EQUESTRIAN COMPETITION CENTER

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in partial fulfillment of the requirements for the degree of

Master of Architecture

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Equestrian Competition Center

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Abstract

This thesis explores the possibilities of using varied long span glue-laminated arches to create a dynamic structural enclosure over an expansive open surface. It investigates using arches that increase and decrease in height and span width, while varying in their lean. When combined with a fabric enclosure, they create a roof that constantly changes. The idea is to create a world class equestrian center that is visually exciting from both the interior and exterior, rather than simply creating a large scale version of a barn.

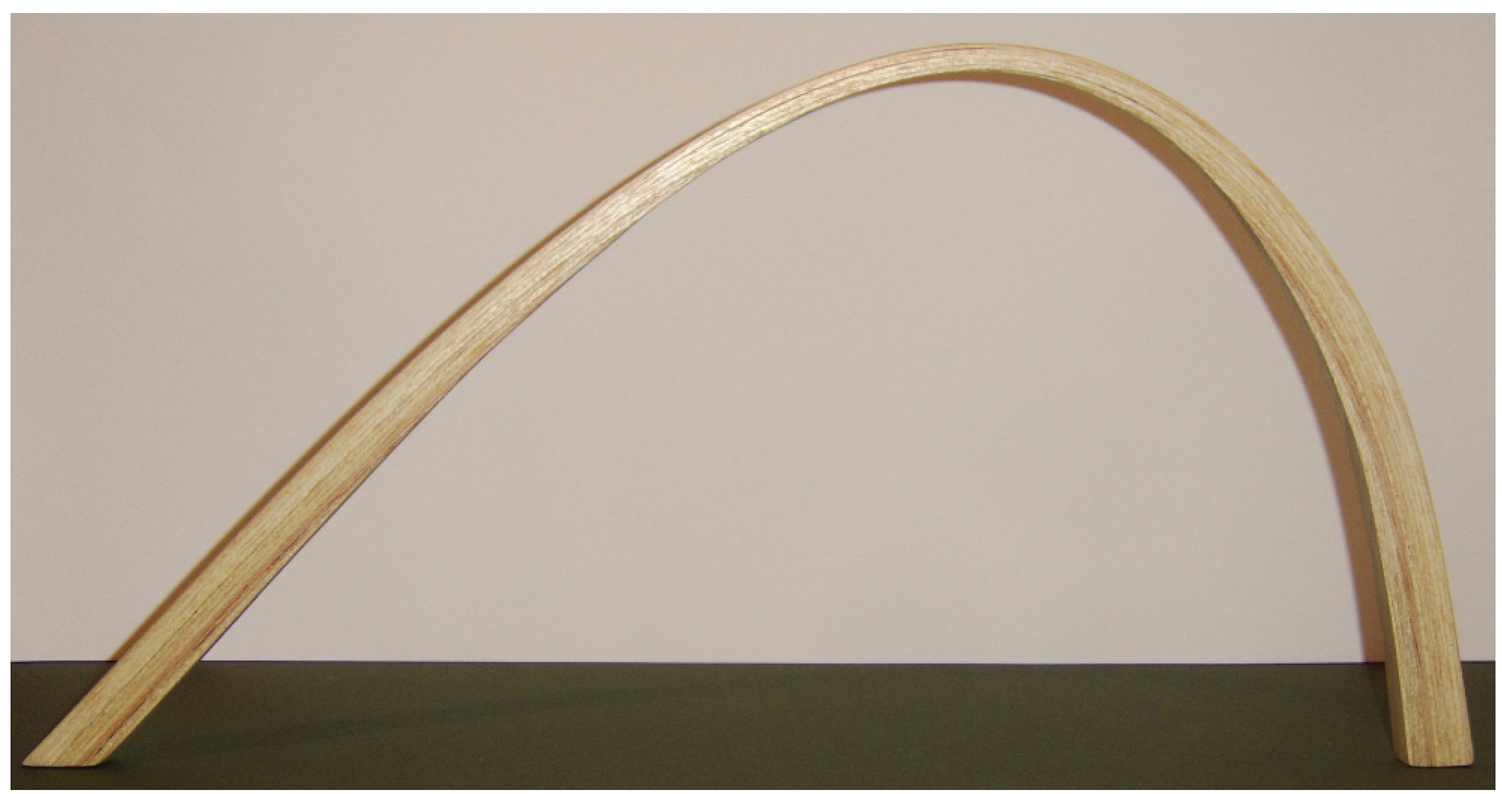

Fig. ii-1 Glue-Laminated Arch (Scale Model)
(Photo By Author)

Acknowledgements

I would like to thank my family for all the love and support they have given me, even from so far away, during my time at Virginia Tech.

I also need to thank my committee members, not only for the guidance and time they have given me on this project, but also for the knowledge they have passed on that will help me in my professional career.

Most importantly, I thank Chelsea. Without her love, support, professional equestrian knowledge, and infinite patience, none of this would have been possible.

Fig. iii-1 Chelsea Roberts on Caruso (Dressage)
(Photo By Author)

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Fig. iv–1 Chelsea Roberts on Starlet Street (Dressage)
(Photo By Author)

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All images are by the Author.

Introduction

Equestrian competitions are subject to nature's whim, and if indoor facilities do exist, they are often merely extra large barns with minimal space. The indoor riding centers are often dark, noisy, and hot buildings that are not conducive to the events they are hosting. Horses are often frightened by banging metal siding, limited by small walkways and low ceilings, and spectators are rarely considered. An elegant sport such as this deserves more than just the cheapest solution to a weather problem. This thesis tries to take advantage of that opportunity to create a space that respects the spectator, the rider, and most importantly, the horse.

Fig. 1-1 Chelsea Roberts on Lady Lucy (Show Jumping)
(Photo By Author)

The concept of this project is to create a world class equestrian center that is both enjoyable to use and exciting to look at. While many methods for creating large volumes currently exist, such as dome or truss construction seen in many large sporting arenas, this thesis studies the possibility of creating a massive building that doesn't seem quite so large. By varying the arches to form an undulating fabric roof, the structure creates depth through multiple layers and volumes, giving the illusion that it is made up of smaller parts. When viewed from a distance, this design also reflects the rolling hills that are synonymous to this sport. In doing so, this design attempts to interact with the land and the events it hosts, rather than completely dominating the horizon and engulfing the occupants in a cavernous box.

Initial Investigations

The initial idea for the Equestrian Competition Center was a large, open space that could host multiple events at the same time under one roof. After having seen and been in many indoor riding arenas, I noticed that they were either to small to do this, or their scale was too imposing on the typical pastoral site. The concept of an irregular roof that rose and fell to create variation on the interior, and to disrupt the sense of scale from the exterior, grew from an admiration of the sense of freedom being on a horse or simply watching a horse evokes. The only straight lines associated with equestrian activities are the ones imposed by humans. Horses are often kept in enclosed paddocks composed of straight lines of fencing or lined up in rows in barn stalls. They are often trained in riding centers that are just larger versions of the barns they sleep in. So much of it seems in conflict with the animal the sport revolves around. The questions that arose were; how do you meet the requirements of the sport while rejecting the limitations of the common building style, and how do you make a roof of rolling hills? For me, the answer could not just be a flowing skin that hid a rigid, rectilinear structural skeleton. However, how do you take an idea, and some modeling clay (Fig. 2-1, 3-1, 3-2), and design a functioning building? This thesis explores one possible response to these questions.

Fig. 2-1 Clay Model (Birds-eye from Side)
(Photo By Author)

Early Clay Models

Fig. 3–1 Clay Model (Front View)
(Photo By Author)

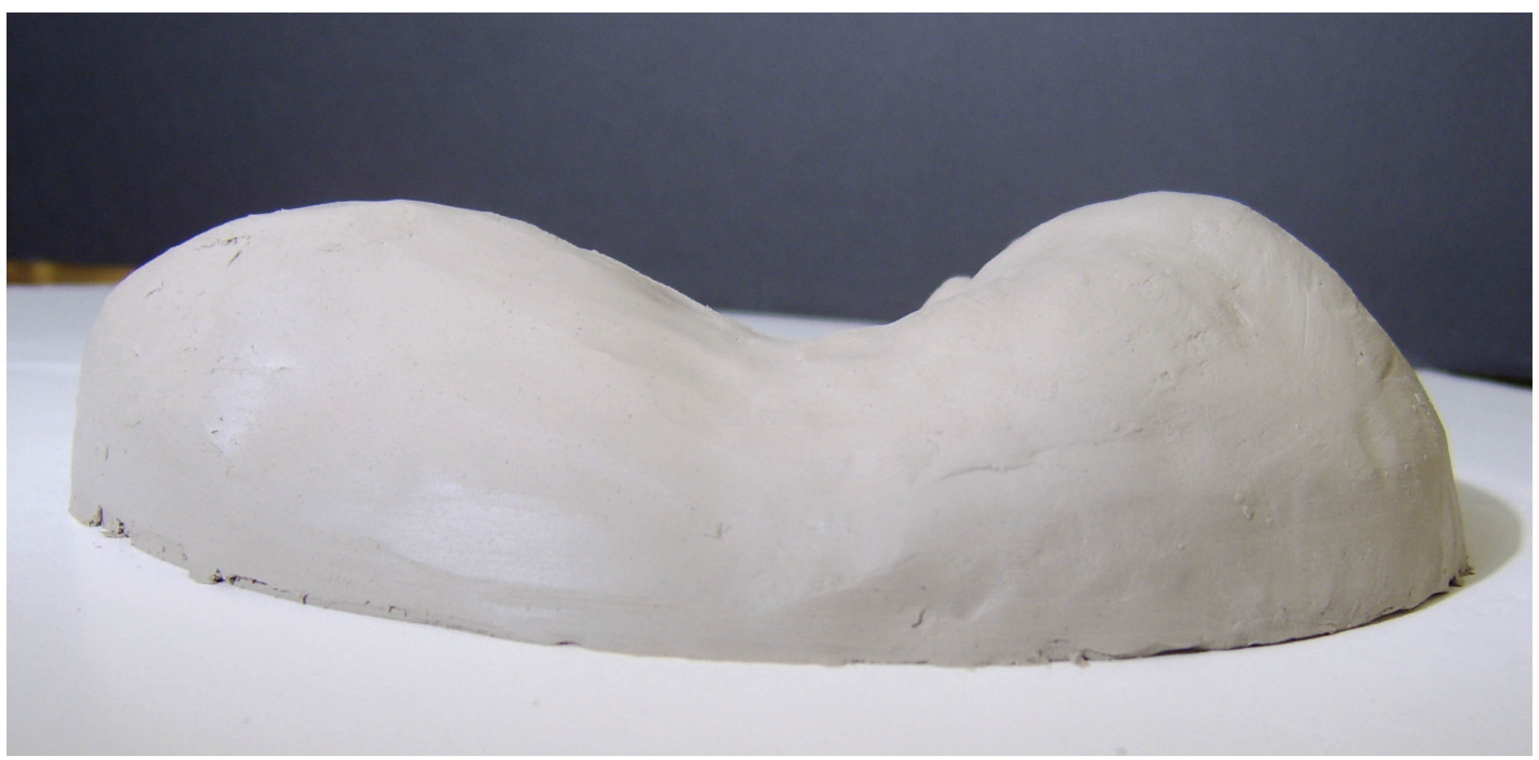


Fig. 3–2 Clay Model (Rear View)
(Photo By Author)

Clay model views from the front (Fig. 3–1) and rear (Fig. 3–2). Previous page shows birds–eye view from the side (Fig. 2–1). The clay was used to study possible undulation variations of the roof.

Funicular Modeling of Arches (No Weights)

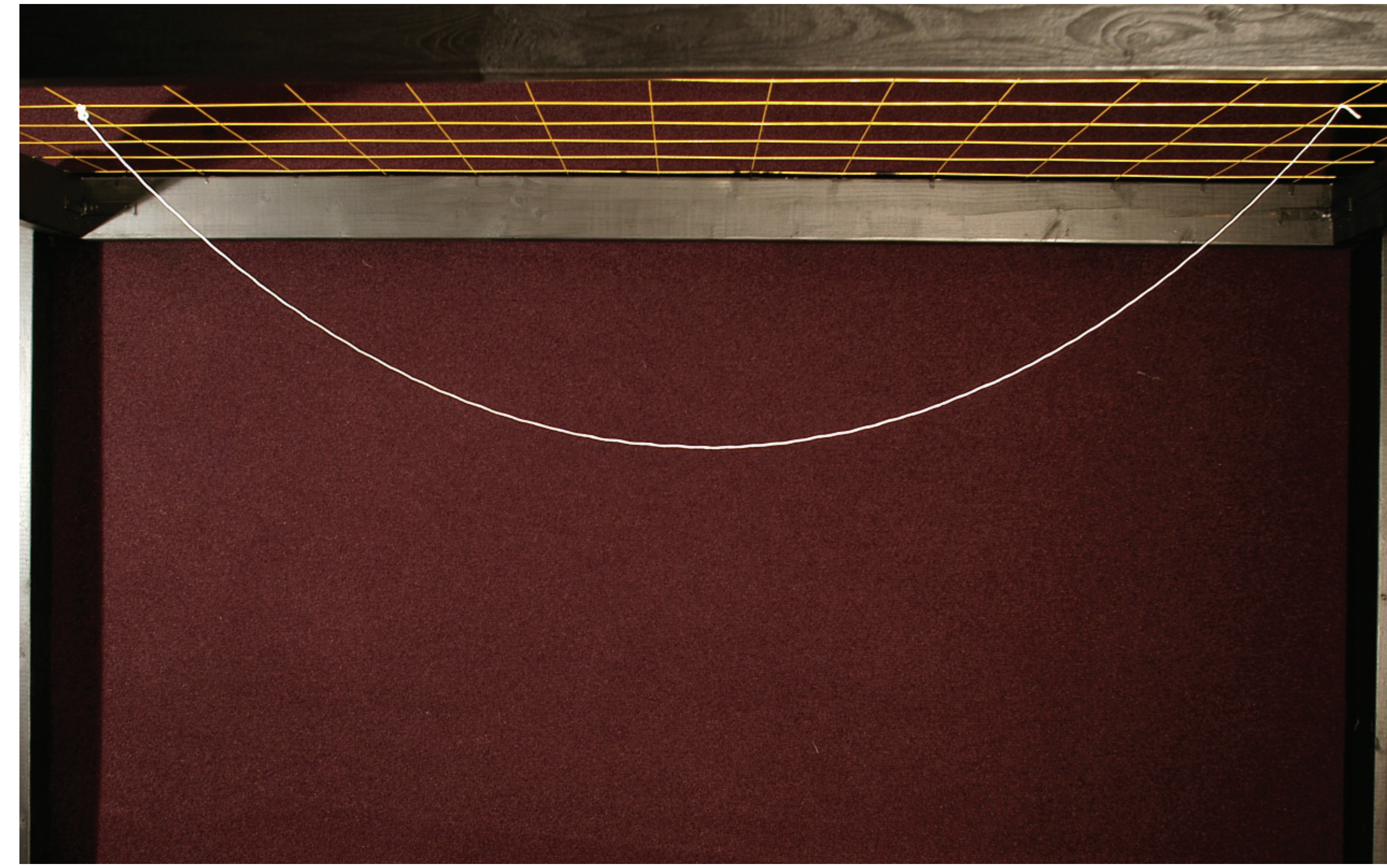


Fig. 4–1 Funicular Model Wide (No Weights)
(Photo By Author)

Strings were used in a funicular model to study how arches could be used to create a structure that formed the roof, The aim of this was to have a dialogue between the structure of the roof and the envelope of the roof, rather than have a structure that was present solely to hold an envelope in place. These two arches show how an arch can vary by altering the width of the base (Fig. 4–1) or by changing the height of the peak (Fig. 4–2).

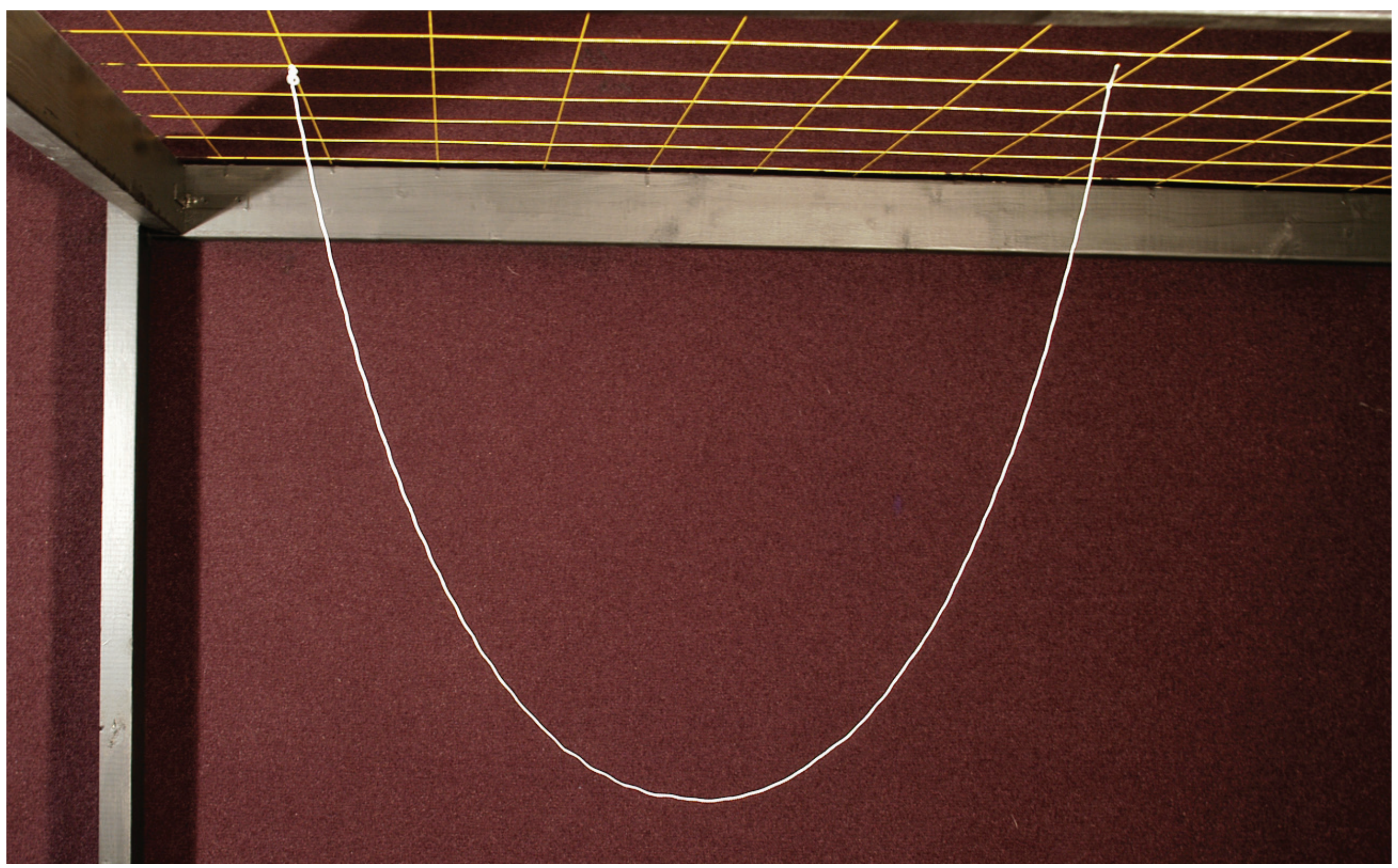


Fig. 4–2 Funicular Model Tall (No Weights)
(Photo By Author)

