POLYMÖBI

TABLE OF CONTENTS

TOC // POLYMÖBI

INTRODUCTION

THIS PROJECT IS AN EXTENSION OF THE WORK DONE BY PREVIOUS SENIOR PROJECT GROUPS IN PROF. ED SALIKLIS' ARCE 415 LABORATORY, WHICH HAS BEEN COLLECTED UNDER POLYSHELLS, LLC.

POLYSHELLS FOCUSES ON THE CONSTRUCTION OF DUAL MEMBRANE SHELLS, CONSTRUCTED FROM LASER CUT PLYWOOD SHEETS.

THE GOAL OF OUR PROJECT IS TO PROPOSE AN INNOVATIVE DESIGN FOR A SUNSHADE USING THESE SHELLS THAT WILL BE CONSTRUCTED AT CAL POLY'S LEANING PINE ARBORETUM.

OUR DESIGN AIMS TO CELEBRATE THE INTERDISCIPLINARY NATURE AND ENHANCE THE EXPERIENCE OF THE ARBORETUM.

MEET THE TEAM

TOM SESIN

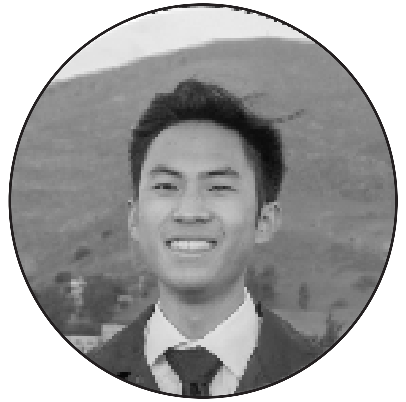
- FOURTH YEAR, ARCE
- CHICAGO, IL
- WON'T SHUT UP ABOUT BEING FROM CHICAGO

EVAN BROOKS

- FOURTH YEAR, ARCE
- SANTA ROSA, CA
- HAS NEVER BEEN TO CHICAGO
- CP LACROSSE PLAYER

GABRIEL GARFIAS

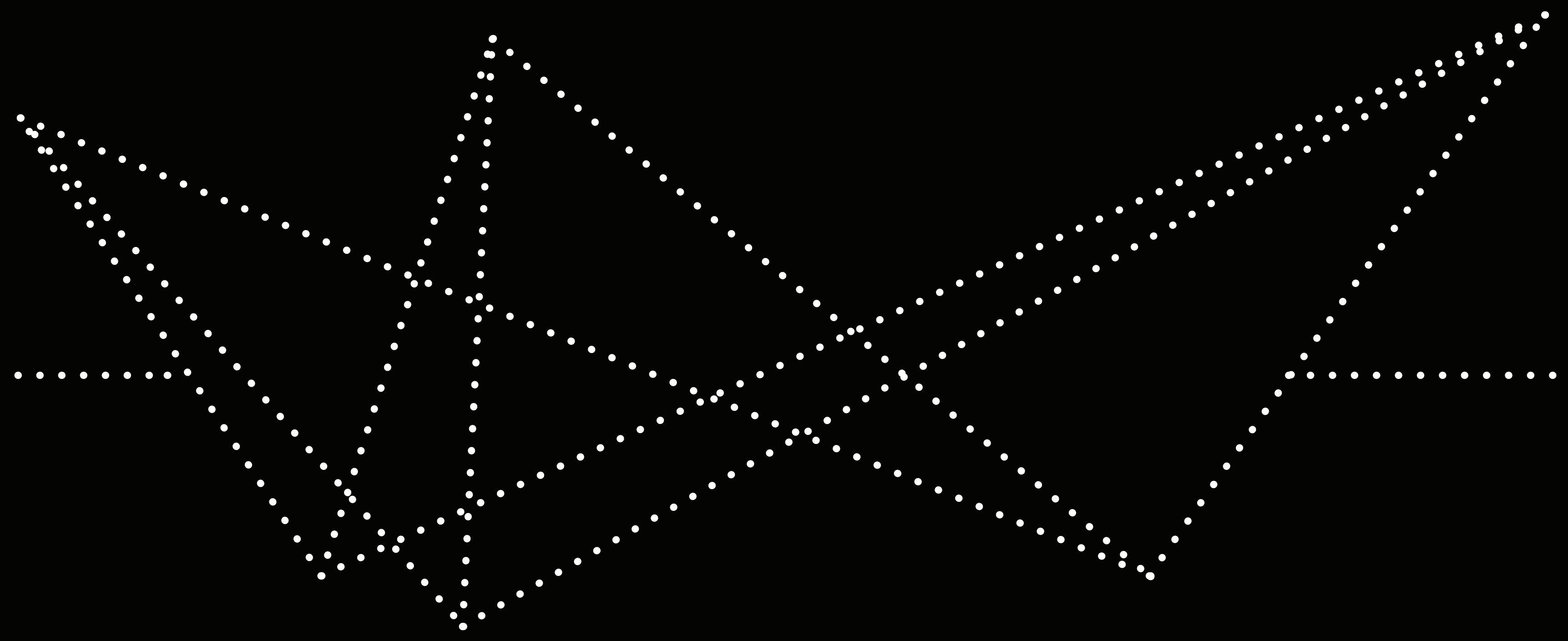
- THIRD YEAR, ARCE
- PACIFICA, CA
- LISTENS TO HIP HOP
- AVID NBA FAN



RYAN KHIEU

- FOURTH YEAR,
- ARCE
- SAN JOSE, CA
- LIKES MUSIC
- PLAYS VOLLEYBALL

TIMELINE - PART ONE



CLIENT
CLIENT INFO
SITE ANALYSIS

INFO & DETAILS
XENAFORMS
THE LOOP

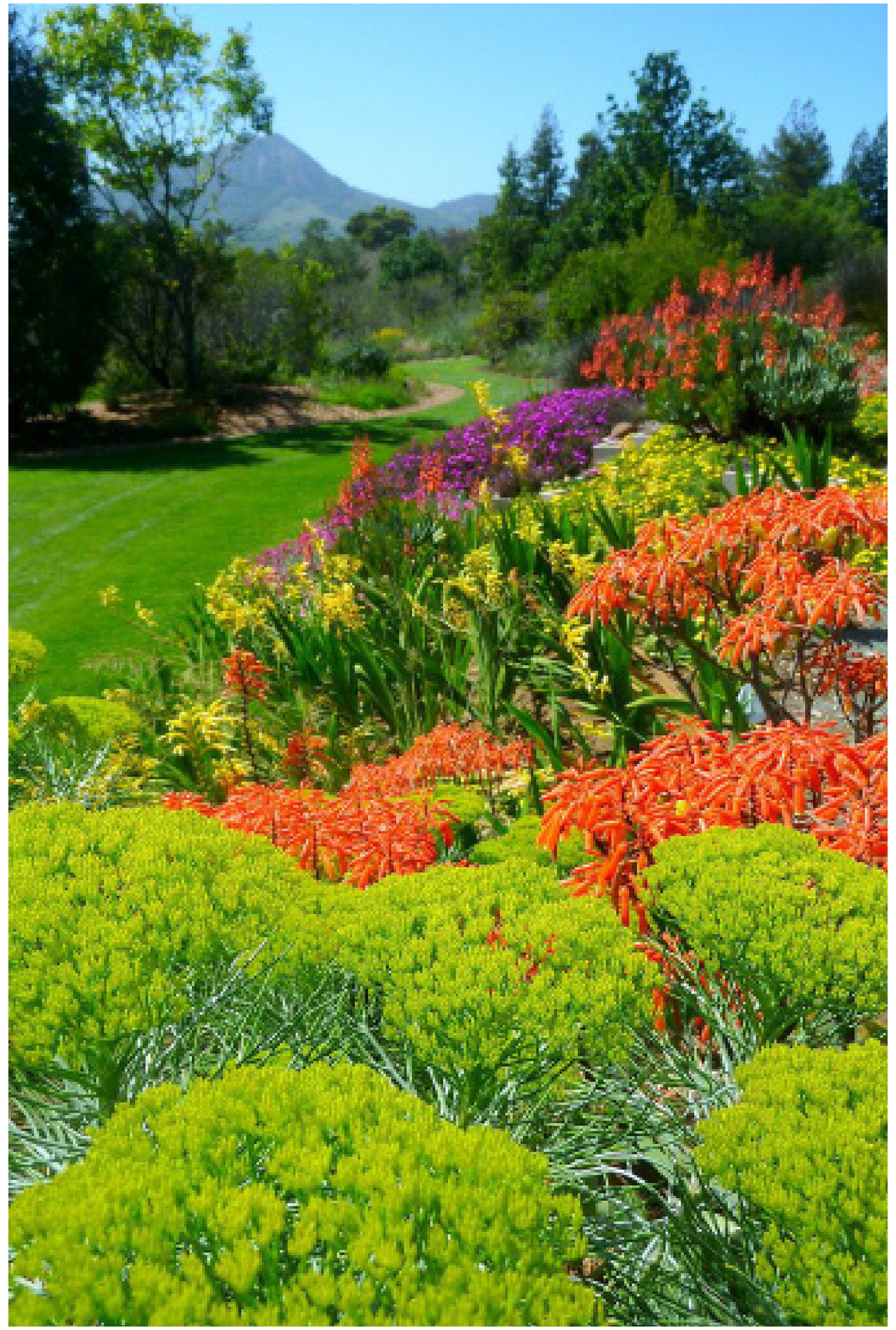
FORM FINDING
BAD IDEAS
POOR IDEAS
MÖBIUS STRIP
MODEL MAKING

POLYMÖBI
INITIAL FORM
PHYSICAL MODEL

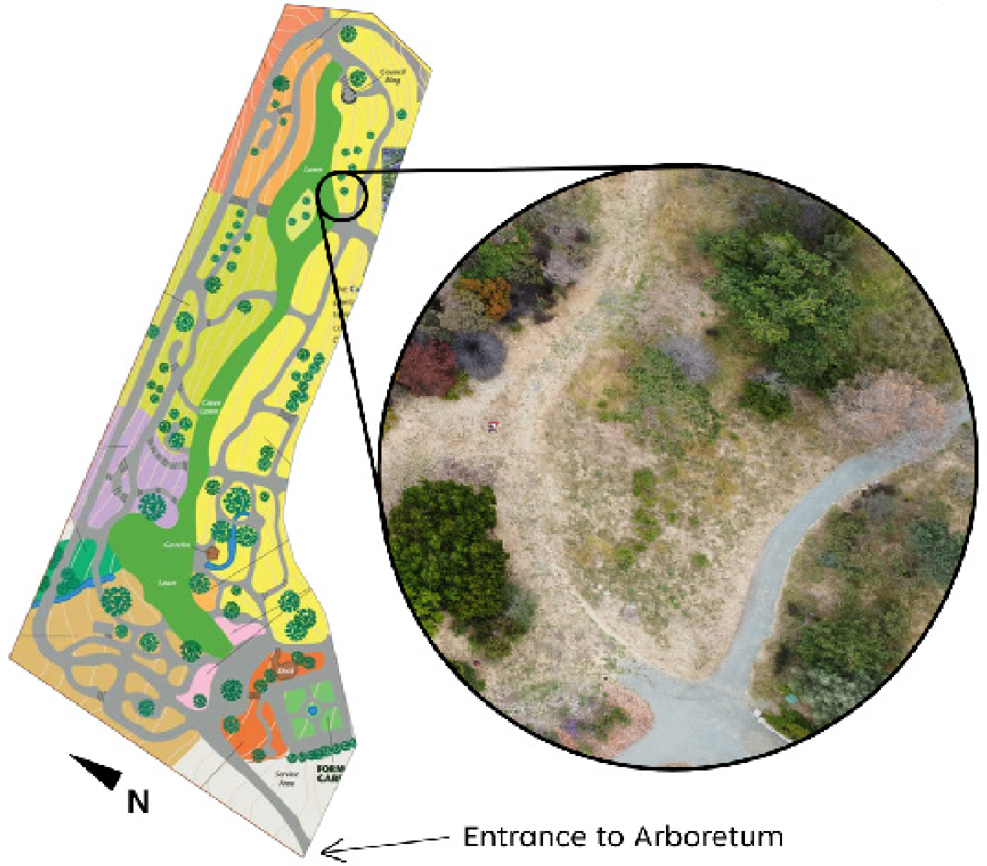
CLIENT DESCRIPTION

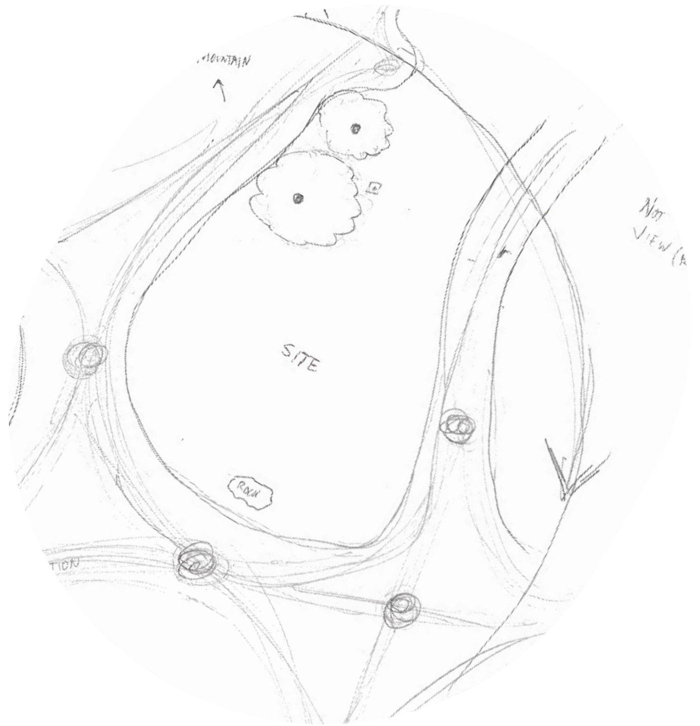
THE LEANING PINE ARBORETUM IS ONE OF CAL POLY'S BEST KEPT SECRETS. TUCKED IN THE BACK OF CAMPUS, THIS 5-ACRE PLANT PARADISE OFFERS MANY PLACES OF RELAXATION AND SERENITY. THE LEANING PINE ARBORETUM PLANS TO EXPAND IT'S AREA AND BE MORE ACCESSIBLE TO THE PUBLIC. AS AN INITIATIVE TO HELP THEM WITH ACHIEVING THIS MISSION, POLYMÖBI IS BEING PROPOSED AS A SHADE STRUCTURE THAT WOULD ACCOMPLISH THREE GOALS:

1. ENHANCE THE EXPERIENCE OF THE LEANING PINE ARBORETUM
2. CELEBRATE INTERDISCIPLINARY WORK AS LEANING PINE ARBORETUM IS A COLLECTION OF SENIOR PROJECTS
3. PROMOTE SUSTAINABLE DESIGN WITH THE MATERIALITY OF POLYMÖBI BEING MAJORITY TIMBER



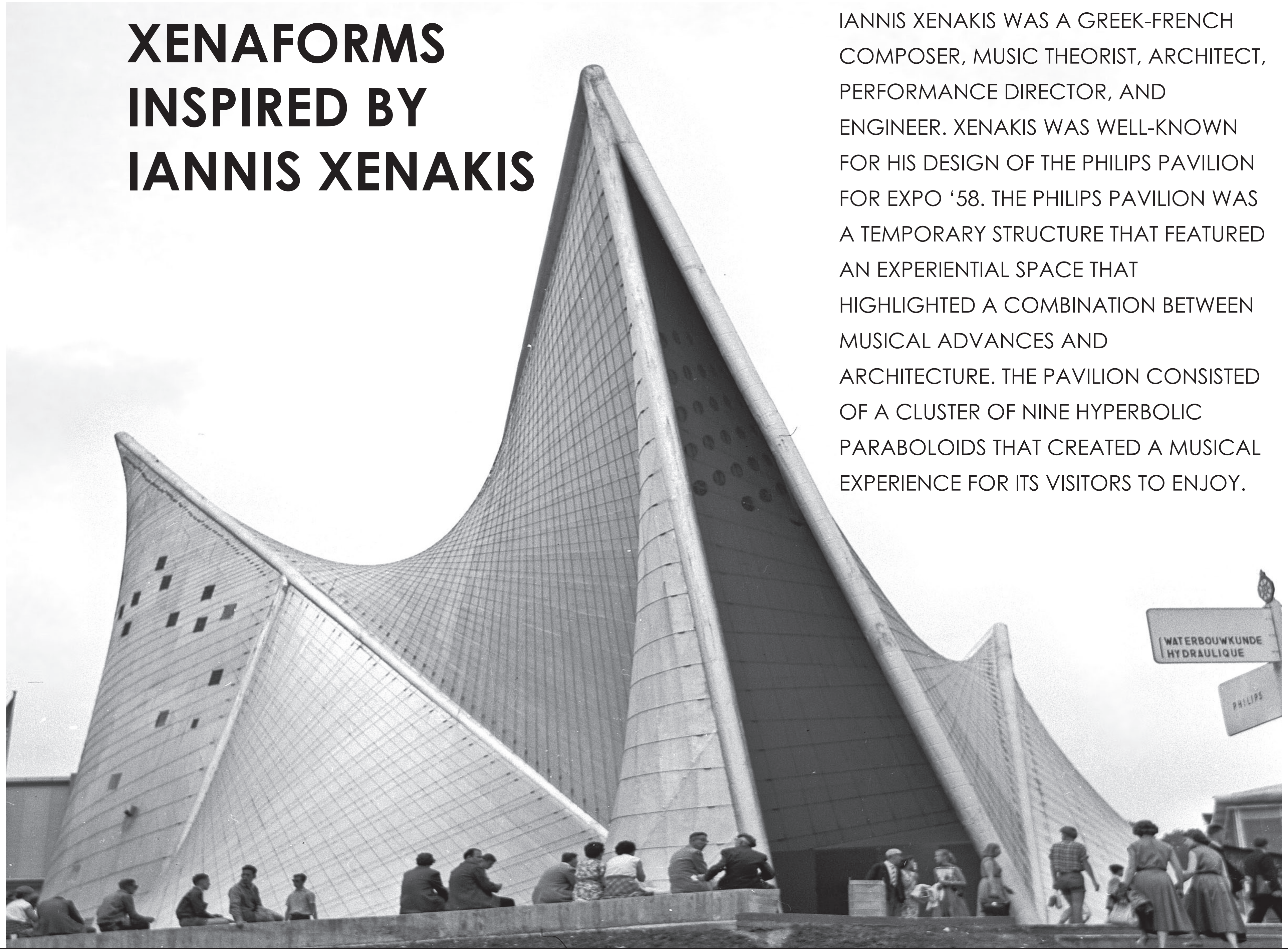
SITE ANALYSIS





AT THE BEGINNING OF THE COURSE, WE VISITED THE LEANING PINE ARBORETUM TO GET A SENSE OF WHERE WE WERE DESIGNING OUR STRUCTURE AND GATHERED INFORMATION ABOUT THE SITE. AFTER SOME TIME, WE DECIDED ON A LOCATION THAT IS FARTHER AWAY FROM THE MAIN ENTRANCE. THIS SITE PRESERVES THE NATURALISTIC GRANDEUR OF THE ENTRANCE AND PROMOTES EXPLORATION THROUGH THE ARBORETUM WITH A DESTINATION AT THE END OF THE JOURNEY. ADDITIONALLY, THIS PLOT OF LAND IS EMPTY AND GREAT POTENTIAL FOR A NODE OF CIRCULATION AND VIEWPOINTS.

XENAFORMS INSPIRED BY IANNIS XENAKIS



IANNIS XENAKIS WAS A GREEK-FRENCH COMPOSER, MUSIC THEORIST, ARCHITECT, PERFORMANCE DIRECTOR, AND ENGINEER. XENAKIS WAS WELL-KNOWN FOR HIS DESIGN OF THE PHILIPS PAVILION FOR EXPO '58. THE PHILIPS PAVILION WAS A TEMPORARY STRUCTURE THAT FEATURED AN EXPERIENTIAL SPACE THAT HIGHLIGHTED A COMBINATION BETWEEN MUSICAL ADVANCES AND ARCHITECTURE. THE PAVILION CONSISTED OF A CLUSTER OF NINE HYPERBOLIC PARABOLOIDS THAT CREATED A MUSICAL EXPERIENCE FOR ITS VISITORS TO ENJOY.

