path at the end of a long descent where speeds of bicyclists are greater

A variation of the Texas Type PR1 Pedestrian Rail was chosen due to its transparency and similarity to the Texas Type 421 Aesthetic Rail. As seen in Figure 16, the PR1 Pedestrian Rail provides a very transparent profile as well as a very modern look that enhances the overall image of the bridge. The railing height of the PR1 is not adequate and would have to be increased to fifty-four inches, as previously discussed.



(a)



(b)

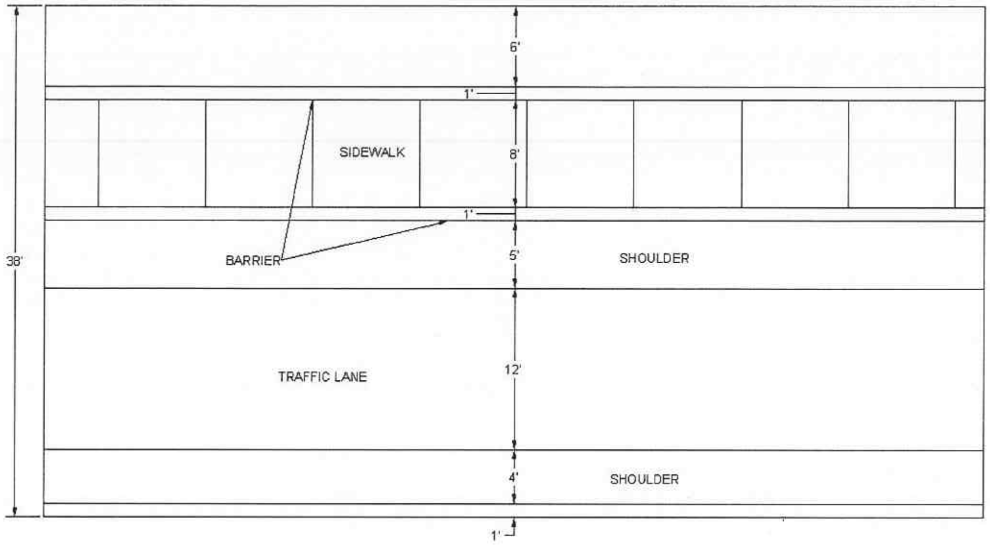
Figure 16: (a) PR1 rail cross-section, (b) PR1rail profile (TxDOT)

The railing dividing the bicycle/pedestrian path and the vehicular traffic had to meet both requirements for traffic safety and bicyclist/pedestrian safety. A railing visually similar to the one chosen for the outside bicycle/pedestrian rail was chosen, with the added requirement that it must meet Test Level Index 2, TL-2, requirements for vehicular impact.

The openness of these railings will hopefully fulfill a secondary goal, of creating a slight sense of discomfort for drivers on the bridge. This discomfort causes drivers to slow, making the roadway safer for the drivers themselves and for the pedestrians in the immediately vicinity.

Traffic Layout

The vehicular and pedestrian bridge will have three barriers with railing, on the outsides and separating the pedestrian and vehicular traffic. The width of the vehicular travel-way is twenty-seven feet. This includes a have a seven-foot interior shoulder, a twelve-foot lane, and an eight-foot outside shoulder. The traffic layout, shown in Figure 17, depicts the vehicular portion and the eight foot pedestrian walkway.



where are cables?

Figure 17: Traffic layout, plan view

Pedestrian safety and ease of travel was a vital concern, which is why the pedestrian walkway is located to the right of the vehicular lane. The walkway is inset from the edge of the bridge due to the cable stay angle, which crosses over the bridge and would limit the height of the pedestrians at the edge. This layout allows pedestrians to enter the bridge from the outside, as opposed to between the lanes of traffic on Stratford Lane. However, for access from the soccer fields, pedestrians would have to cross the road. At this location, it is recommended to install a crosswalk with street flashers and advance road bumps.

Standard one lane striping is required on the bridge, with additional striping to direct traffic onto and off of the bridge. Pedestrian warning signs are also required, as is a yield sign for merging traffic from the bridge.

AESTHETICS

As mentioned previously, this design incorporates the surroundings to provide an aesthetically pleasing bridge for the Austin landscape. Because of the sensitive nature of the park setting, the design attempts to minimize visual disruption to the park and Botanical Gardens, while being a "signature bridge" to help "keep Austin weird".

Several aspects of the Kite Swing Bridge help accomplish these goals. For example, all superstructure sections are slender, smooth, and symmetric in order prevent visual disruptions along the bridge. In addition, they are optimized as truss elements by using single tension chords on the underside of the decks to remove unnecessary material. As a result, the apparent depth is reduced, and the majority of the superstructure is only ten inches thick. Moreover, the total depth of the stiffening girder at its deepest point is only four feet, and it slopes down to its deepest point to provide a smooth and slender appearance. With a suspended bridge length of over 480 ft, the Kite Swing Bridge has a very small span-to-depth ratio.

200' pylon is going to snag a lot of kites

Remembering that people often fly kites in Zilker Park, these structural characteristics are incorporated into the bridge using a kite theme to provide a modern signature bridge for Austin. The kite theme can be seen in the fact that the pylon is inclined away from the superstructure so that it appears that it is "swinging" in the air like a kite. As a result, the slender lines of the pylon, cables, and bridge sections evolve into a light, modern, non-traditional structure. ✓

Nice thought

In addition to modifying structural characteristics to improve aesthetic quality, natural vegetation is also used accent the park and to minimize the visual impact of the bridge. Because the bridge is so close to the Botanical Gardens, the abutments will be constructed with grass on both sides and planters beneath the seat of the superstructure. Natural vegetation on all parts of the abutment will minimize visual disruption to the park, and plants and flowers in the planters on the abutments under the bridge will beautify the area and accent the park and gardens. ✓

CONSTRUCTION PLANNING

Construction scheduling and organization are especially important in an active pedestrian area like Zilker Park. Although it appears at first glance to have space for construction staging and storage, this is not the case when attempting to keep as much of the park open as possible. This goal can be achieved through intelligent construction planning and construction methods, even while staying on budget. Additionally, environmental protection, noise considerations, and road accessibility concerns must be addressed. ✓

Timeline

Zilker Park is used year-round for town athletics, personal fitness, and annual events. It is inevitable that construction will disrupt the daily use of the park, but a schedule can be orchestrated to avoid the biggest of the events in the park, namely, the Fourth of July celebrations, the Austin City Limits Music Festival (in September), and the Trail of Lights and Christmas Tree Lighting Festival (in December).

The use of precast segments will allow for a shorter on-site time, as the segments can be constructed before ground has even been broken on location. The critical path for construction will be in crossing Barton Springs, as that is the most disruptive to traffic in and through the park. ✓

The construction schedule should be laid out so as to disrupt this annual calendar as little as possible, perhaps by starting construction in January. ✓

Staging Areas

The intersection in question is situated between soccer fields, the Nature Center, and a rocky outcropping. Centralized construction operations close to the location of the pylon minimizes construction traffic across the roads while having enough space for trailers, parking, and materials. This would likely require the disabling the public use of the ✓

corner soccer field. The alternative option is on the south side of Barton Springs Road, but the continual disruption of traffic would be more detrimental than the loss of the field.

Segment Placement

Aside from material storage, the objects with the largest potential claim on construction space are the cranes that could be used to place the segmental sections. Because the bridge is not terribly high or difficult to access, stationary cranes are likely the easiest method of lifting the sections into place. For the south section of the roadway, a crane could be placed south of Barton Springs Road, thus removing the need for the segments to be carried across the roadway (which would require closing the road to traffic). However, when working on the northern section of the bridge, the crane would have to be on the inside, lifting the segments over Stratford Drive, as the ground is highly uneven and the space cramped to the west of the road. A wheeled or track-wheeled crane would work well as it could easily relocate to different portions of the project. With all outriggers in place, the crane will be stationary and secured for lifting.

Temporary Supports

The most efficient part of the Kite Bridge design is that it operates on the strengths of the materials: the concrete sections are in compression, the steel cables in tension. These strengths can be utilized during construction, as well: as each segment is lifted into place, the steel cables are attached, helping to hold it up.

Without the next box already in place, however, the system is not yet in equilibrium. It is necessary to design an temporary support system during construction. One such method would be to place a temporary column on the far side of the curve. By using cables from the temporary column to the section, the sections are pulled away from the pylon and held in their final positions as the next piece is put into place.

Another option is to construct temporary horizontal supports where the bridge sections are to be placed. The segments are lifted onto the supports, secured to one another, and secured to the cable stays. Once all segments are in place, the supports would be removed and the forces transferred into the cables and through the arch of the bridge.

How does this interact with traffic seems to be a big problem Cost would also be high

Like a vertically arched bridge, this bridge will be built from both ends, coming together in the middle with the keystone piece, allowing all the boxes to rest against each other, pushing outwards and holding the system in place. At that point, the temporary supports would be removed, and the bridge will stand on its own.

The approach spans are placed using span-by-span construction, supporting underneath one single span while the boxes are placed and post-tensioned together. Once all are in place, the support is removed, leaving a simply-supported or continuous system which? (depending on the stressing above the piers).

??

where are ducts for PT in details?

Traffic Impact

The critical step in this project, in terms of time and inconvenience to those driving through the park, is the crossing of Barton Springs Road. As mentioned previously, this road is a high-traffic thoroughfare between MoPac to the west, and downtown Austin to the northeast. It handles not only park traffic, but daily commuter traffic in and out of the city. Major over-road construction will be during the night. Traffic is at a minimum then, and shutting the road will be less of a problem.

The Kite Swing Bridge has only one span, stretching over four hundred feet. The rest of the nine-hundred foot length of the bridge is handled in the approaches. These solid structures will lie beside Barton Springs Road and Stratford Drive. Unfortunately, an access road for within the park currently exists off Barton Springs Road, just southeast of the intersection. This road will need to be closed with the construction of the new bridge. As it is already only a spur off another road, this closure should not greatly impact the traffic flow. If the city would like to keep the road, the location could be shifted to the west a short distance, where it would either pass under the suspended deck or to the west of the bridge entirely.

OK

Noise Ordinance

The problem with working overnight, however, are the regulations in place in the area. Though South Austin is known for its sound ordinances, the project will seek a waiver in order to do some construction at night to reduce impact on the public's park access. Without such a waiver, the project will still work with the city to minimize construction during major events. Due to the large amount of precast concrete used in the bridge design, on site construction time should be minimized to reduce noise on the surrounding environment.

Site Improvements

In any construction project, it is a minor hope that the site will be left in as good of shape as it was when the project began. In the best sense, the site will be improved by the project. It is important to consider if there are site improvements that could take place during this construction, so as to reduce future impact.

One such improvement is burying power lines through the park. The Kite Swing Bridge layout requires that some lines be moved permanently, so as not to interfere with the pylon's final location, and others will have to be displaced temporarily so that cranes can be used freely. As the roadways are going to be torn up and repaved anyway, it is a perfect opportunity for the power and telephone companies to come in and bury their lines, also removing the potential danger to park-goers, and reducing the possibility of future power outages during stormy weather.

Another improvement is at the dividing fence between the Nature Center and the new roadway. Currently, an old, rusting, wrought-iron fence exists just off Stratford Drive, half-hidden by unruly growth. Considering that much of that space will be torn up to fit the roadway and the construction machinery, it would be a good time to replace the fence and alter the appearance, making it look like the back of a natural area, rather than an overgrown, fenced-off forest.

MAINTENANCE

The Kite Swing Bridge has the advantage that almost all the concrete members will be in compression, which reduces cracking and helps prevent rebar corrosion. As with any cable stay bridge, however, increased attention will need to be placed on maintaining the cable stays. The cables will need to be inspected and replaced periodically. In addition, the stress levels in the concrete superstructure will need to be checked regularly to ensure against cracking. Additional post-tensioning may be required over time to prevent cracking, and the segments will be constructed with post-tensioning ducts available for this purpose.

Self-Cleaning Concrete

In an effort to keep the bridge clean and to limit the required maintenance, the pylon should be constructed with self-cleaning concrete. Concrete becomes self cleaning by adding titanium dioxide to the mixture. The titanium dioxide is photocatalytic, that is, it causes reactions when in the presence of ultraviolet light. The resulting reaction breaks down organic compounds such as soot and exhaust, which settle over time on concrete. The products of the reaction are then washed away when it rains, leaving behind clean concrete. The titanium dioxide is regenerated during the reaction, so it will continue to function throughout the life of the bridge.

Innovative

OTHER DETAILS

Lighting

Situated near one of Austin's well-known moon towers, the site of the Zilker Park Christmas tree, the proposed bridge site has a fair amount of ambient lighting. As a result, extensive roadway lighting was not considered necessary. As well, the addition of light poles to the bridge superstructure was thought to be a detractor from the slim profile chosen. However, some lighting will be added to enhance pedestrian safety and to highlight key elements of the bridge design.

Along the pedestrian walkway, lights will be added at the railing level to increase the illumination of the walkway. Pathway lighting should increase the visibility of any debris or other obstacle on the walkway and increase the pedestrian safety by creating a well-lighted environment.

Lighting of the pylon and the bridge superstructure will provide some additional ambient light to the surrounding area, while enhancing the aesthetic appeal of the bridge. The lighting pattern will draw attention to the slender profile of the superstructure and the handsome pylon. Additionally, having a pylon illumination system in place would allow for easy decorating of the structure for seasonal changes or festivals, though the use of colored or patterned light covers, as is standard on famous buildings like the Empire State Building or the University of Texas tower. This effect can be achieved using solid or patterned foils across the face of the permanent spotlights.

This pylon is huge
Its impact on
aesthetics does not
come across in your
illustrations

Drainage

Due to the heavy rains experienced in Central Texas, it is important to detail an effective drainage system for the bridge roadway. In the spirit of Austin's Green Building Program, the drainage layout can be used as a rainwater collection system. The collected rainwater is redirected to irrigate areas within Zilker Park. The rainwater would have to be filtered before watering plants, to remove road debris and oils that come from the road surface. A relatively simple charcoal filter or fine mesh filter should be sufficient. ✓

The cantilevered bridge deck of the segmental sections are cast with a drip notch, in place to control rainwater off the vertical surfaces of the sections. ✓

ENVIRONMENTAL IMPACT

Though the construction of a bridge in a park setting will certainly mean disruption of the currently in situ natural environment, steps will be taken to minimize the impact. Once construction is finished, the selected design will complement the park setting with its slender profile and minimization of columns. ✓

Tree Removal and Replacement

Regrettably, some of the live oak trees in Zilker Park are in the proposed path of the bridge and will have to be removed prior to construction. After completion of the project, additional trees will be planted in the construction area and along the abutments to provide shade for future park users. The replanting will be in accordance with the City of Austin's "Special Re-vegetation Criteria for Hill Country Roadway Sites." Those trees that can be preserved will be protected using standard methods, such as the City of Austin Type B wood fence that protects the trees root area while maintaining a minimum work area. ✓

Construction Runoff

Silt fences will be installed around the entire work site to protect the watershed from construction runoff. As well, chain link temporary fencing will be erected around the work area to prevent it from becoming an attractive nuisance and endangering the public safety. ✓

COST

The final estimated cost of the Kite Swing Bridge is based off the preliminary estimates, updated to reflect the changes since the preliminary design. Additionally, the foundation and railing costs were included, using volumes of concrete and steel necessary for their construction. Previously the abutments and railings were not considered in the cost estimate. ✓

As designed, the Kite Swing Bridge will cost $880,431. The cost breakdown can be seen in Table 10.

I suspect that cost of the pylon alone would far exceed this in reality

Table 10: Final cost estimates for the Kite Swing Bridge

Design Detail	**Composition**	**Cost**
	SUPERSTRUCTURE	
Main Span	16 – 47.5 cy Precast Prestressed Concrete Sections	$228,096
Cables	50,700 lb	$76,060
Pylon	210.6 cy Reinforced Concrete	$118,465
	Total	$422,621
	FOUNDATIONS	
Pylon Steel Plate	7,840 lb 6" plate	$15,680
Steel Bolts	13,475 lb steel anchor bolts	$67,000
Abutment Concrete	207 cy Reinforced Concrete	$77,030
Back Stay Steel Plate	650 lb 4" plate	$1,300
Back Stay Anchor Bolts	960 lb anchor bolts	$4,800
	Total	$165,810
	RAILINGS	
Bicycle Rail	1200 ft at $50/ft	$60,000
Bicycle / Vehicle Rail	900 ft at $160/ft	$144,000
Vehicular Rail	900 ft at $90/ft	$81,000
Columns	19 cy Reinforced Concrete	$7,000
	Total	$292,000
Total		**$880,431**

Fill ?