Funicular Modeling of Arches (Weighted)

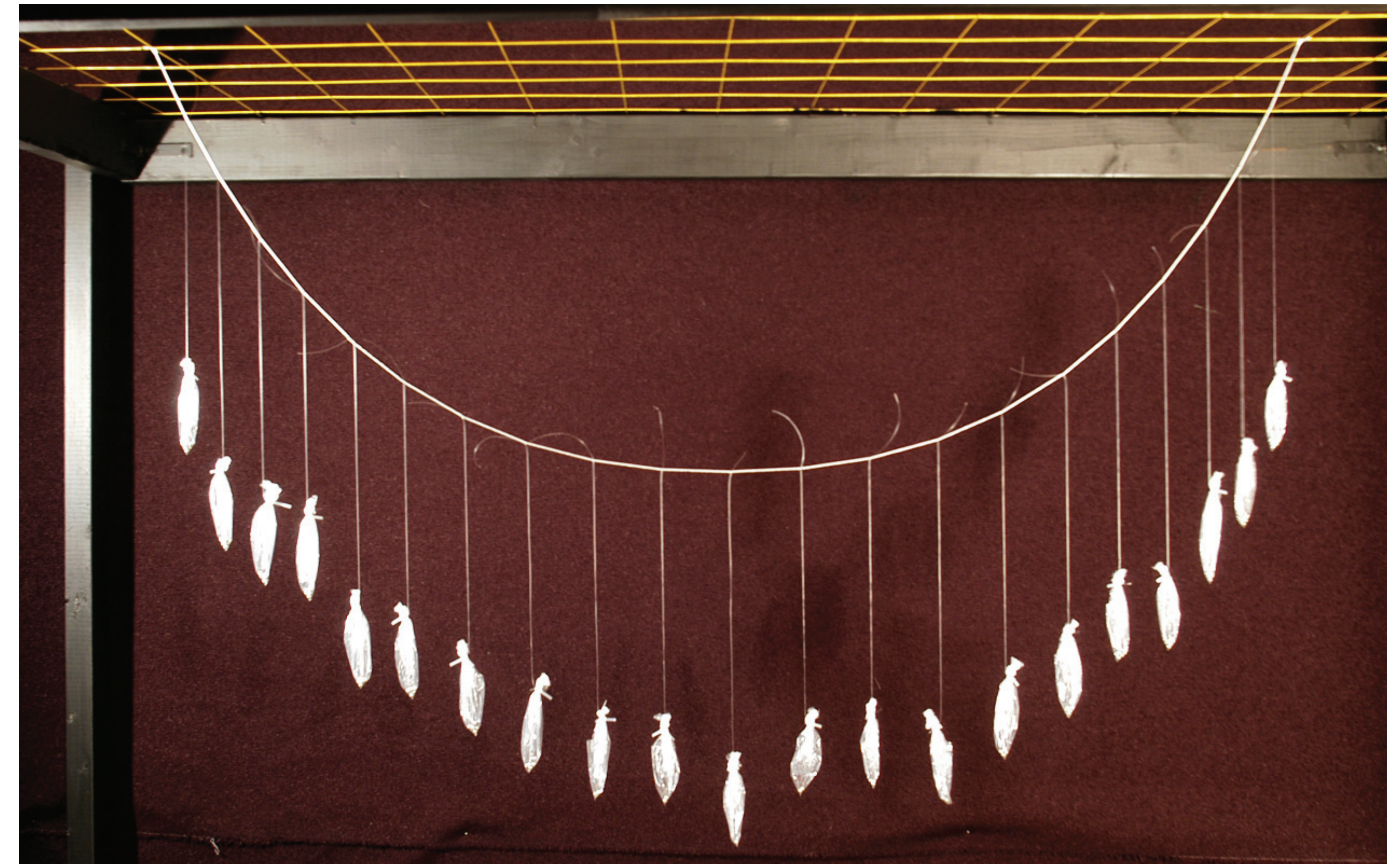


Fig. 5–1 Funicular Model Even Weight Distribution
(Photo By Author)

Weights were added to the strings used in the funicular model to study how loads would effect the arches. The string that was loaded in equal increments on either side (Fig. 5–1) created a symmetrical arch, while the sting loaded more on the left side (Fig. 5–2) created a leaning arch. This demonstrates how in a symmetrical catenary arch, the load is distributed evenly, so the thickness of the arch can increase evenly on either side as it nears the base and the load increases. On the other hand, a catenary arch that is leaning will have uneven load distribution, requiring it to have greater thickness on the side with the greater load.

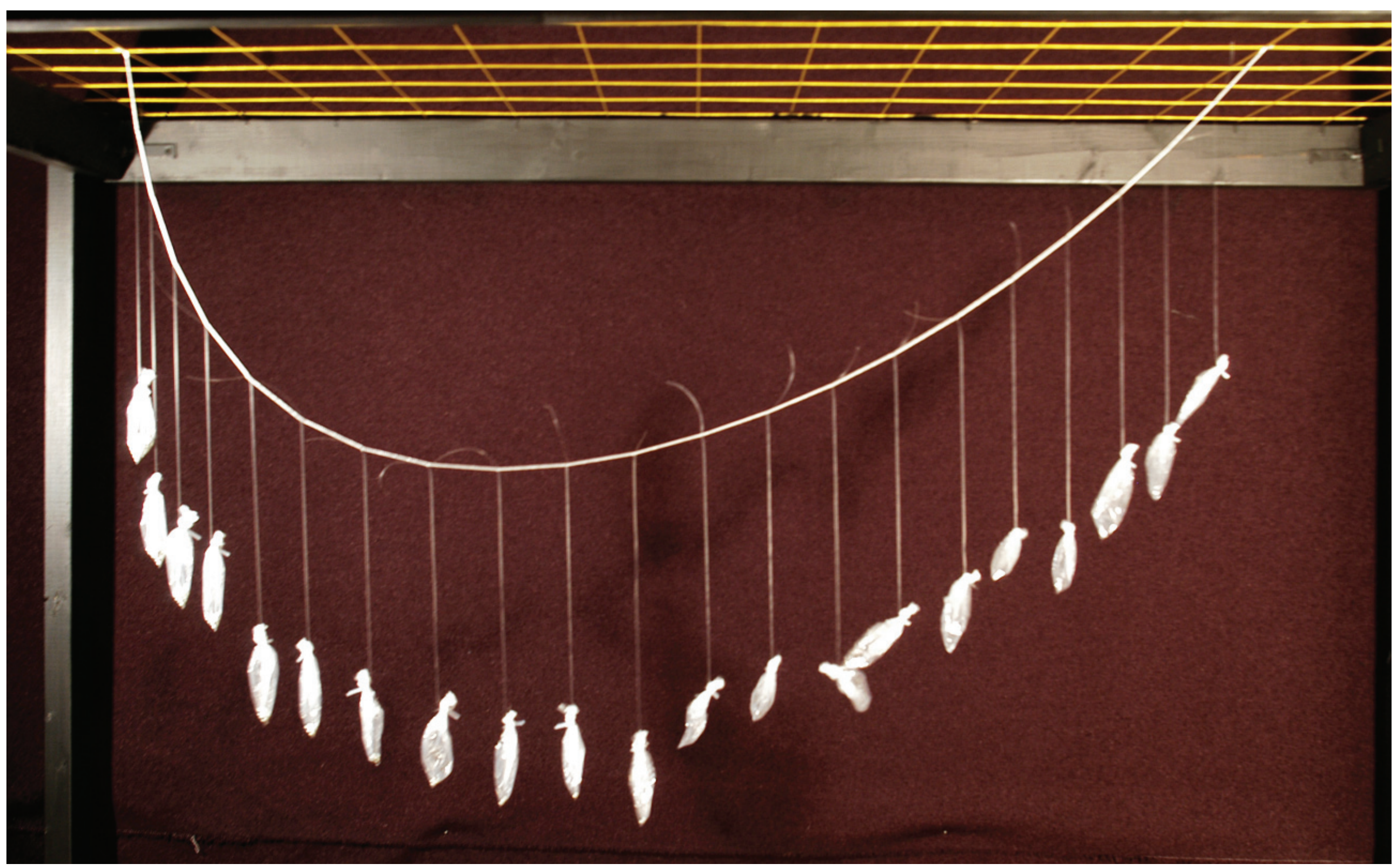


Fig. 5–2 Funicular Model Side Loaded Weight Distribution
(Photo By Author)

Arch Style Test Variations

The structural arches vary by height, distance between bases, and lean, but other variations were considered. The shape of the arch cross–section was considered, including testing pentagonal, diamond shaped, and circular cross sections (Fig. 6–1 and 6–2). The taper of the arch cross–section was also studied, including tapering the height, width, and a combination of each (Fig 6–1 and 6–2). The unnecessary complexity of most of these variation were ruled out. However, a rectangular arch cross–section that tapers in height but remains constant in width became the end result of these studies.

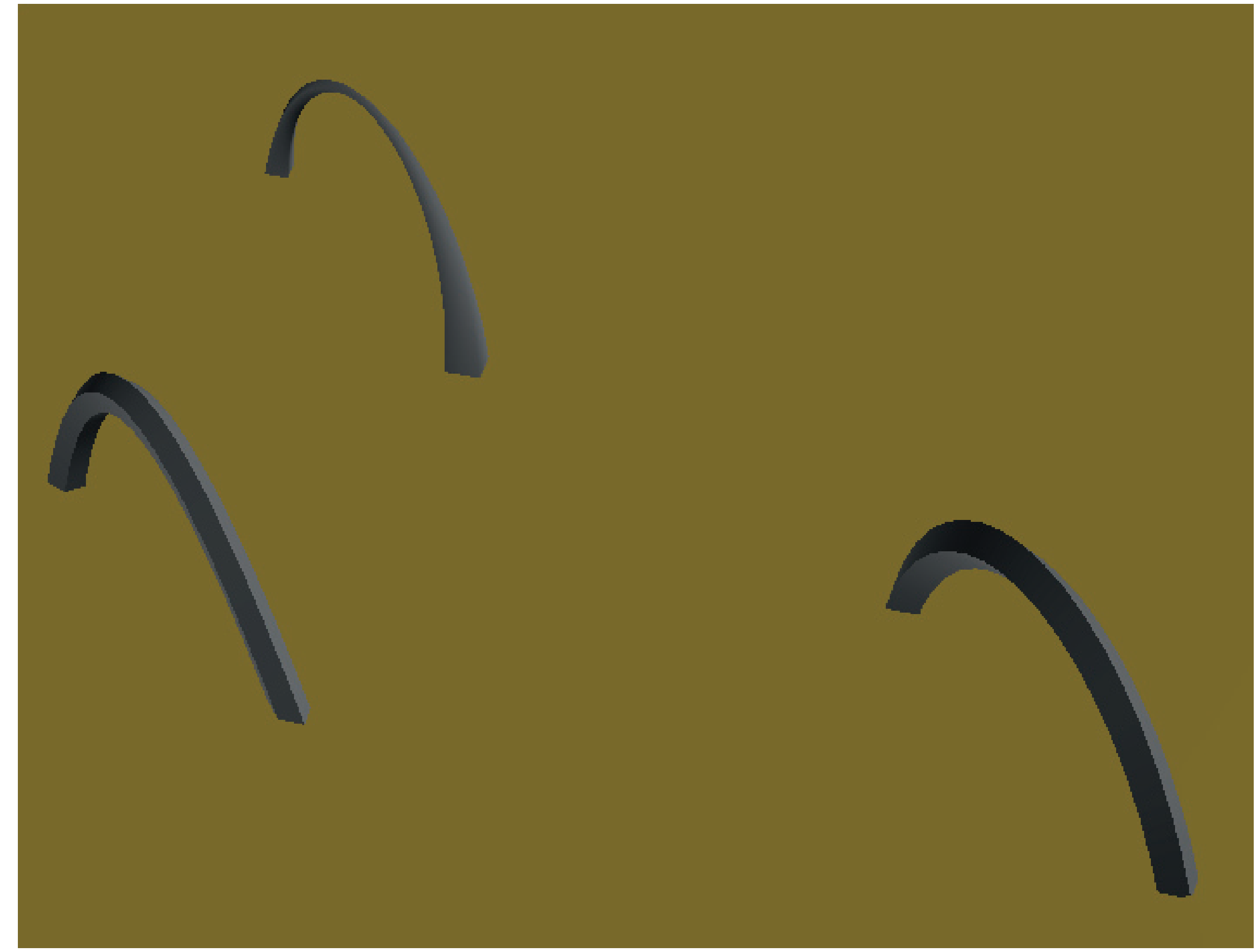


Fig. 6–1 Arch Variation Sample (Birds–eye View)

Fig. 6–2 Arch Variation Sample (Side View)

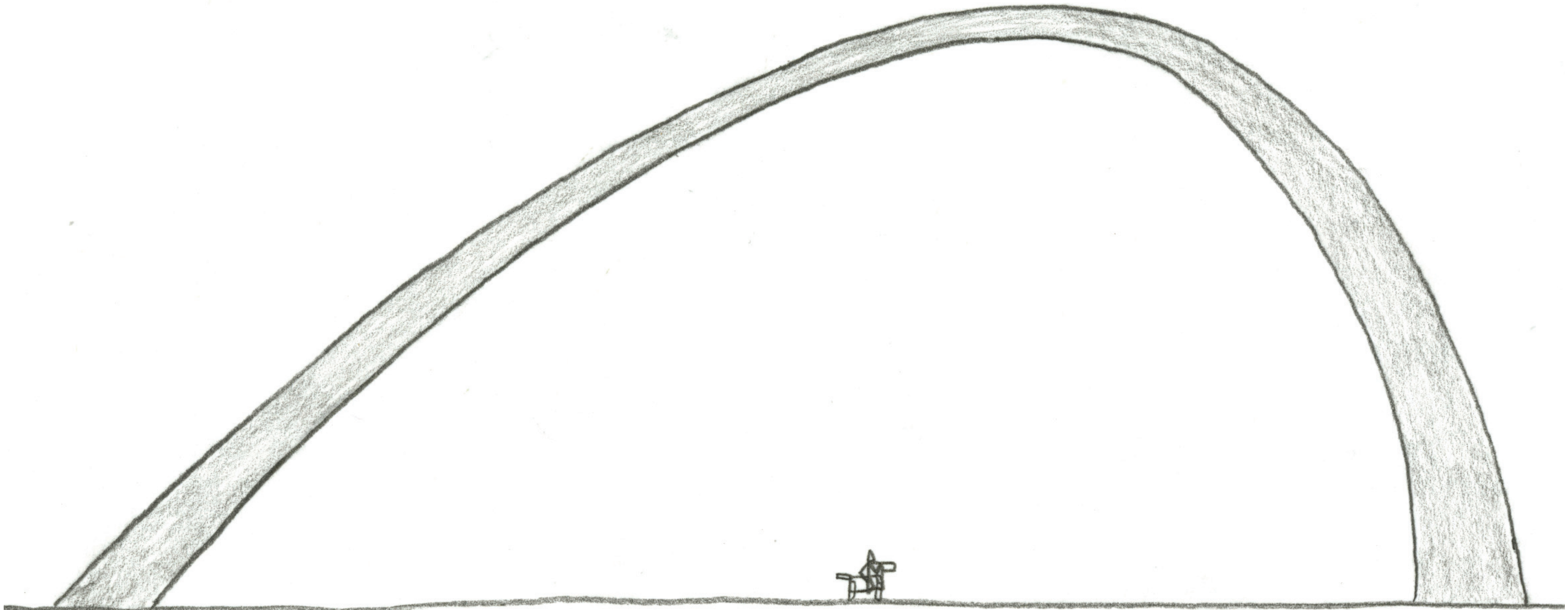


Fig. 7–1 Hand Drawn Arch Elevation Preliminary Sketch

Arch Material Study

In order to design the Equestrian Competition Center, the material of the structural arches needed to be determined. The material choices were narrowed down to glue-laminated wood and stone or concrete. Scale models were built of each, using approximate height, span width, and lean, and the process of making each was taken into consideration. It was discovered that the concrete model (Fig. 8-2) was heavier and required greater thickness to avoid failure, while the process of casting and installing the arches at full scale seemed prohibitive. The glue-laminated model (Fig. 8-1) supported the decision to use glue-laminated arches for their relative slenderness, flexibility, and weight and cost advantage over the concrete arch. The glue-laminated arch was also chosen for aesthetic reasons. Additional images (Fig. 9-1, 9-2, 9-3) of the test arch are included on the following page.