THE LOOP

GEOGEBRA

GEOGEBRA IS A FREE ONLINE GRAPHING AND GEOMETRY SOFTWARE THAT WE USED FOR OUR INITIAL FORM FINDING TO BE ABLE TO CHANGE NUMEROUS PROPERTIES OF OUR STRUCTURE EASILY.

RHINO & GRASSHOPPER

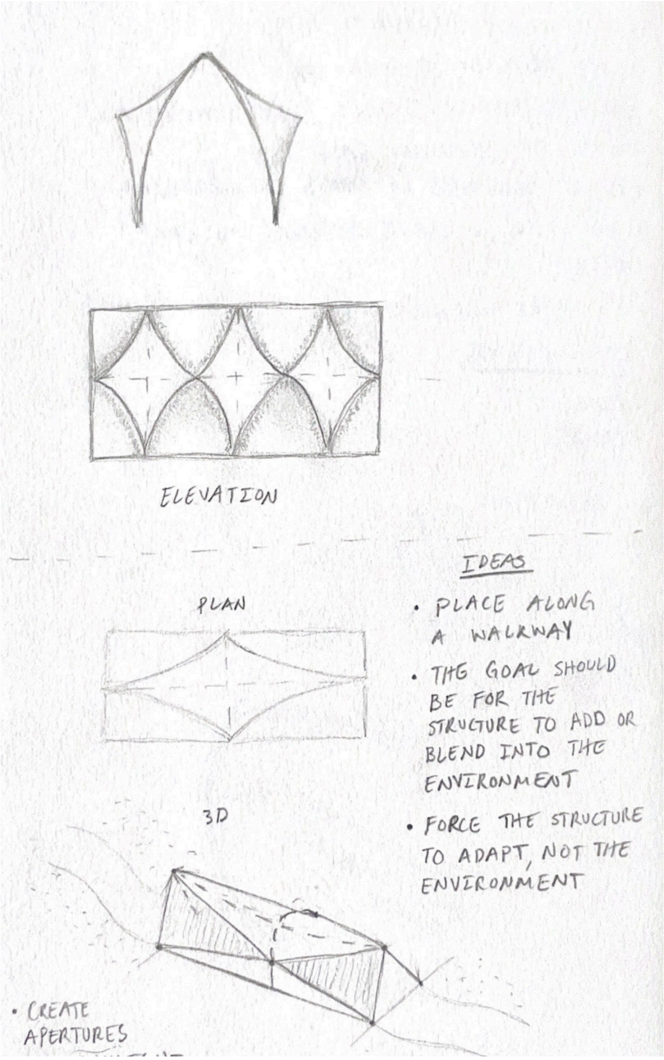
RHINO AND GRASSHOPPER WERE USED IN TANDEM TO REFINE OUR GEOMETRIES AND MODEL THE SHELLS FOR OUR XENAFORMS.

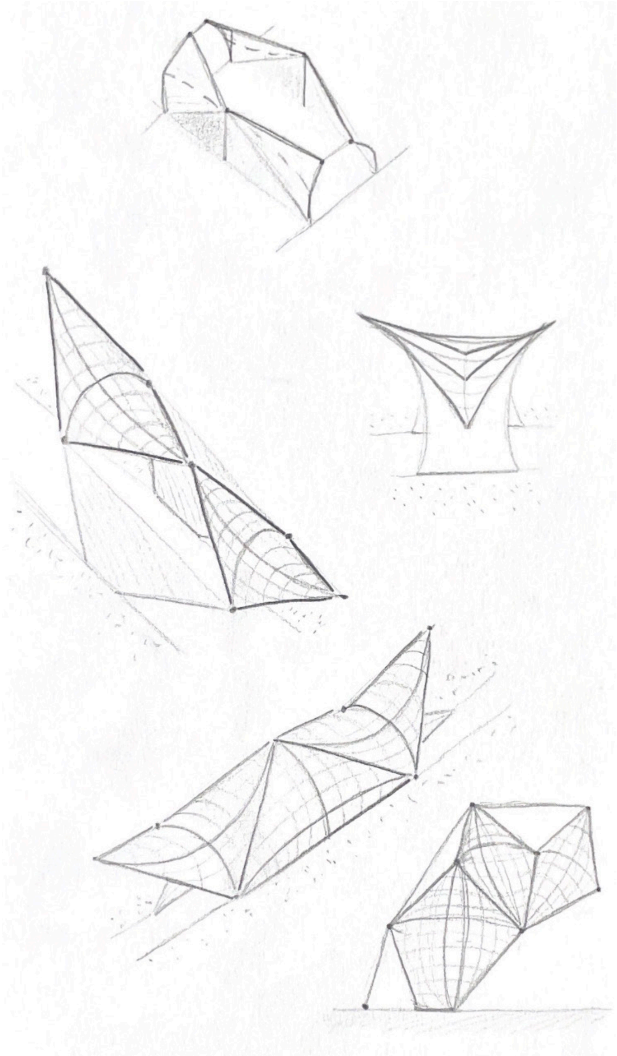
MODEL ITERATIONS

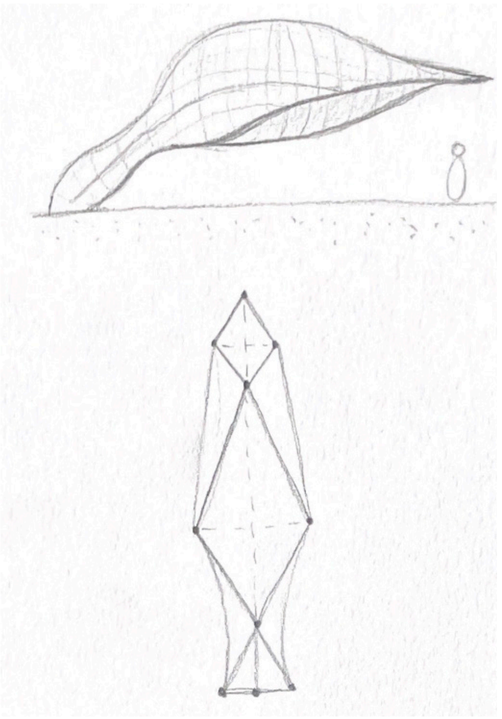
STUDY MODELS WERE MADE TO FURTHER EXPLORE THE FORM OF OUR DESIGNS AND THE SHADOWS CAST BY OUR MODELS, INFORMING THE NEXT ITERATION OF THE DESIGN PROCESS

BAD IDEAS

ANTHROPIC DRAWINGS

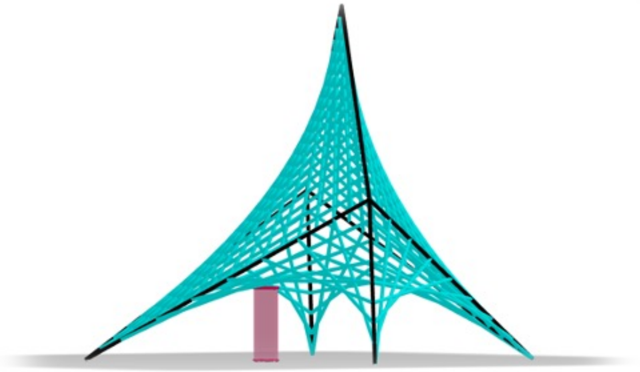


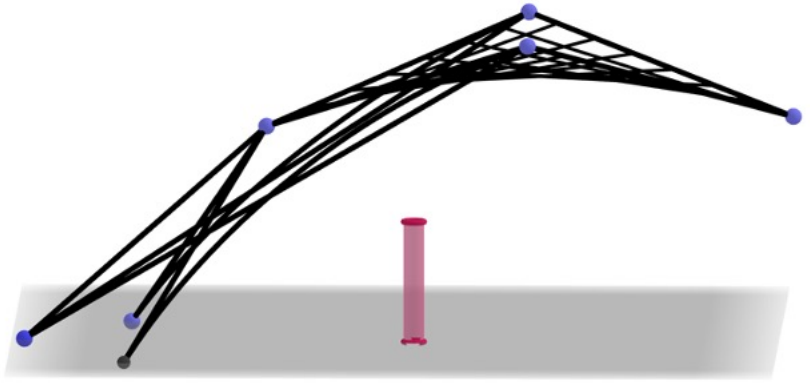


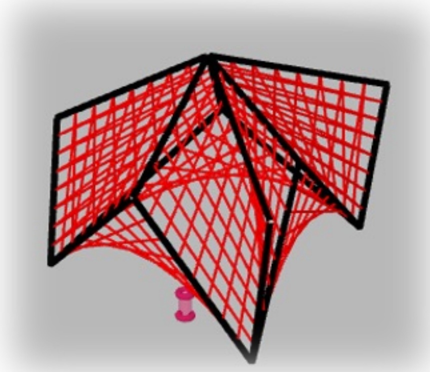


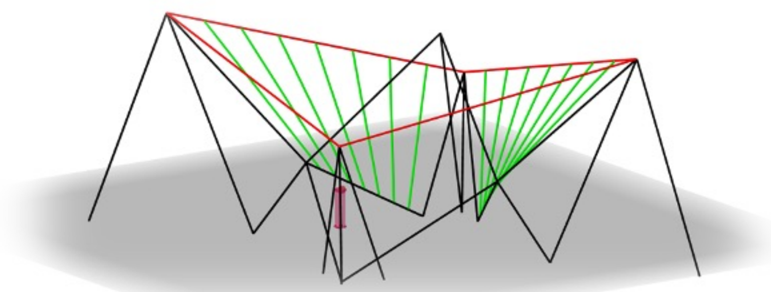
BAD IDEAS

GEOGEBRA



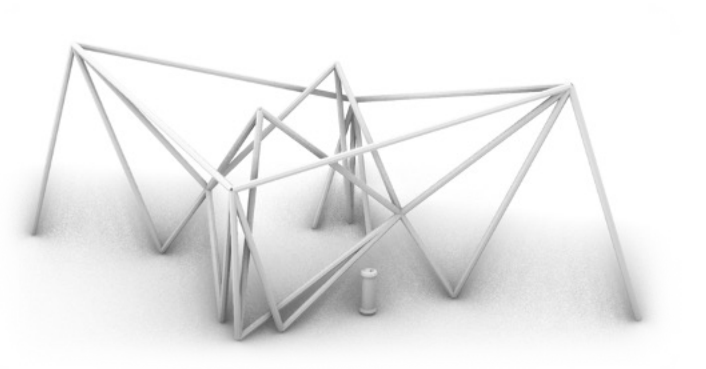


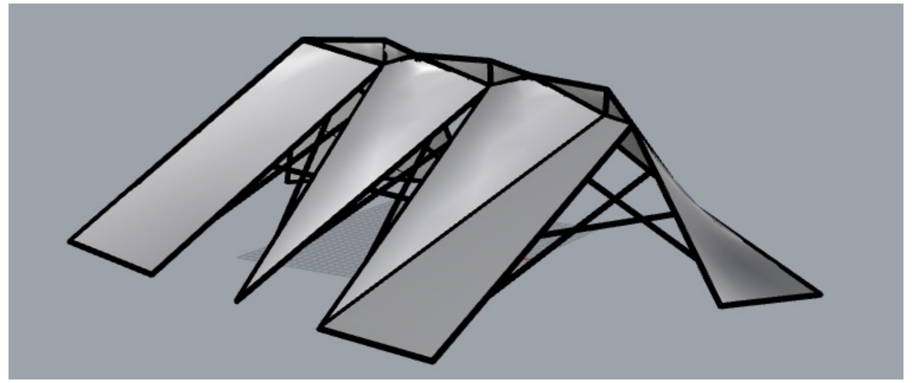


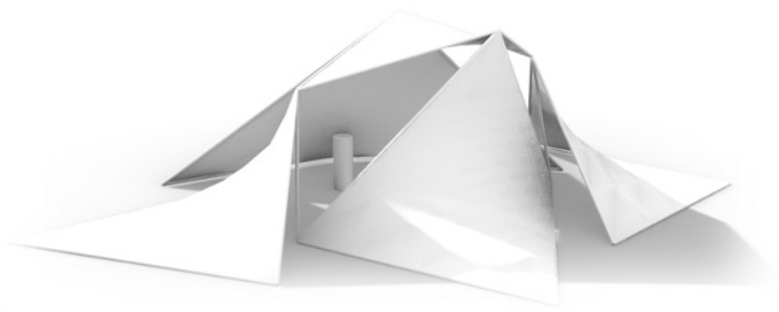


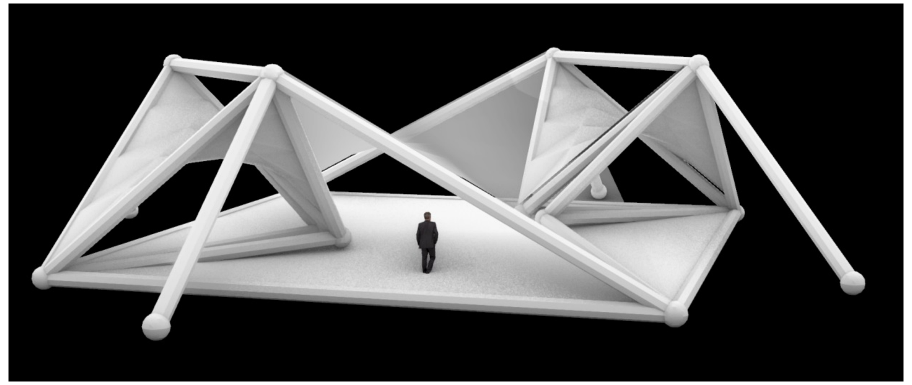
POOR IDEAS

RHINO



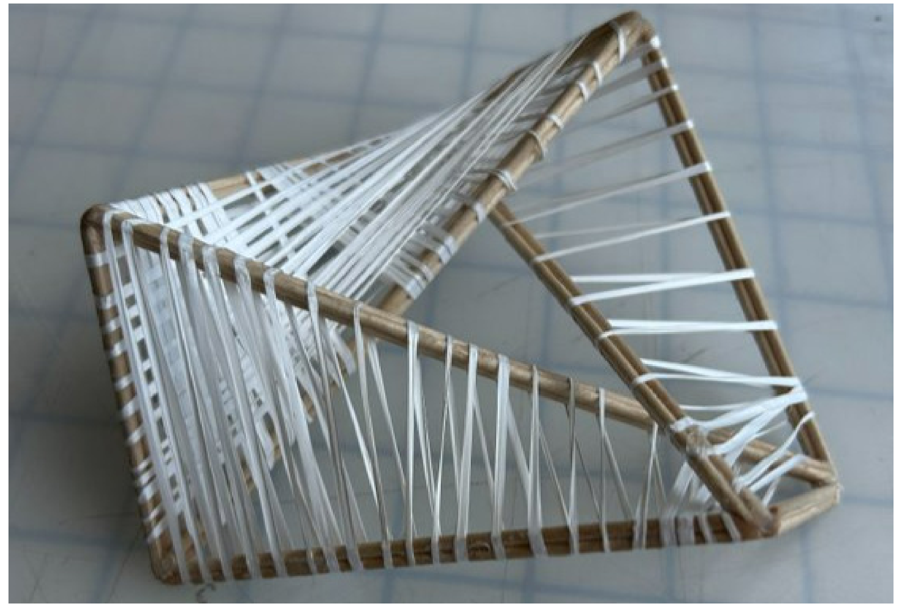


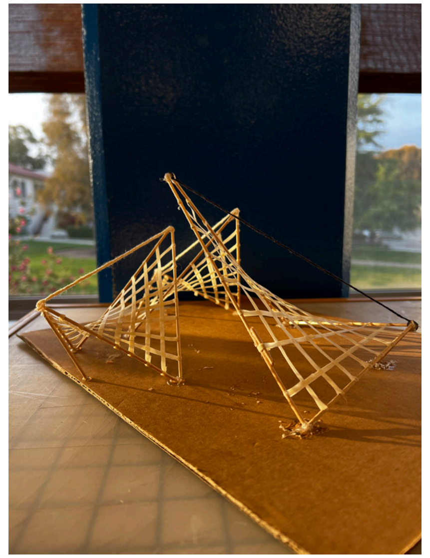




MÖBIUS STRIP

INITIAL MODEL MAKING EXPLORATION





OUR STUDY MODELS WERE CONSTRUCTED FROM WOODEN CRAFT APPLICATOR STICKS AND SUPER GLUE.

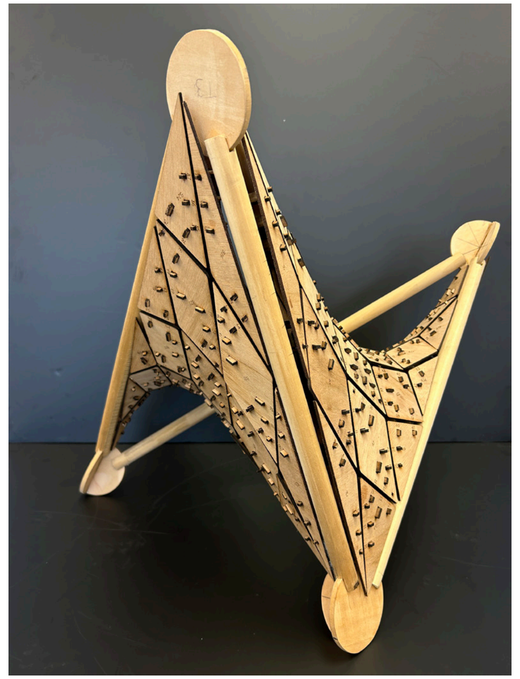
WE EXPERIMENTED WITH MULTIPLE MATERIALS TO REPRESENT THE POLYSHELLS BUT ULTIMATELY FOUND THAT LINES OF THIN MASKING TAPE THAT FOLLOWED THE RULED LINES OF THE SHELL WORKED BEST.

THESE MODELS PICTURED HERE WERE OUR INITIAL MODELS TO EXPERIMENT WITH LIGHT AND SHELLS ORIENTATION AND INTERACTION WITH EACH OTHER.

PHYSICAL MODEL MAKING

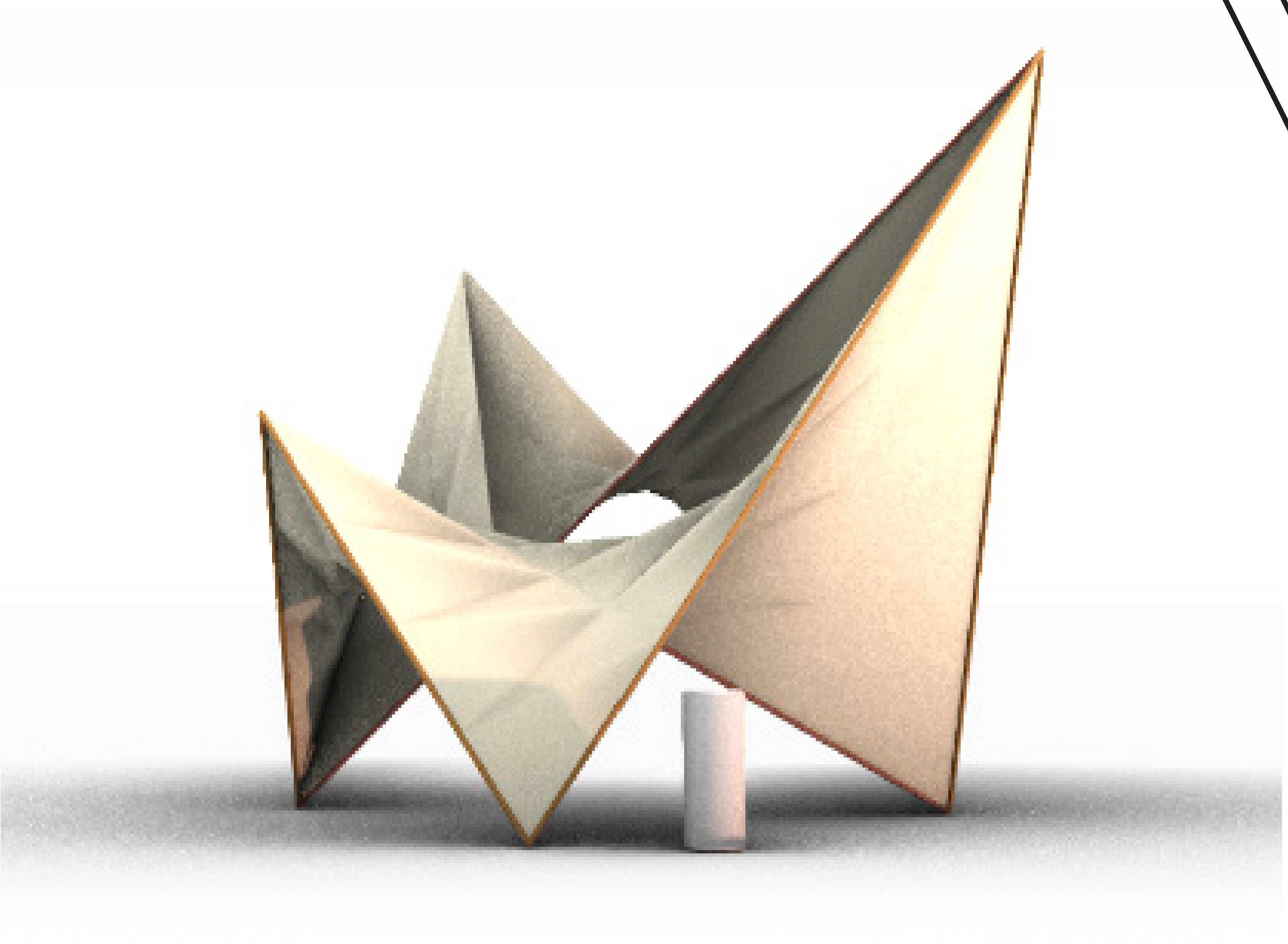
OUR IN-DEPTH PHYSICAL MODEL CONISTED OF A FRAME, AN ITERATION OF OUR STRUT TO STRUT CONNECTION, AND POLYSHELLS. THE FRAME WAS CONSTRUCTED OF 3/4" DOWELS AND THE CONNECTIONS FROM 1/4" BOARDS. THE POLYSHELLS WERE LASER CUT FROM THE 3D GEOMETRY OF THE SHELLS GENERATED BY THE GRASSHOPPER SCRIPT IN RHINO AND HAND ASSEMBLED AND GLUED, THEN FITTED INTO THE FRAME.