✓

Many of the additional suggested design details, such as the use of self-cleaning concrete and accent lighting, are not necessary for the structural integrity of the bridge, but will add another element of interest to the project. These small costs will continue to increase the aesthetic appearance of the bridge, both short- and long-term, and thus should be taken into serious consideration.

SUMMARY

The intersection between Barton Springs Road and Stratford Drive is a consistent bottleneck for traffic through Zilker Park. Motorists wanting to turn left off Stratford Drive often experience long waits before turning across the busy Barton Springs Road, backing up traffic and creating a dangerous situation for pedestrians and motorists alike. In order to alleviate this problem, a flyover bridge has been proposed to carry the left-turning traffic. ✓

Due to the highly visible location of the site, an aesthetically pleasing bridge design was desired. Aesthetics, cost, constructability, and maintenance were the criteria most heavily considered in the design and decision processes. Through the use of a decision matrix with weighted rankings, a final bridge design was selected from among five preliminary designs. ✓

The selected design, a cable stay bridge, is believed to be aesthetically pleasing, efficient in the use of materials, and of reasonable cost. The superstructure design and the use of a single pylon with no columns results in a light and slender bridge which complements the surrounding open park land. As well, the unique structure keeps to the popular town slogan, "keep Austin weird." ✓

with large pylons

Additional design features were incorporated to also keep Austin beautiful. For instance, the abutments are clad in built-in planters to create a cascade of green instead of a wall of textured concrete panels. Rain water collection for irrigation, lighting to highlight aesthetics, and self-cleaning concrete in the pylon will also aid in the beautification of the bridge and surrounding area. ✓

The Kite Swing Bridge is a way to alleviate traffic congestion in Zilker Park while creating a point of interest for the city.

BIBLIOGRAPHY

American Association of State Highway and Transportation Officials (AASHTO). *AASHTO LRFD Bridge Design Specifications*. 3rd ed. United States: American Association of State Highway and Transportation Officials, 2004.

Austin City Connection. "Tree Protection." *City of Austin.* <http://www.ci.austin.tx.us/trees/preserve_code.htm> Updated: 1994. Accessed: 24 April 2006.

Austin City Connection. "Tree Preservation." *City of Austin.* <http://www.ci.austin.tx.us/trees/downloads/tech_manual.doc> Updated: 1994. Accessed: 24 April 2006.

Cassar, L. "Photocatalysis of cementitious materials: Clean buildings and clean air." *MRS Bulletin.* Vol. 29, No. 5. Warrendale, PA: 2005. <www.mrs.org/publications/bulletin/2004/may/may04_cassar_abstract.html> Accessed: 19 April 2006.

Leonhardt, F. *Bridges: Aesthetics and Design.* Cambridge, MA: 1983.

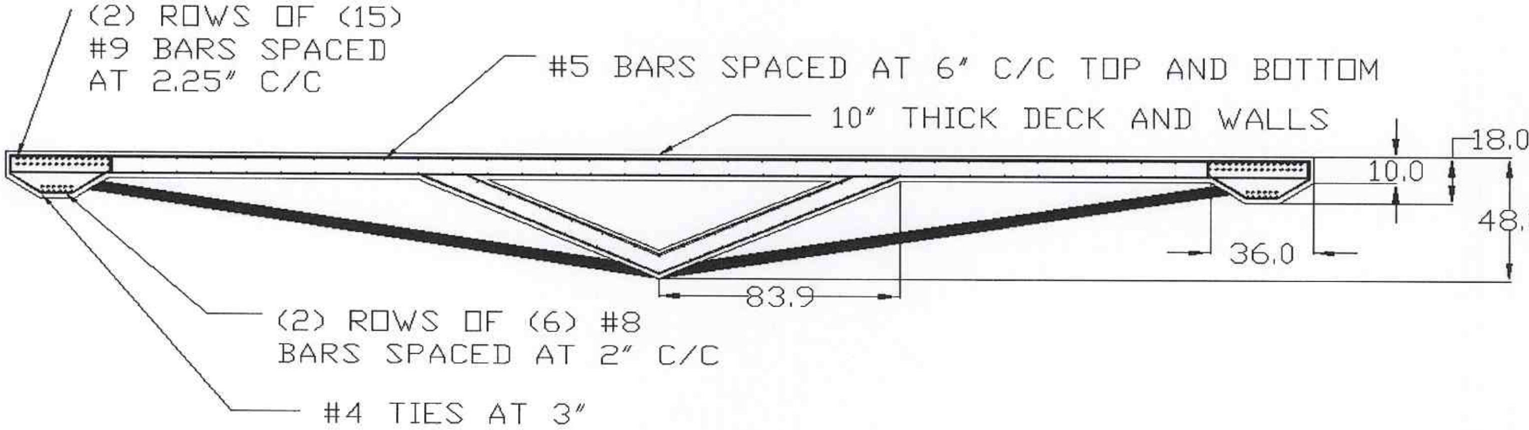
maps.google.com. <maps.google.com/maps?f=q&hl=en&q=austin,+tx&ll=30.267018,-97.770789&spn=0.010823,0.020621&om=1> Updated: 2005. Accessed: 15 April 2006.

Menn, C. *Prestressed Concrete Bridges*. Boston, MA: 1991.

TxDOT. "Bridge Standards." *TxDOT Expressway.* <www.dot.state.tx.us/insdtdot/orgchart/cmd/cserve/standard/bridge-e.htm> Updated: 16 April 2006. Accessed: 17 April 2006.

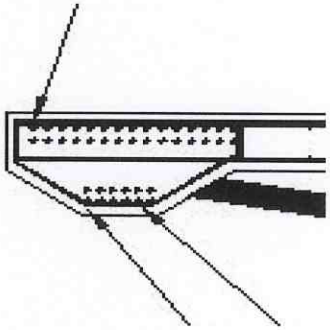
APPENDIX A

Kite Swing Bridge Drawings



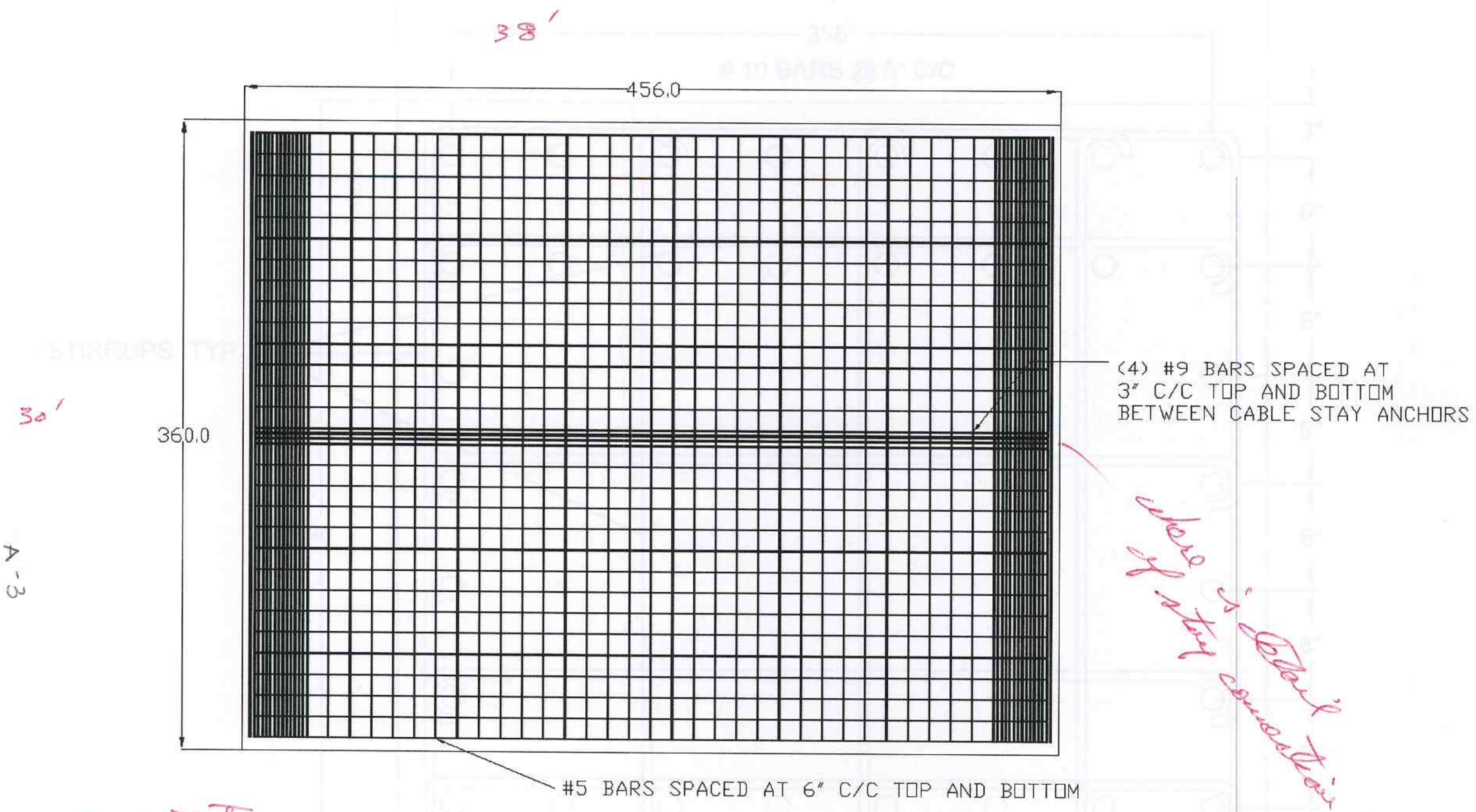
SUPERSTRUCTURE SECTION CROSS-SECTION VIEW (UNITS IN INCHES)

How are stays connected?



EDGE BEAM DETAILS

√



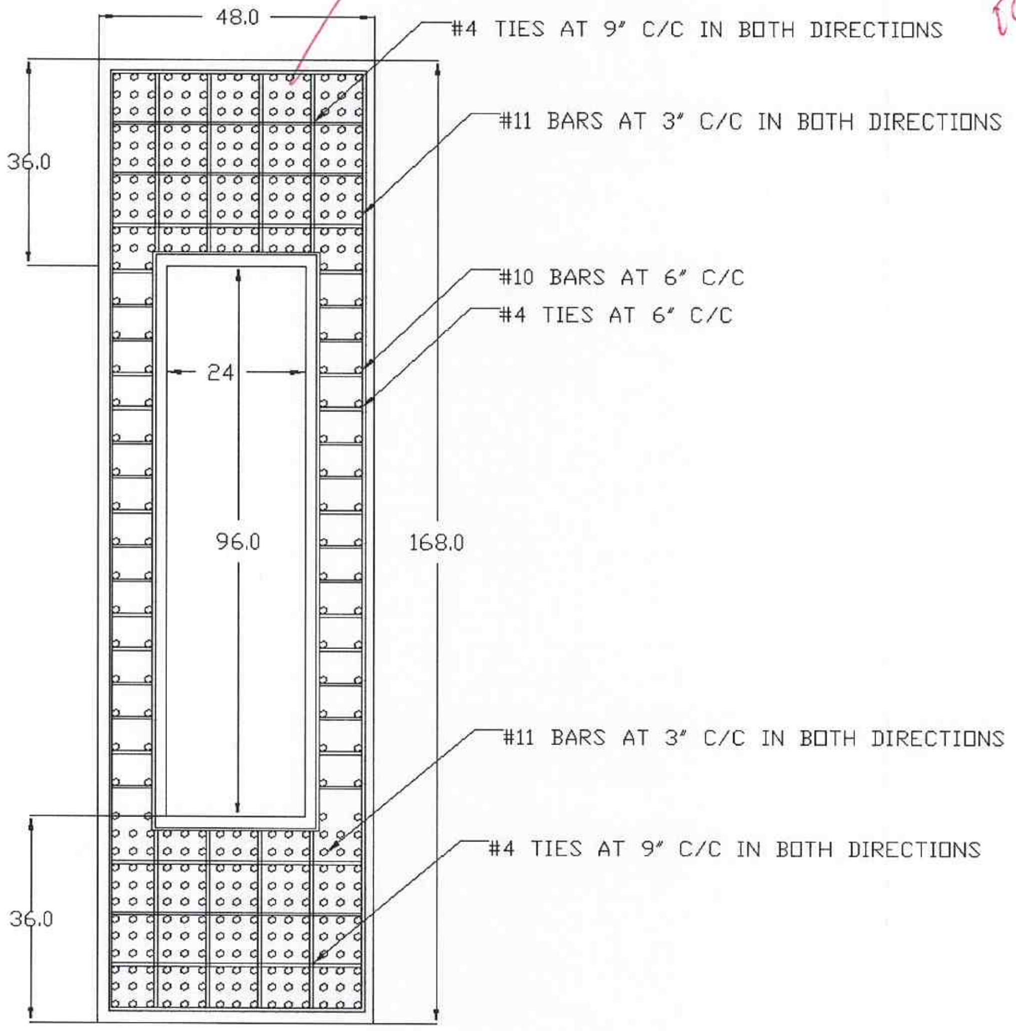
SUPERSTRUCTURE SECTION PLAN VIEW (UNITS IN INCHES)

where is detail
of stay connection?

How does connection
between superstructure
units work?
what type of joints
are bars spliced etc

this is horribly complicated way too difficult to build

Remember you have to get all this developed into rock foundation



PYLON LOWER SECTION PLAN VIEW (UNITS IN INCHES)

APPENDIX B

Kite Swing Bridge Calculations

Strength V Load Factors and Loads

Description	I.D.	Load Factor
Dead weight structural components	DW	1.25
Wearing Surfaces	DC	1.50
Live Load	LL	1.35
Dynamic Load Allowance	IM	1.33
Wind Load on Structure	WS	0.40
Wind Load on Vehicles	WL	1.00

AASHTO Strength V load factors

Thrust in Pylon?