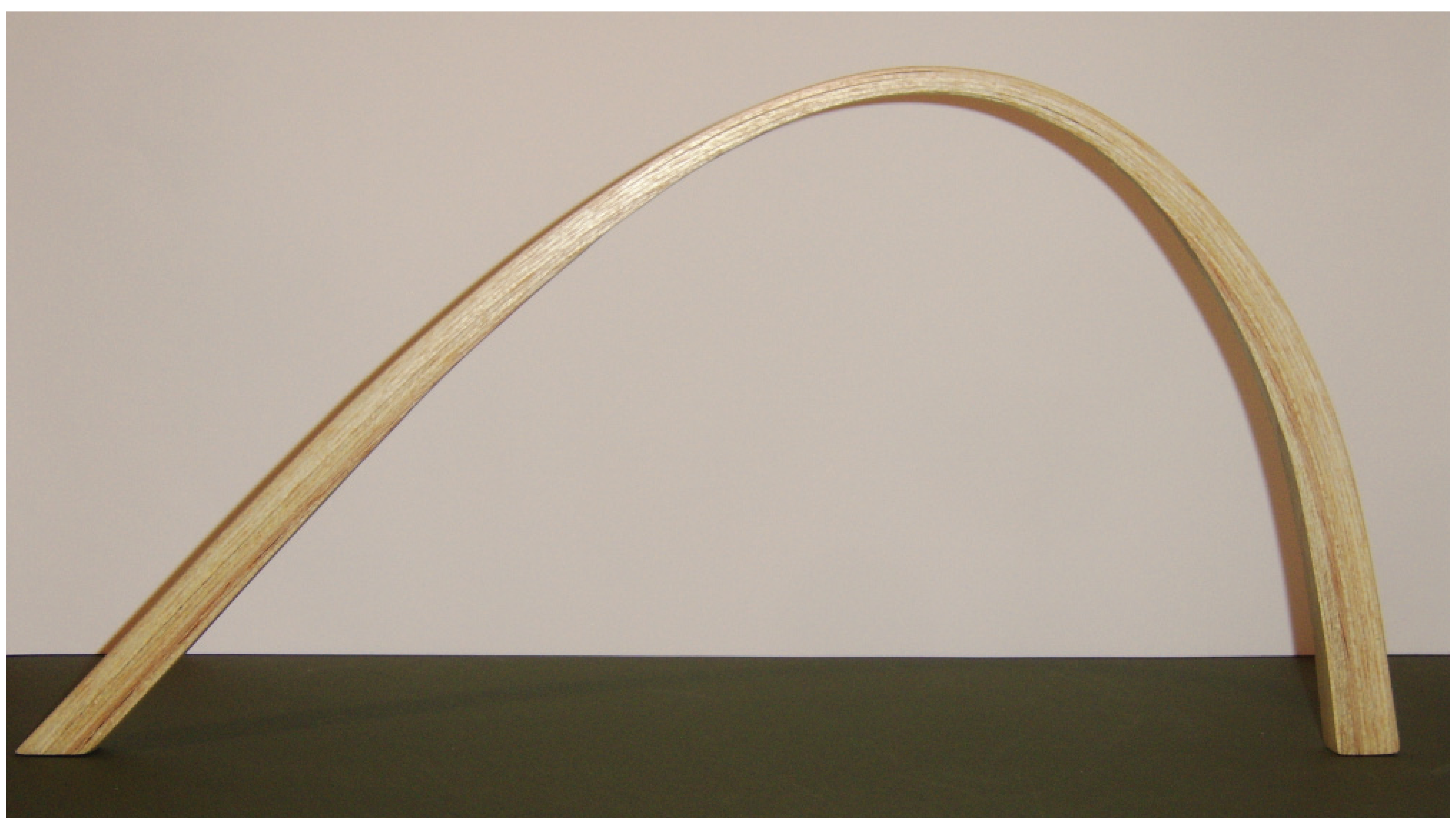


Fig. 8-1 Glue-Laminated Arch Scale Model
(Photo By Author)

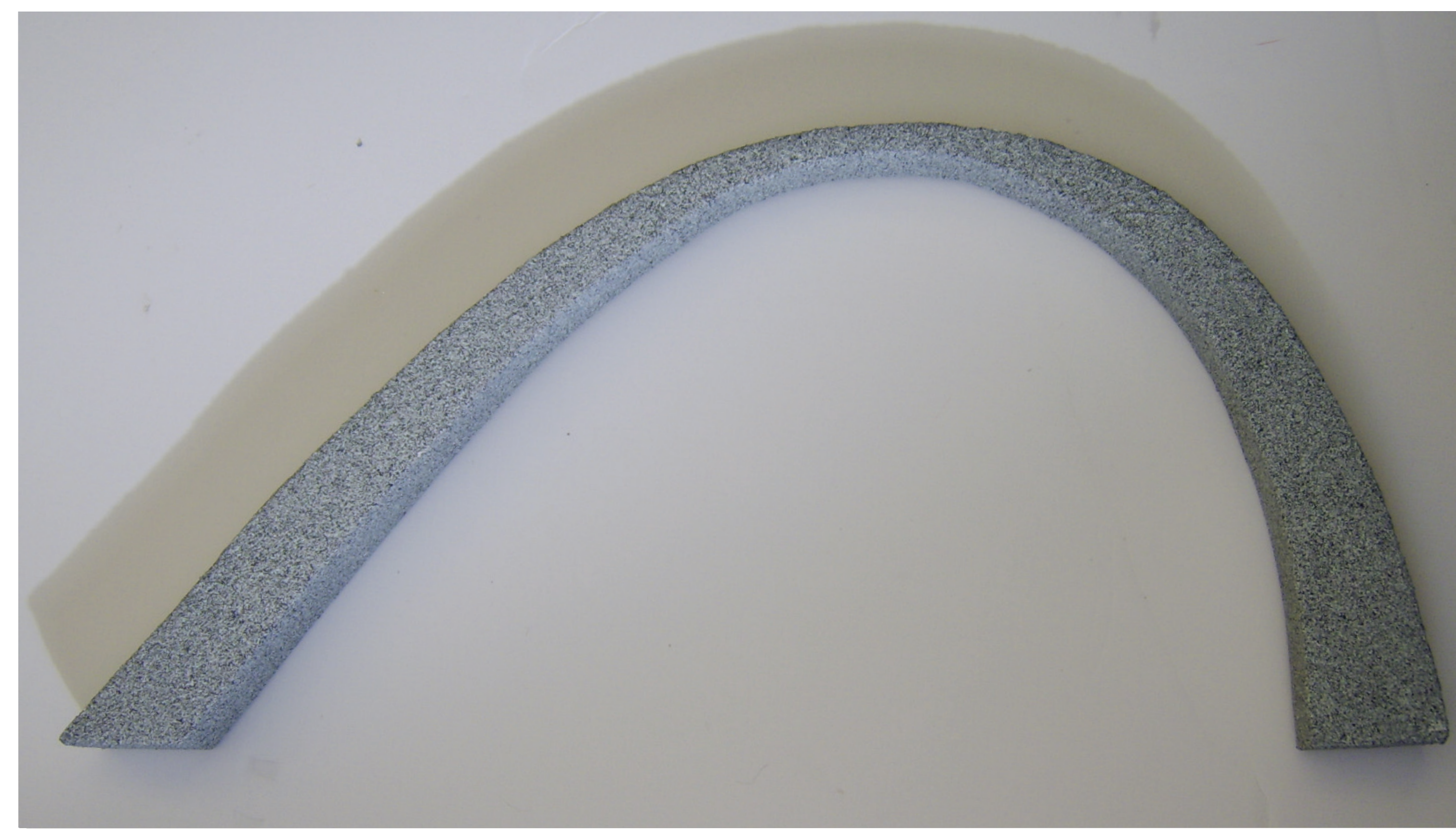


Fig. 8-2 Concrete Arch Scale Model
(Photo By Author)

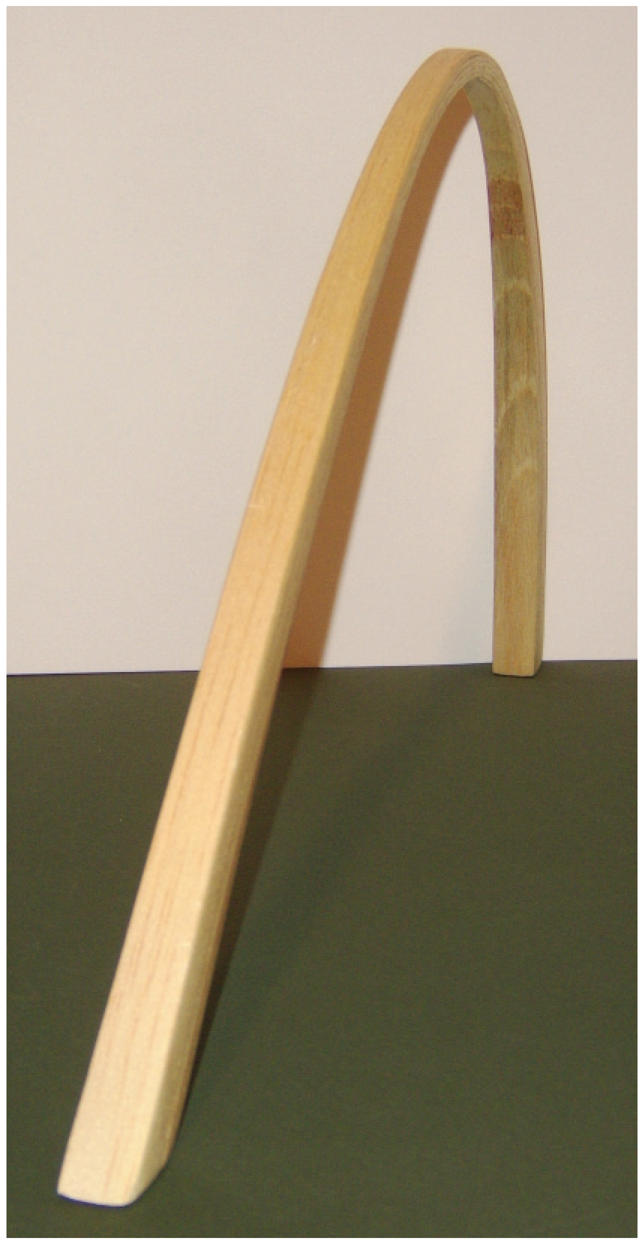


Fig. 9—1 Wooden Arch Model (Rear View)
(Photo By Author)

Fig. 9—2 Wooden Arch Model (Diagonal View)
(Photo By Author)

Fig. 9—3 Wooden Arch Model (Front View)
(Photo By Author)

Geometric Plan Scheme

The initial scheme for the plan of the Equestrian Competition Center was a partial ellipse that used the two foci as the rotational point for two wings of the building. The main competition arena was designated for the larger, central volume, whose arches were arrayed from a focal point in the open courtyard.

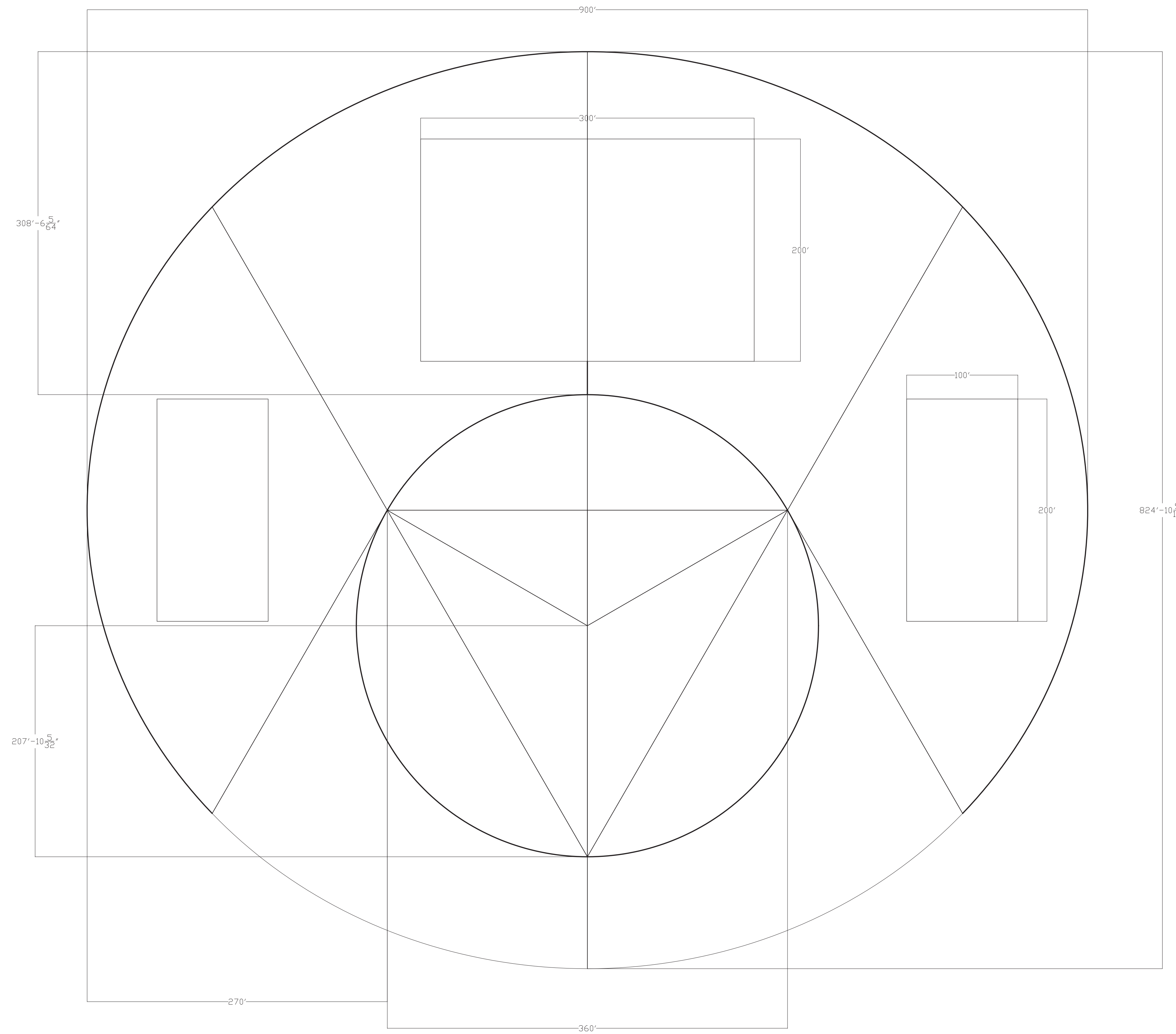


Fig. 10–1 Geometric Plan Scheme

Arch Plan (Angles of Arrangement)

After testing using the arches with equal angle measurements between each primary arch, a system of varying the distance between arches was established. The angle grew or decreased incrementally, with the lower arches (where snow loads would collect) being spaced closer together. This also had the benefit of giving greater variation in the slopes of the roof.

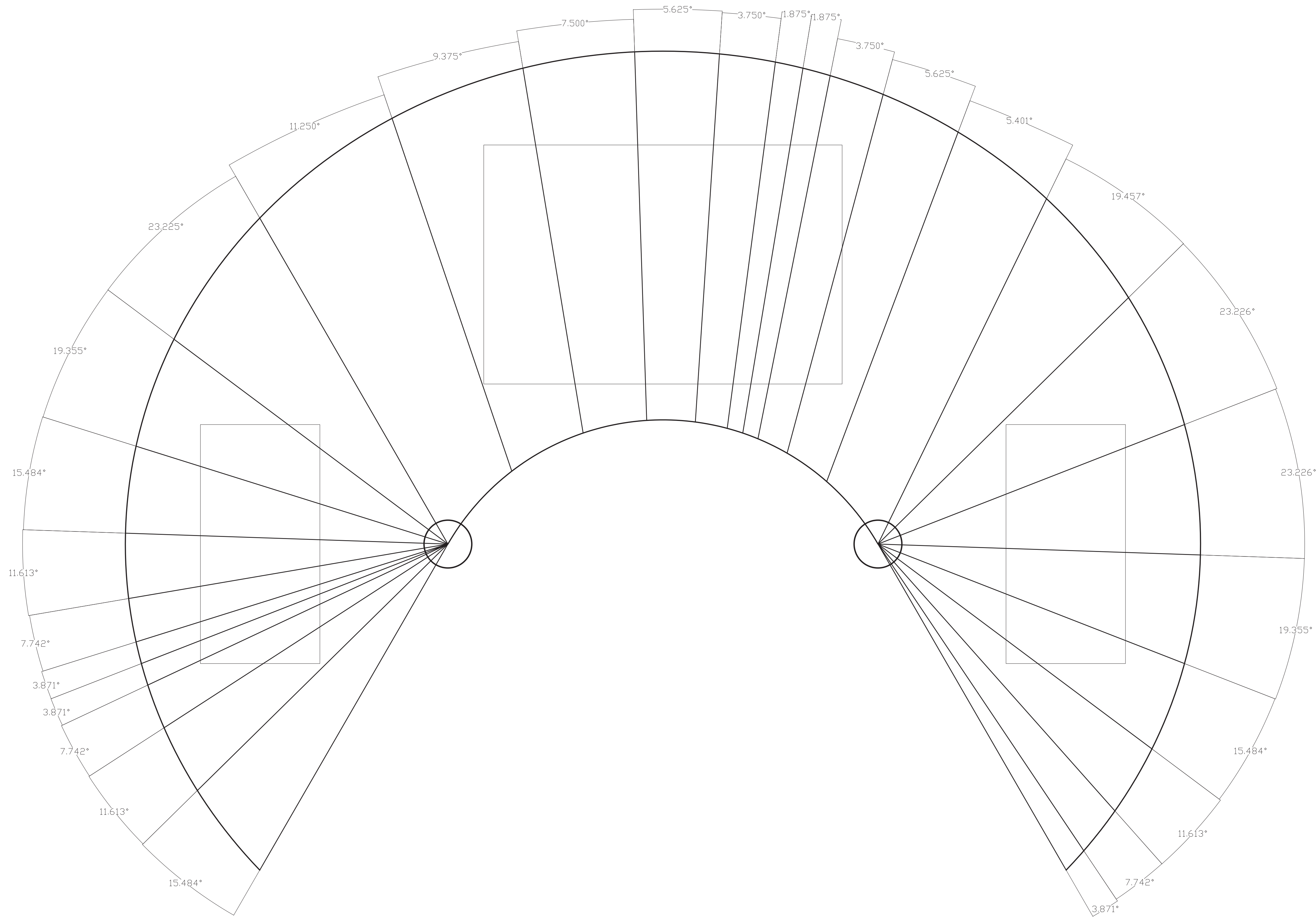


Fig. 11–1 Arch Plan (Angles of Arrangement)

Studying the Lean of the Arches

The circles in Fig. 12–1 represent the relative location of the highest point of each primary arch (represented by the lines). Circles at one end or the other indicate an arch with the most extreme lean one way or the other, while a circle in the middle indicates a symmetrical arch. Arches that do not indicate the peak location were in equal increments from the center to the extreme. The arches in the middle show some possible peak locations, from extreme lean to the left to extreme lean to the right.