THIS IS WHEN WE DISCOVERED THAT WITHOUT AN OFFSET BETWEEN THE SHELLS AND THE STRUTS, THE SHELLS WOULD INTERFERE WITH EACH OTHER AND OVERLAP AROUND THE STRUT WHERE THEY MET.



INITIAL FORM

OUR FIRST ITERATION OF OUR CASCASDING MÖBIUS STRIP WAS MUCH TOO STEEP AND TALL. THE HEIGHT POSED AN ISSUE FOR CONSTRUCTION AND MEMBER LENGTHS, WHILE THE FORM SIMPLY DIDN'T PROVIDE ENOUGH SHADE TO FULFILL ITS INTENDED PURPOSE.



TIMELINE - PART TWO

UPDATED FORM
- DIMENSIONS
- SHADE
- SHELL OFFSET
- GEOGEBRA
- RHINO/GRASSHOPPER

SITE STUDY
- TOPOGRAPHY
- SUN STUDY

FORM TESTING
- MODERN MUELLER BRESLAU METHOD
- AXIAL/BUCKLING ANALYSIS
- BENDING ANALYSIS
- LATERAL ANALYSIS
- CAPACITIES

MATERIALS & FIXITY
- MATERIALITY
- SOIL INVESTIGATION
- FOUNDATION DESIGN
- CONNECTIONS

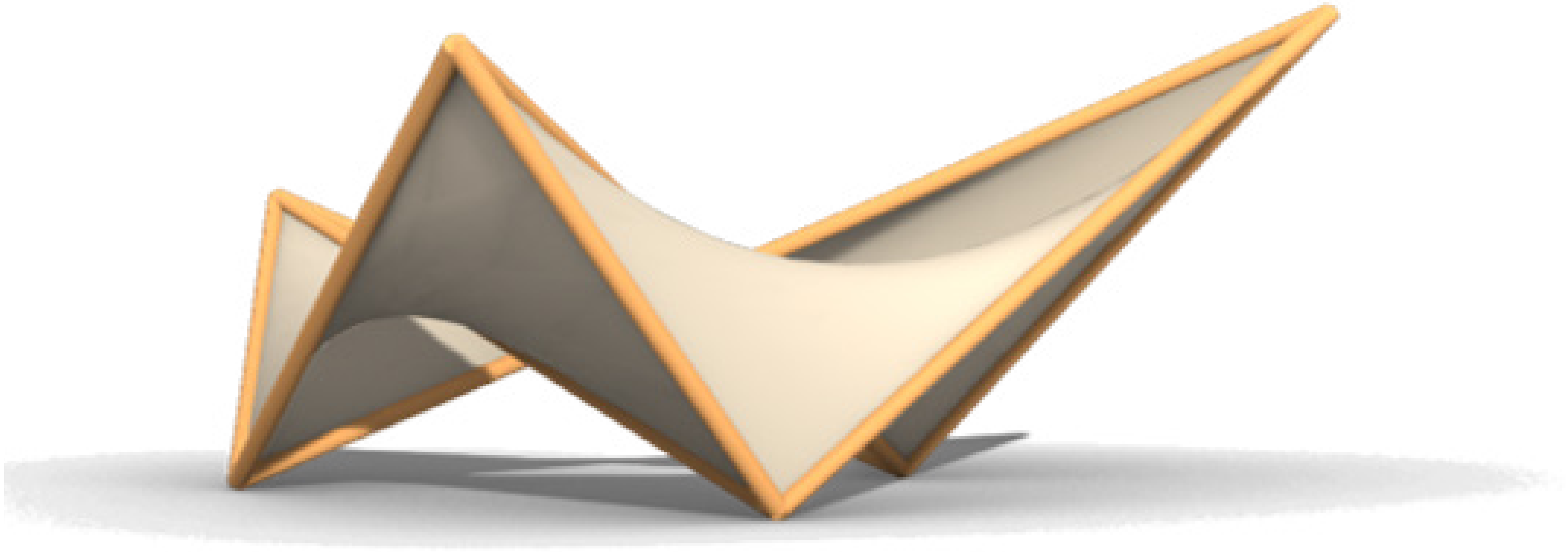
RENDERS
- AERIAL VIEW
- GROUND VIEW

FUTURE THOUGHTS
- GLOBAL
- CULTURAL
- ECONOMIC
- ENVIRONMENTAL

BANDSHELL
- VILNIUS BANDSHELL PROJECT

FINAL WORDS
- COMMENCEMENT
- ACKNOWLEDGEMENTS

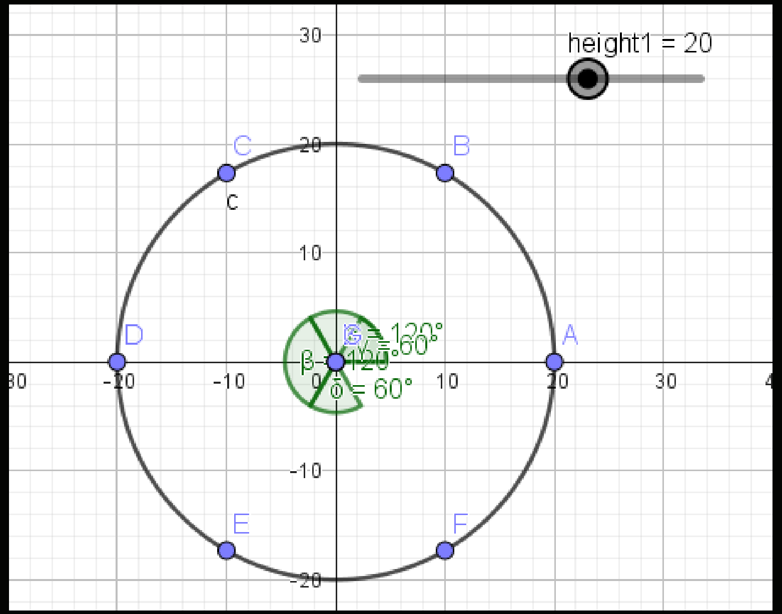
UPDATED FORM



TO SOLVE THESE ISSUES, WE DESIGNED THE MODEL FROM THE GROUND UP TAKING INTO ACCOUNT ALL THAT WE HAD LEARNED FROM THE ANALYSIS OF OUR PREVIOUS FORM AND MODEL MAKING ITERATIONS.

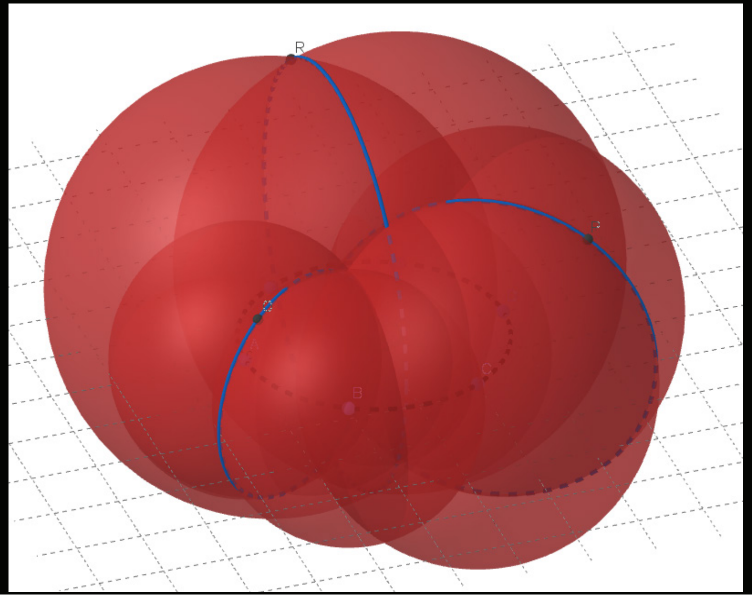
WE DECIDED TO LOWER THE OVERALL HEIGHT OF EACH POINT, WHILE INCREASING THE LEAN OUTWARD TO PROVIDE A MORE DRAMATIC EFFECT AND MORE SHADE DURING THE PEAK OF THE DAY.

GEOGEBRA

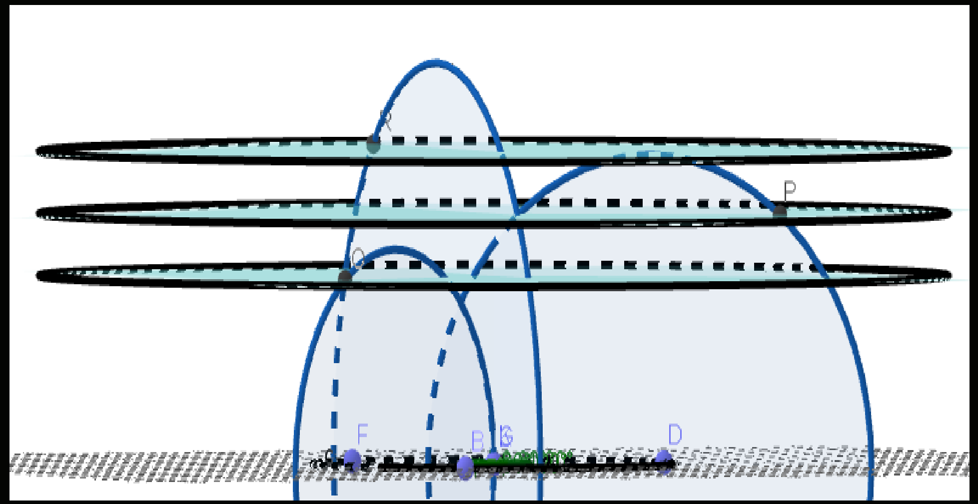


USING THE DIMENSIONS DETERMINED BY SITE ANALYSIS, A CIRCLE WAS MADE AND POINTS WERE PLACED EVERY 60^0 AROUND THE CIRCLE.

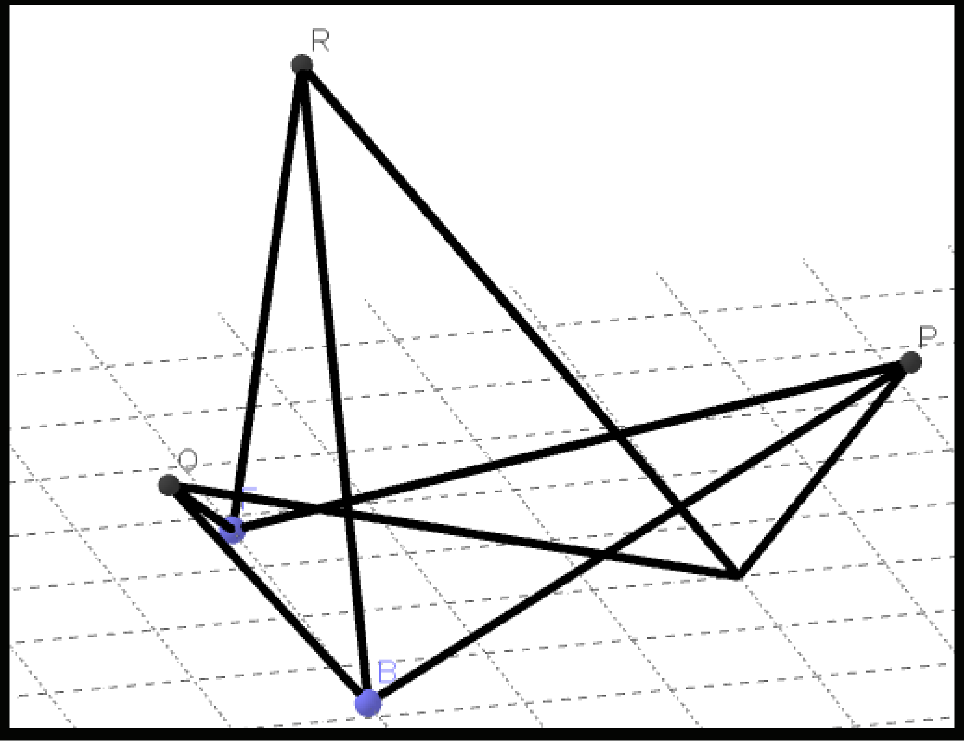
SETS OF SPHERES WITH RADII BASED ON SLIDER "HEIGHT1" WERE MADE AROUND ADJACENT POINTS AND THE INTERSECTING CONIC BETWEEN THEM WAS DEFINED. THERE IS A 33% AND 66% INCREASE BETWEEN THE RADII OF EACH SET OF SPHERES RESPECTIVELY.



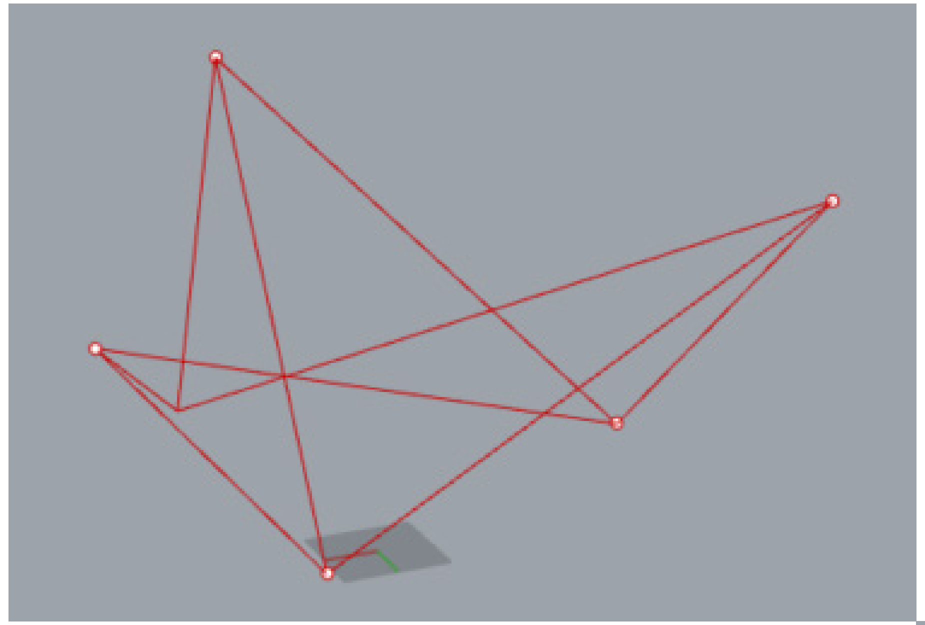
THREE PLANES WERE MADE WITH HEIGHTS BASED ON 75% OF "HEIGHT1" TO INTERSECT THESE PLANES WITH THE RESULTING CONICS AND CONTROL THE HEIGHTS OF THE CROWN LOCATIONS. THESE PLANES' HEIGHTS ALSO INCREASE BY 33% AND 66% RESPECTIVELY.



STRUTS WERE DEFINED BETWEEN THESE NEW CROWNS AND THREE OF THE ORIGINAL GROUND POINTS. THESE STRUTS INFORMED US ON THE FORM BUT WE FOUND THEM TROUBLESOME TO WORK WITH ONCE IMPORTED INTO RHINO 7. WE OPTED INSTEAD TO RECORD THE LOCATIONS OF THE CROWNS AND GROUND POINTS AND GENERATE THE GEOMETRY IN RHINO USING THIS INFORMATION.

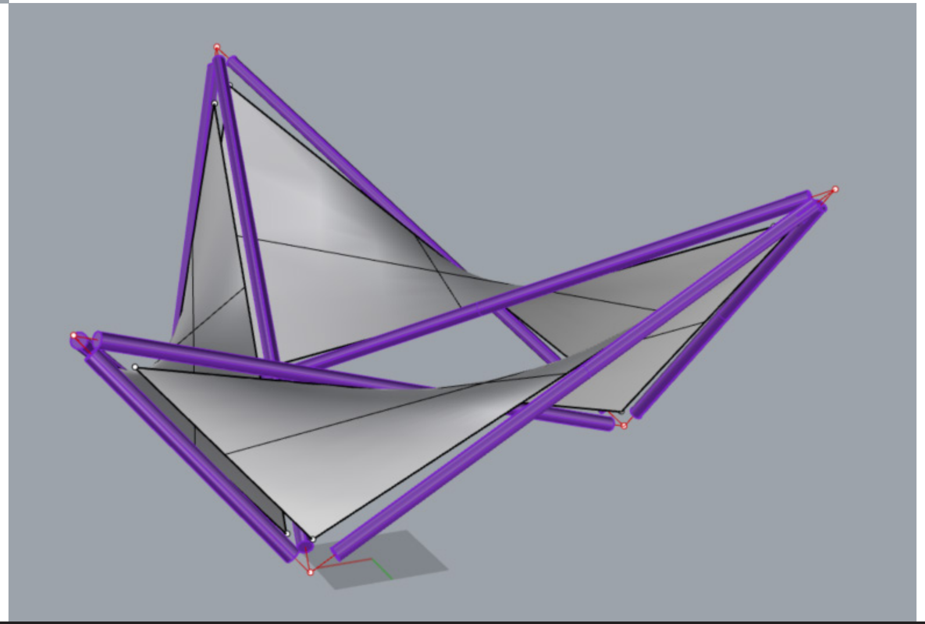


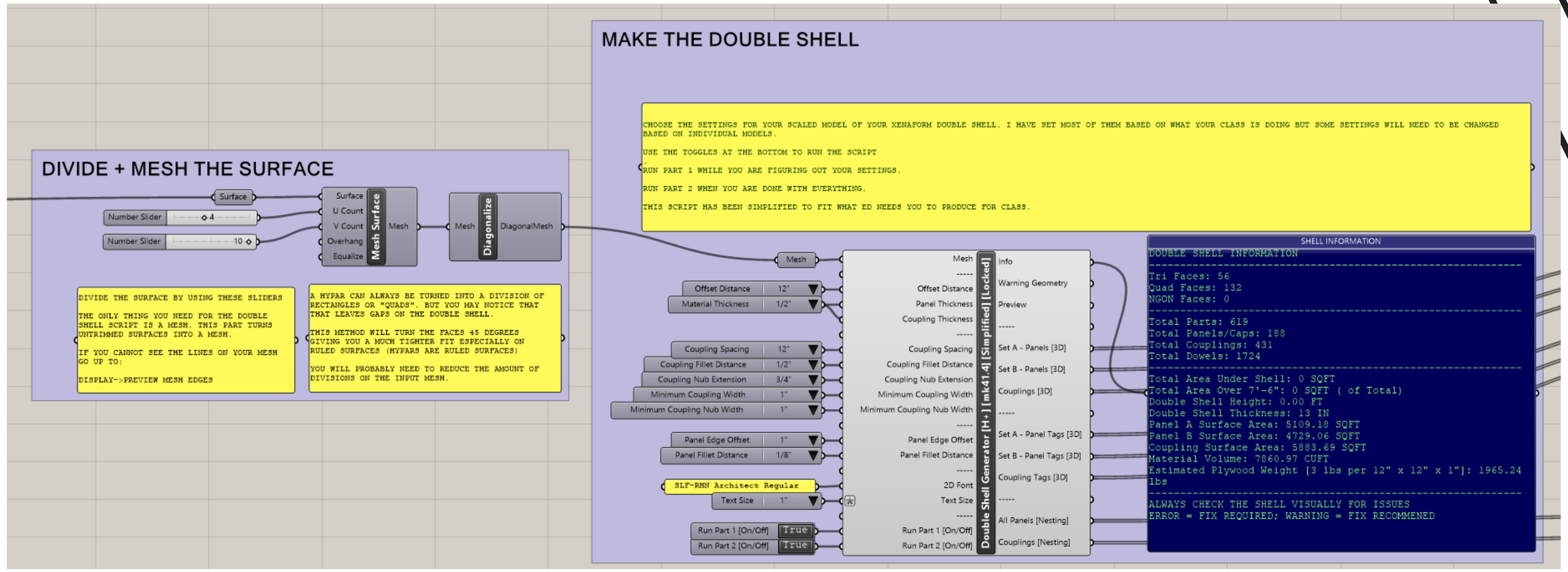
RHINO7 & GRASSHOPPER



TO BEGIN OUR RHINO MODEL, WE TRANSFERRED THE POINTS FROM GEOGEBRA AND CONNECTED THEM TO FORM THE CENTER LINES OF OUR STRUTS.