Force Calculated	Maximum Value
Pylon Stay	5478^{k}
Moment in Pylon	$9796^{k\text{-}ft}$
Shear in Pylon	250^{k}
Axial Force in Interior Stay Cables	310^{k}
Axial Force in Exterior Stay Cables	290^{k}
Axial Force in Segment Underside Cables	351^{k}
Compression in Segment Underside Pipes	120^{k}
Positive Moment in Edge Beams	$167^{k\text{-}ft}$
Negative Moment in Edge Beams	$319^{k\text{-}ft}$
Axial Force in Edge Beams	506^{k} (compression)

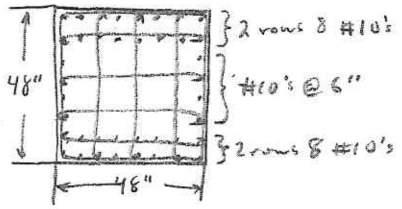
Maximum calculated forces for Strength V

Pylon Design - Top

← w/o stay (P24)

V_u 1018k $M_u = 0$

$N_u = 9000k$



Shear

$$V_c = 2\sqrt{f'_c}\,b_w d = 2\sqrt{5000\,psi}\,(48\,in)(0.8\times 48\,in) = 261k$$

$$V_s = \frac{V_u}{0.75} - V_c = \frac{1018k}{0.75} - 261k = 1096k$$

$$s \leq \frac{A_v f_y d}{V_s}$$

$$s \leq \frac{(.2\,in)(5)(60\,ksi)(0.8)(48\,in)}{1096k}$$

$$s \leq 2.1''$$

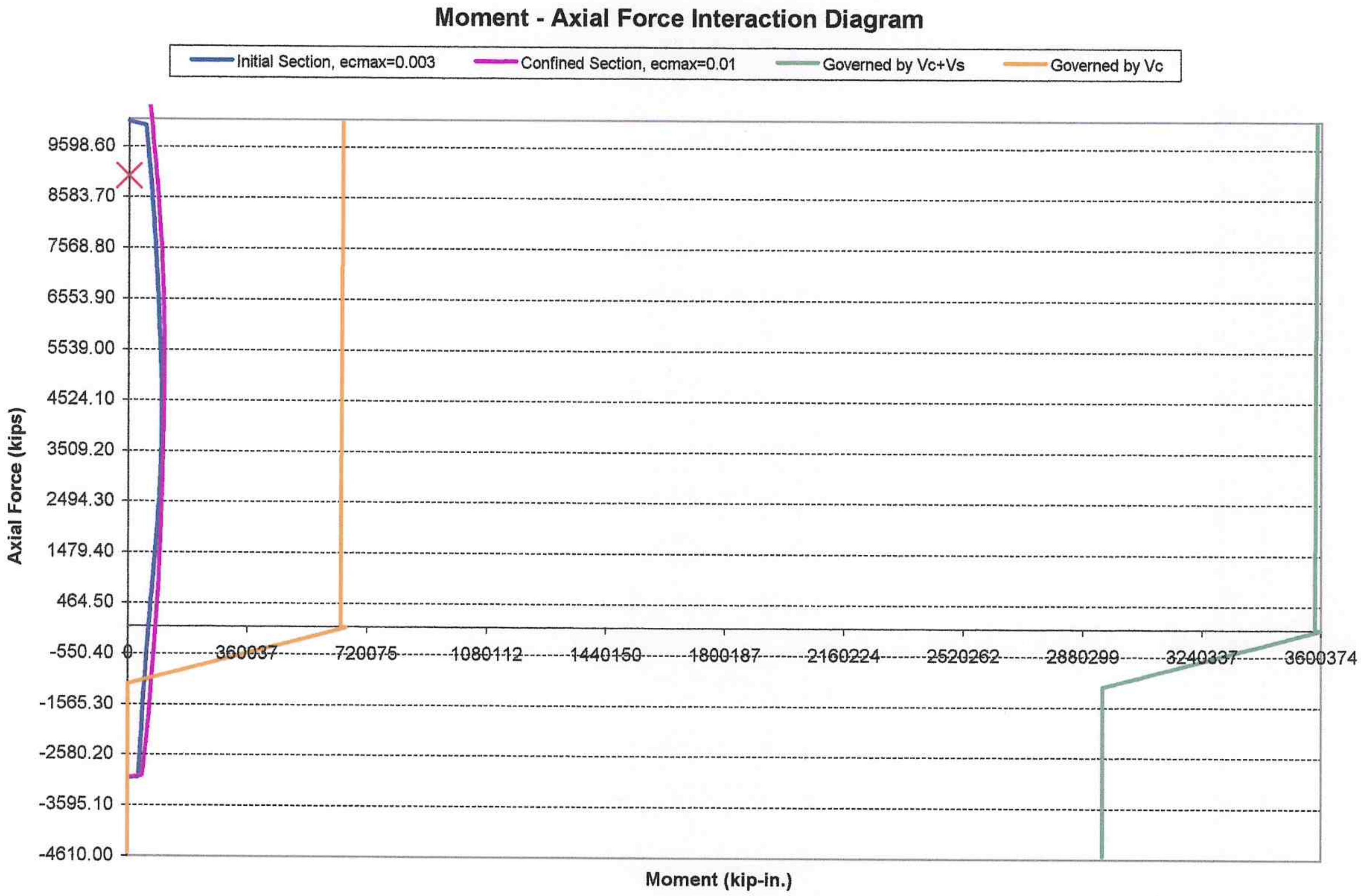
$$s \leq \begin{cases} 16 d_b = 20\,in \\ 48 d_t = 24\,in \\ 24\,in \end{cases}$$

Use $s = 2\,in$

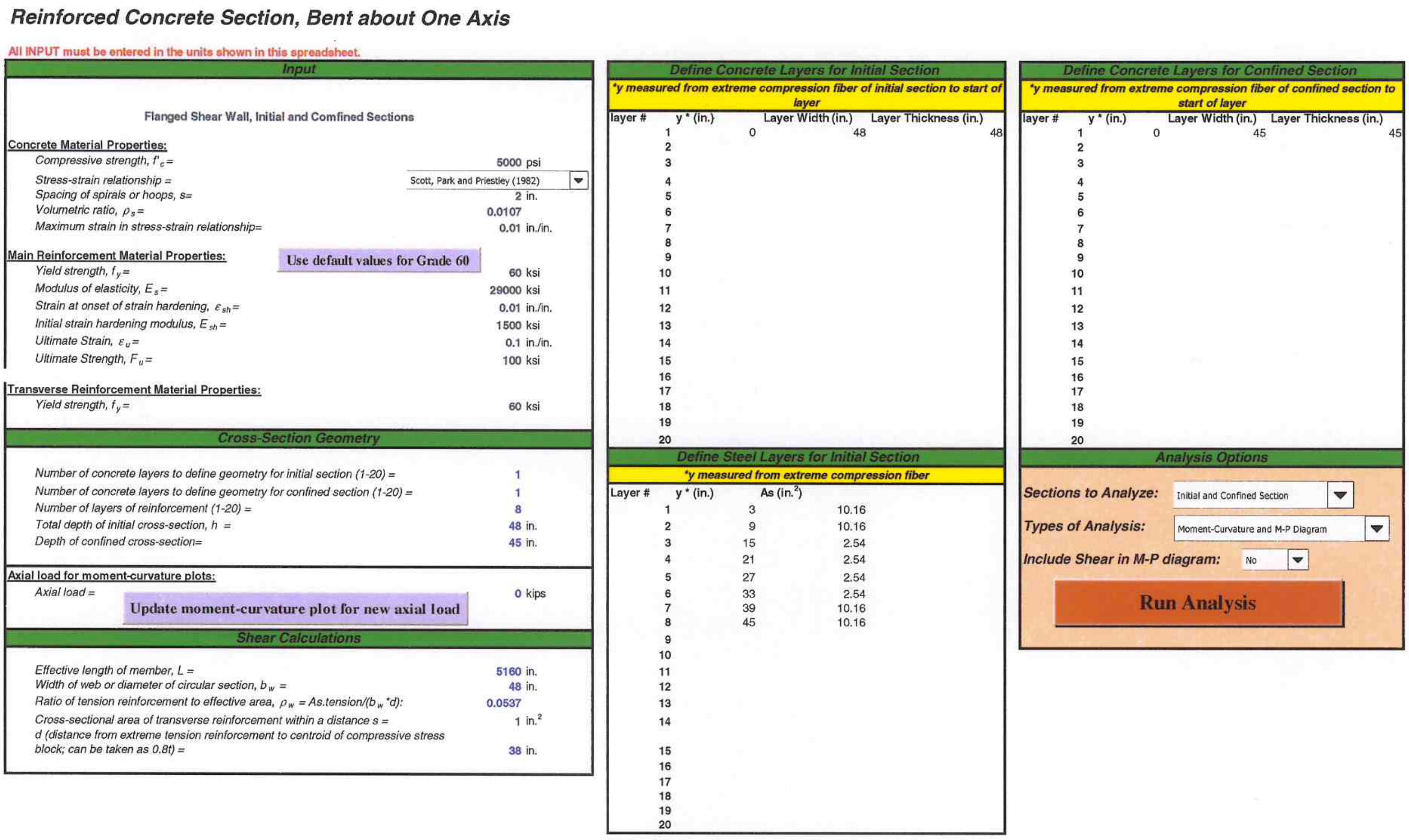
$$\rho_s = \frac{(.2\,in^2)(11\times 45\,in)}{(2\times 48\,in\times 48\,in)(2\,in)}$$

$\rho_s = 0.0107 > 0.0025$ ✓

✓



Pylon Design - Top



Reinforced Concrete Section, Bent about One Axis

All INPUT must be entered in the units shown in this spreadsheet.

Input

Flanged Shear Wall, Initial and Confined Sections

Concrete Material Properties:

Compressive strength, f'_c = 5000 psi
Stress-strain relationship = Scott, Park and Priestley (1982) ▼
Spacing of spirals or hoops, s= 2 in.
Volumetric ratio, ρ_s = 0.0107
Maximum strain in stress-strain relationship= 0.01 in./in.

Main Reinforcement Material Properties: Use default values for Grade 60

Yield strength, f_y = 60 ksi
Modulus of elasticity, E_s = 29000 ksi
Strain at onset of strain hardening, ε_{sh} = 0.01 in./in.
Initial strain hardening modulus, E_{sh} = 1500 ksi
Ultimate Strain, ε_u = 0.1 in./in.
Ultimate Strength, F_u = 100 ksi

Transverse Reinforcement Material Properties:

Yield strength, f_y = 60 ksi

Cross-Section Geometry

Number of concrete layers to define geometry for initial section (1-20) = 1
Number of concrete layers to define geometry for confined section (1-20) = 1
Number of layers of reinforcement (1-20) = 8
Total depth of initial cross-section, h = 48 in.
Depth of confined cross-section= 45 in.

Axial load for moment-curvature plots:

Axial load = 0 kips

Update moment-curvature plot for new axial load

Shear Calculations

Effective length of member, L = 5160 in.
Width of web or diameter of circular section, b_w = 48 in.
Ratio of tension reinforcement to effective area, ρ_w = As.tension/(b_w*d): 0.0537
Cross-sectional area of transverse reinforcement within a distance s = 1 in.^{2}
d (distance from extreme tension reinforcement to centroid of compressive stress block; can be taken as 0.8t) = 38 in.

Define Concrete Layers for Initial Section

*y measured from extreme compression fiber of initial section to start of layer

layer #	y * (in.)	Layer Width (in.)	Layer Thickness (in.)
1	0	48	48
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

Define Steel Layers for Initial Section

*y measured from extreme compression fiber

Layer #	y * (in.)	As (in.^{2})
1	3	10.16
2	9	10.16
3	15	2.54
4	21	2.54
5	27	2.54
6	33	2.54
7	39	10.16
8	45	10.16
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Define Concrete Layers for Confined Section

*y measured from extreme compression fiber of confined section to start of layer

layer #	y * (in.)	Layer Width (in.)	Layer Thickness (in.)
1	0	45	45
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

Analysis Options

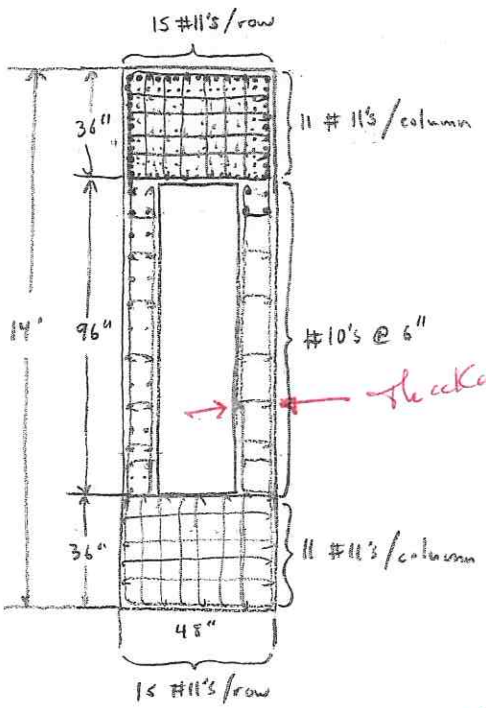
Sections to Analyze: Initial and Confined Section ▼
Types of Analysis: Moment-Curvature and M-P Diagram ▼
Include Shear in M-P diagram: No ▼

B-5

Pylon-Design - Base

$V_u = 586k \quad M_u = 2.160\times10^6\ k\cdot in$

$N_u = 10093k$



thickness ??

12" ?

$2\times12 = 24$

Shear:

$V_c = 2\sqrt{f'_c}\, b_w d = 2\sqrt{5000_{psi}}\,(24in)(0.8\times168in) = 456k$

$V_s = \frac{V_u}{0.75} - V_c = \frac{586k}{0.75} - 456k = 325k$

$s \le \frac{A_v f_y d}{V_s} = \frac{(2)(.2in^2)(60ksi)(0.8)(168in)}{325k}$

$s \le 9.9in$

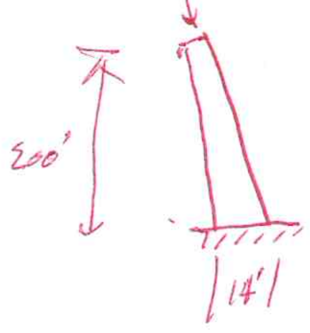
$$s \le \begin{cases} 16d_b = 22.6in \\ 48d_t = 24in \\ 24in \end{cases}$$

Use s = 9 in #4's throughout

$$\rho_s = \frac{(.2in^2)(2\times165in + 2\times96in + 12\times36in + 12\times48in)}{[2\times48in\times36in + 2\times12in\times96in](9in)}$$

$\rho_s = 0.0059 > 0.0025$ ✓

Note: s decreased to 6in to ensure flexural failure mode in RECONASANCE



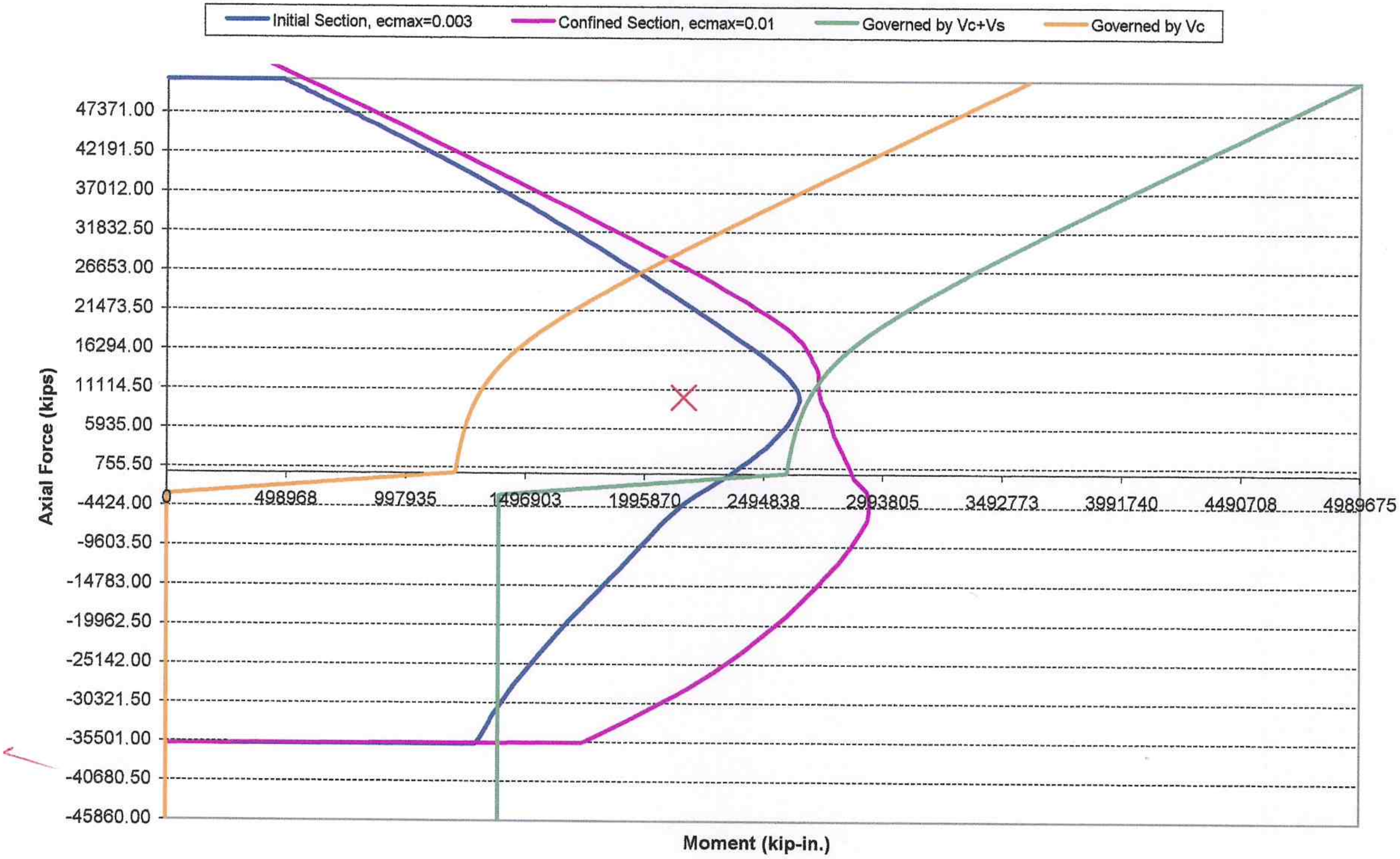
Stability check

Most generous

$k \approx 2 \quad l_u \approx 200 \quad r \cong .3(14) = 4.2$

$\frac{kl}{r} = \frac{2\cdot200}{4.2} \approx 95$ WOW!