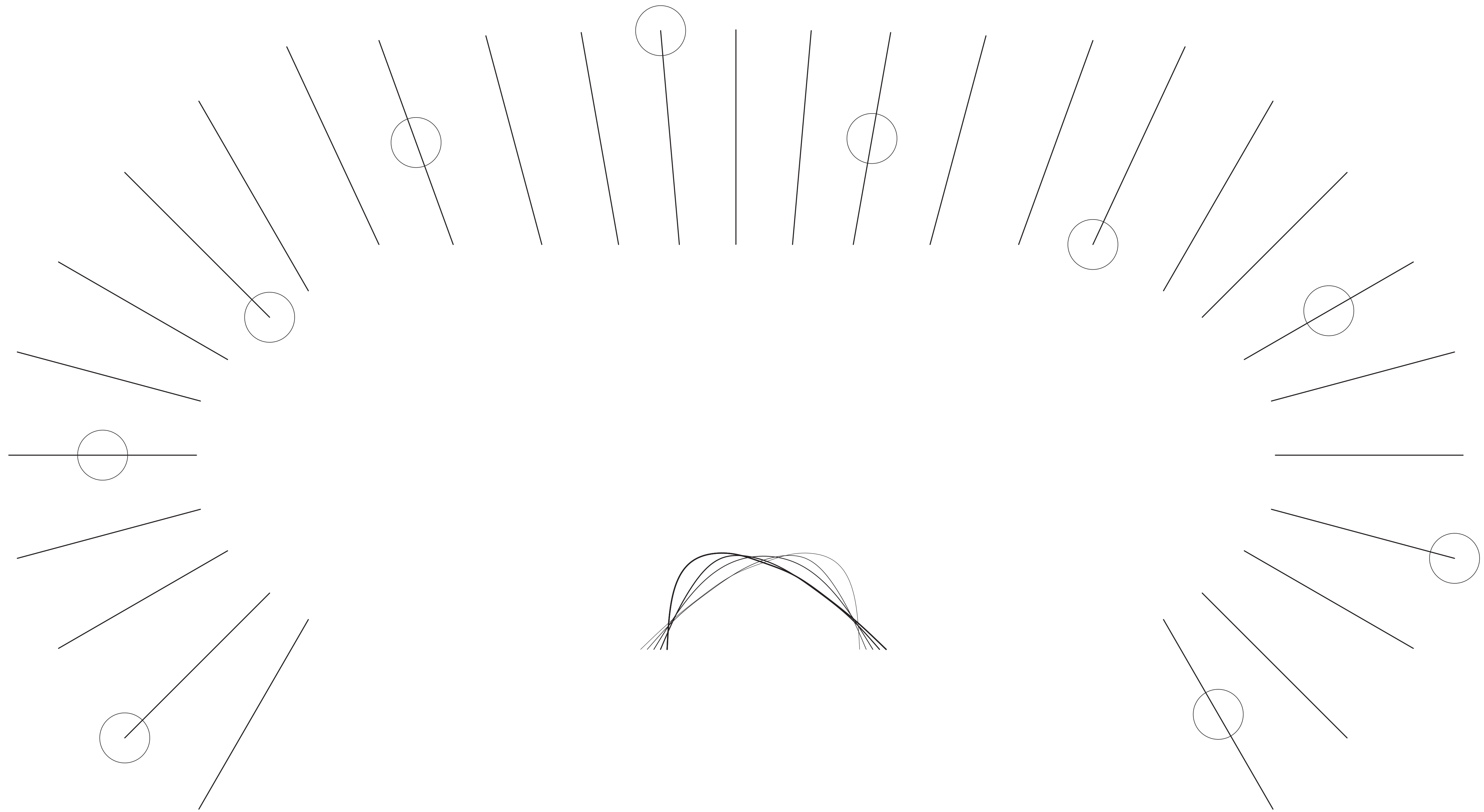


Fig. 12–1 Scheme of Arch Lean

Study of Rotated Undulated Primary Arches

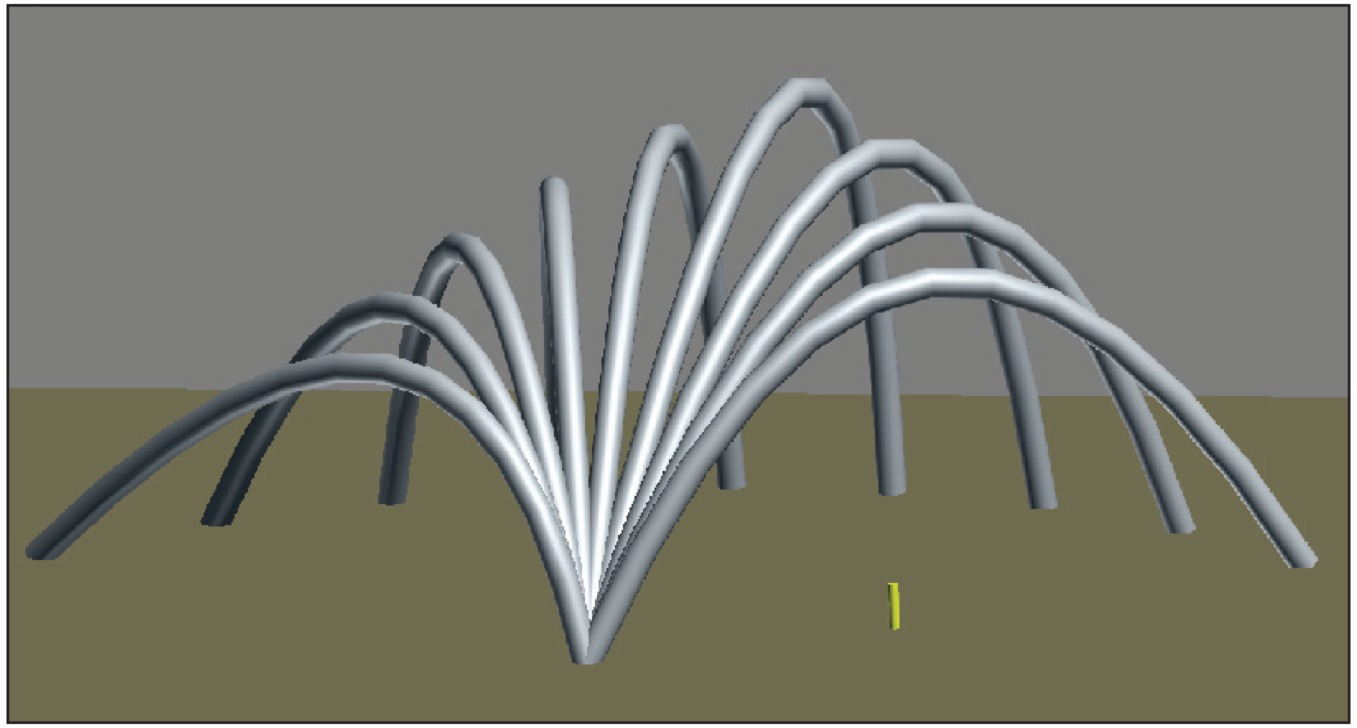


Fig. 13-1 Rotated Arches Study (Front View)

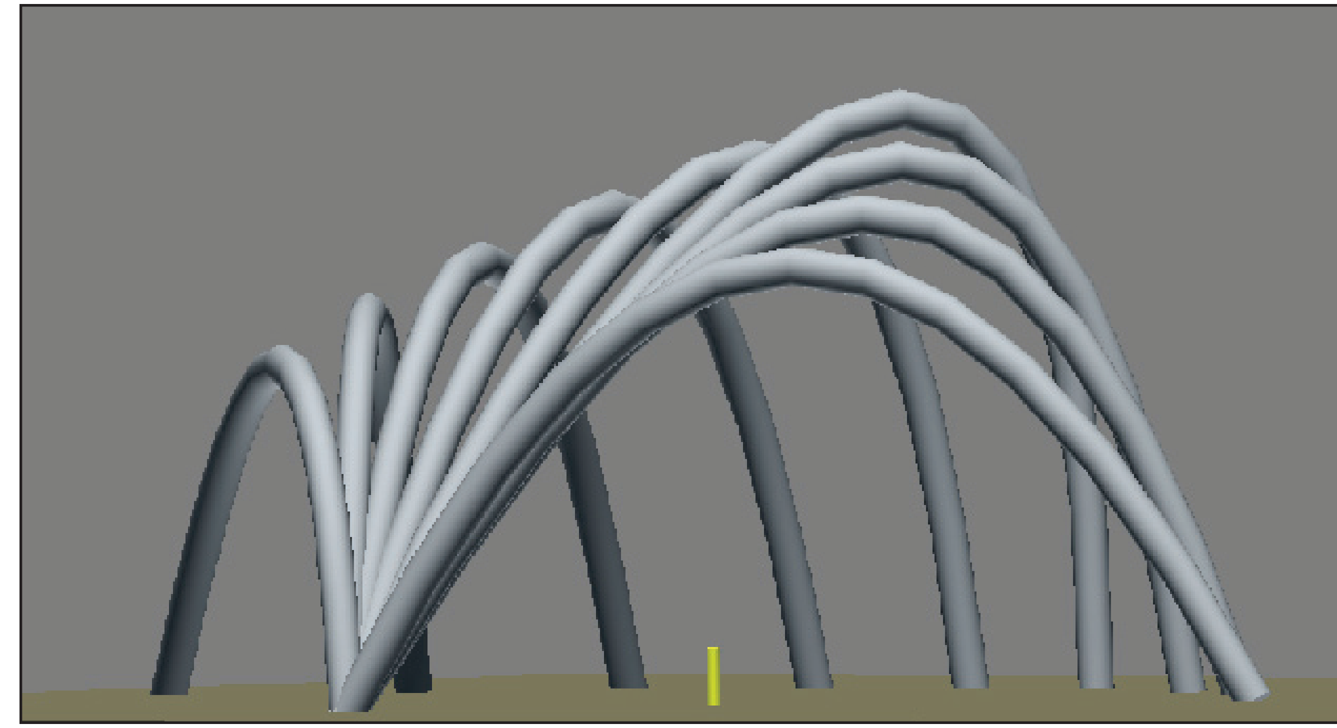


Fig. 13-2 Rotated Arches Study (Side View)

The variations in height, span, and lean were tested in dimension around one of the rotational points. This allowed for testing of many changes in the variable until the desired transitions were discovered.

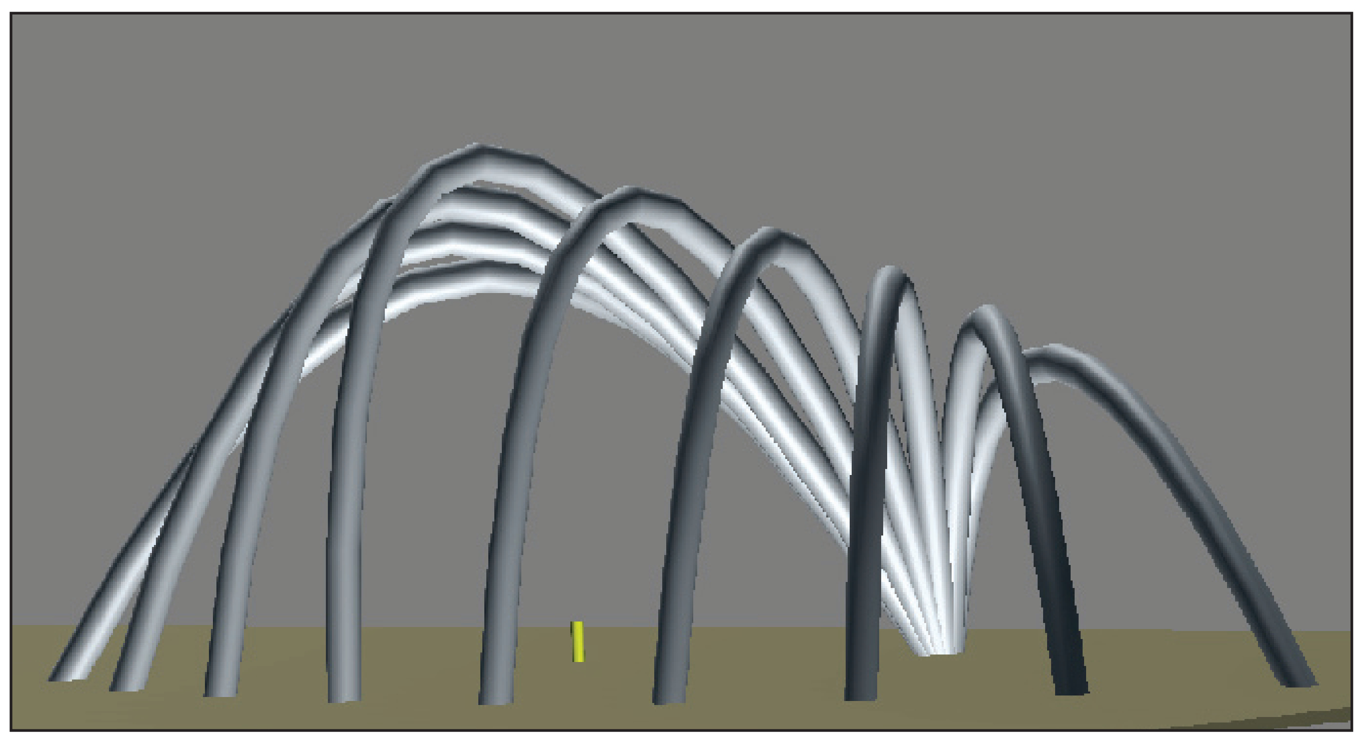


Fig. 13-3 Rotated Arches Study (Rear View)

Rotated Arches Concrete Column Base

The rotated areas of the Equestrian Competition Center's roof create a moment where many of the primary arches come together at the same point. The two column bases for these arches (Fig. 14-1) have wide concrete bases and branching arms to receive the primary arches and transfer their loads. The length of the branches allows each glue-laminated wood arch to be connected to the base without interference from neighboring arches. These locations will also receive a large portion of the rain run-off, so the concrete base also provides a more weather resistant material while the long branches protecting the glue-laminated arches by lifting them away from the exposed ends of the fabric enclosure.

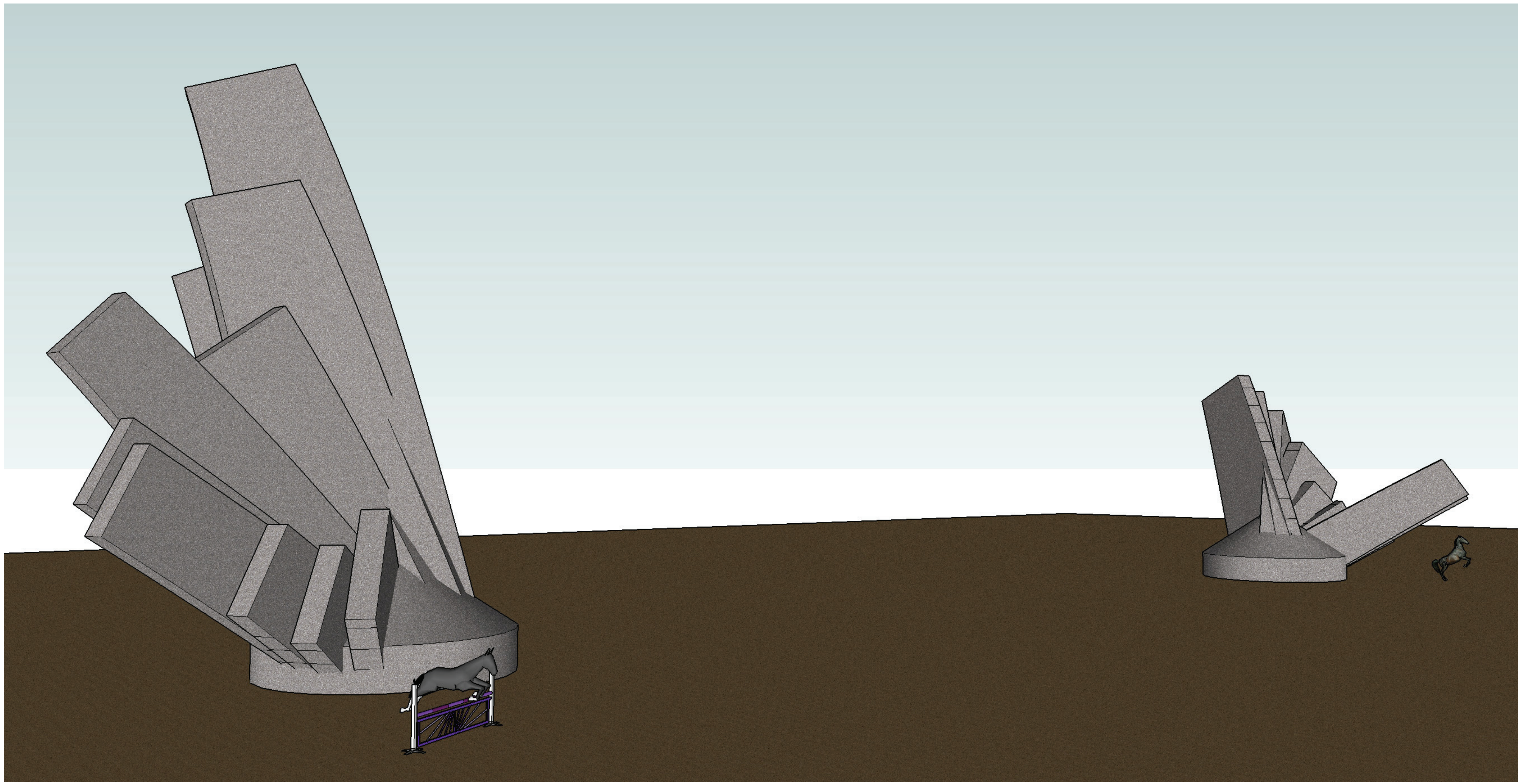


Fig. 14-1 Rotated Arches Concrete Column Base Detail

Primary Arches Connection Assembly

When the primary glue-laminated wood arches meet the concrete bases, they are lifted by crane and slid onto the four metal plates that have been set into the concrete base (Fig. 15-1). Two steel plates and four steel spacers (steps 1, 2, and 3) are installed over the four perpendicular plates, the arch is installed (step 4), and four wood fillers are glue over the slots in the side of each arch (steps 5 and 6). These plates keep the arches from bowing out at the base.