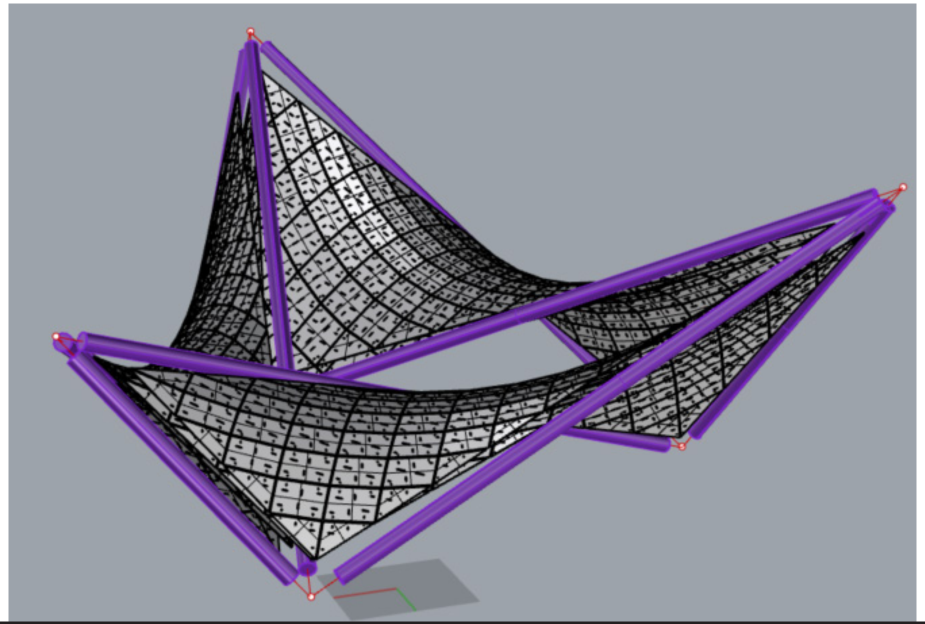
THESE CENTER LINES WERE OFFSET AND INTERSECTED TO FIND THE CORNERS OF THE SURFACES. CYLINDERS WERE EXTRUDED ALONG THE CENTER LINES TO MAKE THE STRUTS.





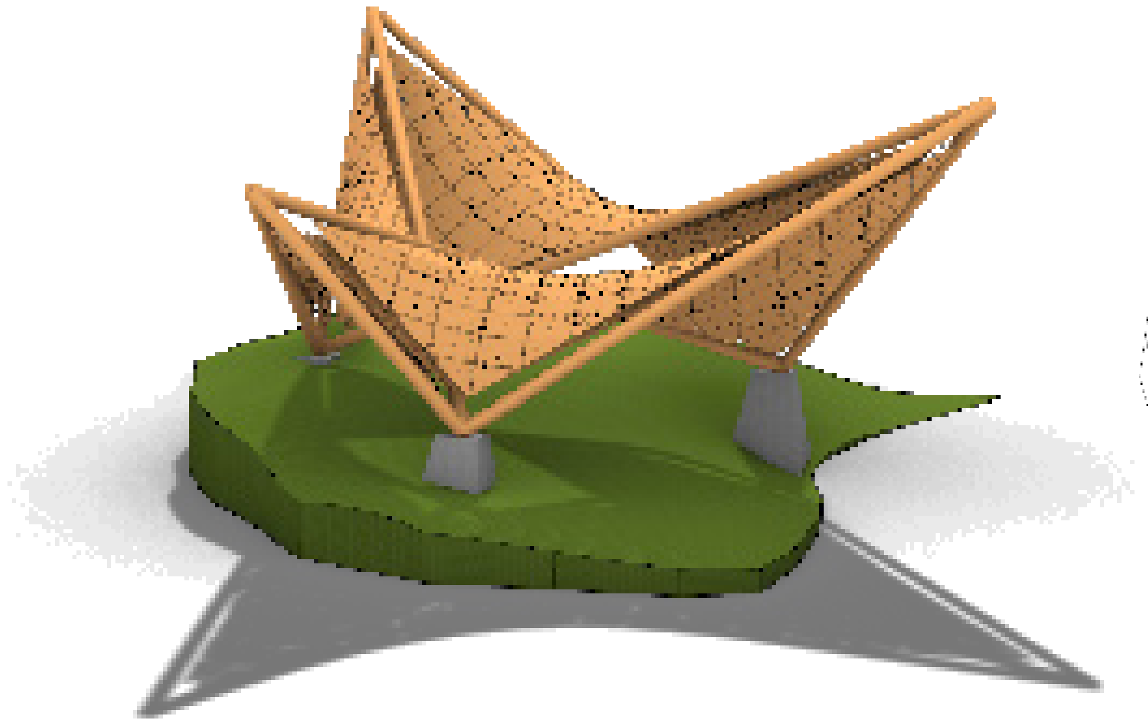
THE POLYSHELL GEOMETRY WAS GENERATED BY A GRASSHOPPER SCRIPT WRITTEN IN A PREVIOUS ITERATION OF THIS SENIOR PROJECT LAB AND PERFECTED THIS QUARTER BY NATHAN LUNDBERG.

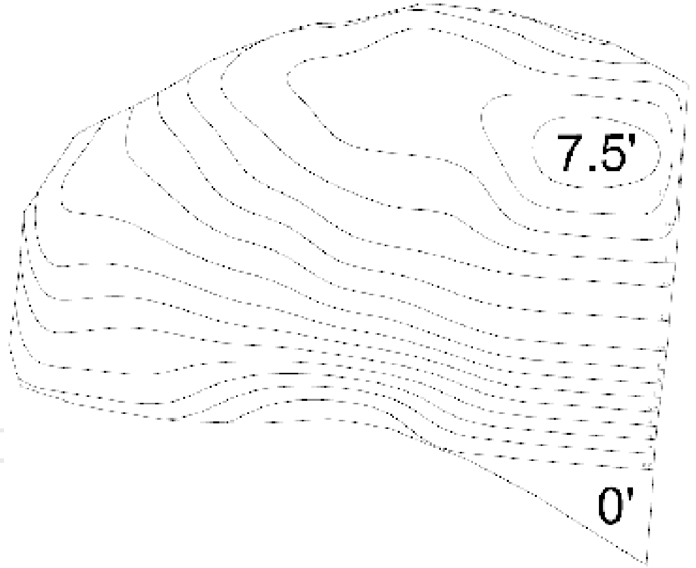
THE SCRIPT DIVIDES THE SELECTED SURFACE INTO A MESH WITH USER DEFINED AMOUNTS OF DIVISION ALONG PARALLEL PAIRS OF EDGES. THESE DIVIDED MESHES ARE THEN OFFSET TO EACH SIDE AND GENERATED INTO 3D GEOMETRIES WITH COUPLERS BETWEEN THEM THAT MAKE UP THE DOUBLE SHELL PICTURED TO THE RIGHT.



SITE TOPOGRAPHY

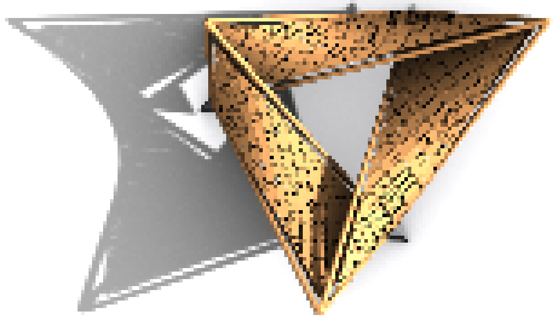
AS THE FINAL FORM WAS NOW COMPLETE, THE FOCUS SHIFTED ONTO HOW TO BEST INTEGRATE POLYMÖBI INTO THE SITE. ONE MAIN CHALLENGE WAS ADJUSTING THE FOUNDATIONS TO THE TOPOGRAPHY OF THE SITE. THE SITE WAS HIGHER IN ELEVATION FROM THE NORTH SIDE, AND DESCENDED DOWN ABOUT SEVEN FEET. THIS MEANT THAT BY KEEPING POLYMÖBI FIXED ON A LEVEL HORIZONTAL PLANE, ONE FOOTING WOULD BE RIGHT AT GROUND LEVEL AND ANOTHER WOULD PROTRUDE SEVEN FEET FROM THE GROUND. THIS WAS DETERMINED BY PHYSICAL INSPECTION AS WELL AS THE RHINO CONTOUR TOOL TO REACH THE MOST ACCURATE TOPOGRAPHICAL BASE FOR THE MODEL TO REST ON. ONCE ACCOMPLISHED, WE THEN WERE ABLE TO BEST UNDERSTAND THE SCALE AND CONSIDERATIONS NECESSARY FOR THE CONCRETE FOOTINGS.



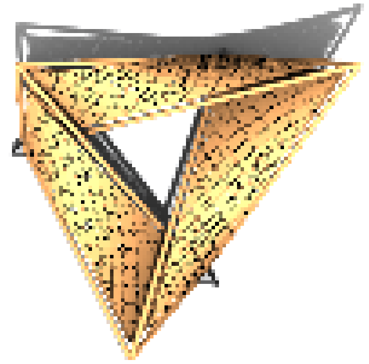


SUN STUDY

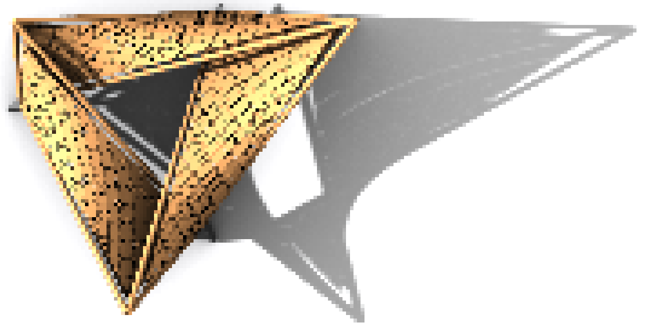
ONCE THE SITE TOPOGRAPHY STUDY WAS COMPLETE, THE UPDATED POLYMÖBI FORM WAS PLACED ON THE TERRAIN TO INVESTIGATE THE INTERACTION OF SUN AND SHADOWS. IN RHINO, THE MODEL WAS PLACED AT THE EXACT GEOGRAPHIC SITE, AND SHADOWS WERE CAST DOWN FROM WHAT A SUNNY DAY WOULD LOOK LIKE IN MID-MAY. THREE TIMEFRAMES WERE EXAMINED FURTHER: 8:00 AM, 12:00 PM AND 4:00 PM, ALL WITHIN HOURS OF OPERATION OF THE LEANING PINE ARBORETUM. THE EXTENDED REACH OF THE CROWNS CREATE LONGER, DRAMATIC SHADOWS, AND THE TRIANGULAR OCULUS IN THE MIDDLE ALLOWS FOR A DYNAMIC EXPERIENCE WHILST INSIDE POLYMÖBI.



8:00 AM



12:00 PM



4:00 PM

MODERN MUELLER BRESLAU METHOD

THE MODERN MUELLER BRESLAU (MMB) METHOD IS A GEOMETRIC, WORK-BASED APPROACH TO DETERMINING THE INTERNAL AXIAL AND MOMENT FORCES OF A MEMBER DUE TO EXTERNAL REACTIONS. DEVELOPED BY CAL POLY, SAN LUIS OBISPO PROFESSOR EDMOND SALIKLIS, THIS MMB METHOD IS USED AS AN ADDITIONAL ANALYSIS TOOL AND HIGHLIGHTING THE GEOSPACIAL IMPORTANCE WITHIN ARCHITECTURAL ENGINEERING.

MMB METHOD WORKS BY PERTURBING AN INDIVIDUAL MEMBER WITH A DEFLECTION (Δ) AND MEASURING THE VERTICAL LOFT CREATED FROM THE ORIGINAL MEMBER TO ITS PERTURBED LOCATION. THIS LOFT IS THEN MULTIPLIED BY THE EXTERNAL FORCE REACTING ONTO THE MEMBER. THERE IS ONLY ONE EQUATION (SEEN BELOW) THAT MMB METHOD EMPLOYS, AND THE UNKNOWN INTERNAL FORCE BEING SAUGHT IS FOUND BY TAKING THE SUM OF THE EXTERNAL FORCES AND THEIR RESPECTIVE LOFTS FROM PERTURBATION AND DIVIDING THAT BY THE DEFLECTION VALUE. AS THE DEFLECTION APPROACHES ZERO, THE ACCURACY OF THE INTERNAL FORCE INCREASES. FOR MOMENT ANALYSIS, THE PERTURBATION IS NOT A DEFLECTION, RATHER AN ANGLE MEASUREMENT CAUSED BY A ROTATION AT A KINK AT THE MIDSPAN OF THE MEMBER.

MMB METHOD ACCOMPLISHES EFFECTIVE STRUCTURAL ANALYSIS WHILE STILL ALLOWING THE ARCHITECTURE OF A STRUCTURE TO BE MODIFIED AT THE SAME TIME. IF THE FORCES AGREE IN COMPARISON WITH OTHER ANALYSIS SOFTWARES, WE CAN TRUST **AND** VERIFY THE MMB METHOD.

$$Unknown * \Delta + \Sigma(Force_i * Loft_i) = 0$$

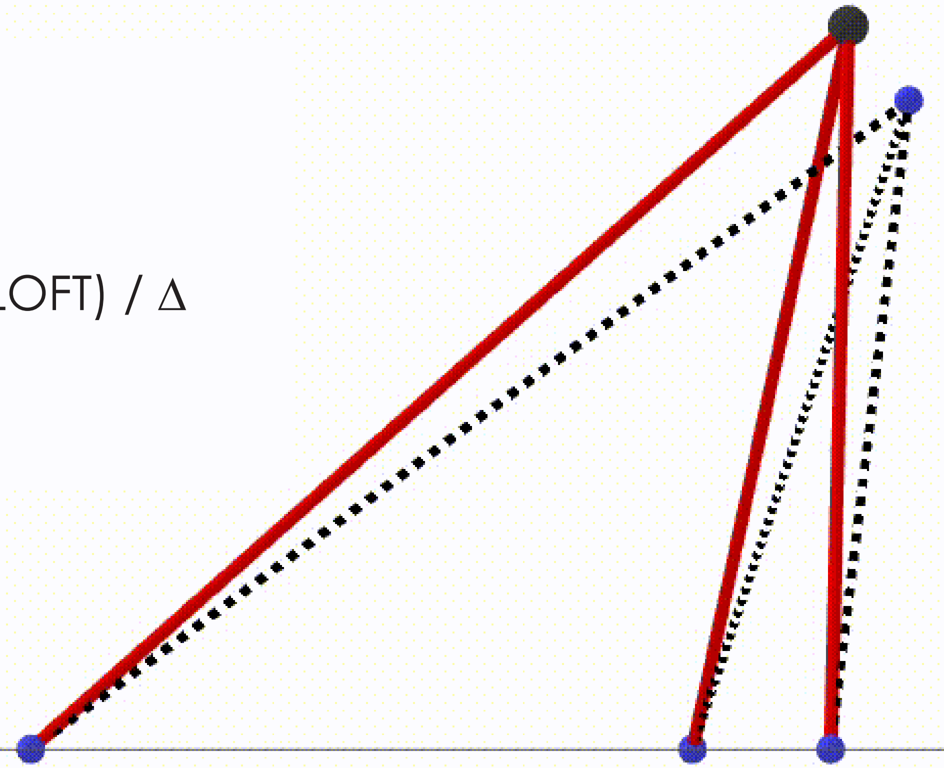
CLAIRE BALLARD (2021). EQUILIBRIUM WITHOUT STATICS, THE MODERN MUELLER BRESLAU METHOD.
CALIFORNIA POLYTECHNIC STATE UNIVERSITY, SAN LUIS OBISPO

PERTURBATION (Δ) ➤ MEASURE VERTICAL LOFT ➤ CALCULATE FORCE

FOR POLYMÖBI, MMB METHOD WAS USED TO VERIFY THE AXIAL AND BENDING MOMENT REACTION FORCES FROM SAP2000. SOME DESIGN CRITERIA IS IMPORTANT TO NOTE FOR AGREEMENT WITH CONSERVATIVE SAP2000 DESIGN ASSUMPTIONS TO ENSURE HIGH FACTORS OF SAFETY. WE WERE ABLE TO UNDERSTAND MMB METHOD MORE AND BEGIN TO UTILIZE IT FOR ITS BENEFITS OF SIMPLICITY, VERSATILITY AND ACCURACY.