Moment - Axial Force Interaction Diagram



Pylon Design - Base

Reinforced Concrete Section, Bent about One Axis

All INPUT must be entered in the units shown in this spreadsheet.

Input

Flanged Shear Wall, Initial and Comfined Sections

Concrete Material Properties:

Compressive strength, f'_c =	5000 psi
Stress-strain relationship =	Scott, Park and Priestley (1982) ▼
Spacing of spirals or hoops, s=	6 in.
Volumetric ratio, ρ_s =	0.0085
Maximum strain in stress-strain relationship=	0.01 in./in.

Main Reinforcement Material Properties: Use default values for Grade 60

Yield strength, f_y =	60 ksi
Modulus of elasticity, E_s =	29000 ksi
Strain at onset of strain hardening, ε_{sh} =	0.01 in./in.
Initial strain hardening modulus, E_{sh} =	1500 ksi
Ultimate Strain, ε_u =	0.1 in./in.
Ultimate Strength, F_u =	100 ksi

Transverse Reinforcement Material Properties:

Yield strength, f_y =	60 ksi

Cross-Section Geometry

Number of concrete layers to define geometry for initial section (1-20) =	3
Number of concrete layers to define geometry for confined section (1-20) =	3
Number of layers of reinforcement (1-20) =	20
Total depth of initial cross-section, h =	168 in.
Depth of confined cross-section=	165 in.

Axial load for moment-curvature plots:

Axial load =	0 kips

Update moment-curvature plot for new axial load

Shear Calculations

Effective length of member, L =	5160 in.
Width of web or diameter of circular section, b_w =	24 in.
Ratio of tension reinforcement to effective area, ρ_w = As.tension/(b_w*d):	0.0798
Cross-sectional area of transverse reinforcement within a distance s =	0.4 in.^{2}
d (distance from extreme tension reinforcement to centroid of compressive stress block; can be taken as 0.8t) =	134.4 in.

Define Concrete Layers for Initial Section

*y measured from extreme compression fiber of initial section to start of layer

layer #	y* (in.)	Layer Width (in.)	Layer Thickness (in.)
1	0	48	36
2	36	24	96
3	132	48	36
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

Define Steel Layers for Initial Section

*y measured from extreme compression fiber

Layer #	y* (in.)	As (in.^{2})
1	3	32.175
2	8	32.175
3	12	32.175
4	16	32.175
5	20	32.175
6	24	32.175
7	28	32.175
8	33	32.175
9	55.2	20.25
10	74.4	20.25
11	93.6	20.25
12	112.8	20.25
13	135	32.175
14	140	32.175
15	144	32.175
16	148	32.175
17	152	32.175
18	156	32.175
19	160	32.175
20	165	32.175

Define Concrete Layers for Confined Section

*y measured from extreme compression fiber of confined section to start of layer

layer #	y* (in.)	Layer Width (in.)	Layer Thickness (in.)
1	0	45	33
2	36	18	96
3	132	45	33
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

Analysis Options

Sections to Analyze:	Initial and Confined Section ▼
Types of Analysis:	Moment-Curvature and M-P Diagram ▼
Include Shear in M-P diagram:	Yes ▼

Run Analysis

from 2nd ed AISC steel handbook ...

length of member

$l = \sqrt{16^2 + 3^2}$
$= 16.3'$

look to $Kl = 17'$ to be conservative

assume $K = 1$ (pinned-pinned case) for conservative estimate

quick selection
for steel pipe, $F_y = 36$ ksi
$\phi = 6''$, $t_w = .280$ in
$w_{sw} = 18.97$ lb/ft
if $KL = 17''$ $\phi P_n = 111^k > 109^k > 44^k$ ✓
($\phi = .85$)

✓

if $F_y = 60$ ksi, using the same section

$\lambda_c = \frac{Kl}{r\pi}\sqrt{\frac{F_y}{E}} = \frac{1(17' \times 12''/')}{2.25'' \times \pi}\sqrt{\frac{60ksi}{29000ksi}} = 1.31 < 1.5$

$\therefore F_{CR} = .658^{\lambda_c^2} F_y = .658^{(1.31)^2}(60ksi) = 29.2$ ksi

$\phi P_n = .85(A_g F_{CR}) = .85(5.58in^2)29.2ksi$

$\phi P_n = 138^k > 109^k > 44^k$ ✓ design fine/a little conservative

if 16.3' and $F_y = 60$ksi;

$\phi P_n = 147^k > 109^k > 44^k$

if 16.3' and $F_y = 36^{ksi}$:

$\phi P_n = 115^k > 109k > 44^k$

Assumptions : 7 strand ½" diam low lax strands

$f_{pu} = 270$ ksi

$A_s = 0.153$ in^2

$f_{py} = 0.9 f_{pu} = 243$ ksi

Pylon Stay

Axial force in stay 5478k.

$$A = \frac{5478k}{\boxed{243\text{ ksi}}} = 22.5\text{ in}^2 / 0.153\text{ in}^2 = 148 \text{ strands}$$

$2.62/lb

Cables from Pylon to Bridge

Interior tensile force 320k

$$A = \frac{320k}{\boxed{243\text{ ksi}}} = 1.32\text{ in}^2 / 0.153\text{ in}^2 = 9 \text{ strands}$$

Exterior tensile force 290k

$$A = \frac{290k}{243k} = 1.19\text{ in}^2 / 0.153\text{ in}^2 = 8 \text{ strands}$$

$ 3.03/lb

Their stress level is OK for prestress tendons but cable stays are quite a bit lower stress. look at PTI cable stay standards

where is detail on how cables attach to: pylon bridge

Need a lot more strands

Cables on Underside of Bridge

Interior tensile force 381 k

$$A = \frac{381k}{243\text{ ksi}} = 1.57\text{ in}^2 / 0.153\text{ in}^2 = 11 \text{ strands}$$

Exterior tensile force 135 k

$2.62/lb

$$A = \frac{135k}{243\text{ ksi}} = 0.56\text{ in}^2 / 0.153\text{ in}^2 = 4 \text{ strands}$$

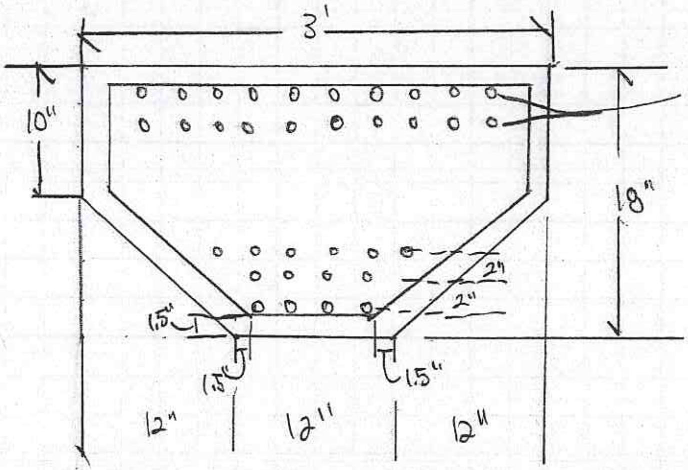
EDGE BEAMS

$+M_{max} = 209$ K·FT
$-M_{max} = -357$ K·FT

$+V_{max} = 75^K$
$-V_{max} = -105^K$

AXIAL
-573^K

PRELIMINARY DESIGN



L=30'

$A_g = 852\,in^2$
$A_{ch} = 417\,in^2$

#8's

Maybe use #11s to open up spaces

Place fewer bars

$+M_{max}$

BOTOM LAYER OF STEEL

$12'' \overset{COVER}{-3''} = 9''$

TRY #8's $\dfrac{9''}{1''+1''} = 4$ BARS
BAR SPACING

$s = 3''$

$$\rho_s = 0.45\left(\frac{A_g}{A_{ch}} - 1\right)\frac{f'_c}{f_{yt}}$$

$$= 0.45\left(1.324 - 1\right)\frac{5000\,psi}{60} = 0.0123$$

RECONASSANCE GRAPH FOR P-M DIAGRAM

$-M_{max}$

TOP STEEL

$36'' \overset{COVER}{-3''} = 33''$

TRY #9's $\dfrac{33''}{1.128+1.128} = 15.95$ - 15 #9 BARS $= 15\,in^2$

RECONAISSANCE GRAPH FOR P-M DIAGRAM

SHEAR = #4's @ 6" SPACING GOOD

✓

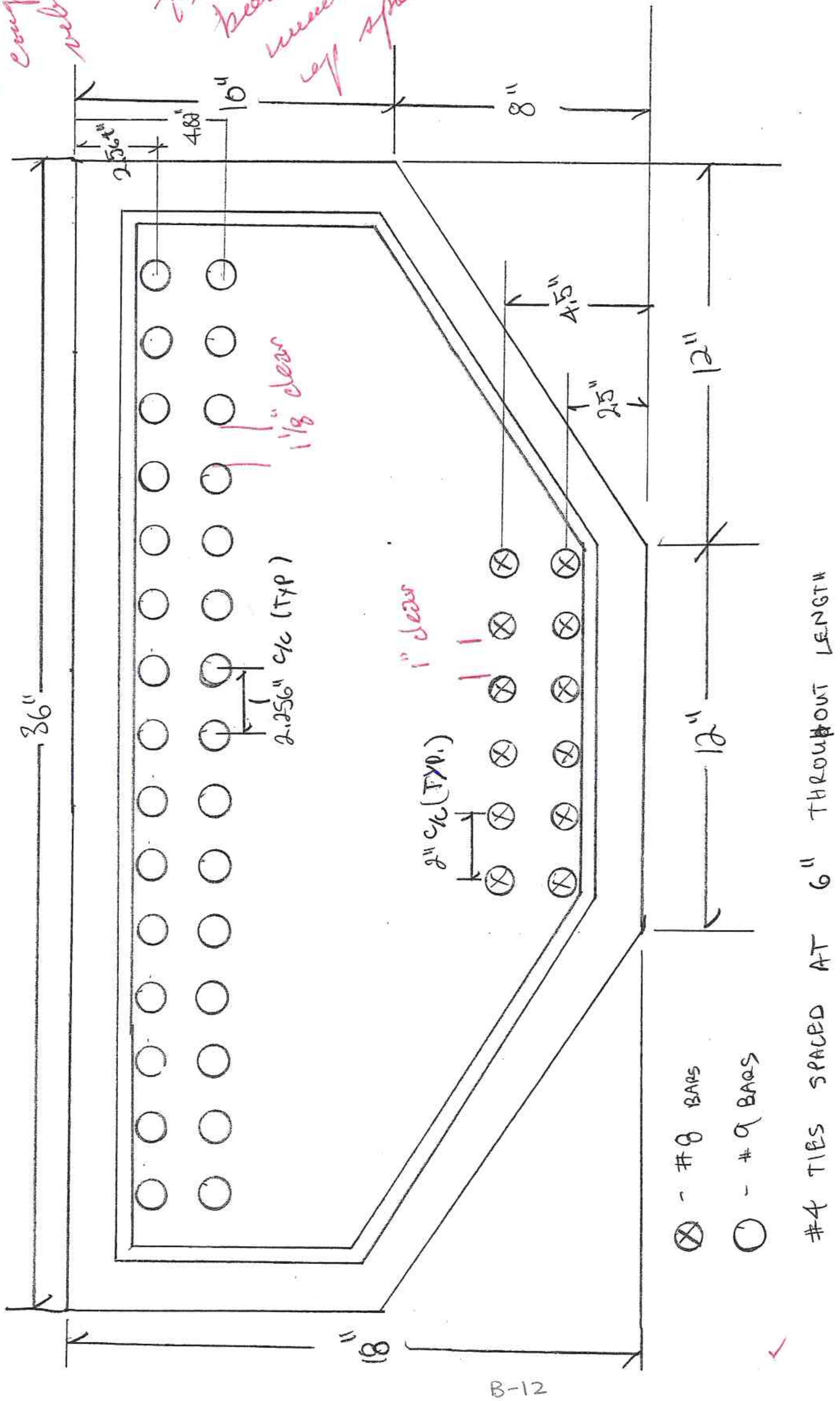
FINAL PROJECT | CE 383S | MATT O'CALLAGHAN

EDGE BEAMS

30' LONG

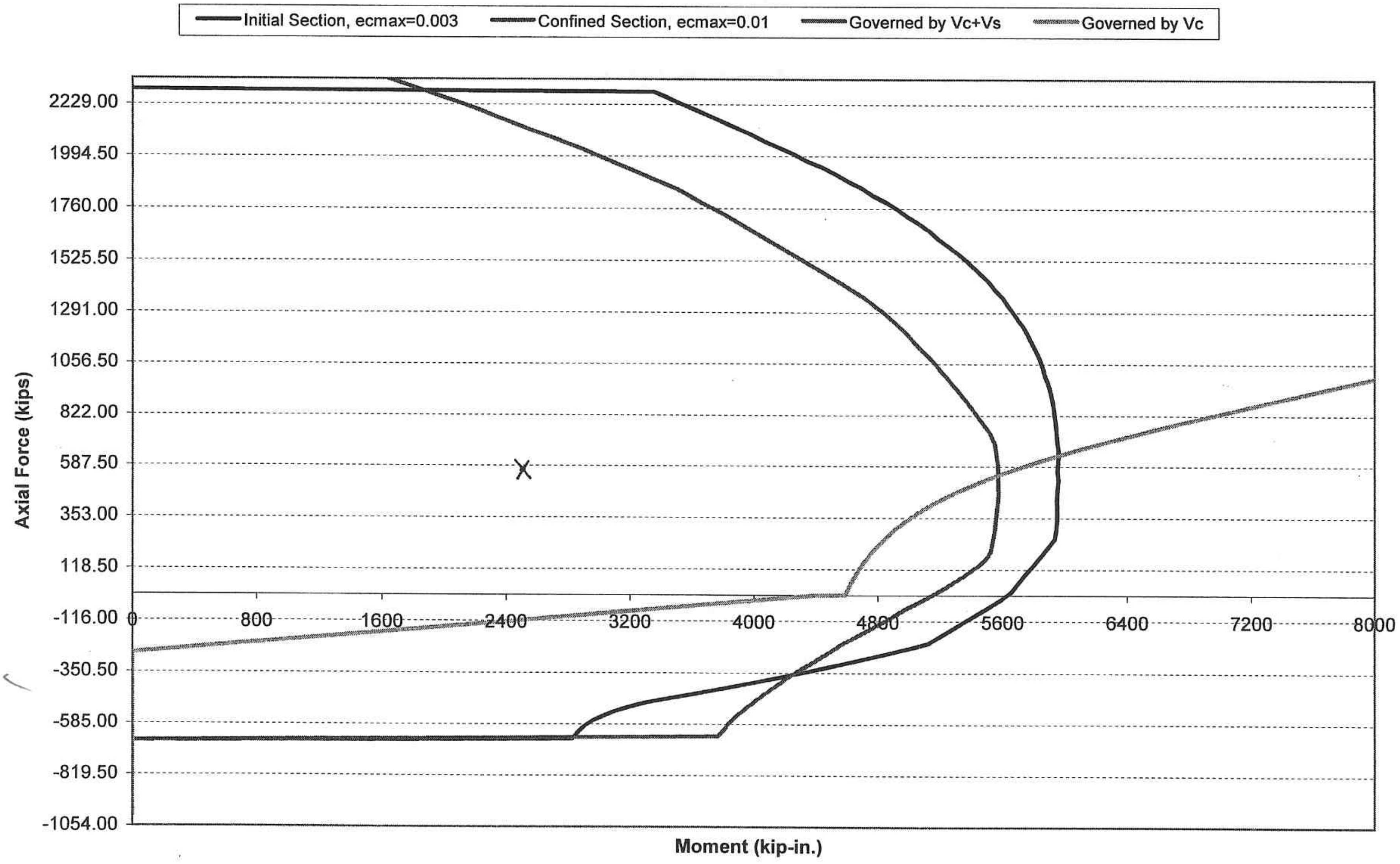
Probably use larger bars to get fewer number and open up spaces between bars