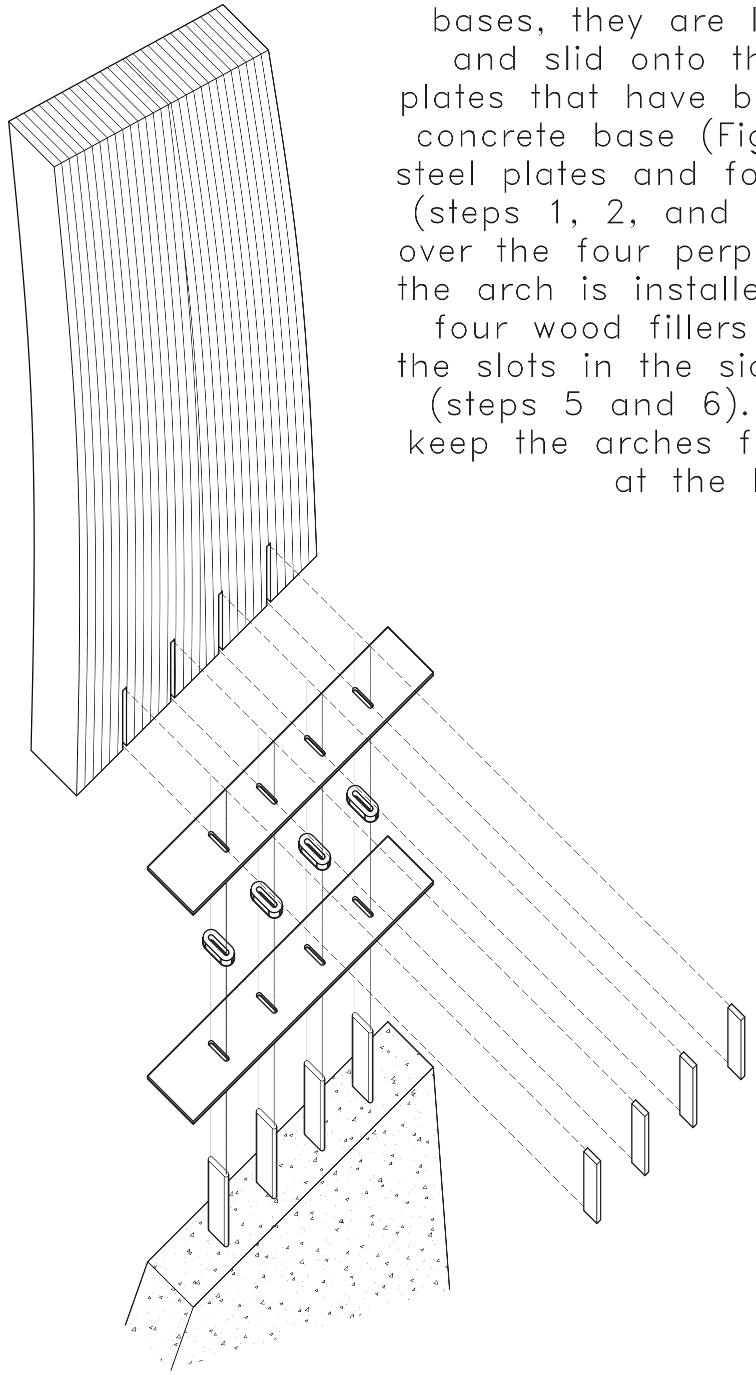
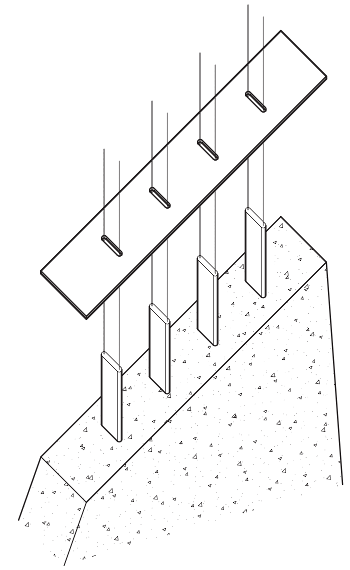


Fig. 15-1 Primary Arches Connection Assembly



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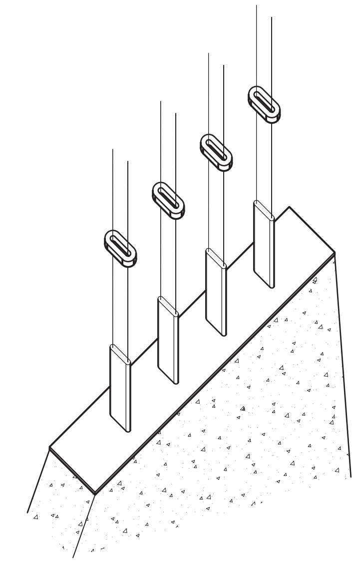

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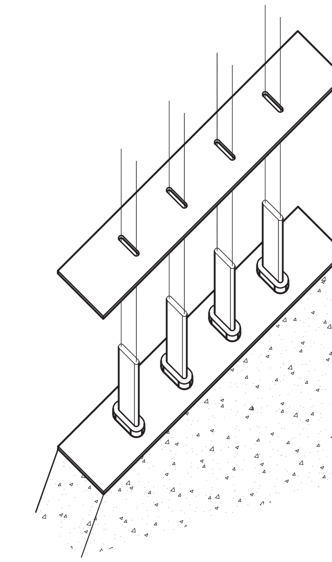

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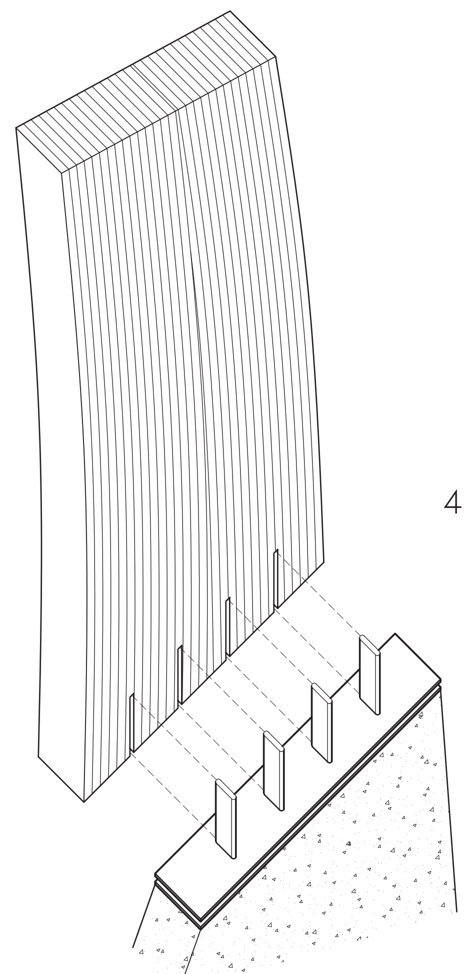

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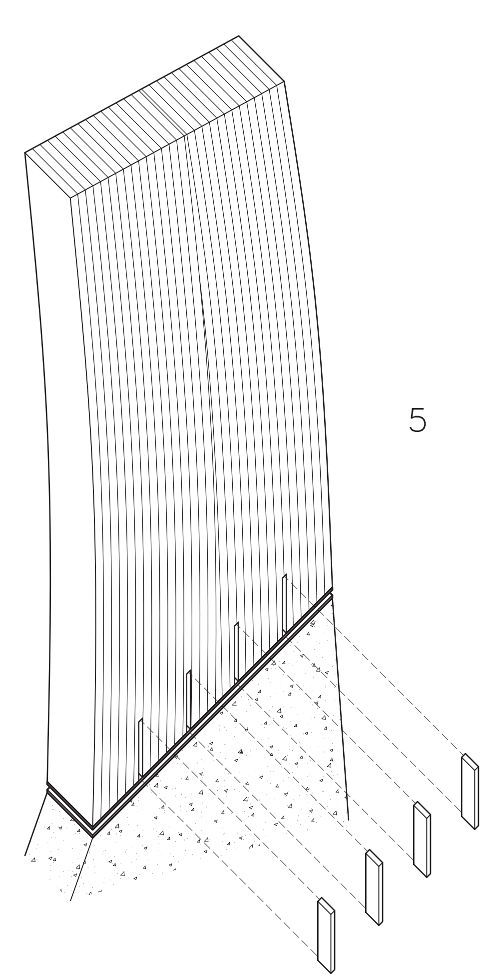

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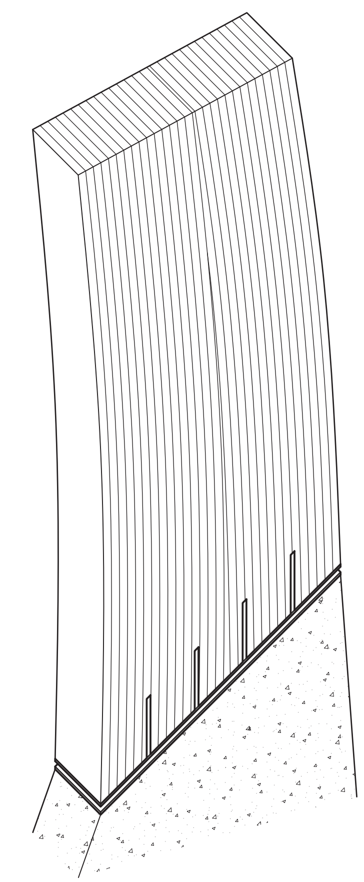

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Primary Arches Connection Detail

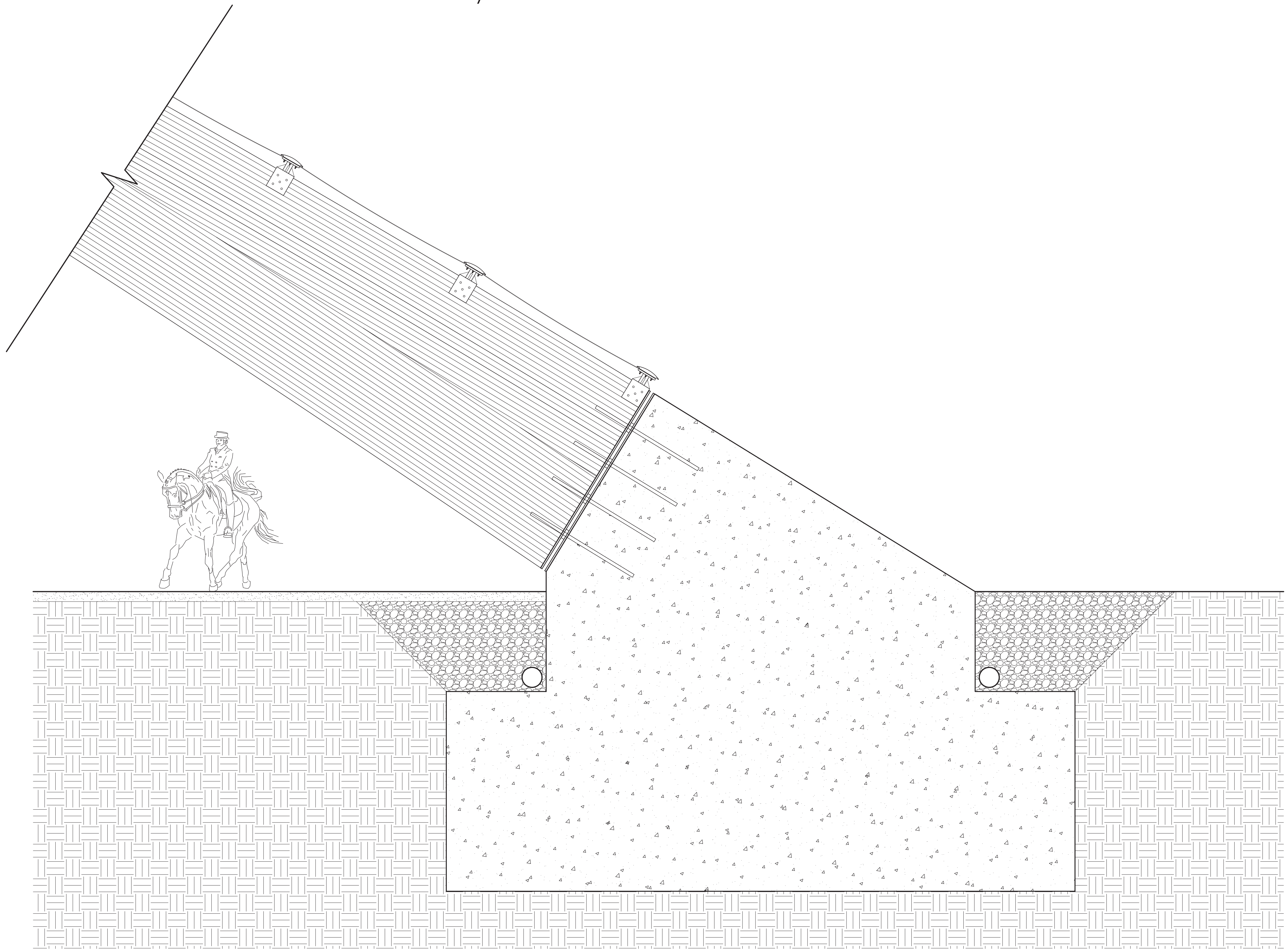


Fig. 16-1 Primary Arches Connection Detail

Secondary Arches Connection Detail

The surface area at the end of each secondary arch, when bracketed on either side of the primary arches, aids in supporting the primary arch against lateral loads. When this connection is combined with all the fabric enclosure connections on each primary, secondary, and tertiary arch, the structure is able to withstand the lateral loads it encounters.

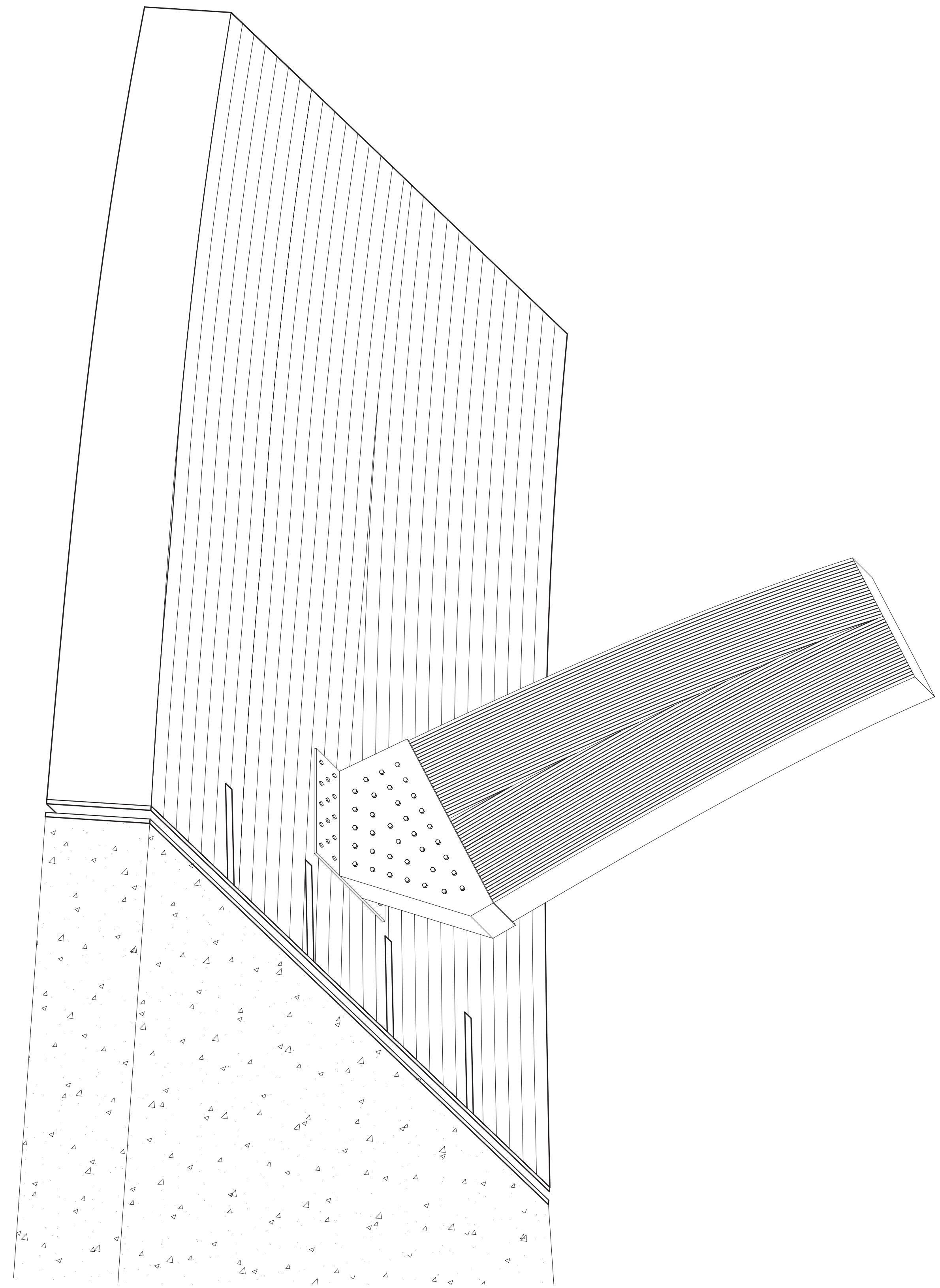


Fig. 16-1 Secondary Arches Connection Detail

Tertiary Arches Connection Detail

The tertiary arches run in the same direction as the primary arches, connecting off of the secondary arches. These tertiary arches allow the fabric enclosure to have shorter spans without support and create a regular rythym of arches inside of the building.