Δ = 0.73 in
LOFT = 0.66 in
WEIGHT = 1000 lbs

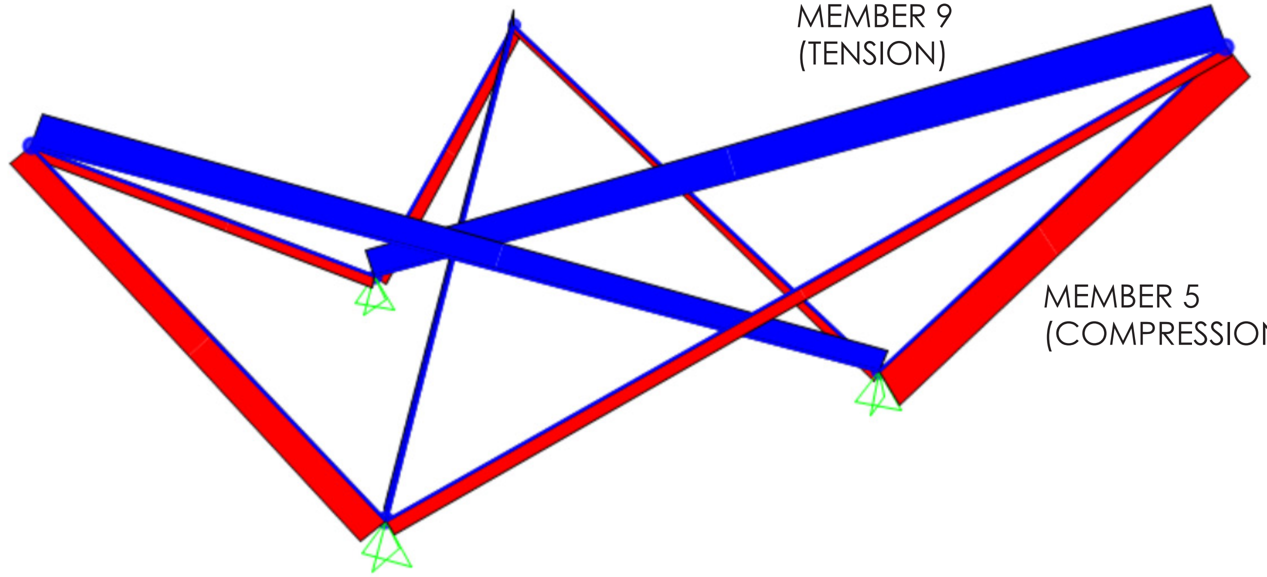
FORCE = (WEIGHT * LOFT) / Δ
FORCE = 907.28 lbs



DESIGN CRITERIA:

- DENSITY = 40 pcf
- E = 1,000,000 psi
- 12" DIA. STRUTS
- PINNED JOINTS

SAP2000 ANALYSIS - AXIAL FORCE



Frame Text	P Lb
5	-8339.56
3	-6452.35
1	-4673.51
4	-2922.18
2	-2748.34
6	-2590.3
8	4215.1
7	6114.38
9	7944.62

MAXIMUM COMPRESSION FORCE: 8,340 LBS

MAXIMUM TENSION FORCE: 7,945 LBS

MMB METHOD - AXIAL FORCE

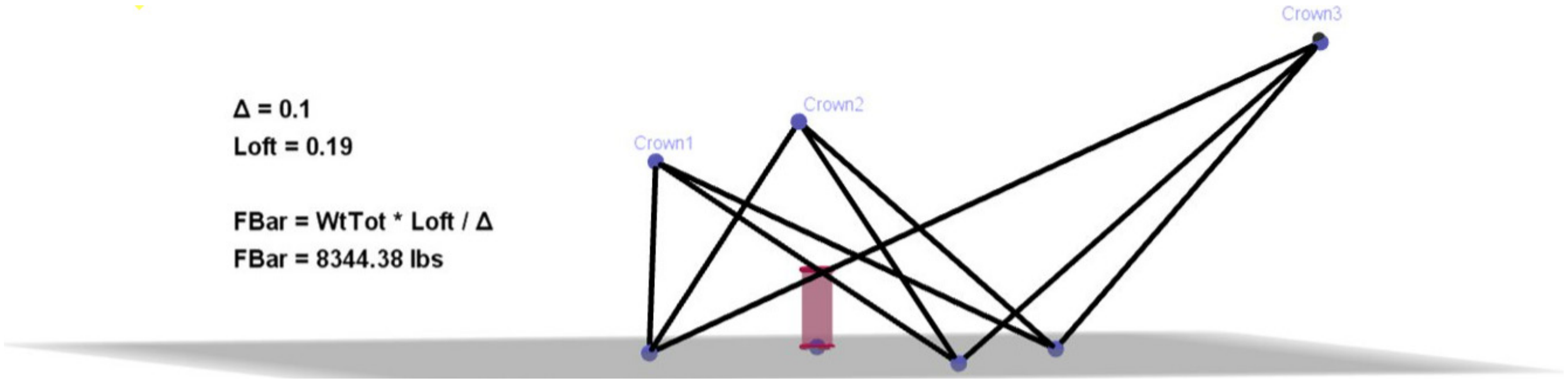
FORCE COMPARISON

SAP2000: 8,340 LBS

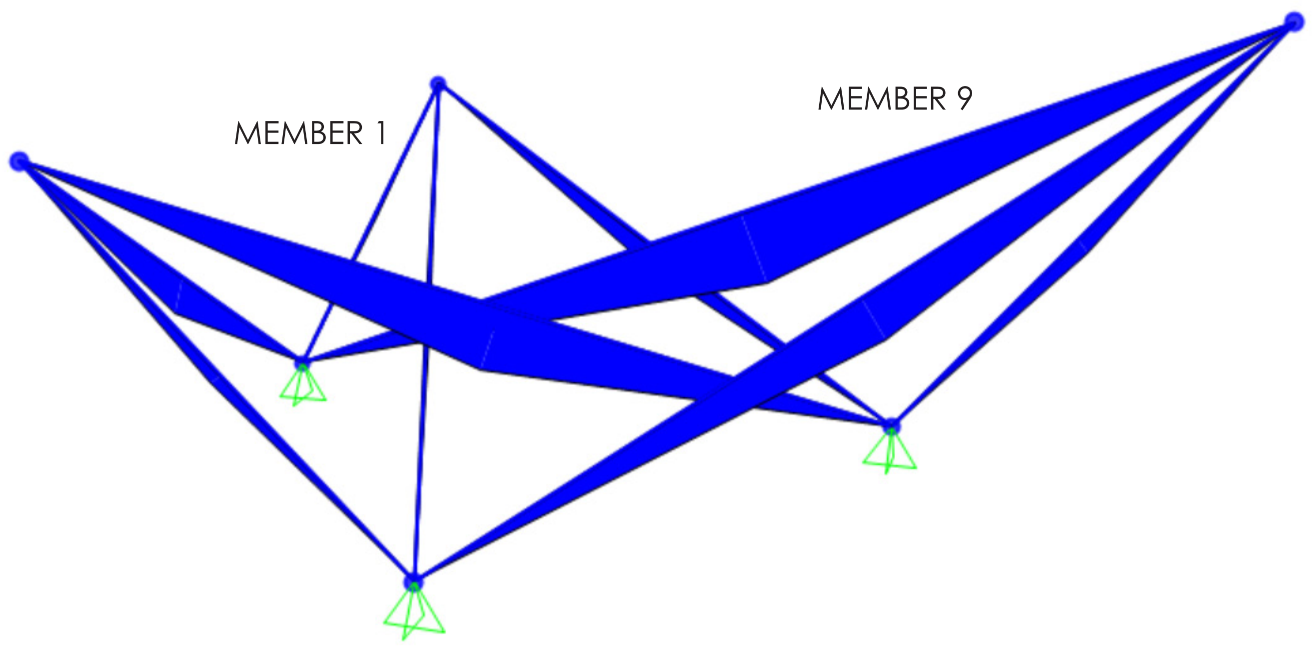
GEOGEBRA: 8,344 LBS

Δ = 0.1
Loft = 0.19

FBar = WtTot * Loft / Δ
FBar = 8344.38 lbs



SAP2000 ANALYSIS - BENDING MOMENT



Frame Text	M3 Lb-ft
1	1038.61
3	1838.3
5	2862.91
6	4644.51
2	6275.04
4	8034.82
8	8186.66
7	10620.58
9	13085.41

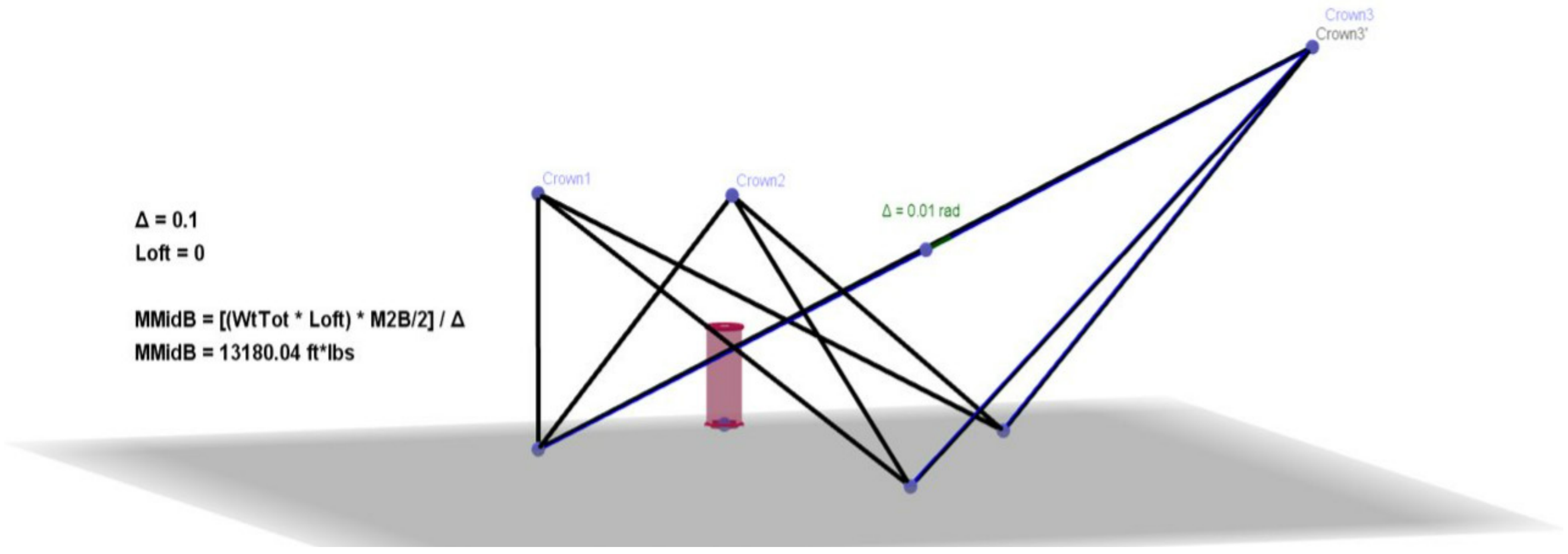
MAXIMUM BENDING MOMENT: 13,085 LB-FT

MMB METHOD - BENDING MOMENT

FORCE COMPARISON

SAP2000: 13,085 LB-FT

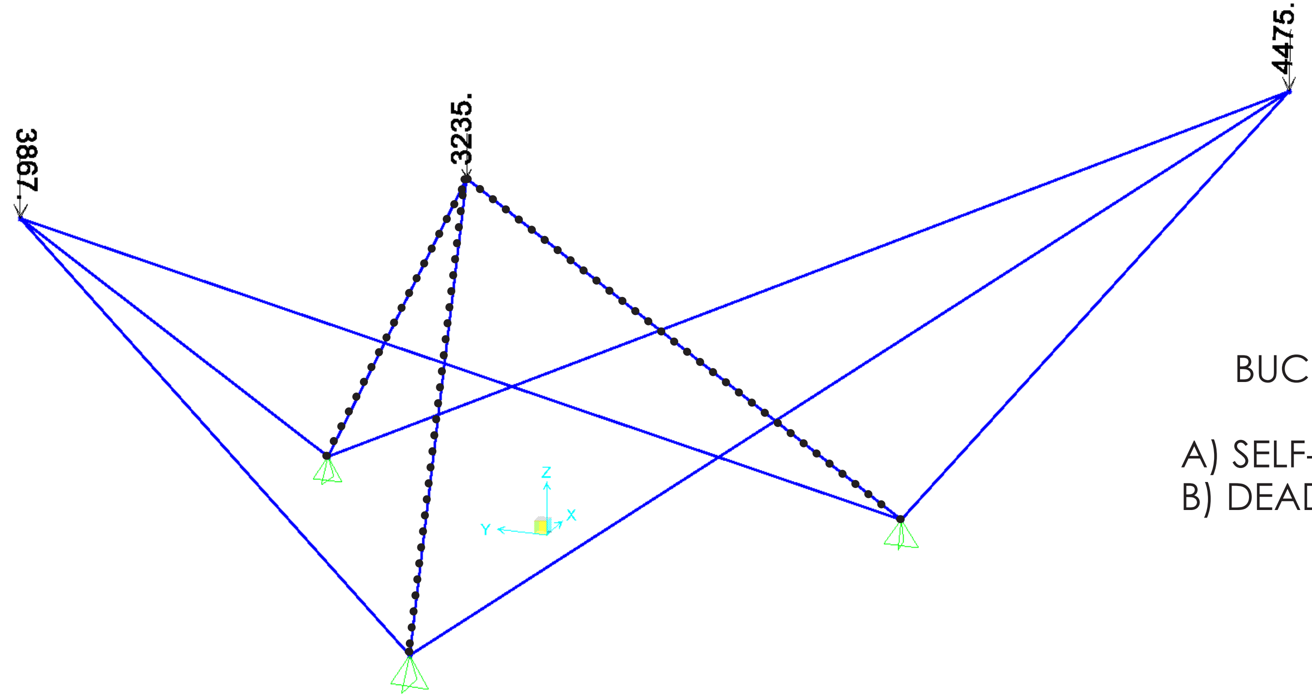
GEOGEBRA: 13,180 LB-FT



SAP2000 ANALYSIS - BUCKLING

TWO LOADING CONDITIONS:

A) SELF-WEIGHT THROUGHOUT STRUCTURE
B) DEAD LOAD OF TRIPOD APPLIED AT CROWN (SHOWN)



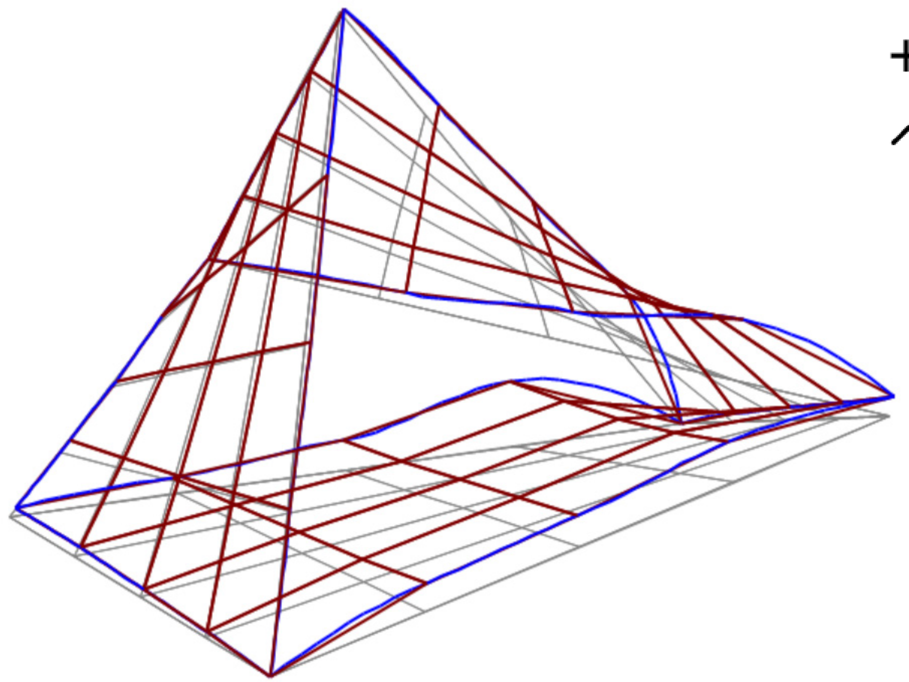
BUCKLING SAFETY FACTORS:

A) SELF-WEIGHT: 2,061
B) DEAD LOAD CROWN: 1,030

SAP2000 ANALYSIS - STATIC LATERAL

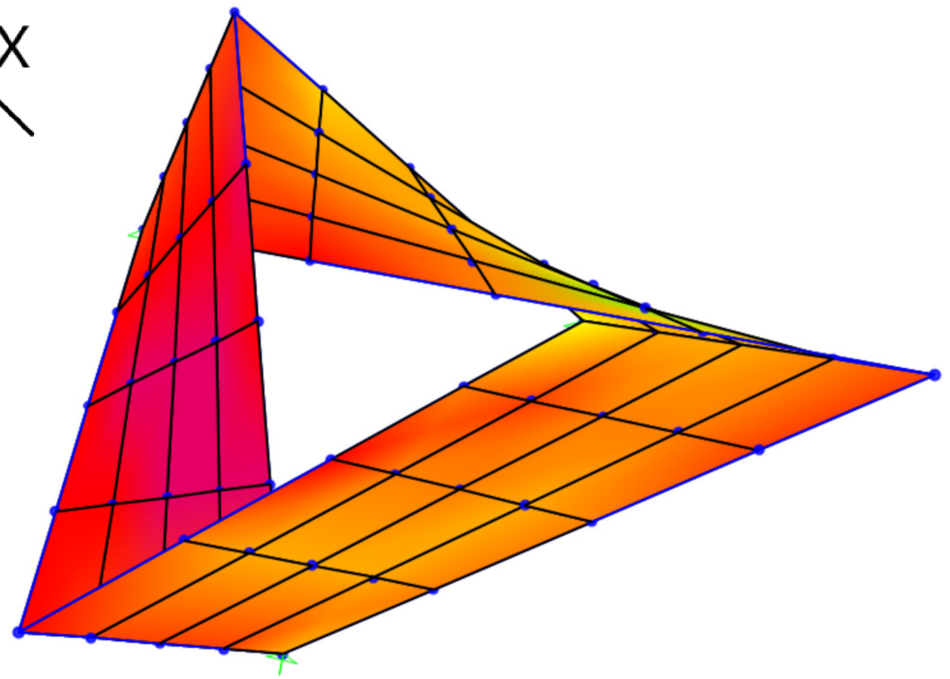
(0.3 * DEAD LOAD) APPLIED IN X-DIRECTION

MAX JOINT DISPLACEMENT: 0.004 INCHES



+X

MAX SHELL STRESS: 3.2 PSI

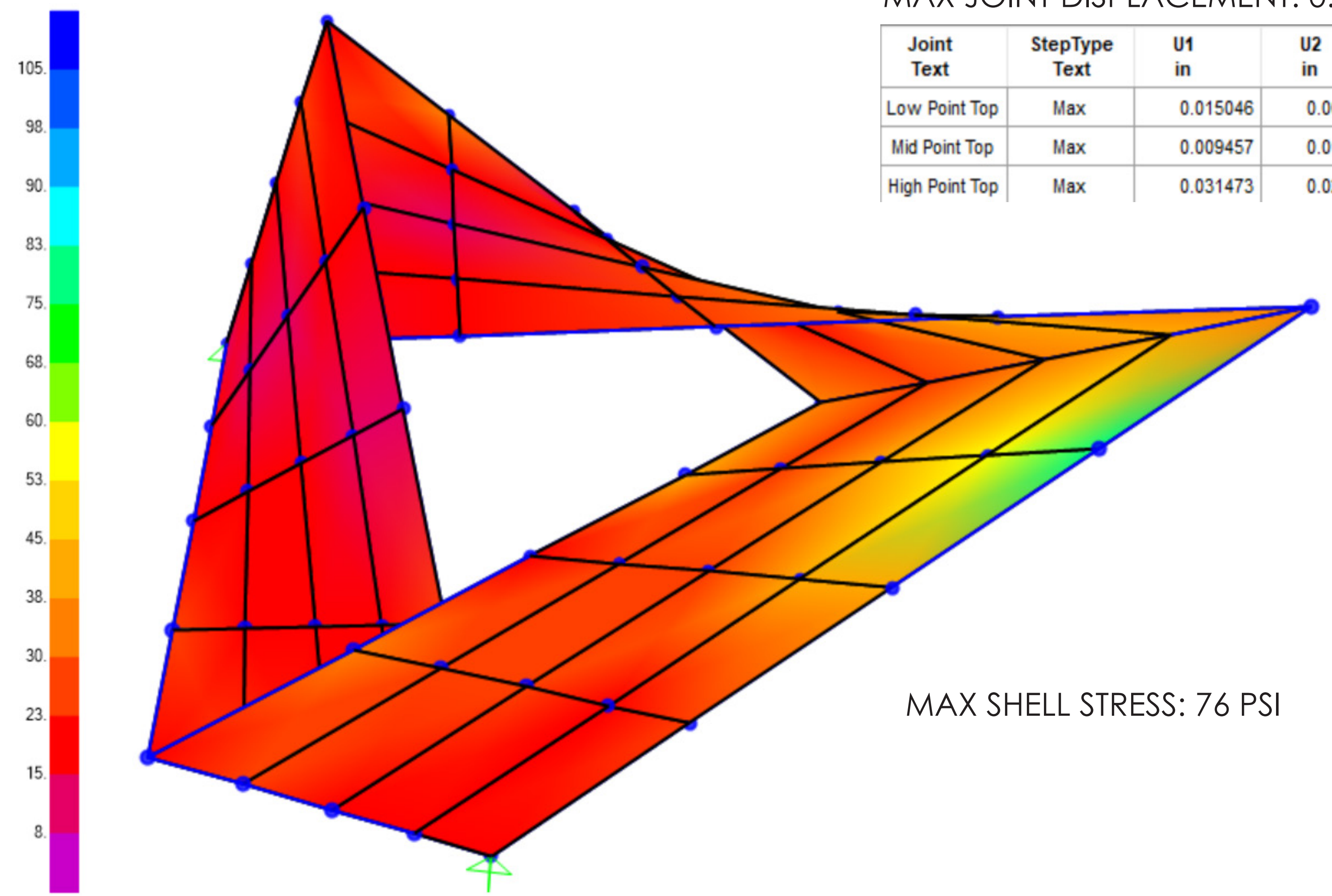


SAP2000 ANALYSIS - TIME HISTORY

EL CENTRO EARTHQUAKE GROUND MOTION

MAX JOINT DISPLACEMENT: 0.031 INCHES

Joint Text	StepType Text	U1 in	U2 in	U3 in
Low Point Top	Max	0.015046	0.005894	0.013962
Mid Point Top	Max	0.009457	0.014828	0.014611
High Point Top	Max	0.031473	0.021551	0.027529