These are too congested to vibrate concrete



$+M_{MAX} = 2508^{k \cdot in}$

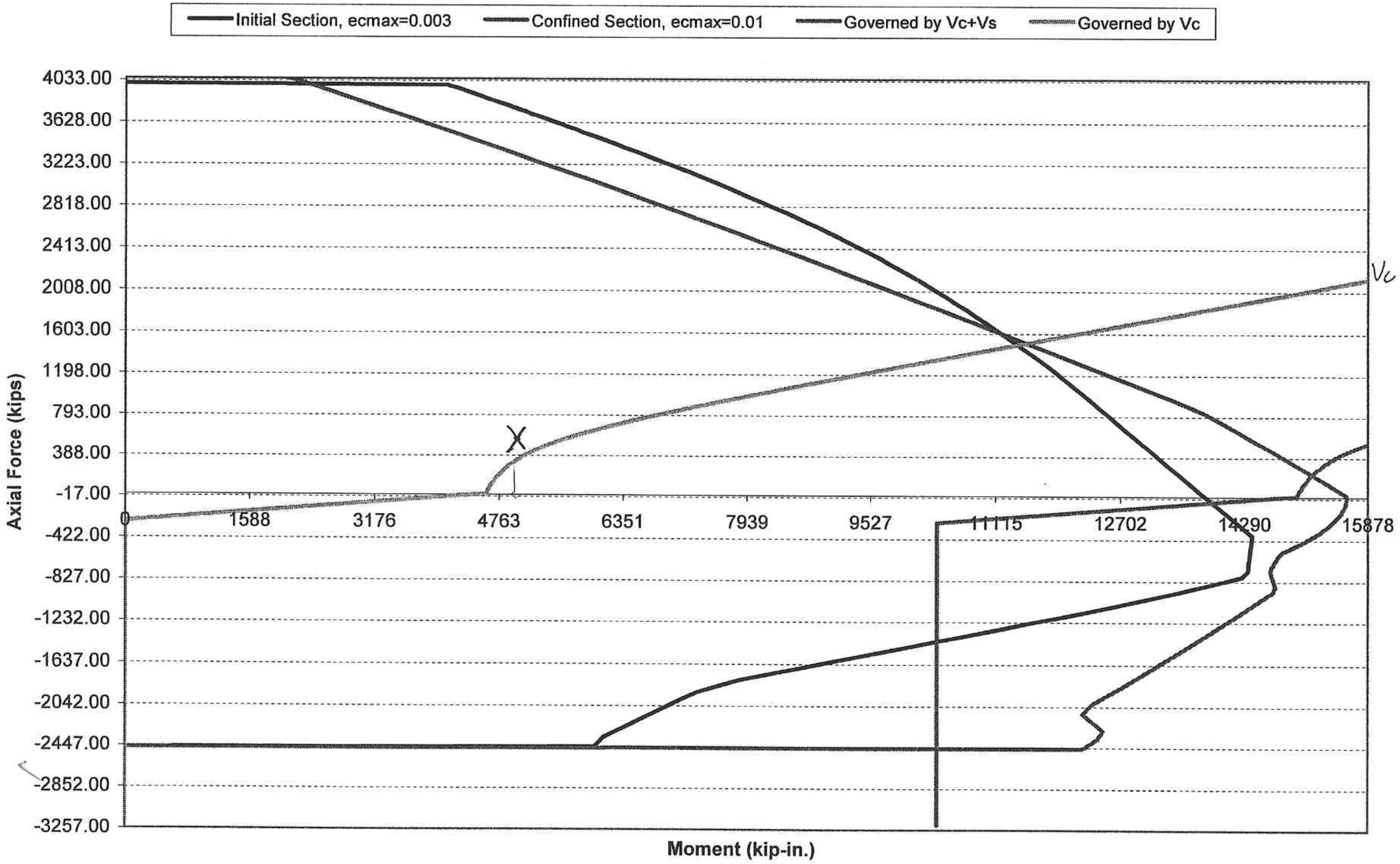
Moment - Axial Force Interaction Diagram



Edge Beams Positve Moment

$-M_{max} = -4824$ k·in

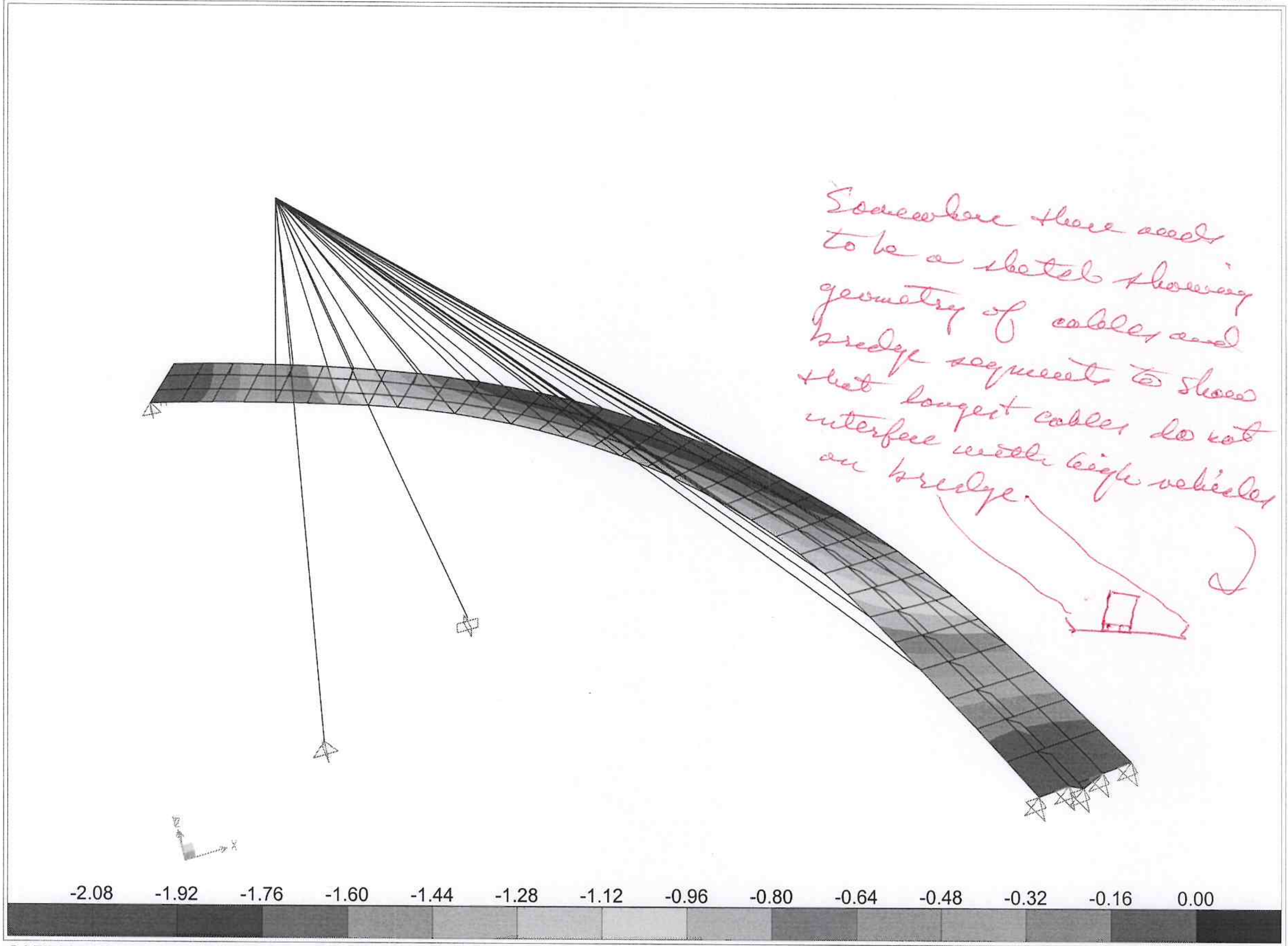
Moment - Axial Force Interaction Diagram



Edge Beams Negative Moment

SAP2000

4/25/06 0:00:58



Somewhere there needs to be a sketch showing geometry of cables and bridge segments to show that longest cables do not interfere with high vehicles on bridge.

SAP2000 v8.2.7 - File:Concrete_Bridge_SAP_Model_Shells_Loads_Test2 - Deformed Shape (DEAD) - Kip, ft, F Units

APPENDIX C

Preliminary Design Calculations

I-BEAM PRELIMINARY

Type IV Girders Traditional TxDOT Design									
Type IV Girders	NO	Area	Length	Vol.	Vol.	NO	Vol.	Cost/cy	Total Cost
	ea	in^2	in	in^3	cy		cy	$/cy	
Main Span		788.4	1320	1,040,688	22	4	89.22	300	$ 26,766.67
Additional Spans	6	788.4	1200	946,080	20	4	81.11	300	$ 146,000.00
Superstructure									
	Width	Depth	Length	Vol.	Vol.	NO		Cost/cy	
	ft	ft	ft	cf	cy			$/cy	
Deck	32	0.67	710	15147	561	1		375	$ 210,370.37
Bent Caps	3.25	3.5	30	341	13	6		375	$ 28,437.50
Substructure									
	Diam.	Height		Vol.	Vol.	NO		Cost/cy	
	ft	ft		cf	cy			$/cy	
Main Span Columns	3.25	18		149	6	6		375	$ 12,443.65
Adjacent Spans to Main	3.25	12		100	4	6		375	$ 8,295.77
Next Set of Spans	3.25	6		50	2	6		375	$ 4,147.88
Abutments	3.25	2.5	32	260	10	2		375	$ 7,222.22
	1	4.17	32	133	5	2		375	$ 3,703.70
Foundations									
	Diam.	Height		Vol.	Vol.	NO		Cost/cy	
	ft	ft		cf	cy			$/cy	
Main Span Drilled Shafts	3.5	20		192	7	6		375	$ 16,035.21
Adjacent Spans to Main	3.5	20		192	7	6		375	$ 16,035.21
Next Set of Spans	3.5	20		192	7	6		375	$ 16,035.21
Abutments	3	20		141	5	6		375	$ 11,780.97
Total Cost									$ 507,274.38

Railings (203k on next page)

You need to get cost of approaches to make up 900' length of bridge

U-Beam Preliminary | Cost Data

Columns: $\left[2(7\,ft + 12.5\,ft + 18\,ft)\right]\pi\left(\frac{5\,ft}{2}\right)^2 = 1472\,ft^3 = 54.5\,yd^3$

Reinforced Concrete (cast-in-place GR5) or Post-Tensioned Concrete (GR 8)

$(54.5\,yd^3)(\$375/yd^3) = \$20{,}400$

U40 Beams: $\left[3\times 6\times 100\,ft + 3\times 110\,ft\right]\left(979.9\,in^2 \times \frac{1\,ft^2}{144\,in^2}\right) = 14495\,ft^3 = 536.9\,yd^3$

Prestressed Concrete (GR 8) $(536.9\,yd^3)(\$300/yd^3) = \$161{,}100$

910'

Slab: $(8\times 100\,ft + 110\,ft)\left(32\,ft \times 8\,in \times \frac{1\,ft}{12\,in}\right) = 19413\,ft^3 = 719\,yd^3$

1/2 Pretensioned Concrete (GR8) + 1/2 Reinforced Concrete (cast-in-place GR5)

$(719\,yd^3)\left(\frac{\$300/yd^3 + \$375/yd^3}{2}\right) = \$242{,}700$

Abutments: $2(2.5\,ft\times 3.25\,ft\times 32\,ft) + 2(1\,ft\times 3.33\,ft\times 32\,ft) = 733\,ft^3 = 27.2\,yd^3$

Reinforced Concrete (cast-in-place) $(27.2\,yd^3)(\$375/yd^3) = \$10{,}200$

Bents: $(6\times 27\,ft\times 3.5\,ft\times 5\,ft) = 2835\,ft^3 = 105\,yd^3$

Reinforced Concrete (cast-in-place) GR5

$(105\,yd^3)(\$375/yd^3) = \$39{,}400$

Railing: $(3\times 910\,ft) = 2730\,ft$

$(2730\,ft)(\$75/ft) = \$204{,}800$

Total: $\$678{,}600 / 29120\,ft^2 = \$23/ft^2$

Standard U-beam: $(\$31/ft^2)(29120\,ft^2) = \$902{,}700$

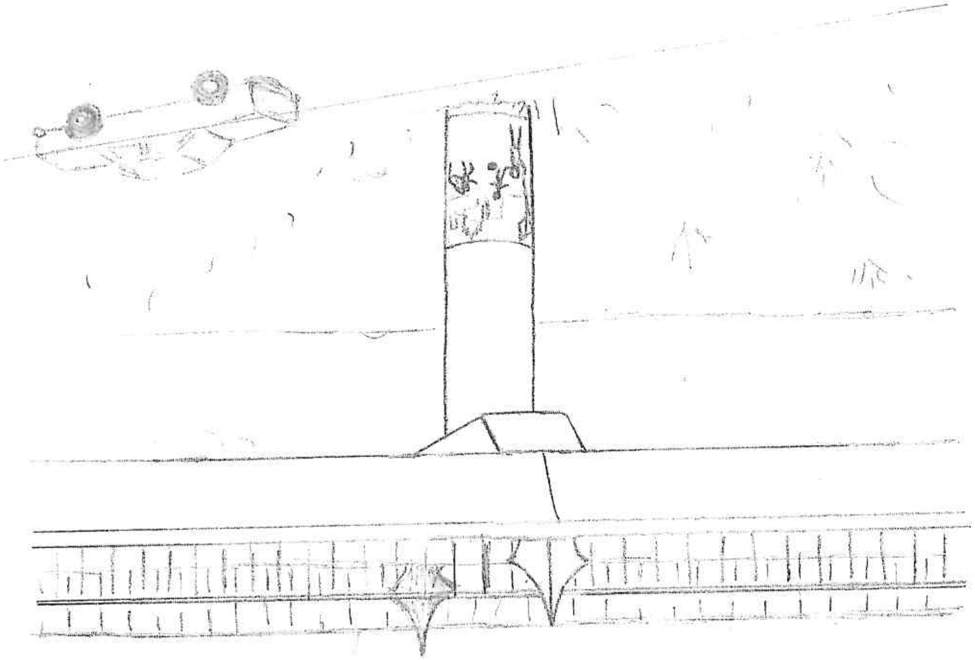
Avg: $(\$39/ft^2)(29120\,ft^2) = \$1{,}135{,}700$