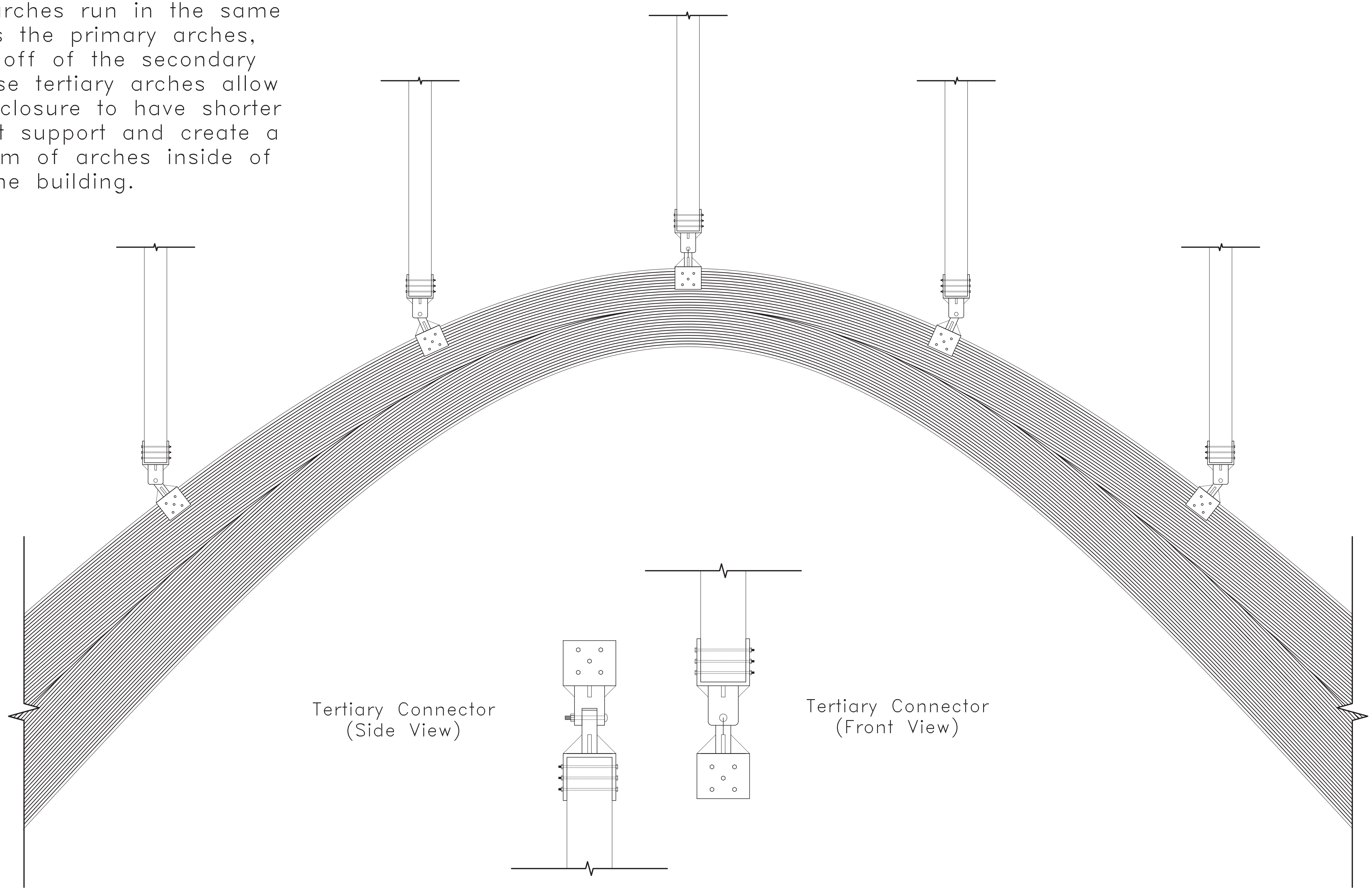


Fig. 18–1 Tertiary Arches Connection Detail

Fabric Enclosure Connection Detail

The fabric enclosure is attached to the primary, secondary, and tertiary arches. This detail is of the connection on a primary arch. The fabric enclosure is marked “A” and the electrical conduit is marked “B”. The electrical conduit is run along a groove in the top of the arch, down a notch on the side, and into the light.

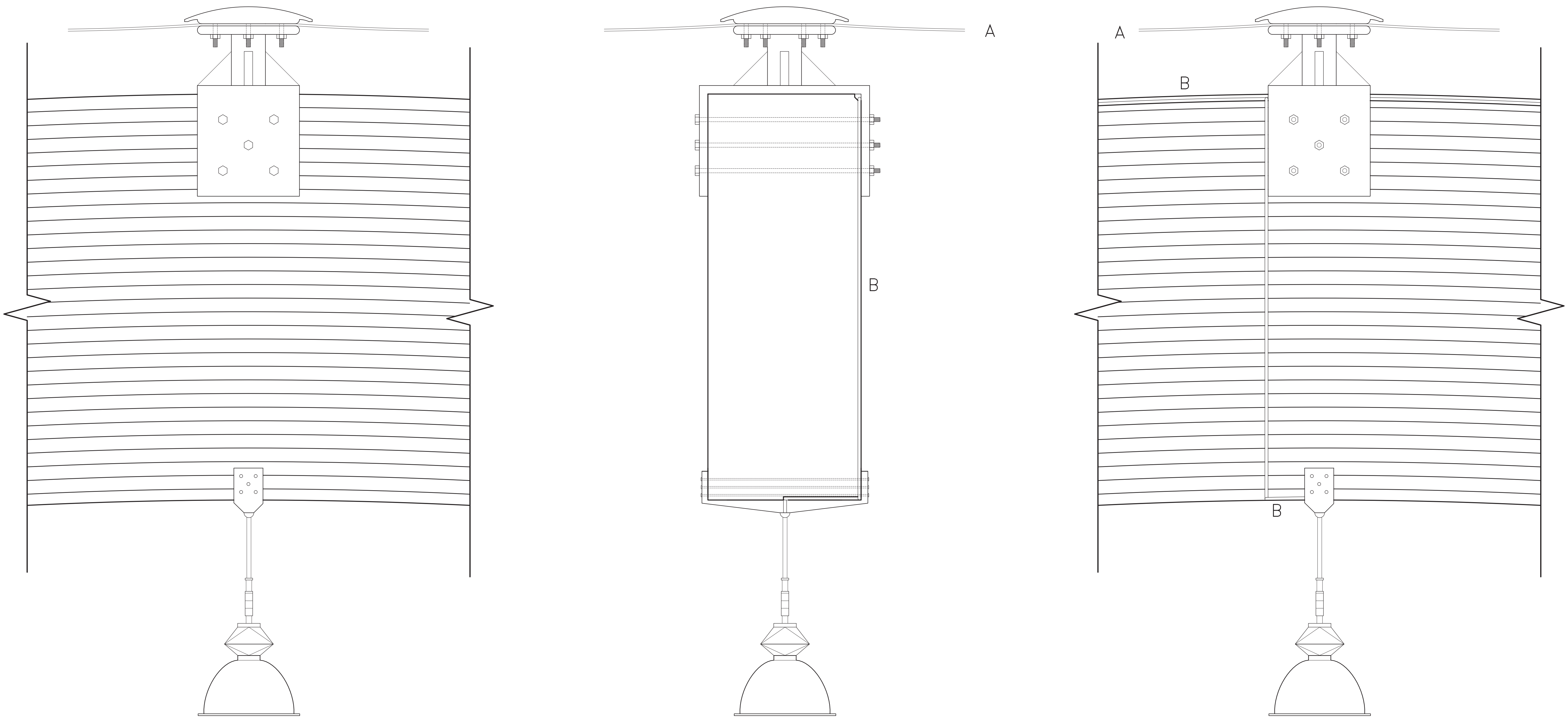


Fig. 19–1 Fabric Enclosure Connection Detail

Elevations of Primary Arches: 1–10

The Primary Arches are shown from left to right on the plan (Fig. 26–1), with the left side of each arch elevation being on the outside edge of the building plan and the right side of each arch elevation being on the inside edge of the building plan.

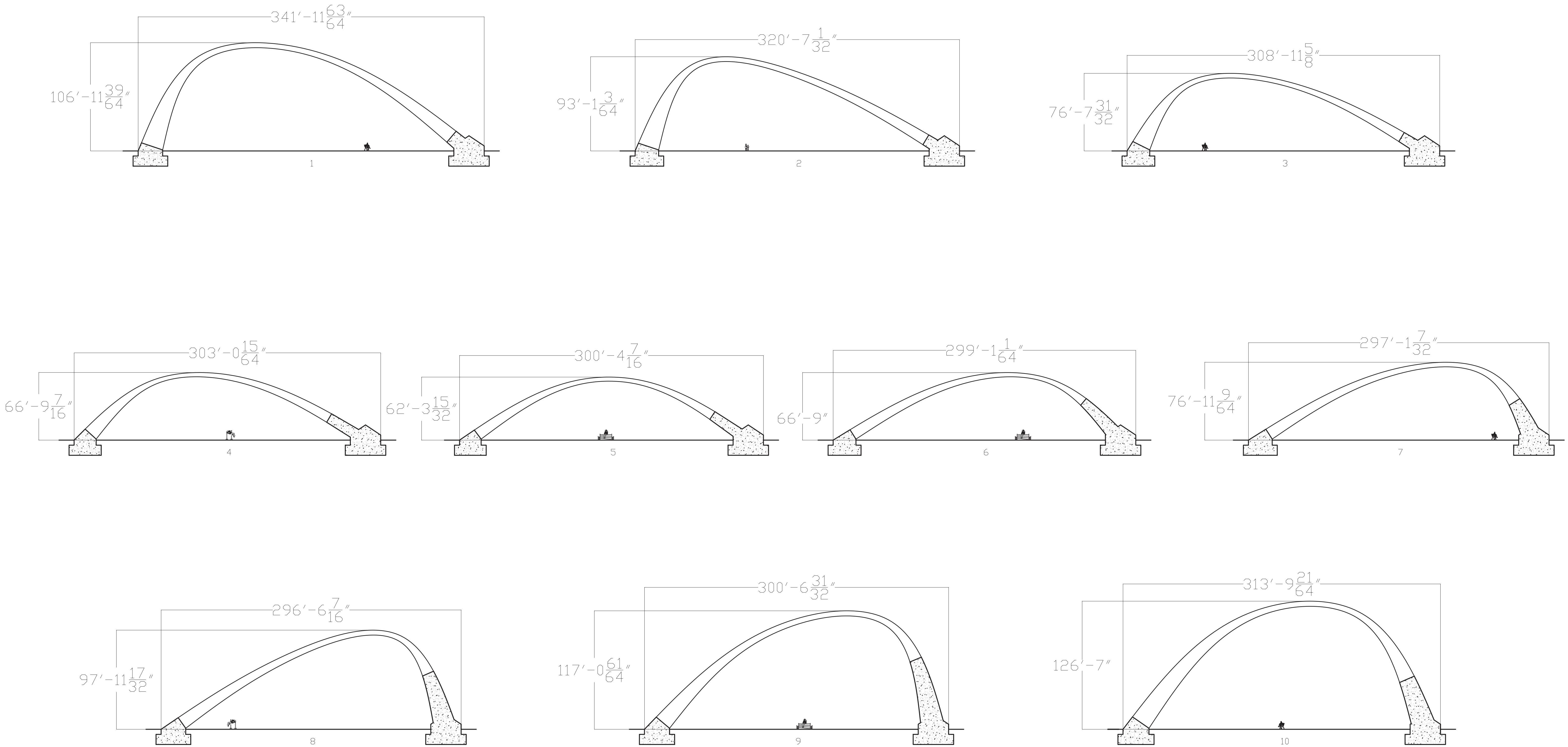


Fig. 20–1 Elevations of Primary Arches (Arches 1–10)

Elevations of Primary Arches: 11–20

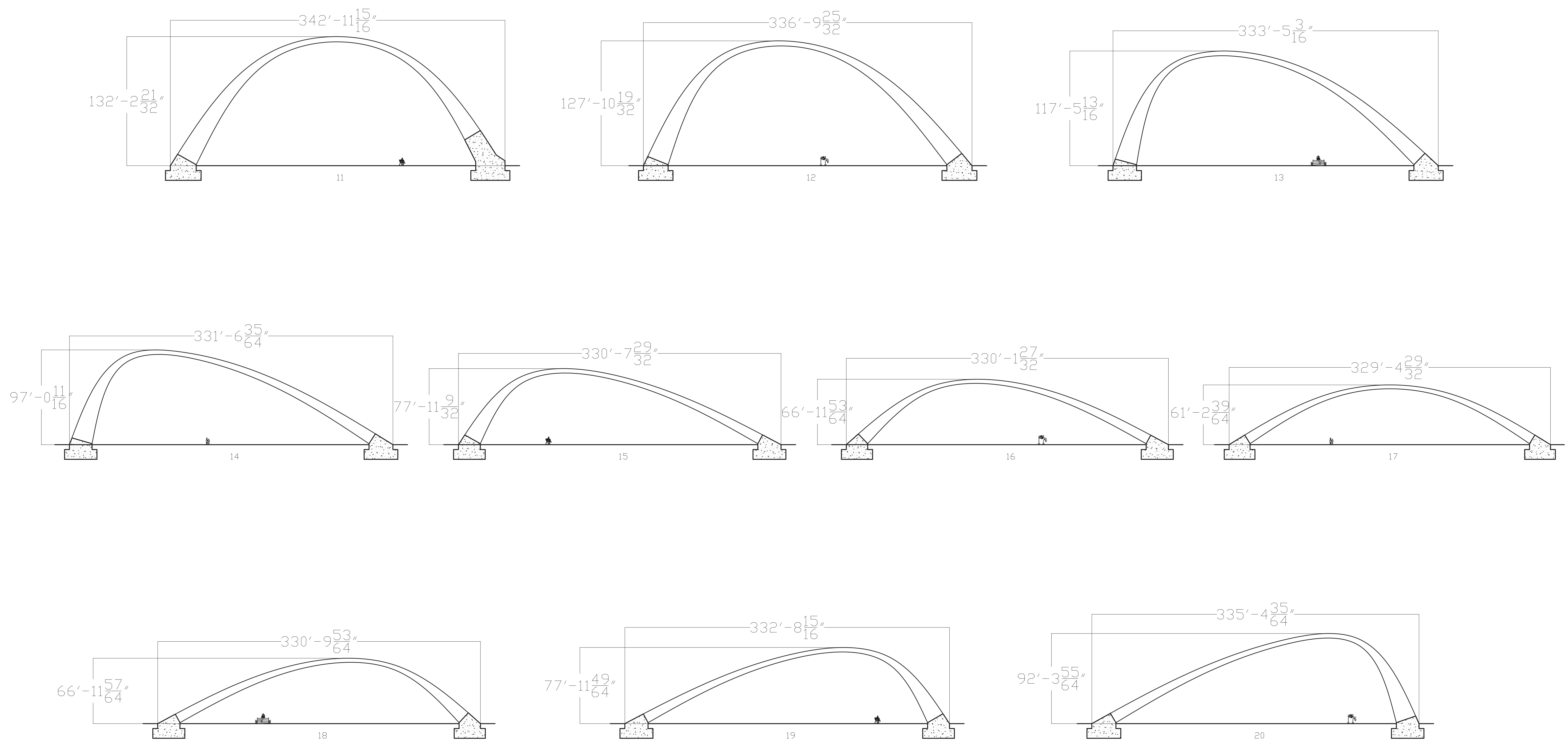


Fig. 21–1 Elevations of Primary Arches (Arches 11–20)

Elevations of Primary Arches: 21–29

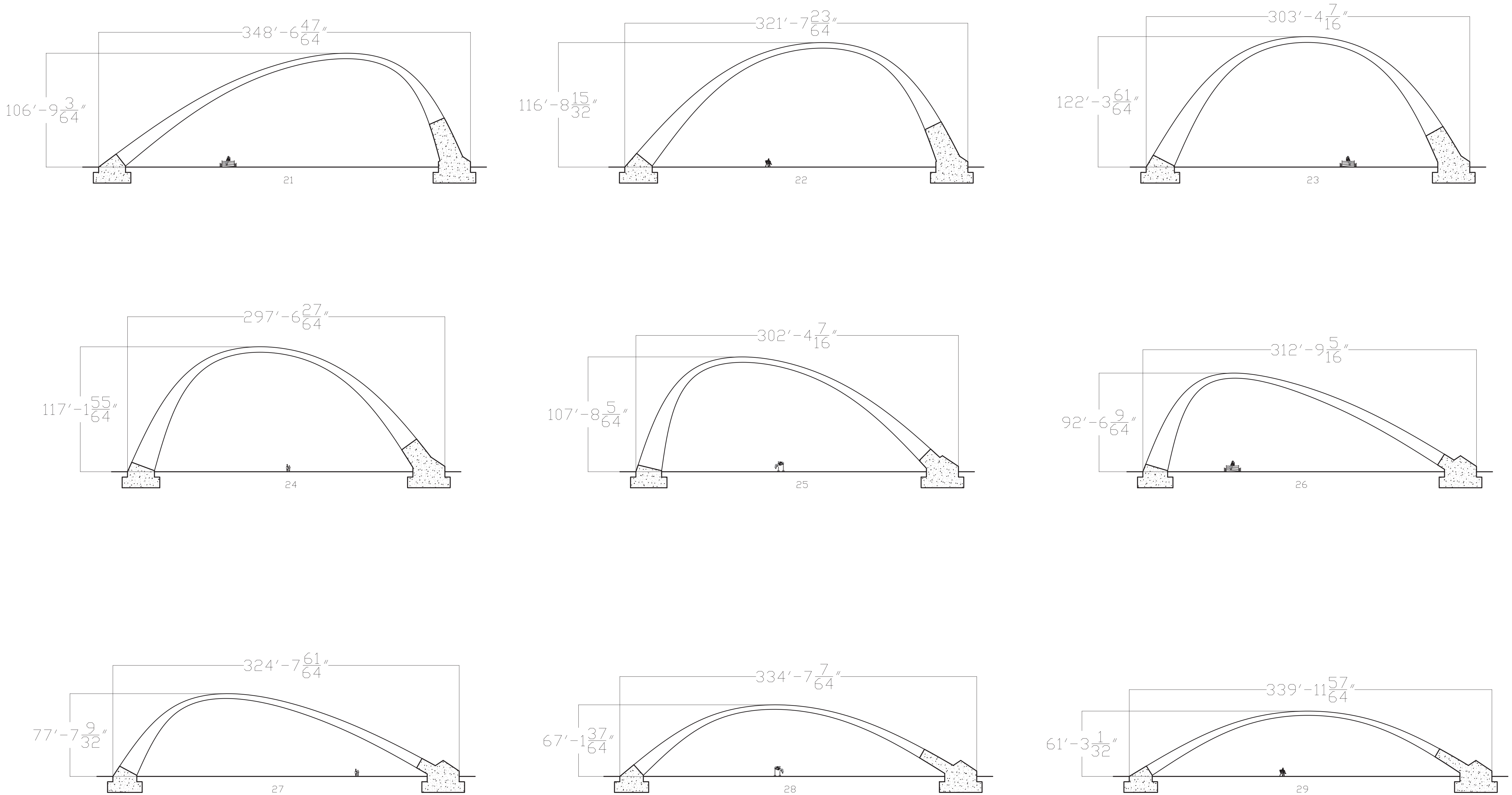


Fig. 22–1 Elevations of Primary Arches (Arches 21–29)

Structural Skeleton From Front

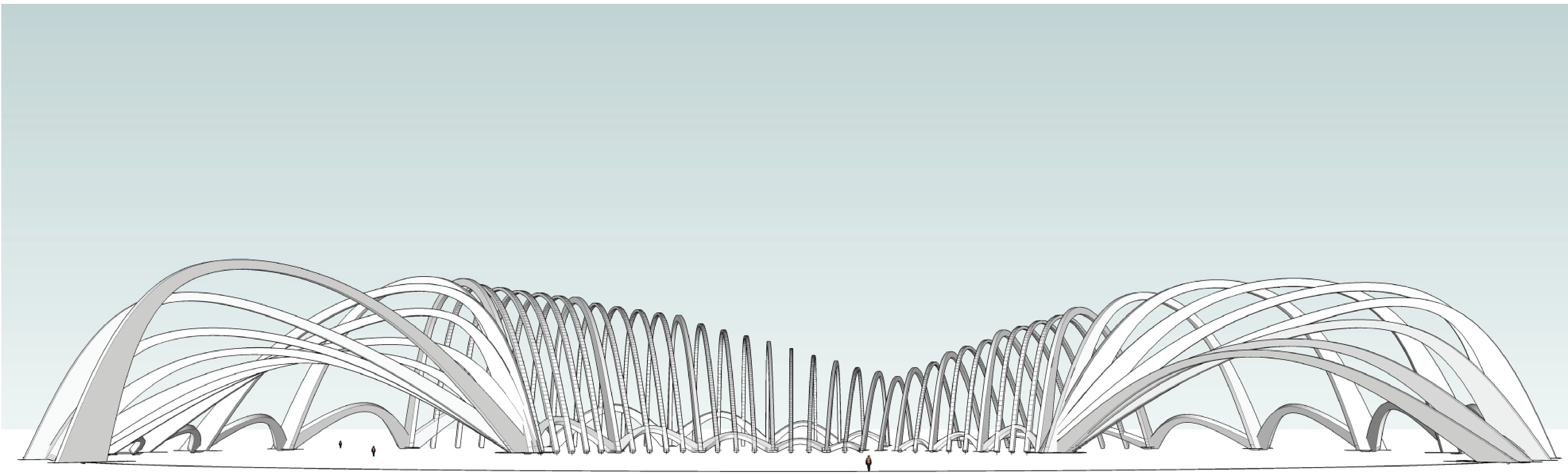


Fig. 23-1 Structural Skeleton From Front

Note: The extra length of the secondary arches passing through the tertiary arches are a by-product of testing all the arch designs at the same time and not part of the design of the final building.