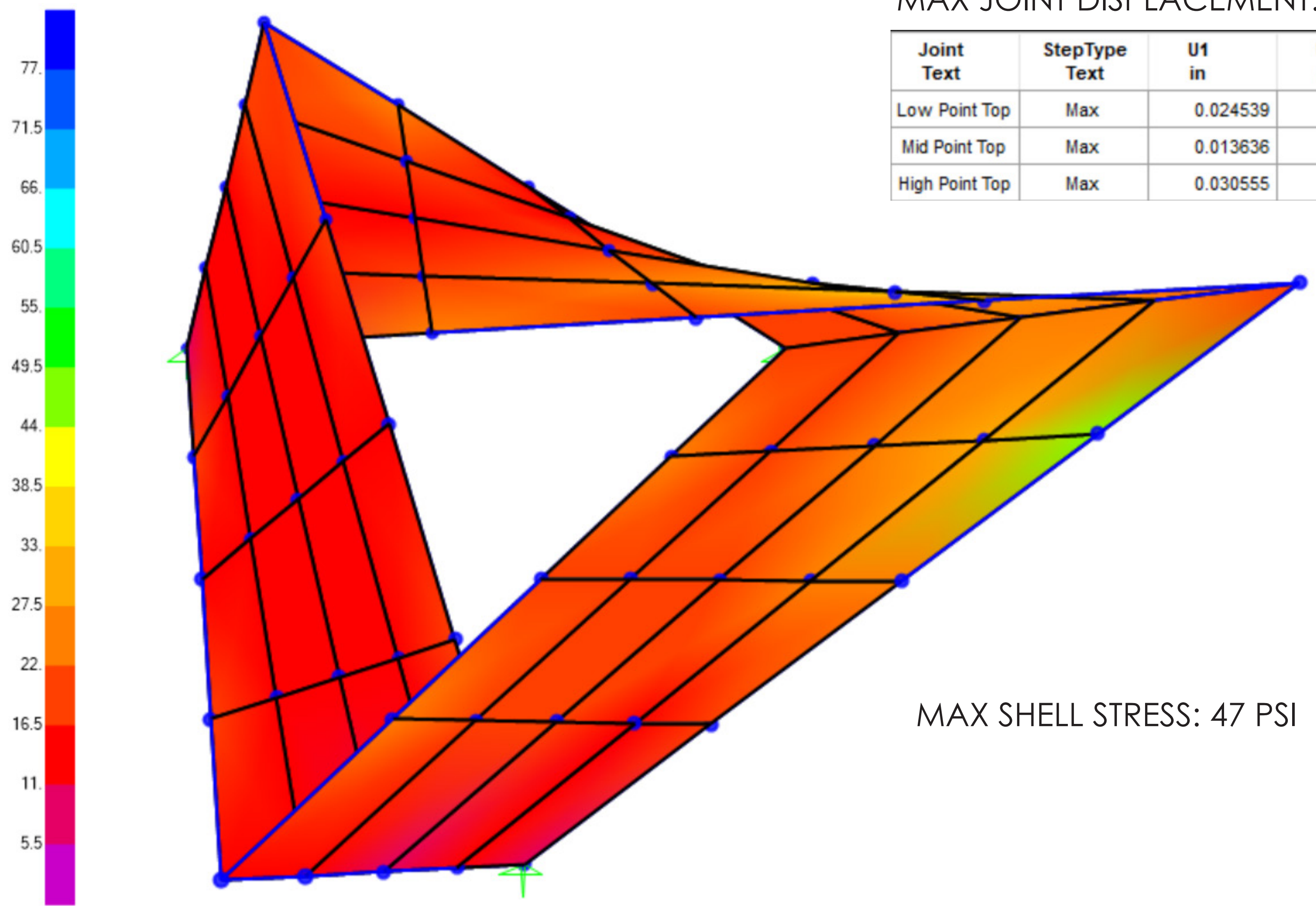
MAX SHELL STRESS: 76 PSI

SAP2000 ANALYSIS - TIME HISTORY

NORTHRIDGE EARTHQUAKE GROUND MOTION

MAX JOINT DISPLACEMENT: 0.030 INCHES

Joint Text	StepType Text	U1 in	U2 in	U3 in
Low Point Top	Max	0.024539	0.00863	0.020562
Mid Point Top	Max	0.013636	0.021321	0.02276
High Point Top	Max	0.030555	0.023077	0.027814

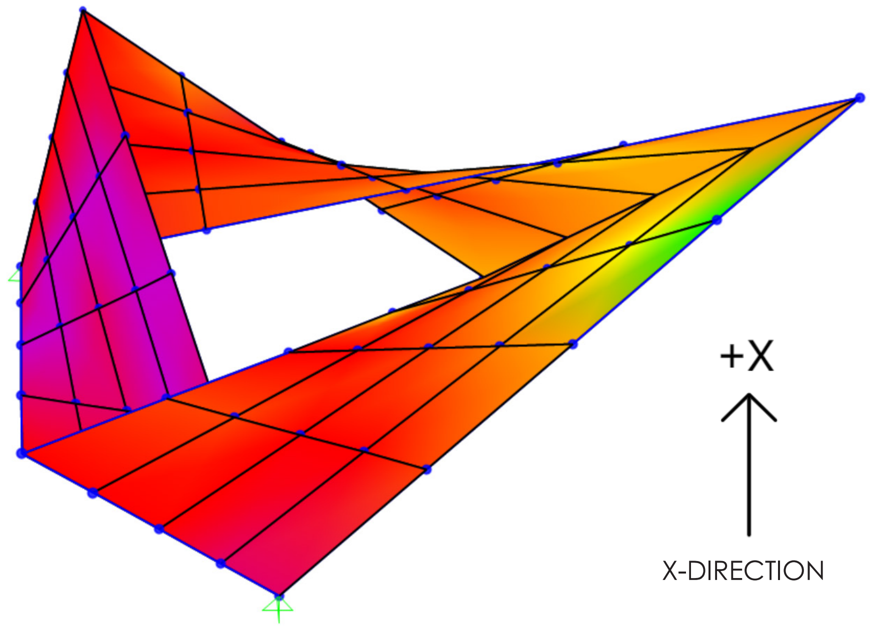


MAX SHELL STRESS: 47 PSI

SAP2000 ANALYSIS - RESPONSE SPECTRUM

IBC 2021 CODE, LATITUDE: 35.3102, LONGITUDE: -120.6622

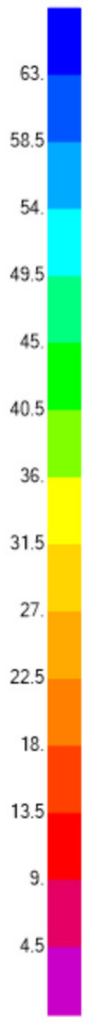
MAX JOINT DISPLACEMENT: 0.015 INCHES



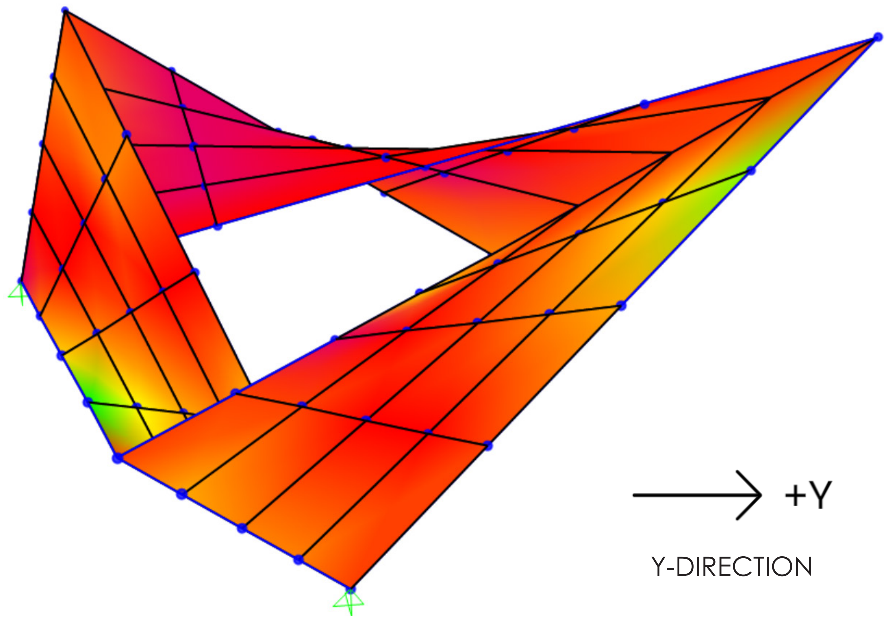
+X

X-DIRECTION

MAX SHELL STRESS: 41 PSI



MAX JOINT DISPLACEMENT: 0.012 INCHES



+Y

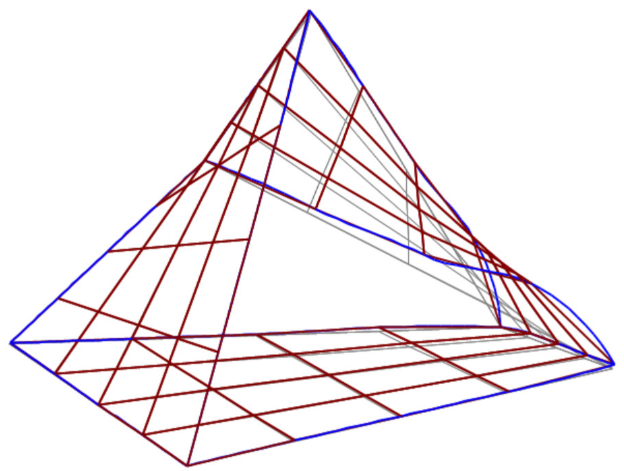
Y-DIRECTION

MAX SHELL STRESS: 32 PSI

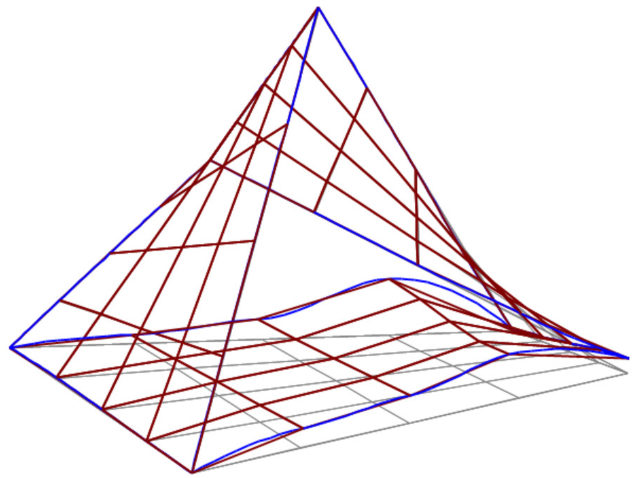
SAP2000 ANALYSIS - WIND LOADING

ASCE 7-16 CODE, WIND SPEED: 87 MPH, EXPOSURE TYPE B

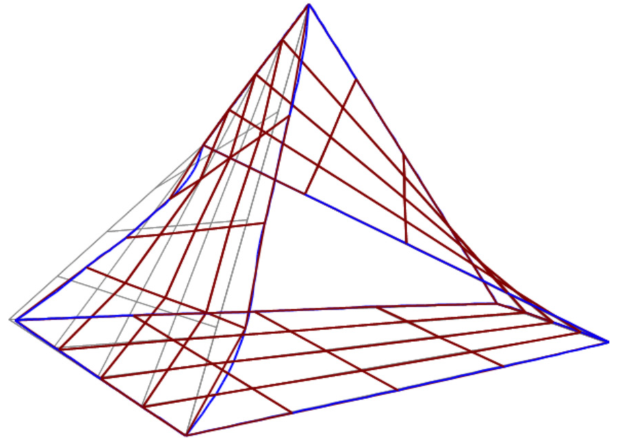
MAX DISPLACEMENT: 0.005 INCHES



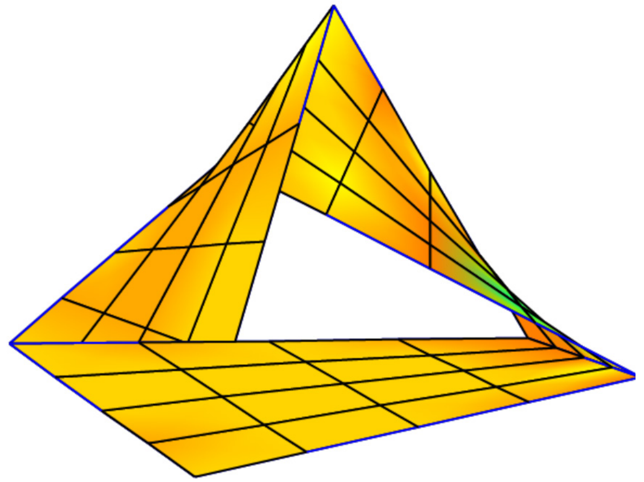
MAX DISPLACEMENT: 0.018 INCHES



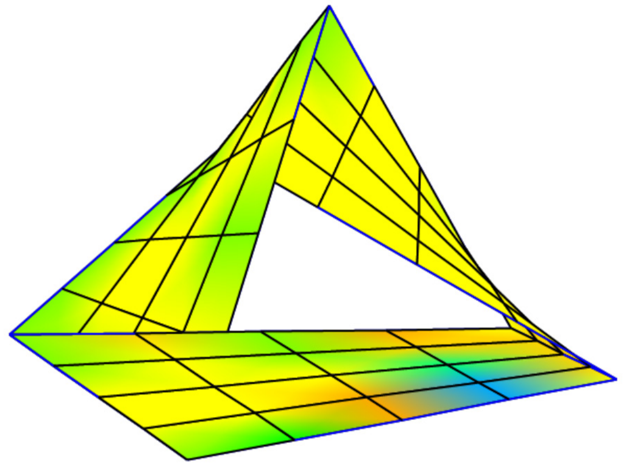
MAX DISPLACEMENT: 0.012 INCHES



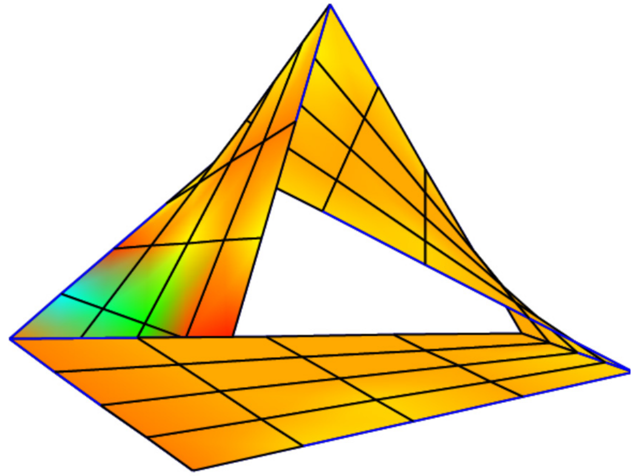
MAX SHELL STRESS: 16 PSI



MAX SHELL STRESS: 31 PSI



MAX SHELL STRESS: 23 PSI



STRUT CAPACITIES

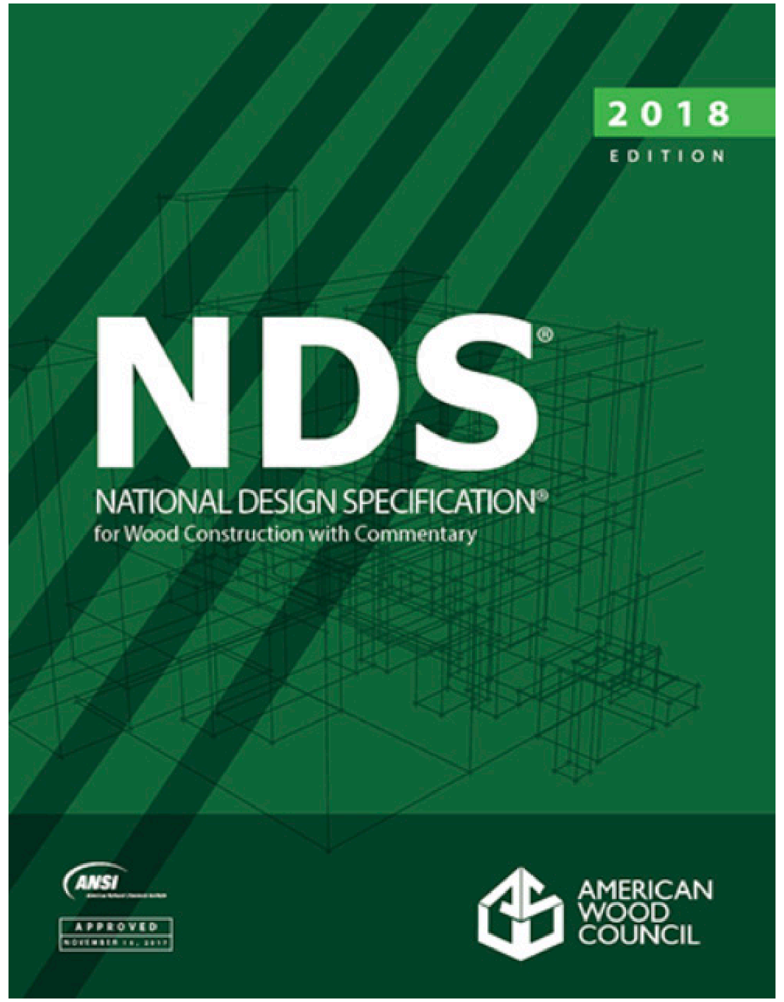


Table 6B Reference Design Values for Round Timber Construction Poles Graded per ASTM D3200

(Tabulated design values are for normal load duration and wet service conditions. See NDS 6.3 for a comprehensive description of design value adjustment factors.)

Species	Design values in pounds per square inch (psi)						Specific Gravity[4]
	Bending	Shear parallel to grain	Compression perpendicular to grain	Compression parallel to grain	Modulus of elasticity		
	F_b	F_v	$F_{c\perp}$	F_c	E	E_{min}	G
Pacific Coast Douglas Fir[1]	2,050	160	490	1,300	1,700,000	690,000	0.50
Lodgepole Pine	1,275	125	265	825	1,100,000	430,000	0.42
Ponderosa Pine	1,200	175	295	775	1,000,000	400,000	0.43
Red Pine[2]	1,350	125	270	850	1,300,000	520,000	0.42
Southern Pine (Grouped)[3]	1,950	160	440	1,250	1,500,000	600,000	0.55
Western Hemlock	1,550	165	275	1,050	1,300,000	560,000	0.47
Western Larch	1,900	170	405	1,250	1,500,000	660,000	0.49
Western Red Cedar	1,250	140	260	875	1,000,000	360,000	0.34

1. Pacific Coast Douglas Fir reference design values apply to this species as defined in ASTM Standard D 1760.
2. Red Pine reference design values apply to Red Pine grown in the United States.
3. Southern Pine reference design values apply to Loblolly, Longleaf, Shortleaf, and Slash Pines.
4. Specific gravity, G, based on weight and volume when oven-dry.