+ aesthetics $(1.07\%)(\$1{,}135{,}700) = \$1{,}215{,}200$

Does Not Include: mosaic tile, lighting, aesthetic aggregates

✓

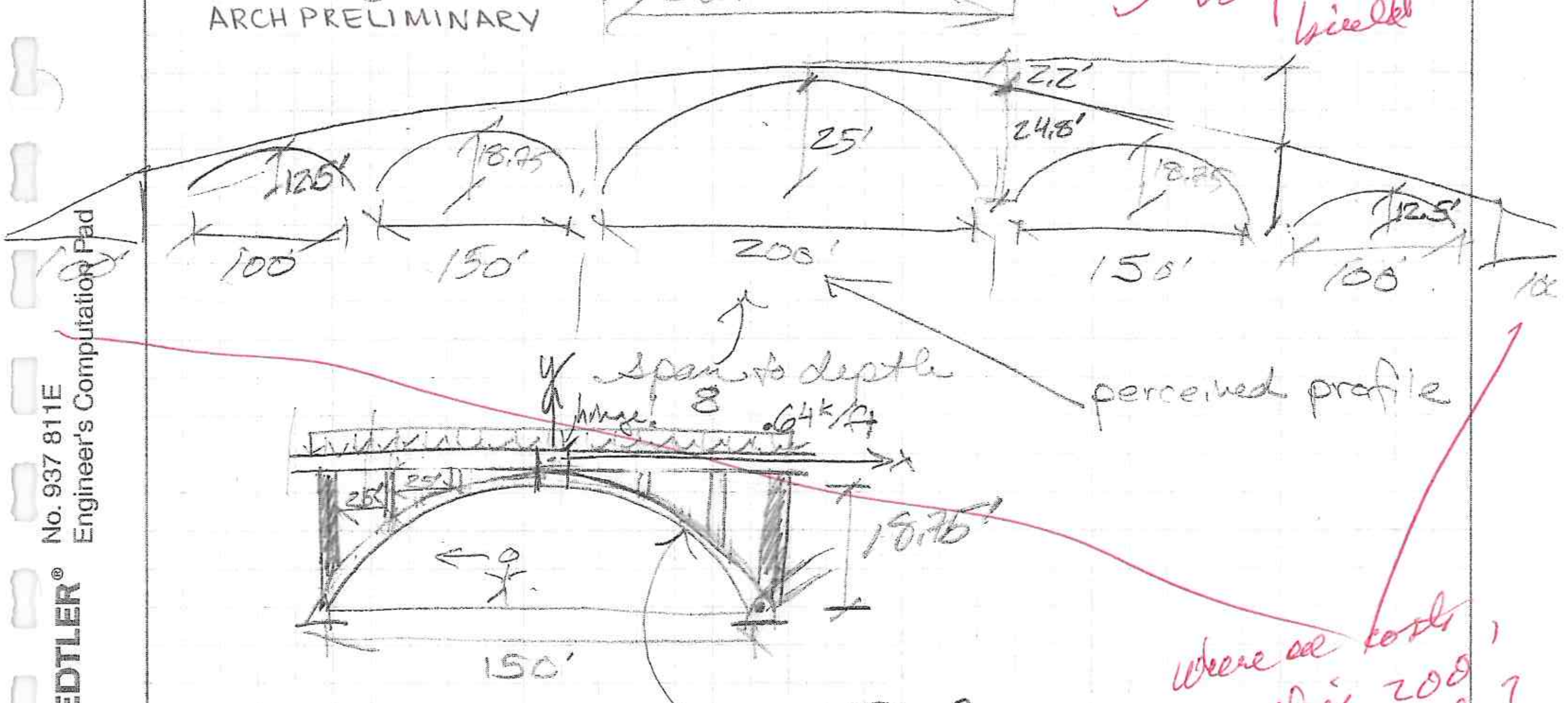
U-BEAM COLUMNS



✓

ARCH PRELIMINARY

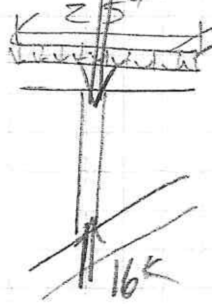
✓ very tricky to build

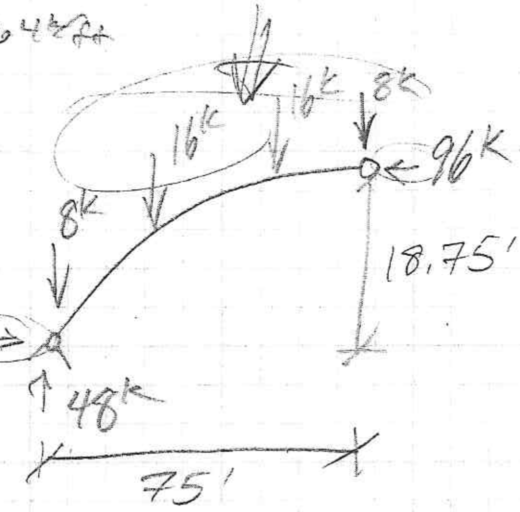


where are costs for this 200' of approaches?

$y = \frac{-25}{(50)^2}x^2$

each column has 25' of tributary area
big column/walls at hinges 2' thick
all other walls 1' thick 9' 1' thick deck
... arch 1' thick at top - widening at base



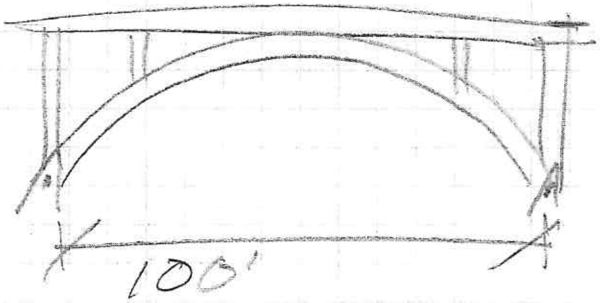


$0=48^k\left(\frac{75}{2}\right)-48(75)+R_x(18.7$

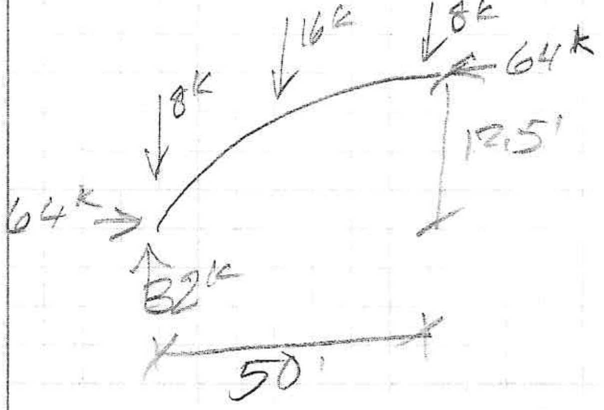
$R_x=\left(\frac{48\left(75-\frac{75}{2}\right)}{18.75}\right)$

$R_x=96^k$

✓



using same principle as before



$0 = 32^k(25') - 32^k(50') + R_x(12.5')$

$R_x = \frac{32^k(50')(\frac{1}{2})}{12.5'}$

$R_x = 64^k$

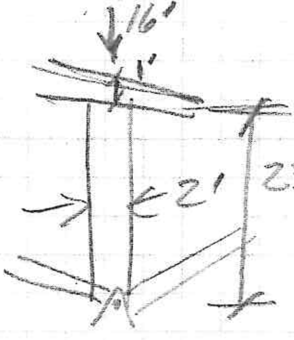
\$562500 – \$750000

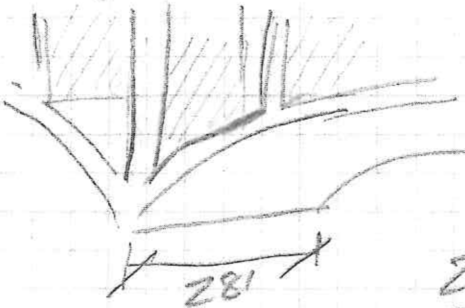
approx 1500-2000 CY concrete (ask Catherine for calcs) ?

ck strength of columns

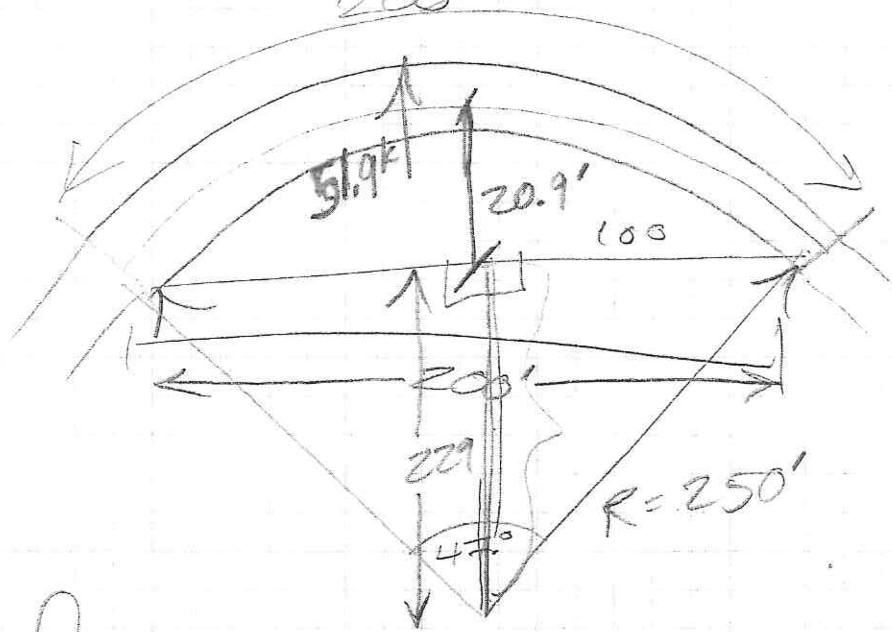
$y = \frac{-27}{(350)^2} x^2$ ← borrowing parabola formula from Hibbeler

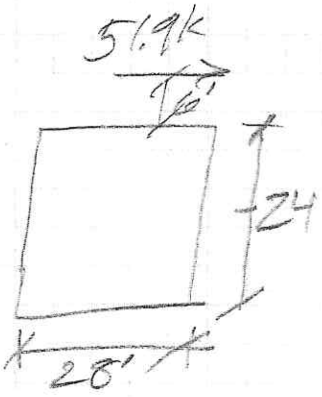
$@\, x = 100' \Rightarrow y = \frac{-27}{(350)^2}(100^2) = -27\left(\frac{10}{35}\right)^2$





2' overhang
28' depth of wall





$30' \times 51.9^k = 1557k\text{-}ft$

from eqn 3.6.3-1

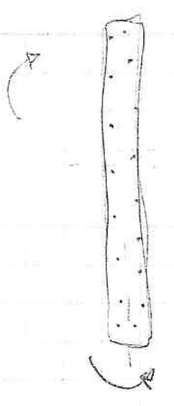
$$C = f\frac{v^2}{gR} = \frac{4\,(66\,ft/sec)^2}{\left(32.2\frac{ft}{sec^2}\right)(250\,ft)} = .72$$

$.72 \times 72^k = 51.9^k$

↑ design truck

$$\frac{45\text{ miles}}{\text{hour}}\left|\frac{5280\text{ ft}}{\text{mile}}\right|\frac{1\text{ hour}}{3600\text{ sec}} = 66\,\frac{ft}{sec}$$

$$\text{Circum } \frac{\pi \overset{500'}{d}}{360} \times 47.156 = 206'$$



$M_n = A_s f_y d$

$20\,in^2(60)(8)$

$9600k\cdot in$

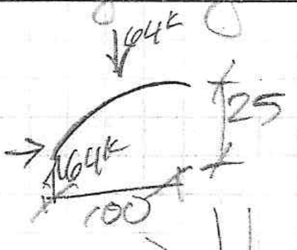
$800\,k\cdot ft$

$(14\,ft)(12\,in^2)(60\,ksi)$

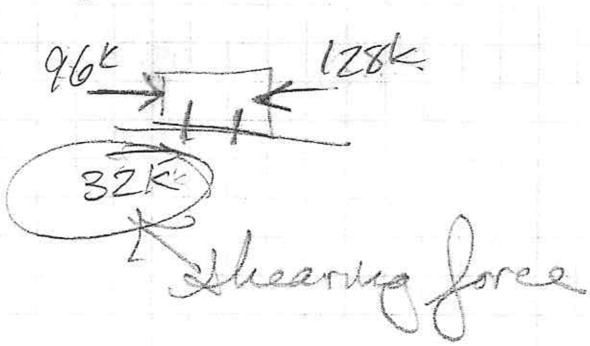
$= 10080\,k\cdot ft$

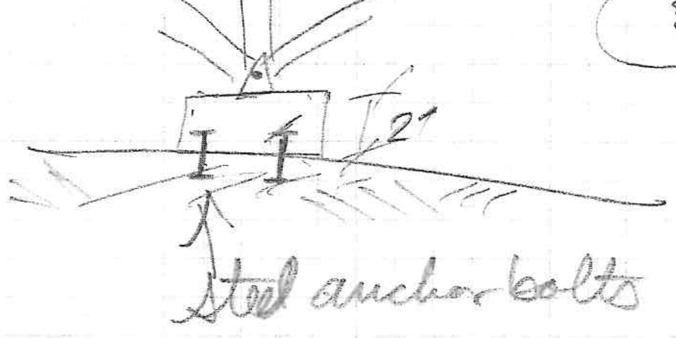
So will easily resist centripetal overturning moment

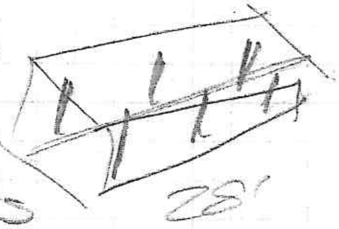
✓



$\frac{64(100)(1/2)}{25} = 128^k$





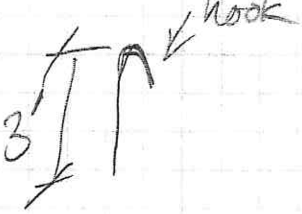


P = .6 Fu Abolt × #bolts

$32^k = .6(60ksi)(A_{bolt})6$

$A_{bolt} = .148 in^2$

#9 bars @ 1.00 in²



steel for anchor bolts

6 bases × 6 bolts = 36 bolts

if say 4' × 1.00 in² = .0278 ft³
× 36 bolts
1 ft³

450 lb × $5/lb = $2250 for anchor bolts

footings RC

126 ft³ × 6 footings
= 756 ft³ / 27 ft³/CY = 28 CY

28 × $375 = $10 500 footings

So total Bridge (not abutments)

$750 000 Bridge concrete
$ 2 250 Anchor Bolts
$ 10 500 footing concrete
$ 762 750

Abutments

(100 ft)(1/2)(10 ft)(2) = 1000 ft²
4" thick, ~350 ft³

$$\$390\left(\frac{350\,ft^3}{27}\right) = \$13\cancel{4},500$$

$5056

All under $1 mill
(approx $900k)

Abutments for end
spans must be designed
to take area reaction
Need much more cost

Railings etc
Prelim costs
not consistent

Preliminary Design

probably not true even w/stay

Two Scenarios: (a) Stay anchored, no moment in pylon

(b) Moment in pylon b/c stay broken

Killer

Think of building pylon - it has big moment before deck taken off temp support

Assumptions:

1. Unit compressive strength 18,000psi very strong, stronger than concrete
2. Excellent foundation conditions, RQD 90-100
3. Limestone 2' below grade. Soil does not contribute to capacity or frictional resistance.
4. Limestone $E = 1E^5 \rightarrow 8E^5$ tons/sf
5. End bearing pressure 70% q_u b/c of unknown discontinuities $q_b = 0.7 q_u$
6. Skin friction, $f_s = 2.5 q_u^{2.5}$
7. Uplift frictional resistance, $f_r = 0.7 f_s$
8. Factor of safety, $FS = 3$

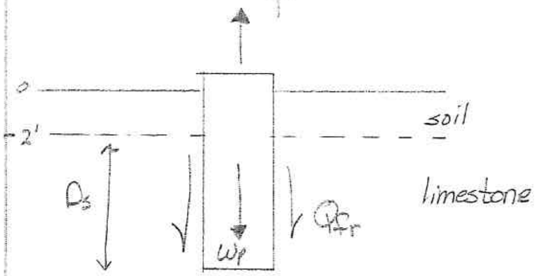
Foundation Options:

1. Drilled shaft → uplift resistance for tension
   moment resistance
2. Grouted steel rods anchoring steel plates or concrete slabs.

Note: For prelim design, foundation interaction not considered. Any further assumptions stated when assumed.

CASE A　Stay tensile force　T = 1352k　✓
Pylon axial force　A = 5332k

Stay Drilled shaft



neglect shaft self wt.