Structural Skeleton From Rear

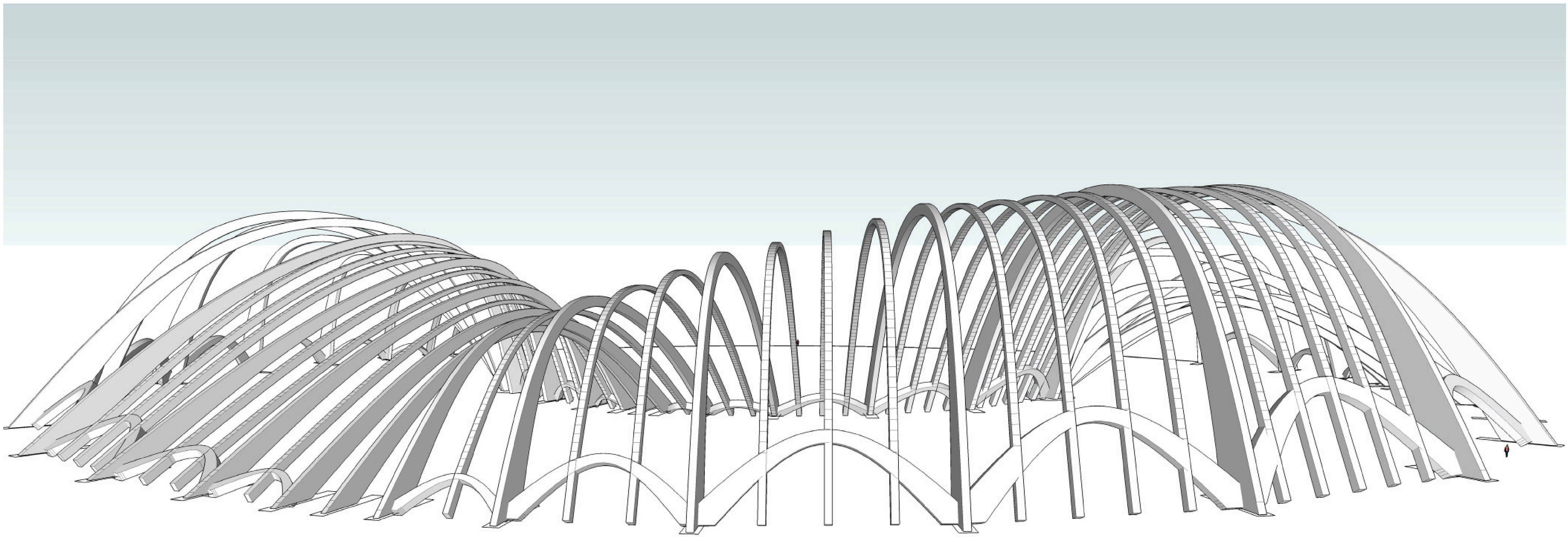


Fig. 24-1 Structural Skeleton From Rear

Note: The extra length of the secondary arches passing through the tertiary arches are a by-product of testing all the arch designs at the same time and not part of the design of the final building.

Structural Skeleton From Interior

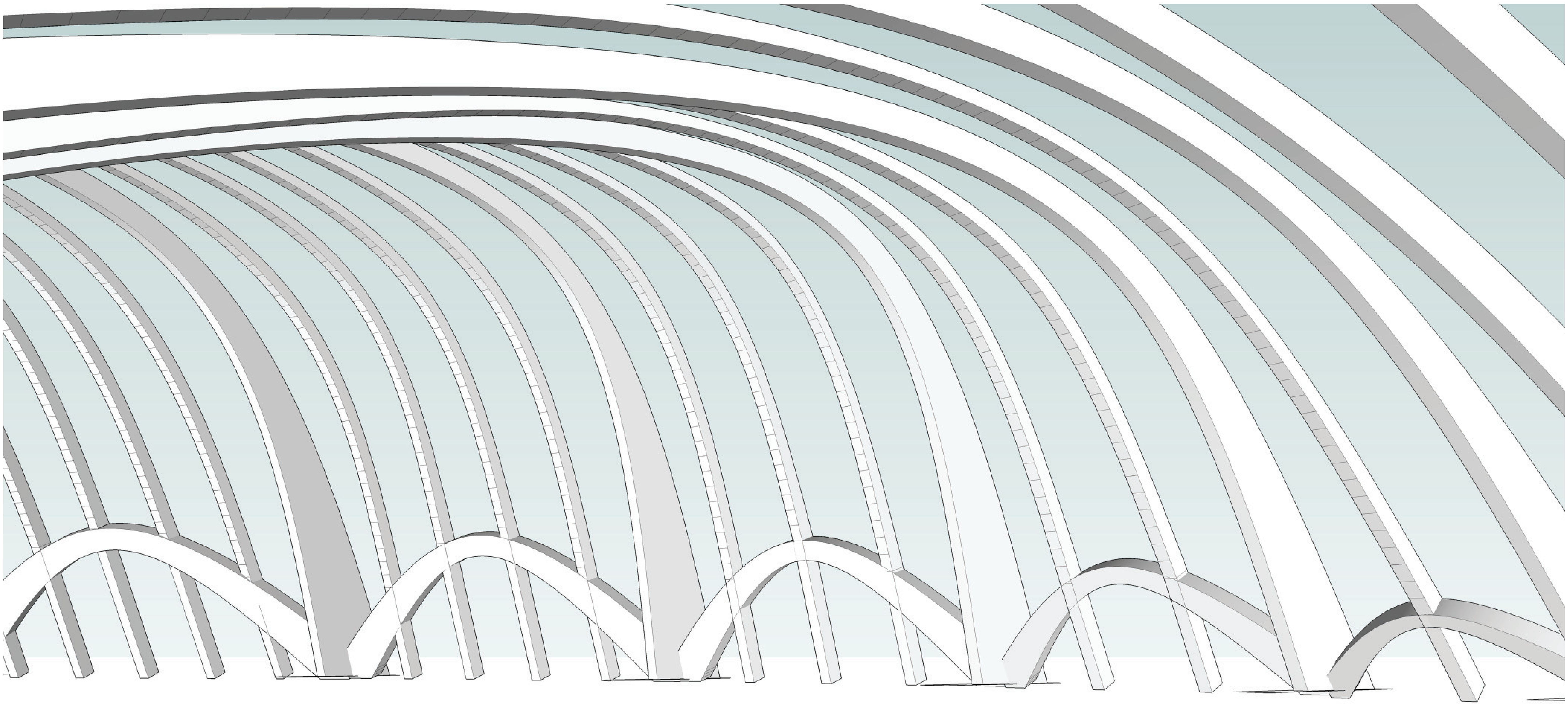
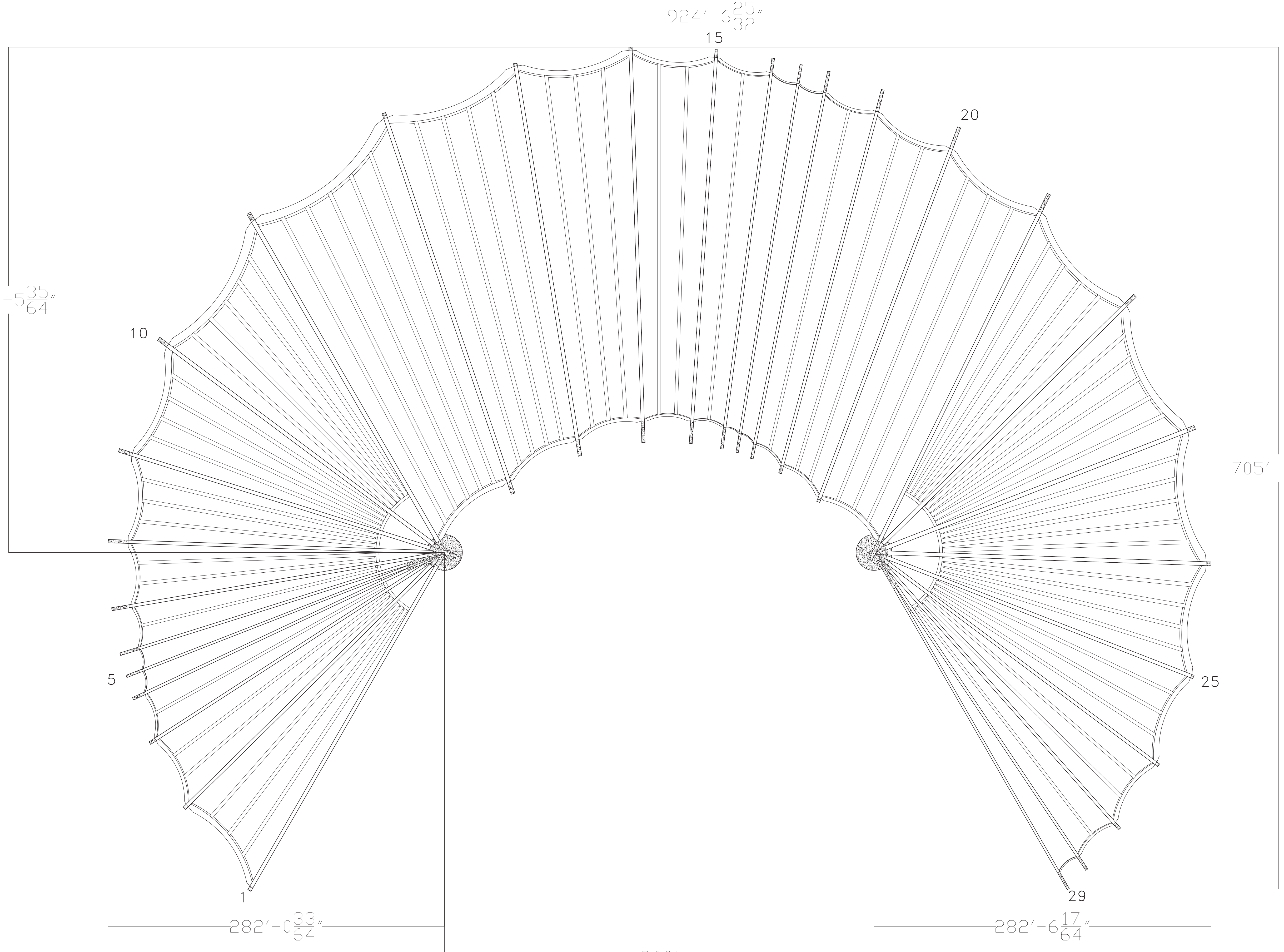


Fig. 25–1 Structural Skeleton From Interior

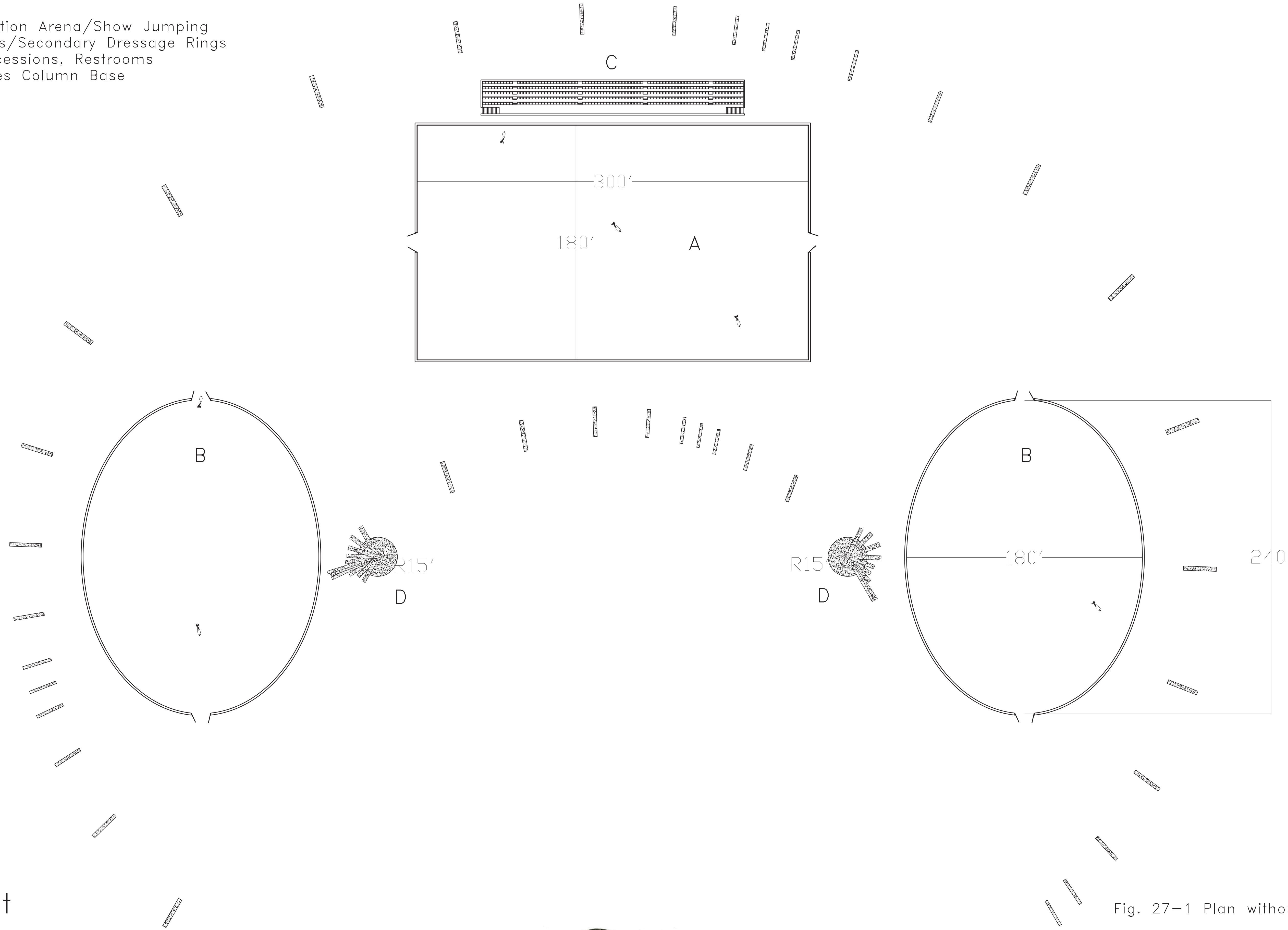
Note: The extra length of the secondary arches passing through the tertiary arches are a by–product of testing all the arch designs at the same time and not part of the design of the final building.



Plan with Arches

Fig. 26-1 Plan with Arches

Key:
A – Main Competition Arena/Show Jumping
B – Warmup Rings/Secondary Dressage Rings
C – Seating, Concessions, Restrooms
D – Rotated Arches Column Base



Plan without Arches

Fig. 27–1 Plan without Arches

This area of the Equestrian Competition Center is the focal point. The main events take place in the central over-sized riding arena, while the rest rooms and concessions are located underneath the stadium seating. From these seats, spectators will be able to see the whole arena and watch riders warming up in the two warm up rings.