MATERIAL: LODGEPOLE PINE

DIAMETER: 12”

F_C' = 140 PSI

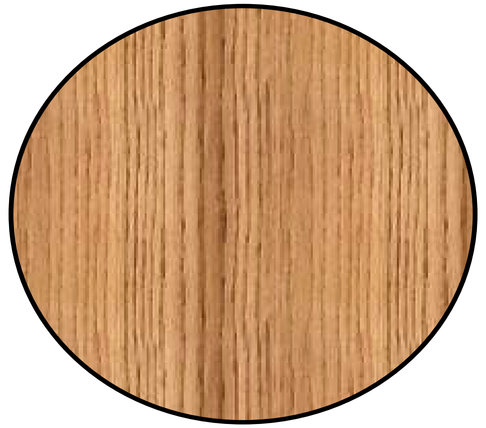
F_T' = 315 PSI*

F_B' = 723 PSI

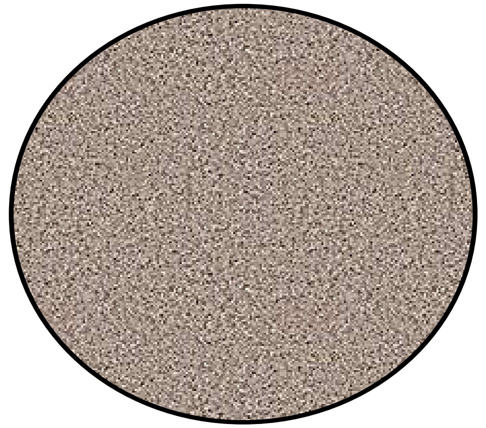
F_V' = 71 PSI

*INITIAL CAPACITY, F_T, INTERPOLATED TO BE 500 PSI BASED ON SPRUCE-PINE-FIR

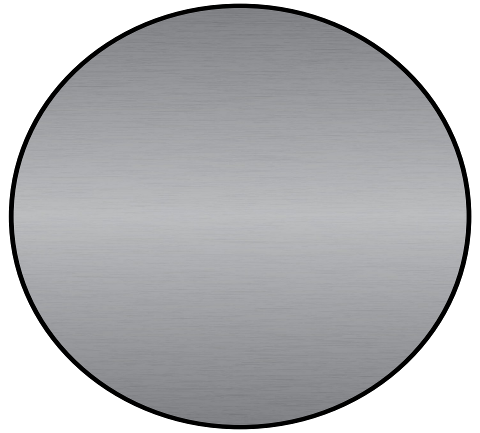
MATERIALITY



WOOD



CONCRETE



STEEL

FOR THE STRUT MEMBERS WE ARE LOOKING AT LODGEPOLE PINE CIRCULAR MEMBERS, TYPICALLY USED IN TELEPHONE POLES AND OTHER APPLICATIONS

THE PLYWOOD SHELLS WILL USE RECYCLED PLYWOOD SHEETS WHENEVER POSSIBLE

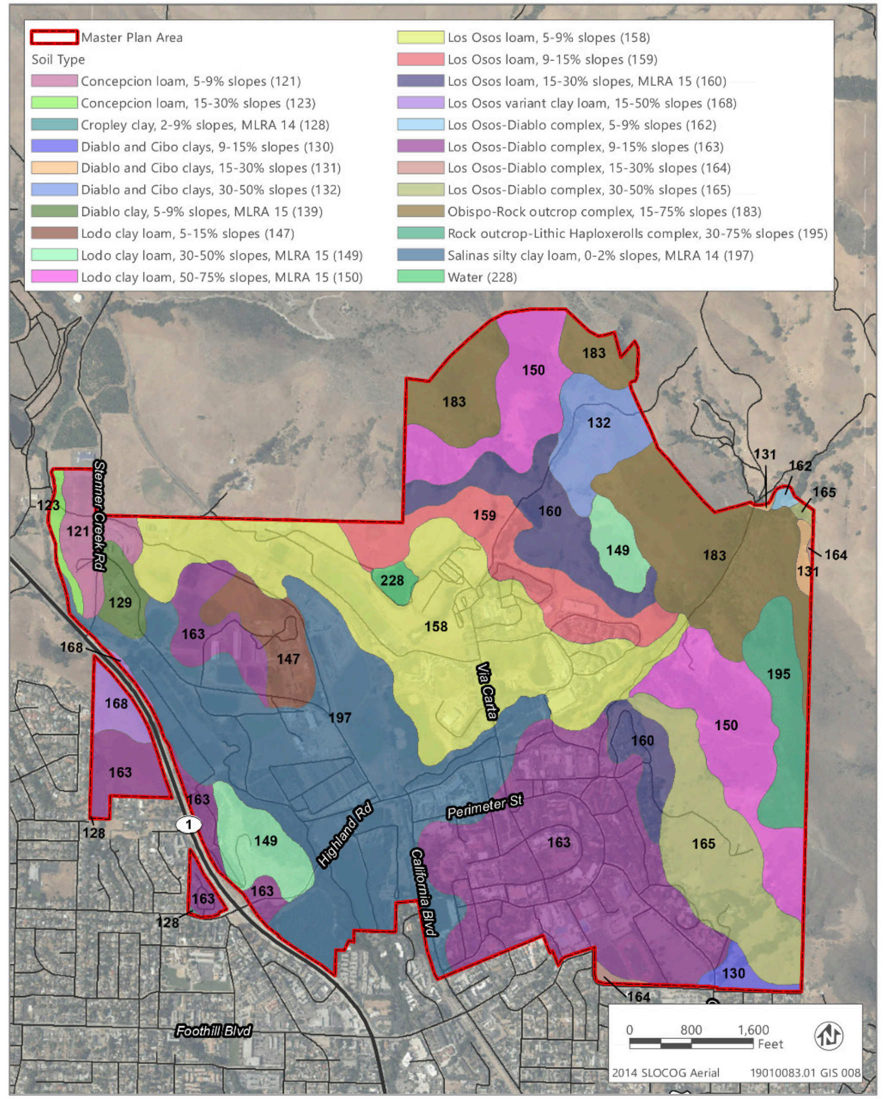
THE FOOTINGS ARE SIZED TO THEIR MINIMUM REQUIREMENTS TO REDUCE THE AMOUNT OF CONCRETE NECESSARY FOR THE PROJECT

SUSTAINABLE CEMENT ALTERNATIVES WILL BE USED TO REDUCE THE CARBON FOOTPRINT OF THE PROJECT

STEEL IS ONLY USED WHERE NECESSARY TO RECIEVE ADEQUATE STRENGTH IN CONNECTIONS

SOIL INVESTIGATION

Ascent Environmental — Geology and Soils



Source: Data downloaded from the NRCS in 2019

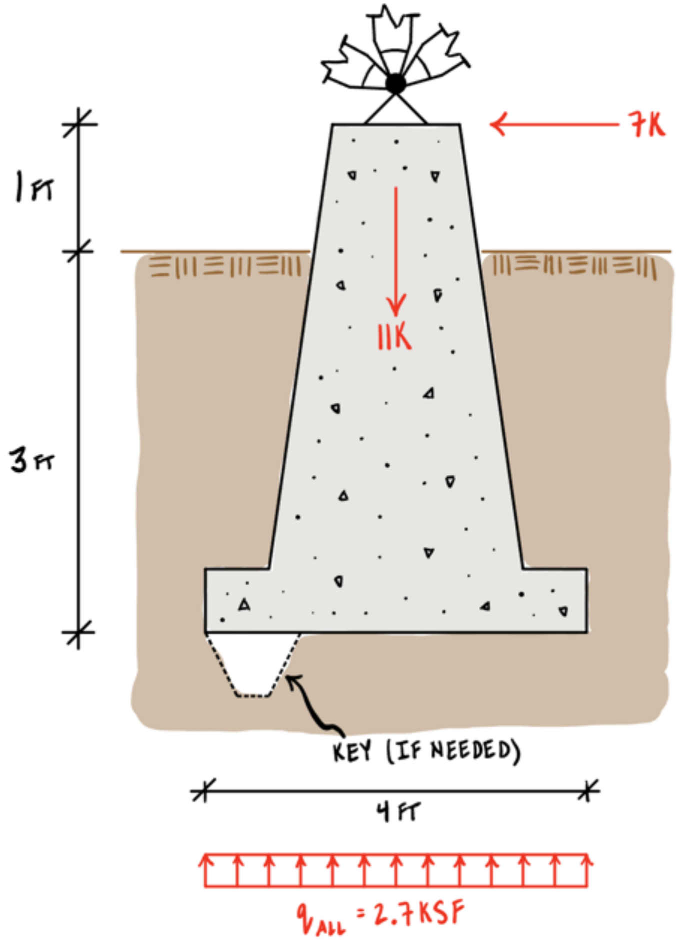
Figure 3.7-1 Soils in the Master Plan Area

California Polytechnic State University, San Luis Obispo
2035 Master Plan Final EIR 3.7-5

A BRIEF, PRELIMINARY SOIL INVESTIGATION WAS PERFORMED TO UNDERSTAND THE UNDERLYING SOIL AT THE SITE. THE SITE CONTAINS LOS OSOS LOAM AT 9-15% SLOPES WITH HIGH SHRINK-SWELL POTENTIAL AND EROSION HAZARDS.

FOUNDATION CONSIDERATIONS

THE FOLLOWING ASSUMPTIONS WERE MADE IN THE PRELIMINARY DESIGN OF THE FOUNDATION: THE SOIL BEARING CAPACITY IS 2.7 KSF, 4'X4' ISOLATED FOOTINGS WOULD BE USED, AND A HEEL OR KEY WOULD BE INCORPORATED TO RESIST THE OVERTURNING MOMENT CAUSED BY THE LATERAL LOAD. THE LOADS DEPICTED IN THE DIAGRAM AT RIGHT ARE BASED ON WORST CASE LOADING SCENARIOS FROM THE 1940 EL CENTRO EARTHQUAKE GROUND MOTION. PROPER DESIGN OF THE FOUNDATION WOULD FIRST REQUIRE GEOTECHNICAL INVESTIGATION.

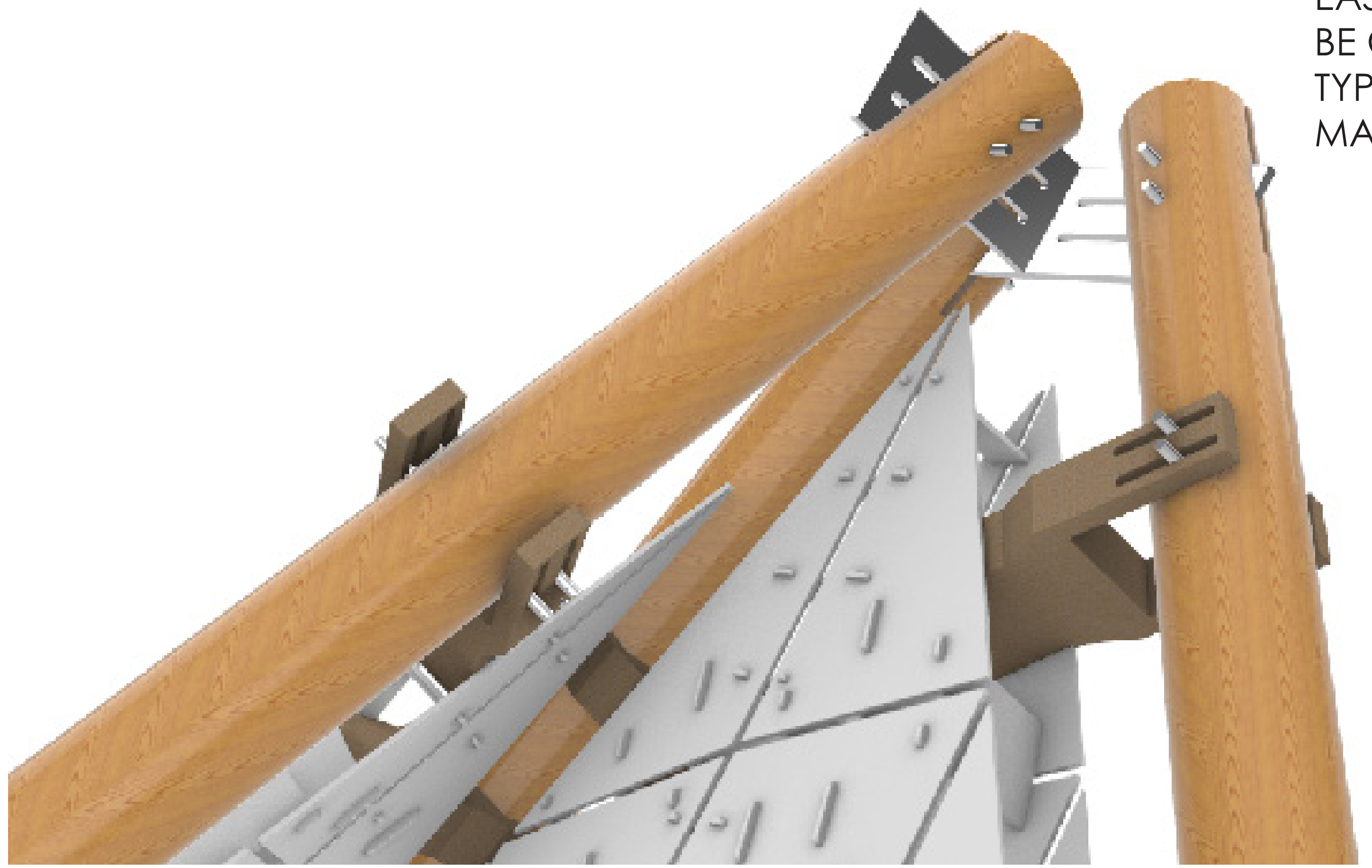


CONNNECTIONS

WE IDENTIFIED 3 CONDITIONS THAT NEEDED TO BE ADDRESSED WITH DESIGNED CONNECTIONS

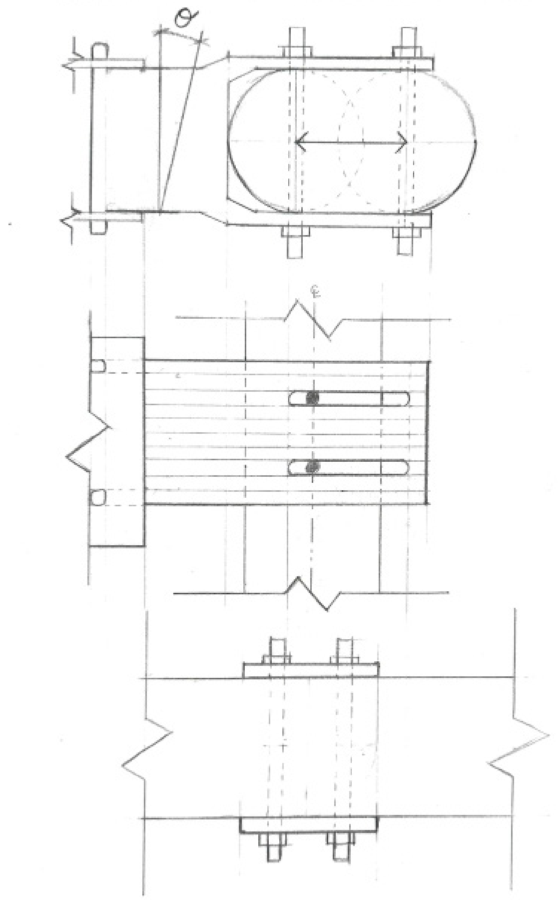
» SHELL TO STRUT
» STRUT TO STRUT
» STRUT TO FOUNDATION

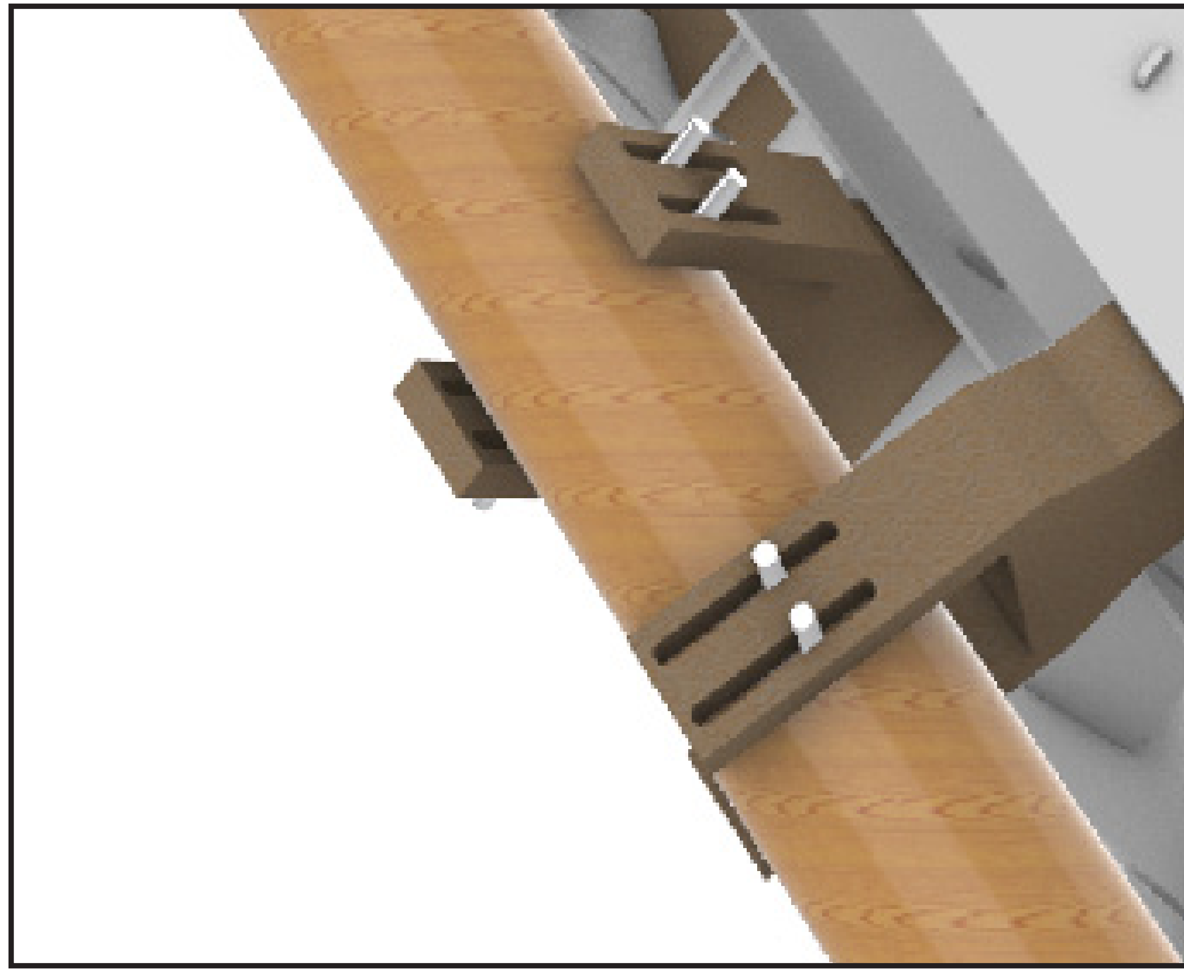
OUR MAIN CONCERNS WHEN DESIGNING THESE CONNECTIONS WERE THAT THEY WERE ADJUSTABLE TO FIT ALL THE CONDITIONS OF OUR STRUCTURE AND BE EASILY INSTALLED, AS WELL AS BE CONSTRUCTABLE FROM TYPICAL COST EFFECTIVE MANUFACTURING PRACTICES.



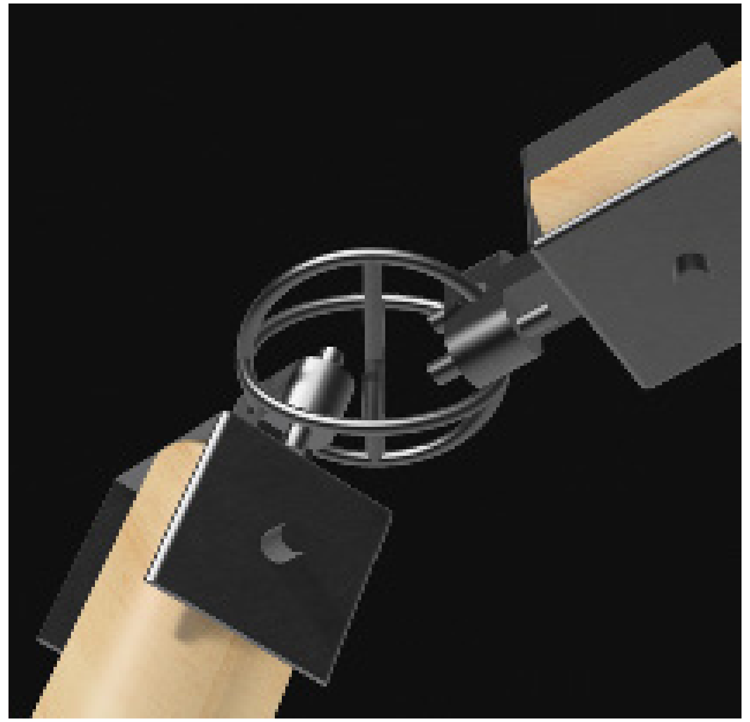
SHELL TO STRUT

OUR CONNECTION FOCUSES ON DEALING WITH THE VARIABLE DISTANCE THAT EXISTS BETWEEN THE SHELLS AND STRUTS THAT IS GENERATED FROM THE SHELL OFFSET DISCUSSED EARLIER. THIS IS ACCOMPLISHED BY TWO SLOTS IN THE FLANGES OF THE CONNECTION THAT ALLOW THE CONNECTION TO SLIDE ALONG THE BOLTS, THAT ARE TIGHTENED TO LOCK THE CONNECTION AROUND THE STRUT, WHILE THE PAIR PREVENTS ROTATION. CONSTRUCTED FROM CUT STACKED AND BONDED PLYWOOD SHEETS.