$T = Q_{fr}$

$Q_{fr} = A_s f_r$

Assume limestone ~120pcf

$f_s = 2.5(18\,ksi)^{2.5} = 3437\,ksi$

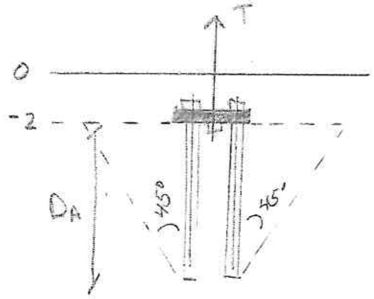
$f_r = 0.7 f_s = 2406\,ksi$

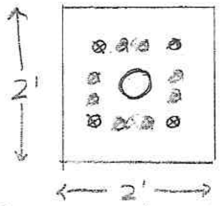
$A_s = \pi d D_s = \pi(12")D_s$　✓

$T = Q_{fr}$

$1352k = 2406(12\pi)D_s \Rightarrow D_s = 0.089 \Rightarrow$ not realistic

Stay Anchored Plate





$f_y = 60\,ksi$ bars

$t = 4in$

Assume bond bet. grout & limestone only 80%

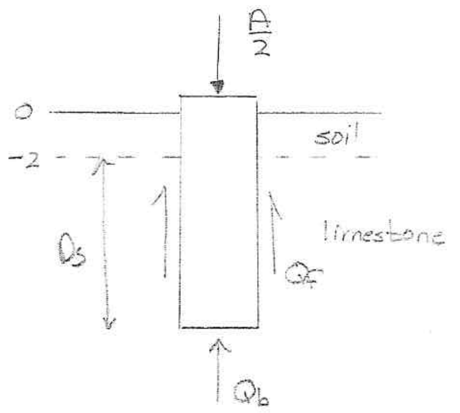
$1352k = 0.8(\underset{\uparrow \#\ bars}{16})(60\,ksi)A_b \Rightarrow A_b = 1.76\,in^2$

$1352k = \frac{1}{3}\pi(D_A \tan 45)^2 D_A(0.12\,kcf) \Rightarrow D_A = 22\,ft$

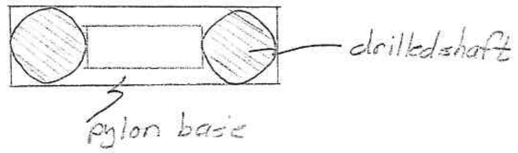
but can go 10ft

✓

Pylon Drilled Shaft



Try 2 drilled shafts, diam = 4'



$f_s = 3437$ ksi (from pg 2)

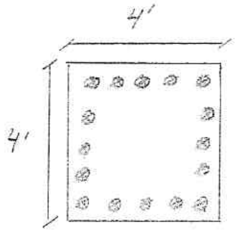
$q_b = 0.7 q_u = 0.7(18\text{ ksi}) = 12.6\text{ ksi}$ ✓

$3\frac{A}{2} = Q_b + Q_f = q_b A_b + f_s A_s$

$3(\frac{1}{2})(5332k) = 12.6\text{ksi}(\pi)(24'')^2 + 3437\text{ksi}(\pi)(48'')(D_s)$

$\Rightarrow D_s = 0.029$ again not realistic b/s limestone so strong.

Pylon Anchored Plate

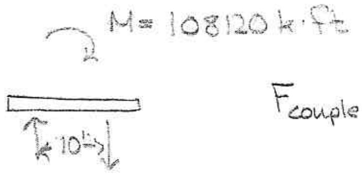


compressive stress $f_c = \frac{A/2}{\text{Area}}$

$f_c = \frac{3(\frac{1}{2})(5332k)}{2304\text{in}^2} = 3.5\text{ ksi} << 18\text{ksi}$ ✓

$t_{plate} = 6''$

Area of steel must meet shear rqmt for moment connection.



$F_{couple} = \frac{108120\text{ k·ft}}{10'} = 10812k \simeq 10800k$

$A_s = \frac{10800k}{60\text{ksi}} = 180\text{ in}^2/\text{plate}\left(\frac{1}{1\text{ in}^2}\right) = 15\text{ bars/plate}$

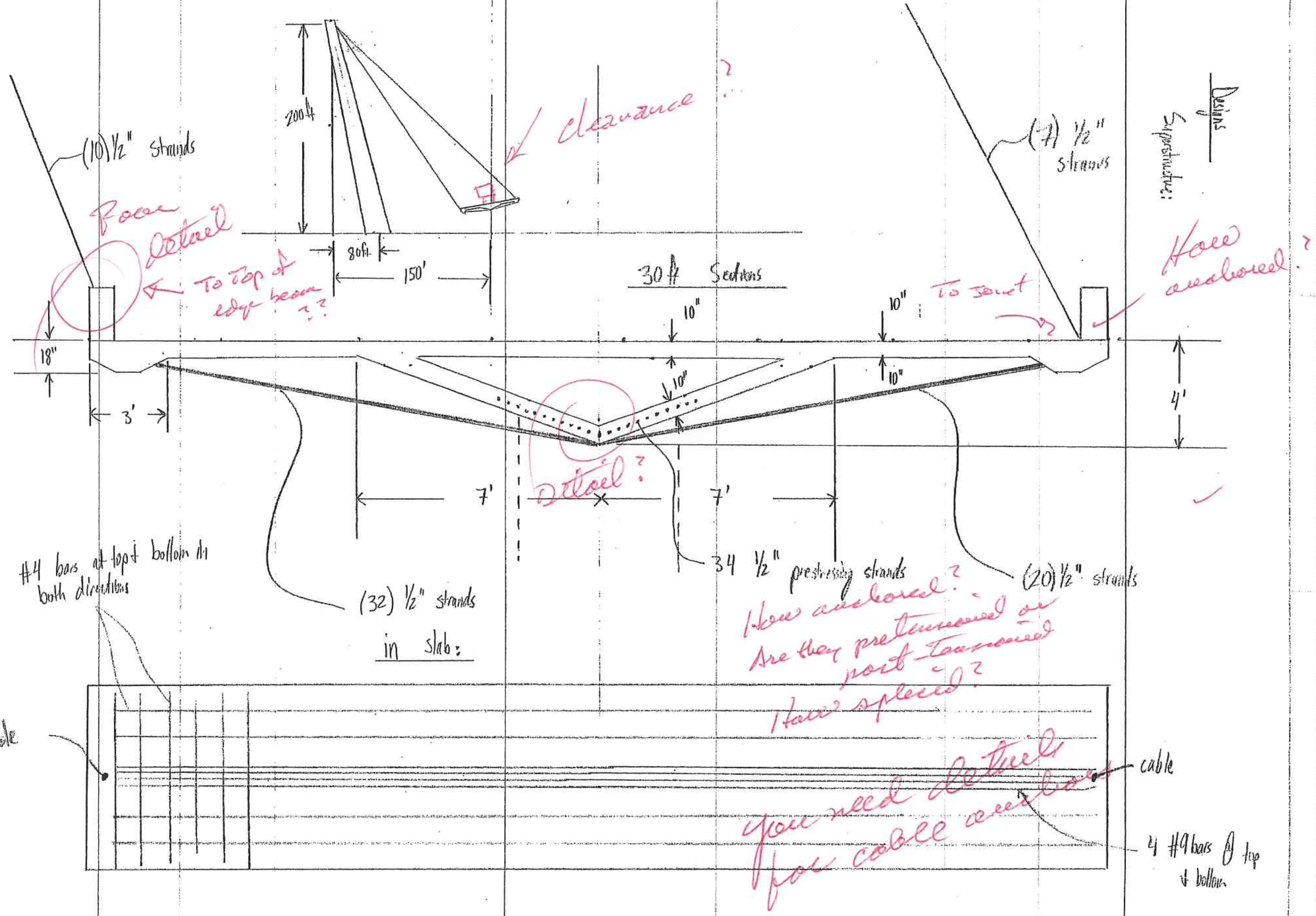
$10800k = \frac{1}{3}\pi(D_A \tan 45)^2 D_A (0.12\text{ kcf})$

$\Rightarrow D_A = 44$ ft

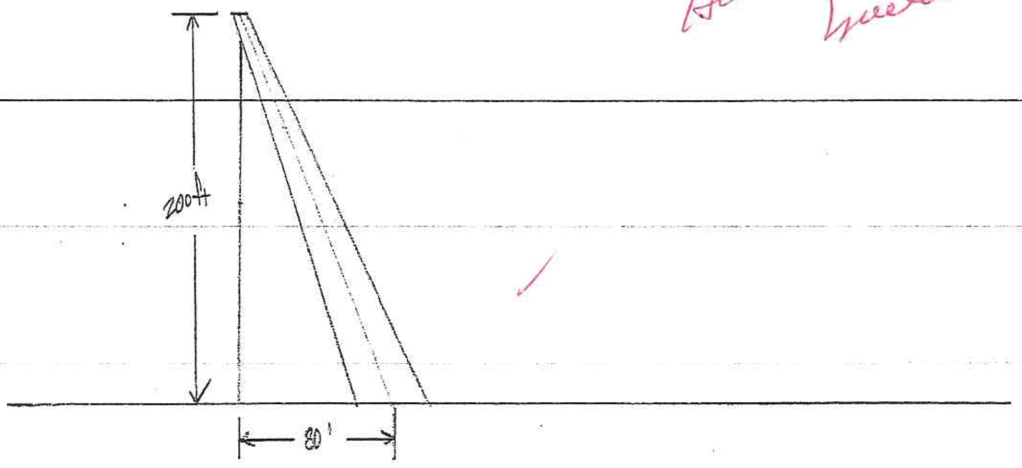
but can go 22ft

Designs

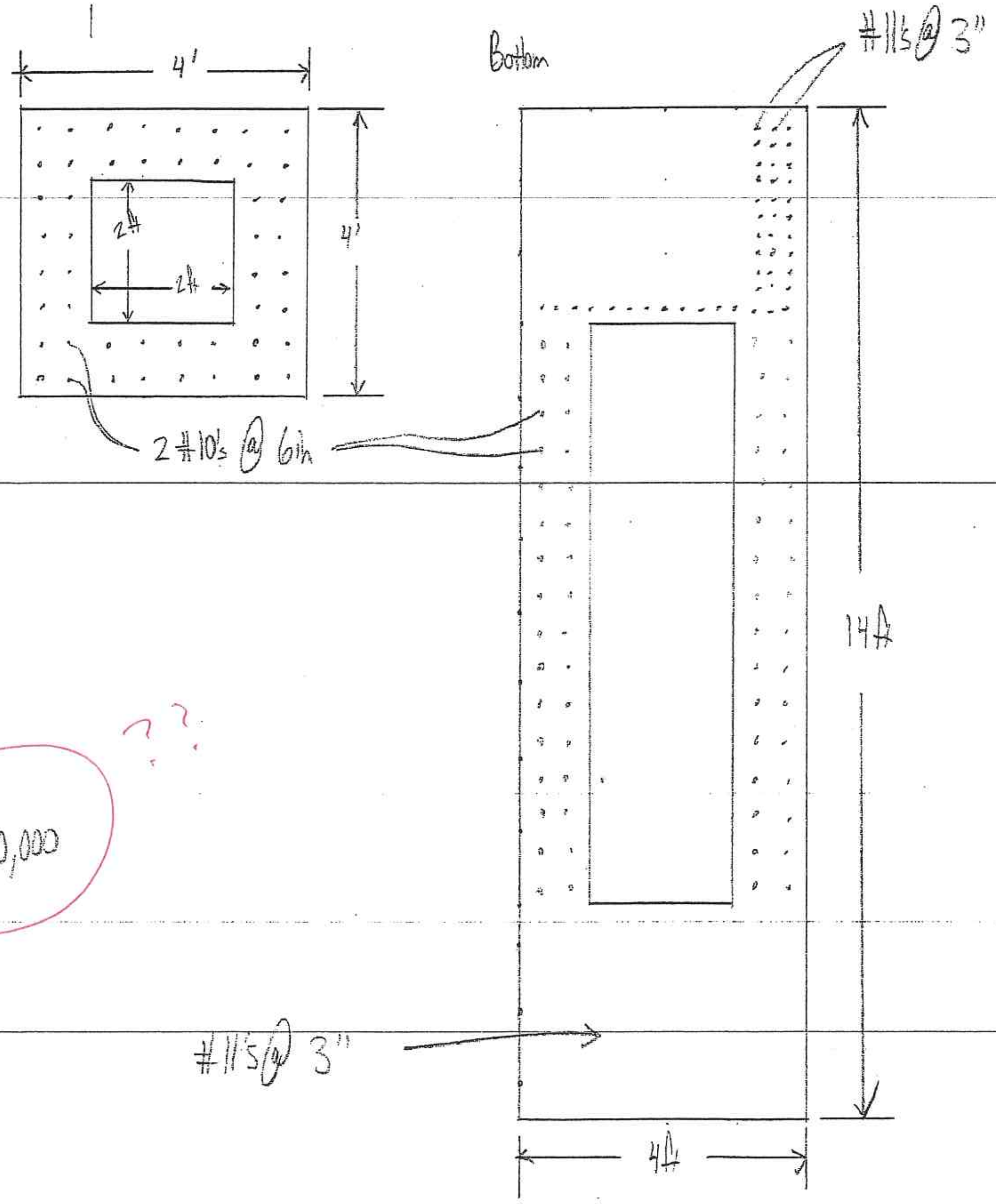
Superstructure:



How do you build?



Wow!

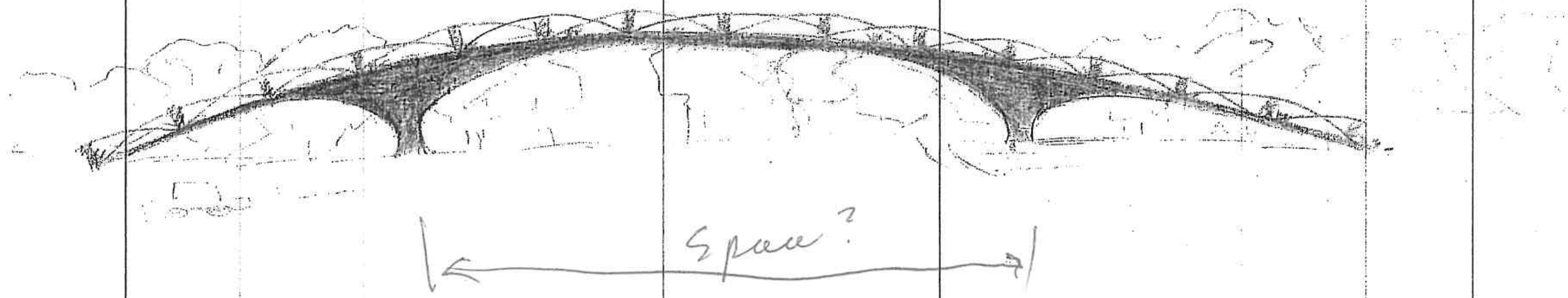


??

$11,700,000

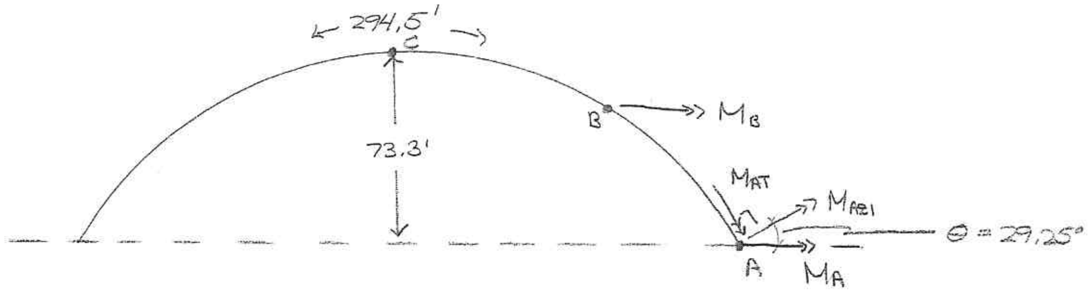
Zilker Park
Stratford Lane / Barton Springs
Vehicular + Pedestrian Bridge

- heavy supports keep thin bridge from floating away
- curves of Austin oak tree trunks
- playful railing for Austin & park feel
- stays w/ tree line so sky not broken



Analysis

Plan



$$M_A = 294.5w(73.3) = 21587w$$

$$M_{AZ1} = M \sin\theta = 18835w$$

$$M_{AT} = M \cos\theta = 10548w$$

$$M_B = \tfrac{1}{2} M_A = 10793w$$

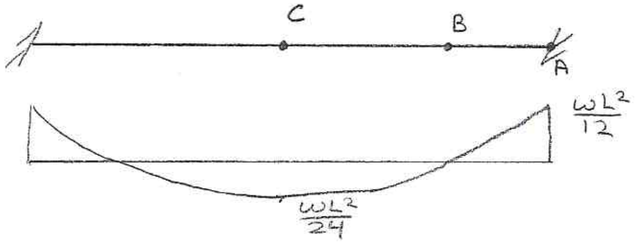
$$M_{BZ1} = 9417w$$

$$M_{BT} = 5274w$$

If you want something like this -- why not Design as arch instead of 300' span beam - Doesn't make much sense to me