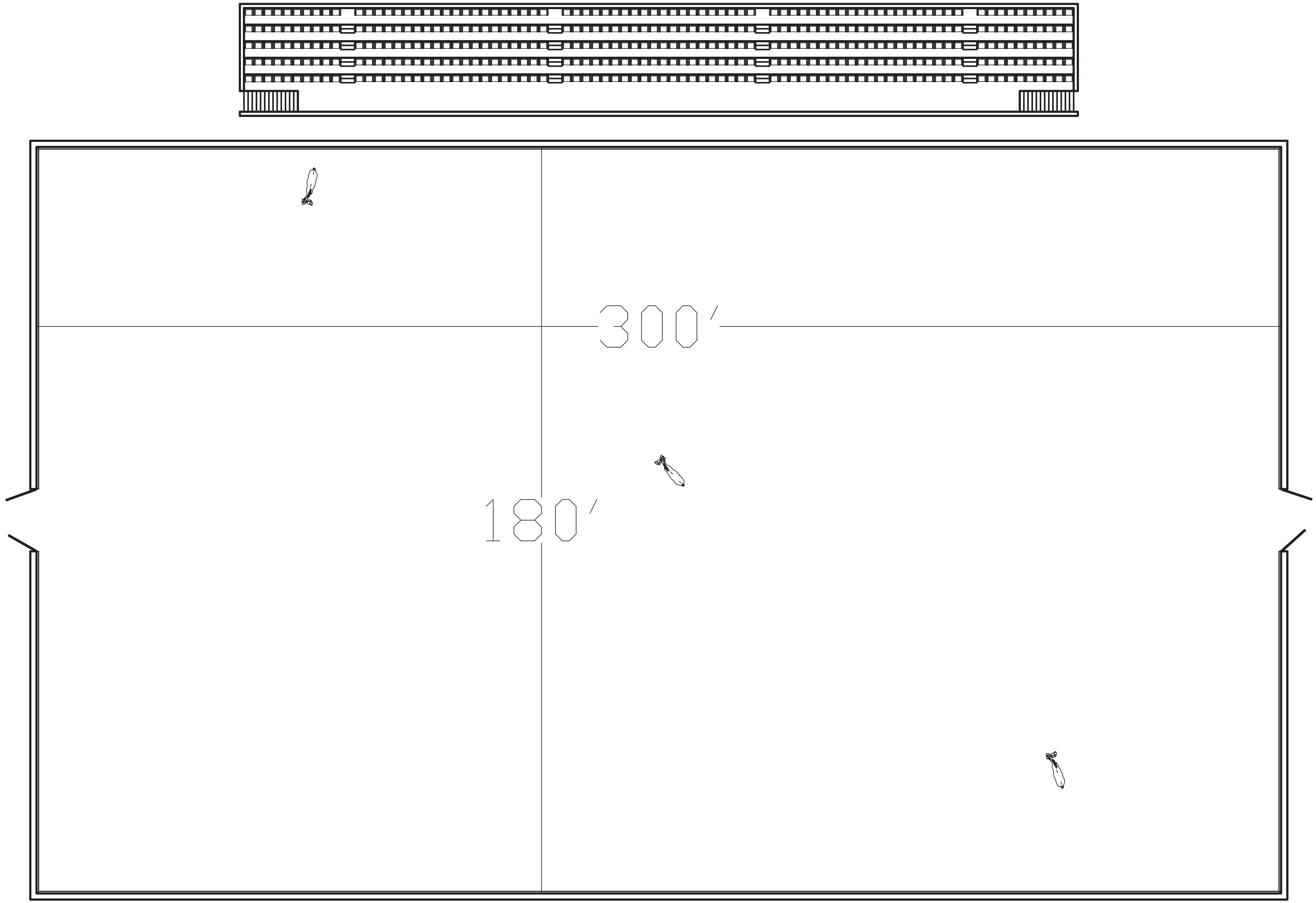
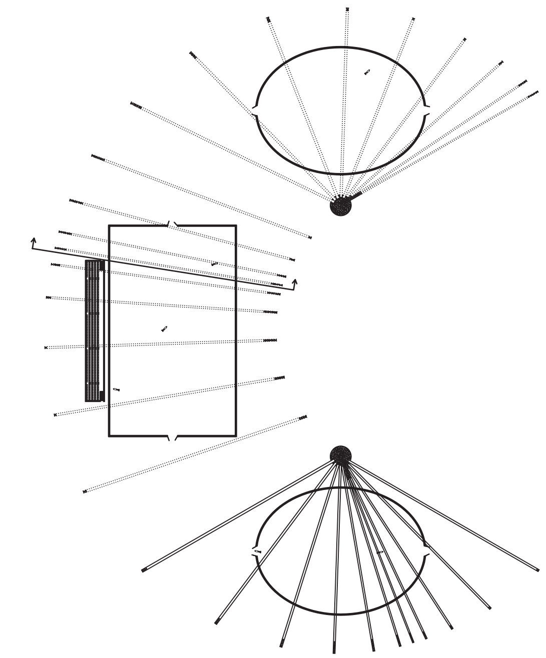


Fig. 28-1 Plan of Main Competition Arena

Plan of Main Competition Arena

Section Through Lowest Part of Competition Center Roof



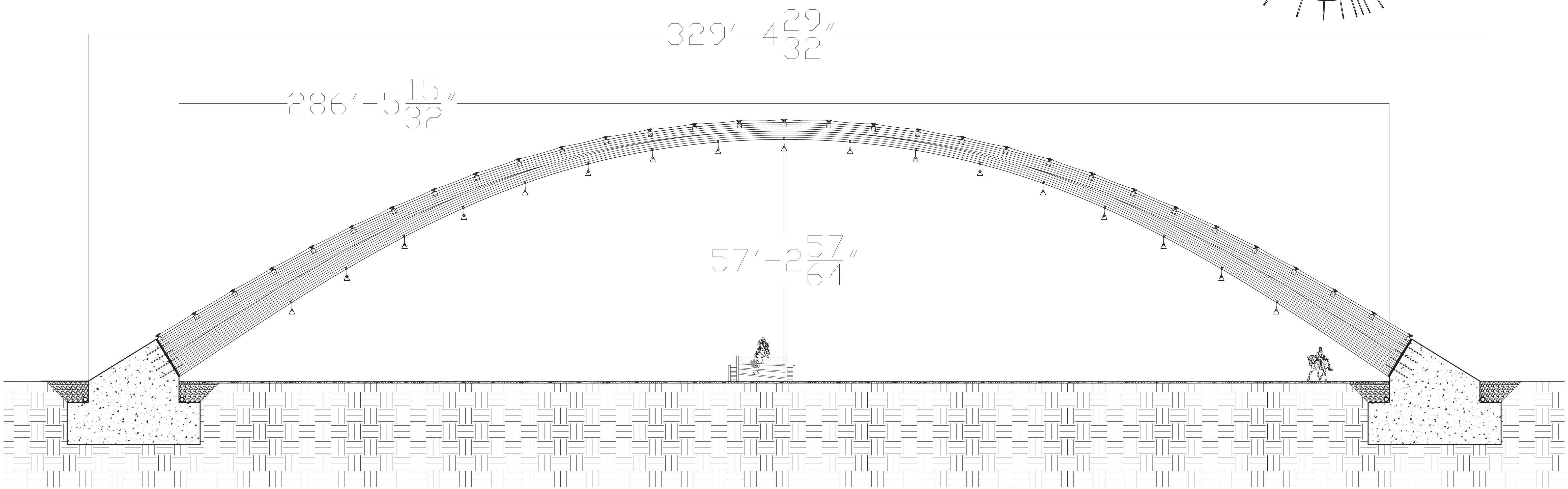


Fig. 29–1 Section at Lowest Arch

Section Through Main Competition Arena

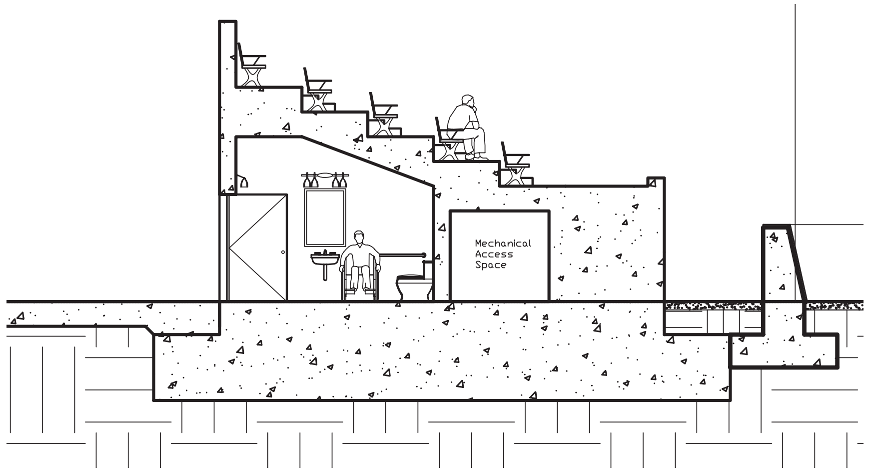
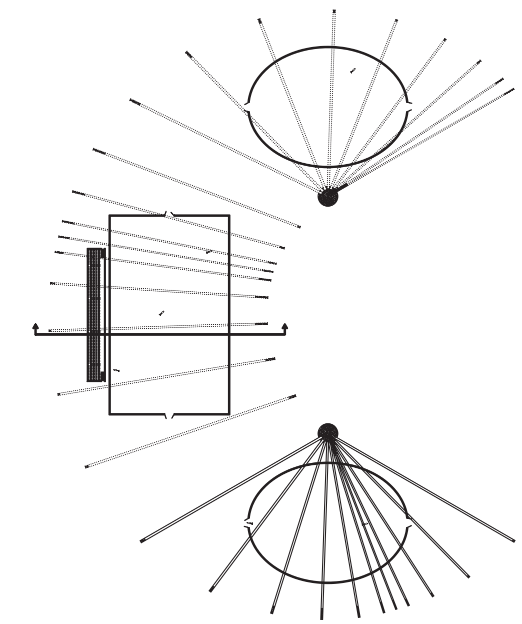


Fig. 30–2 Section Through Seating of Main Competition Arena



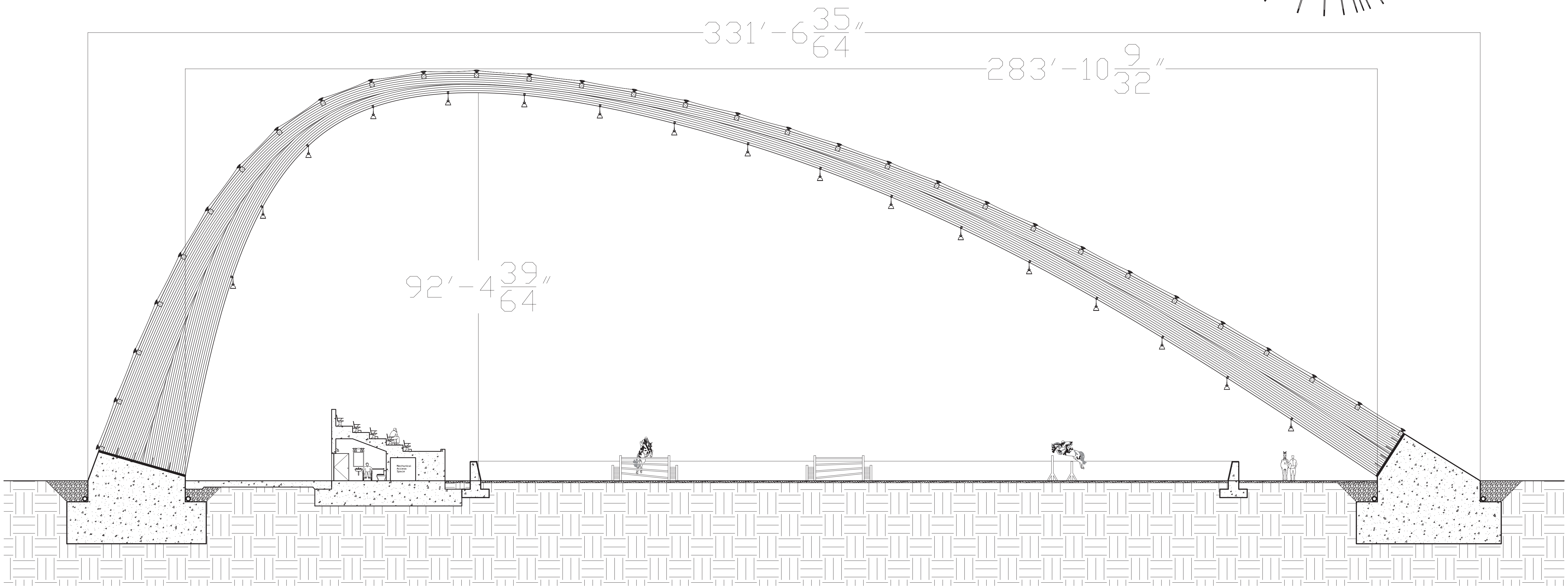


Fig. 30–1 Section Through Main Competition Arena

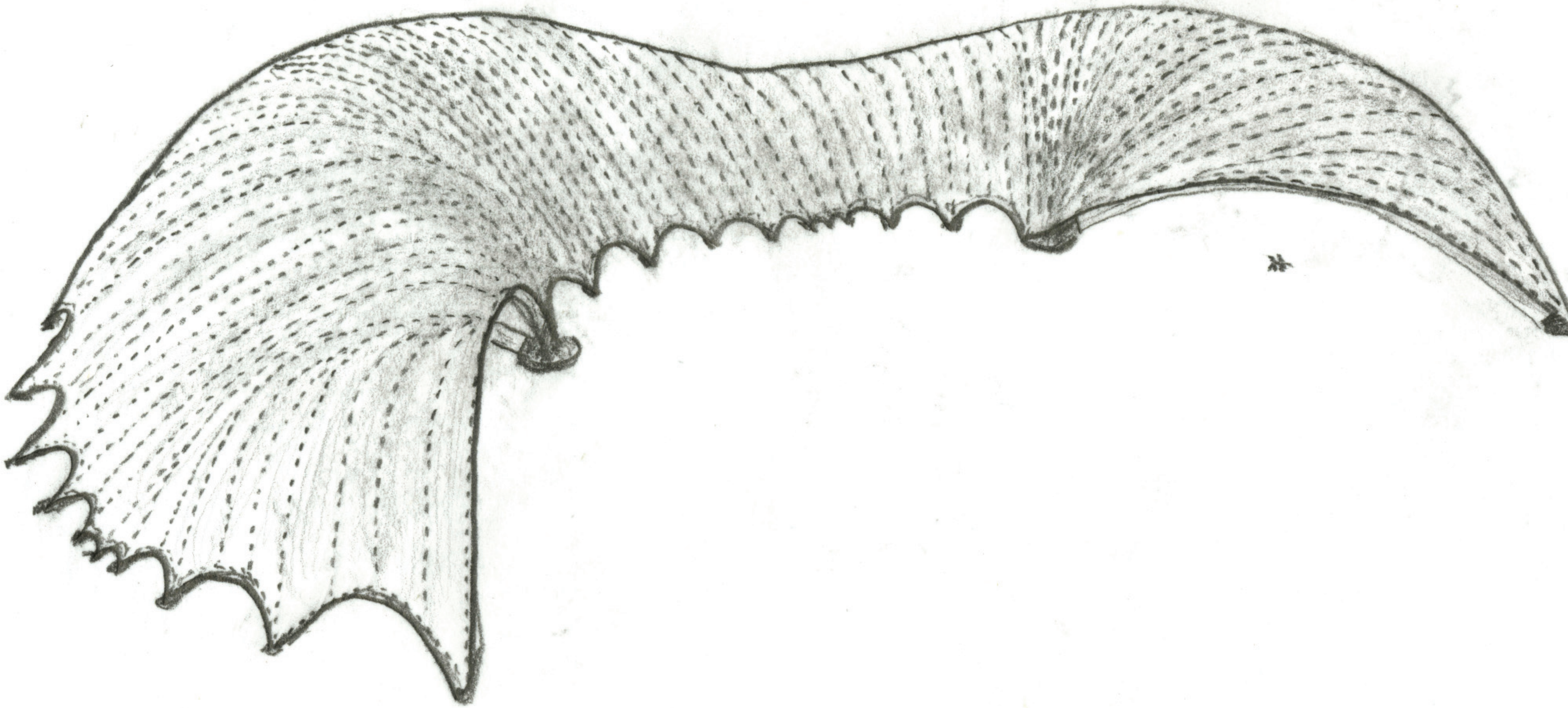


Fig. 31—1 Birds—eye View Hand Drawing

The fabric roof will have a translucency that will allow in adequate day-time light without having the blinding glare of sun lights, which can distract spectator, judge, horse or rider. Not only is the more evenly dispersed, ambient light more appealing, avoiding the more contrasting bright sun spots and dark corners of many riding arenas, but it is also a safety improvement. By not completely enclosing the Equestrian Competition Center, the riders and spectators can enjoy the protection from uncooperative weather without completely sacrificing the natural aspect of the sport that makes it so special to so many people. Instead of trapping heat in a metal box, this riding center will enjoy the cooling breeze passing through, and the light colored fabric roof will help repel the hot afternoon sun.

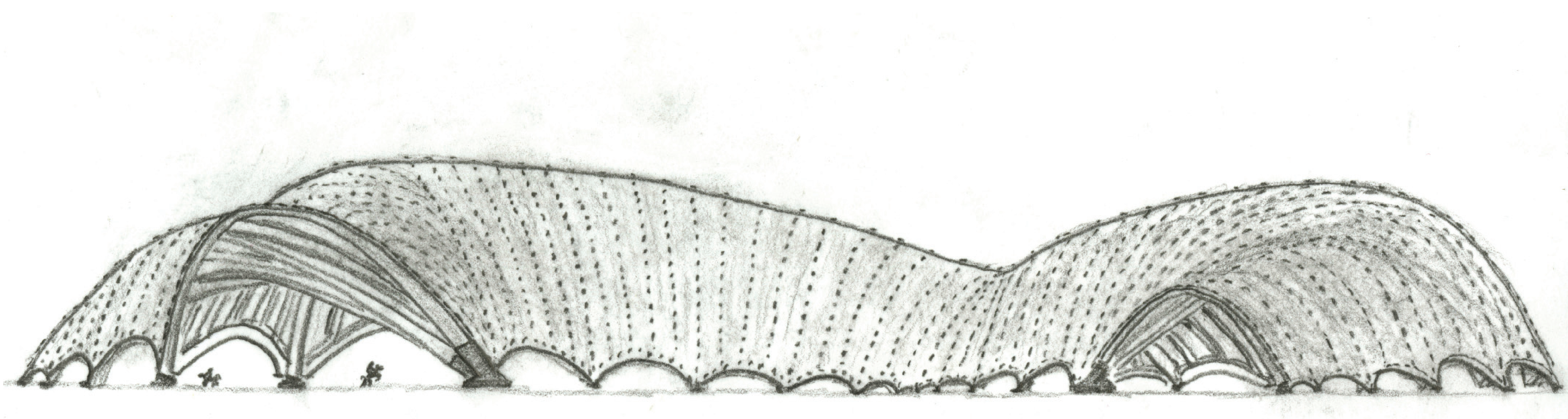


Fig. 32-1 Front Elevation Hand Drawing

Conclusion

This thesis has been an investigation into using glue-laminated wood arches to an extreme, which while demanding to design, build, or fund, presents an opportunity to create a building that can honor and respect the elegance or the sport it is designed for. This design process would be extremely expensive to build at this scale due to the customizing of most major parts, but it also allows a lot of flexibility for creativity. I found that if you try to understand the tectonics of the building and let that guide you along with your original concepts, you can achieve a complete building that is not only exciting to look at, but exciting to use. The gracefulness of the roof is heightened by the gracefulness of the structure, creating appeal from its’ functionality as much as from its’ form. I believe the attempt to design a world class equestrian center, that respected spectator, rider, horse, and the land was successful in at least showing that there are other options available besides just a big box.

Fig. 33-1 Chelsea Roberts on Huckleberry Finn (Show Jumping)
(Photo By Author)