Profile

approximated as beam for conservatism



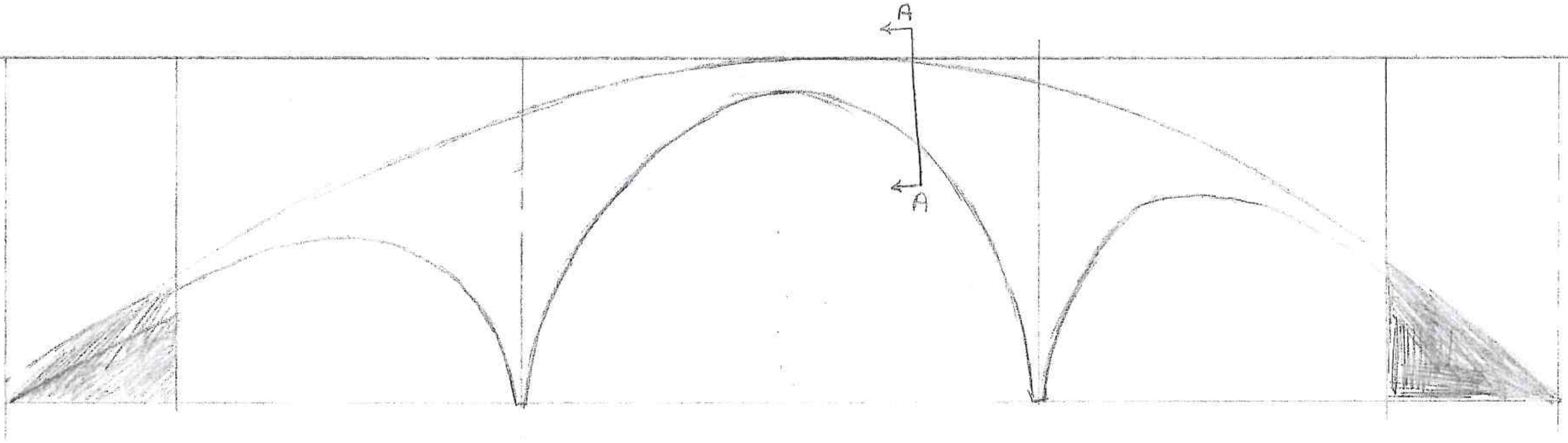
$$M_{AZ2} = \frac{w(294.5')^2}{12} = 7228w \qquad V_A = \frac{wL}{2} = \frac{294.5'w}{2} = 147.3w$$

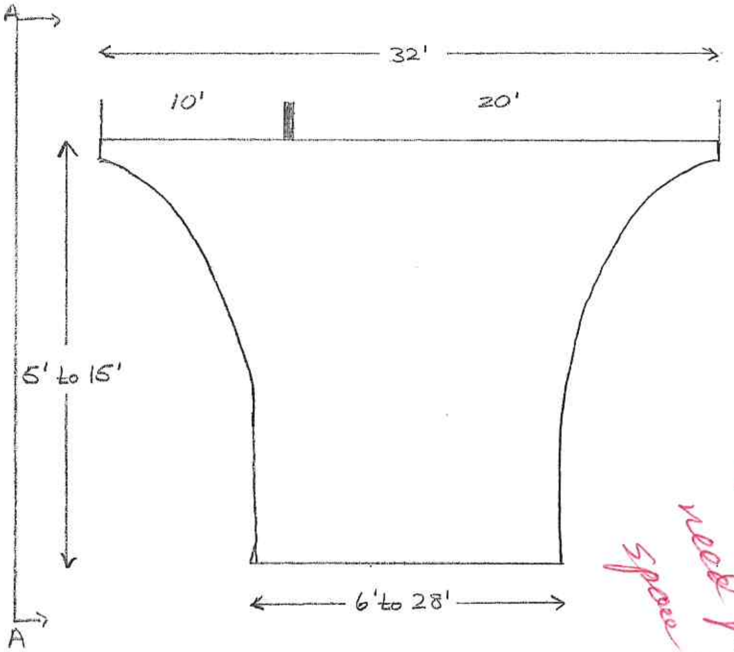
$$M_{BZ2} = \sim 0$$

$$M_{CZ} = \frac{1}{24} w(294.5')^2 = 3614w$$

tandem truck as distributed load $w = 2.03^{k}/ft$

Profile not drawn to scale





Volume of Concrete {approximate}

$\left[(700')(20')\right] - \frac{4}{3}(18')(150') - \frac{4}{3}(12')(100')(2)$

$- 2(\frac{1}{3})(150')(10') = A$

$V = 6200\,sf\,(9') = 117800\,cf$

$= 4363\,cy$

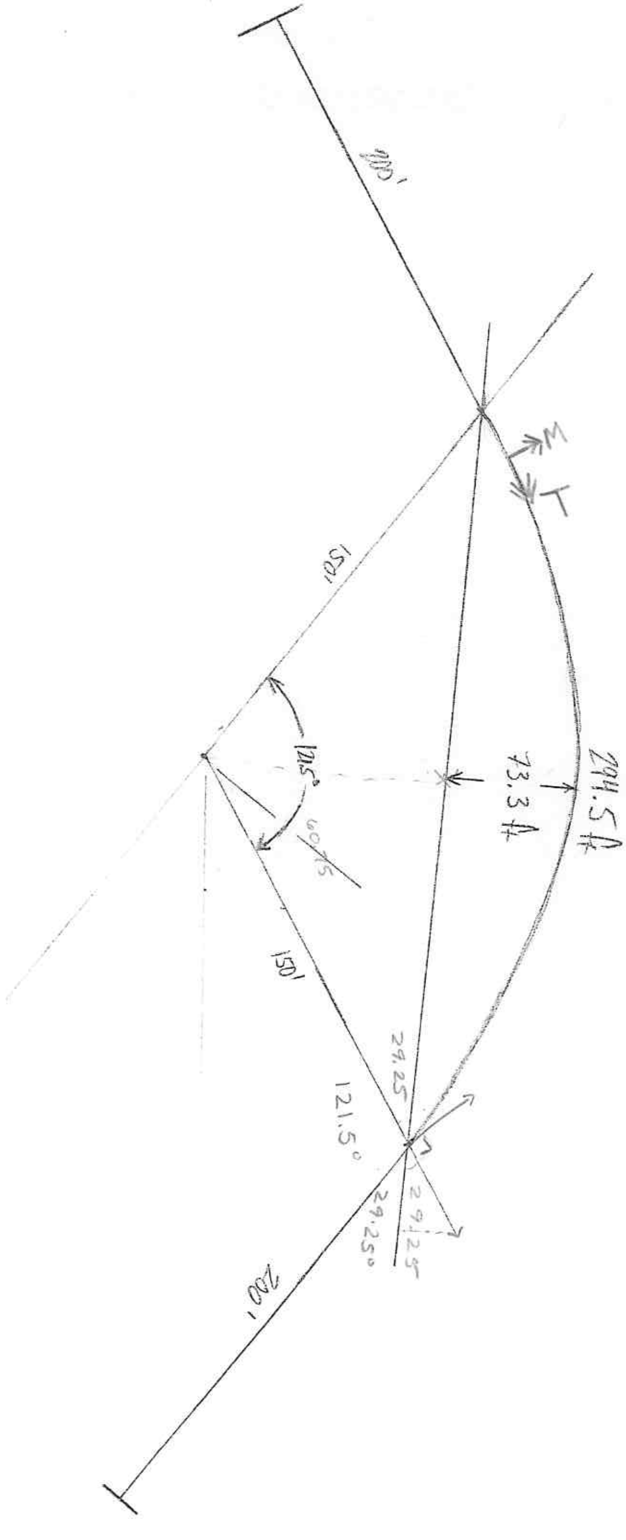
Area of Steel Excluding Flexure

$A_s = 0.25\,(6200\,sf) = 1550\,sf$

Prelim. Cost Estimate {concrete}

$1,635,000

this is because there is no need for 300' span there


200'
M
T
150'
121.5°
60.75
294.5 ft
73.3 ft
150'
29.25
121.5°
29.25
29.25°
200'

✓

✓

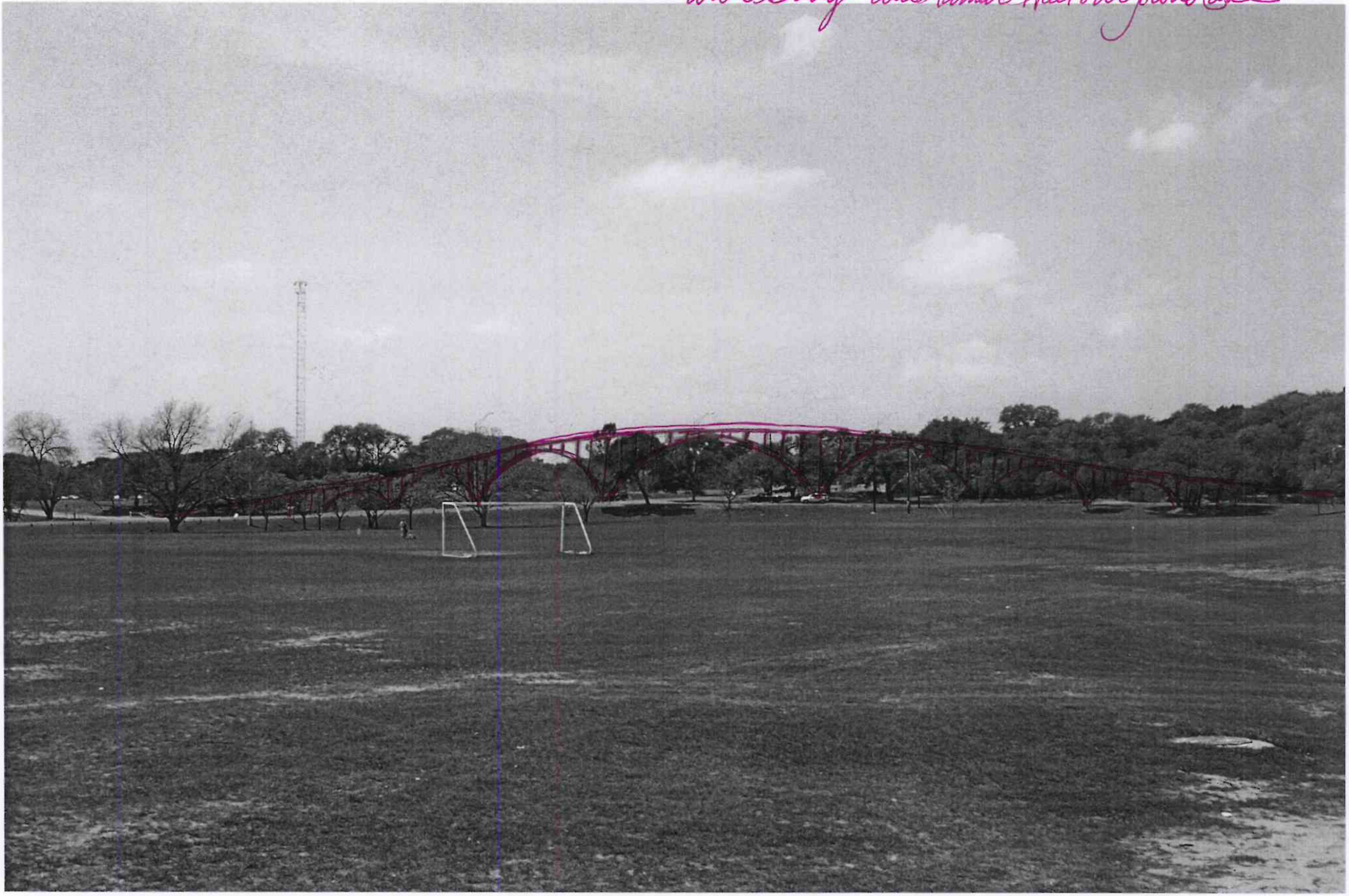
APPENDIX D

Pre-Preliminary Bridge Concepts

These are good
but where is
Kite Swing Bridge ?


Suspension Bridge

arch bridge ala Lamar Street over Town Lake



bridge w/ "tree" columns

APPENDIX E

Provided Information

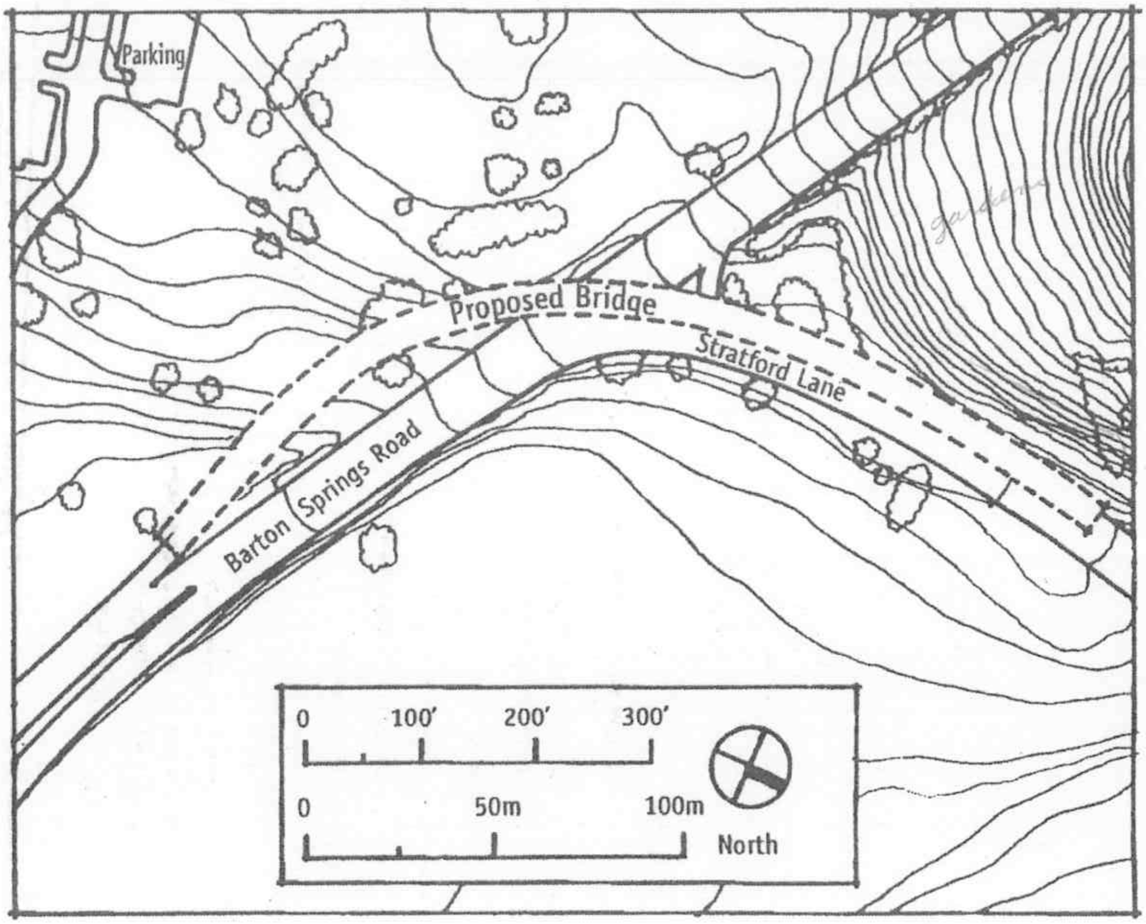
Unit Costs

Structural Steel Shapes (GR 36)	$1.50/lb in place
Steel Plate (GR 45)	$2.00/lb in place
Steel Stays or Ropes (GR 250)	$1.50/lb in place
Steel Anchor Bolts (GR 120)	$5.00/lb; includes rock drilling and adhesive
Reinofrced Concrete [cast-in-place] (GR 5)	$375/cyd; includes forms and GR 60 reinforcement
Reinforced Concrete [cast-in-place or precast]	Premium for higher strength: add $15/cyd/1ksi increase
Reinforced Concrete [precast] (GR 5)	$325/cyd; includes GR 60 reinforcement
Pretensioned Concrete (GR 8)	$300/cyd; includes 270ksi prestressing strand
Pretensioned Concrete (GR 14)	$375/cyd
Post-Tensioned Concrete (GR 8)	$375/cyd; includes 270ksi prestressing strand
Post-Tensioned Concrete (GR 12)	$425/cyd
Timber – treated structural grade	$1.20/board foot
All temporary Douglas Fir supports	Material 33% and placement 33%, (including connectors) of unit costs shown for permanent construction

Cable Stays Pylons – for members having an inclination for more than 5° from vertical, increase costs by 25%

For cable stay corrosion protection systems when cable material is used in permanent systems, increase cable costs $1/lb.

Site Plan


Parking
Proposed Bridge
Stratford Lane
Barton Springs Road
gardens
0
100'
200'
300'
0
50m
100m
North