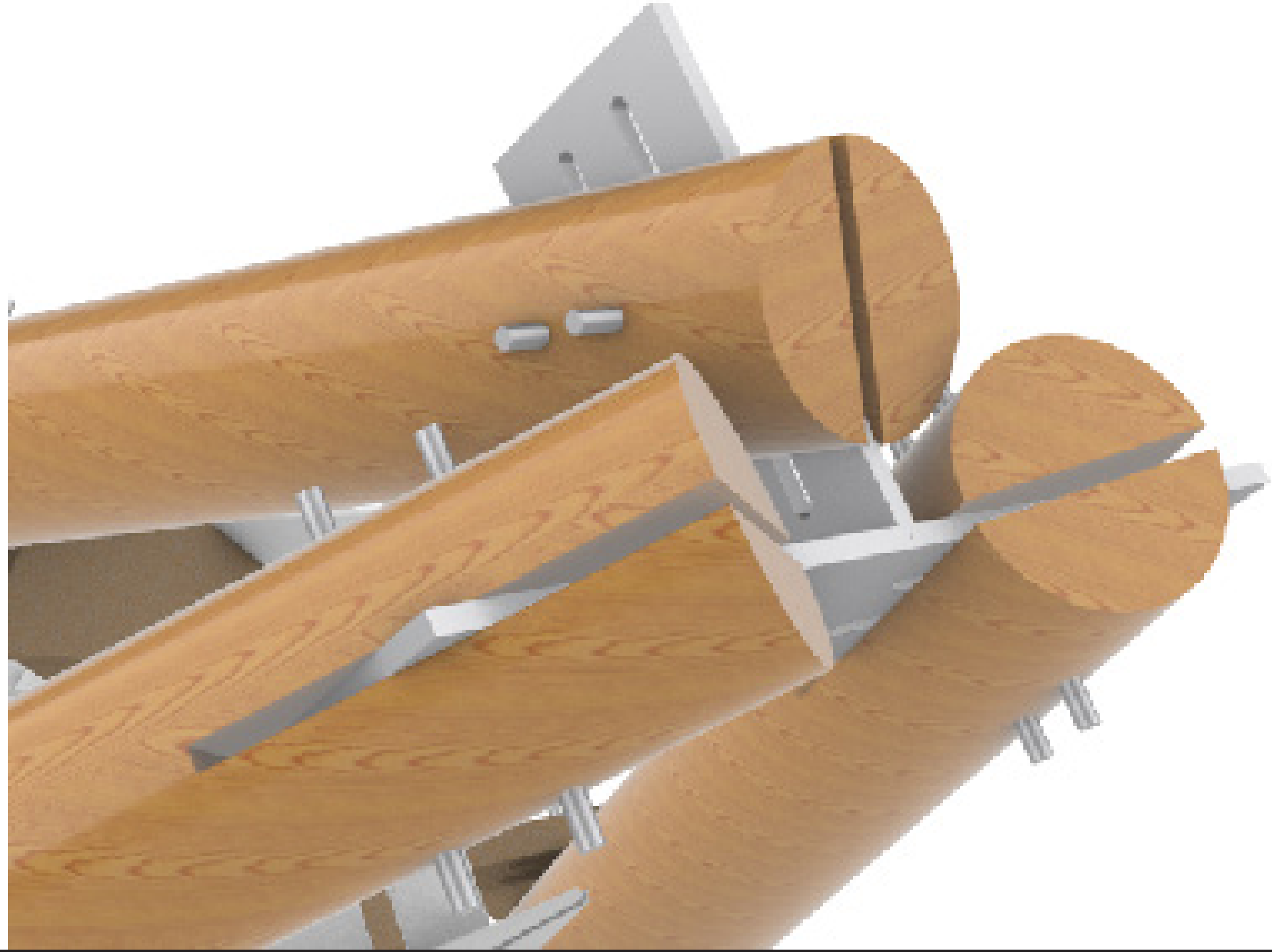
STRUT TO STRUT

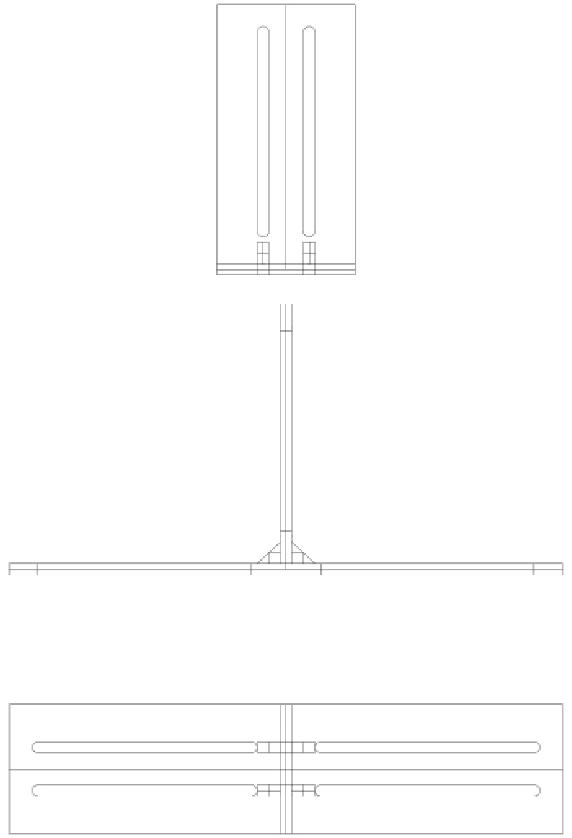


THE INITIAL CONNECTION WAS A SPHERE MADE BY STEEL RODS WHICH ALLOWED CONNECTIONS TO ATTACH TO IT FROM ANY ANGLE. HOWEVER, WE REALIZED THAT LINE OF ACTION OF THE MEMBERS NEEDED TO BE CONSIDERED.

OUR SECOND ITERATION TOOK THE SPHERE IDEA AND COMBINED IT WITH THE IDEA THAT THE LINES OF ACTION OF THE MEMBERS COULD BE KEPT CONCURRENT BY FINDING THE PLANE MADE BETWEEN TWO MEMBERS AND THE PERPENDICULAR PLANE THAT ALIGNED WITH THE THIRD MEMBER'S LINE OF ACTION.

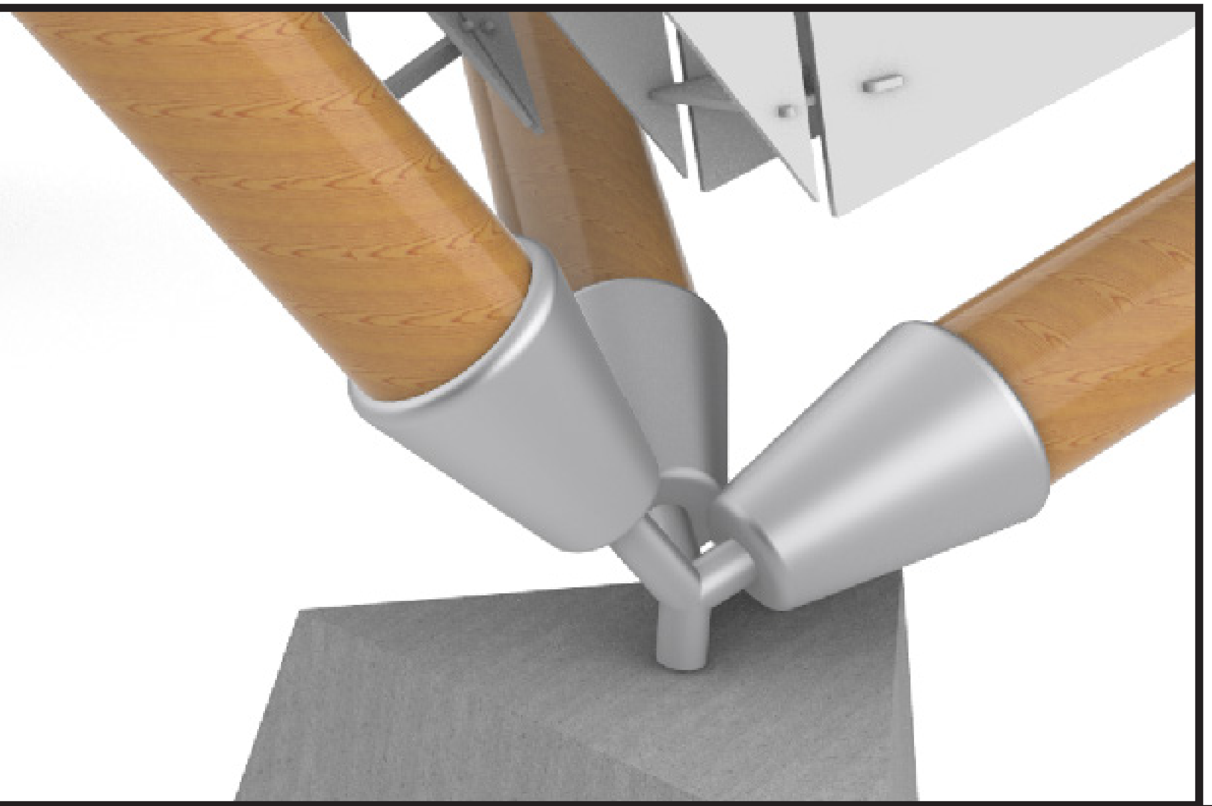
THE LAST ITERATION OF THIS CONNECTION THAT WAS DESIGNED KEPT THE IDEOLOGY FROM THE SECOND, BUT AIMED TO ADDRESS THE BULKINESS AND INELEGANCE OF THAT DESIGN BY REDUCING THE SPHERE TO ITS ESSENTIAL COMPONENTS, THE TWO PERPENDICULAR PLANES.
ALL ITERATIONS OF THE DESIGN COULD ADAPT TO THE VARYING ANGLES BETWEEN MEMEBERS AT THE DIFFERENT





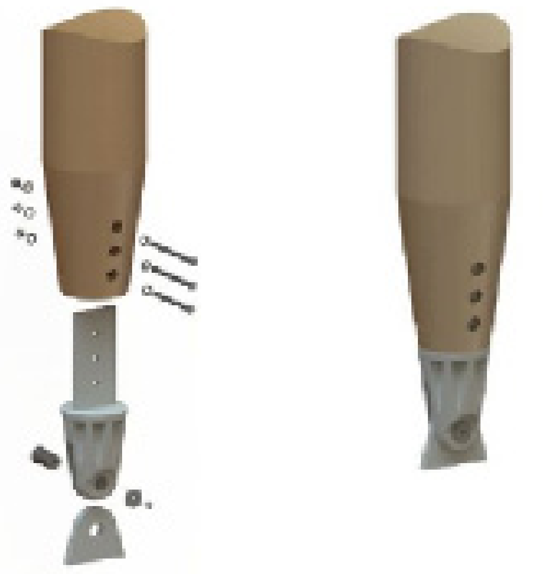
STRUT TO FOUNDATION

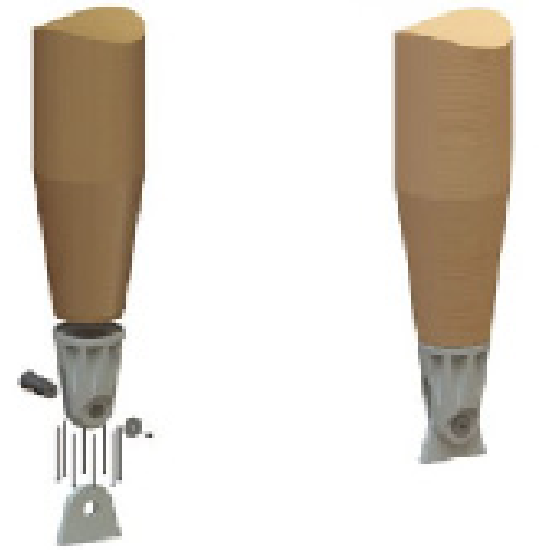
THE DESIGN HERE FOCUSED ON KEEPING THE LINES OF ACTION OF ALL MEMBERS MEETING AT ONE POINT ON THE SURFACE OF OUR FOUNDATION PIERS. TO ALLOW THE MEMBERS TO REACH THE GROUND WITHOUT INTERFERENCE, WE EXPLORED A COMBINATION OF OFFSETTING AND TAPERING. EVENTUALLY, OUR GROUP LEARNED OF A COMPANY CALLED CAST CONNEX®, WHICH HAD ALREADY DESIGNED A CONNECTION, FEATURED ON THE NEXT PAGE, THAT ACCOMPLISHED OUR GOALS MUCH MORE ELEGANTLY.

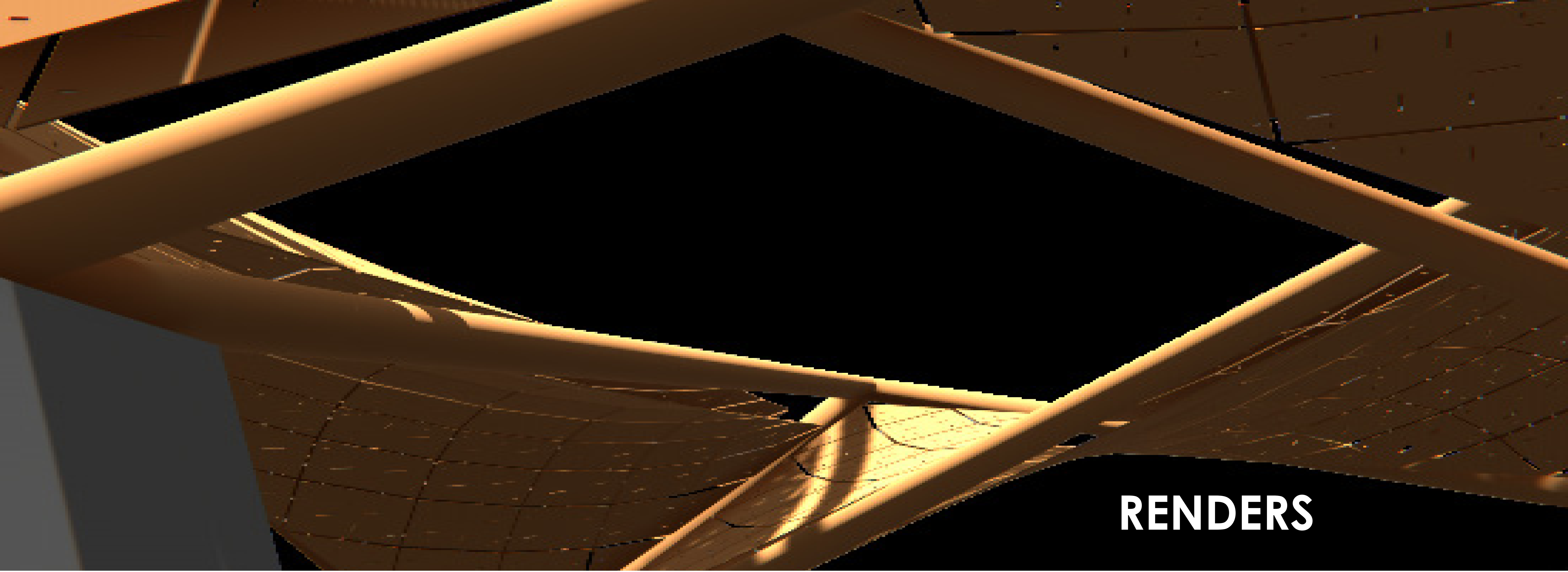


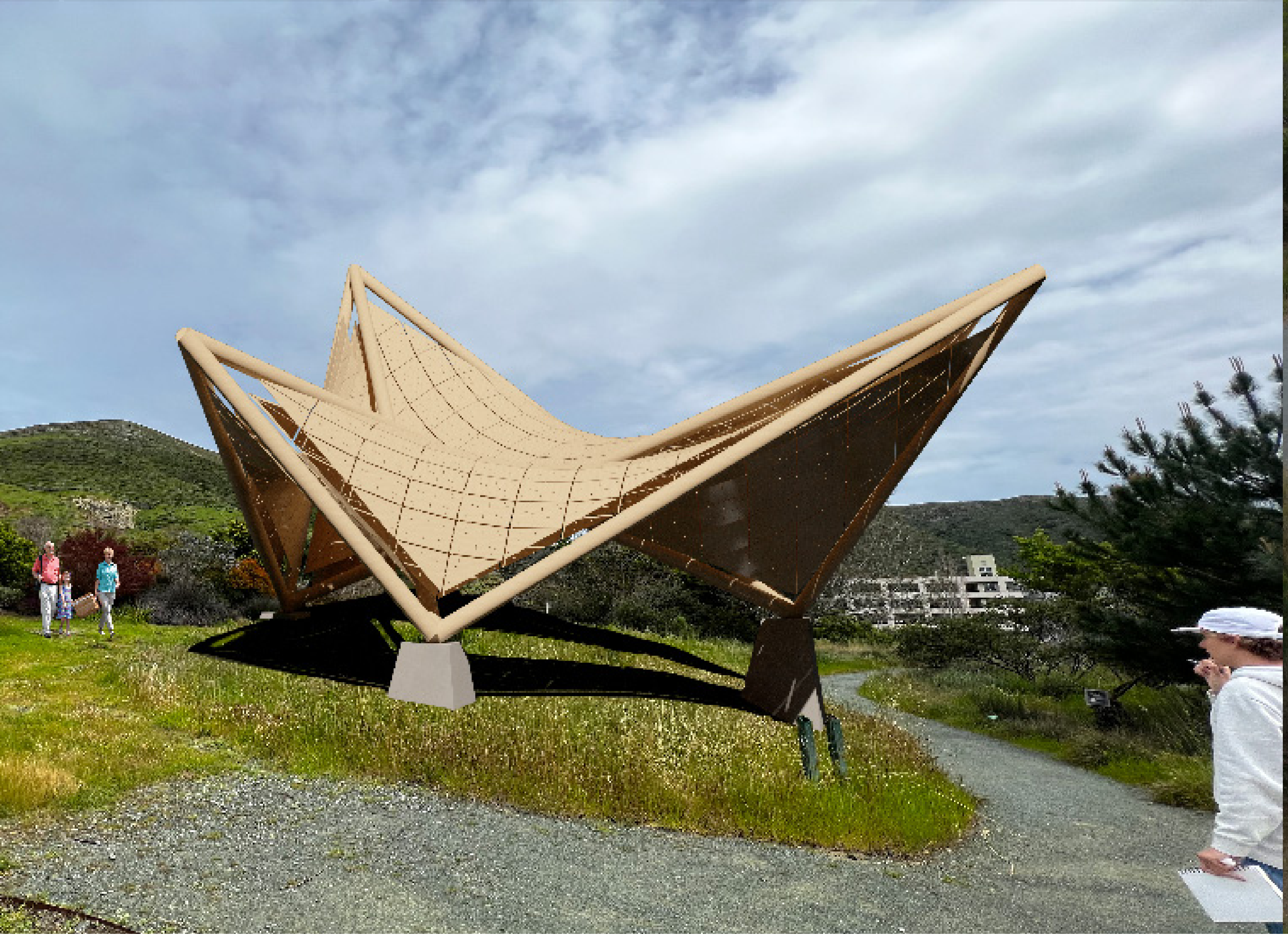
TIMBER END CONNECTOR

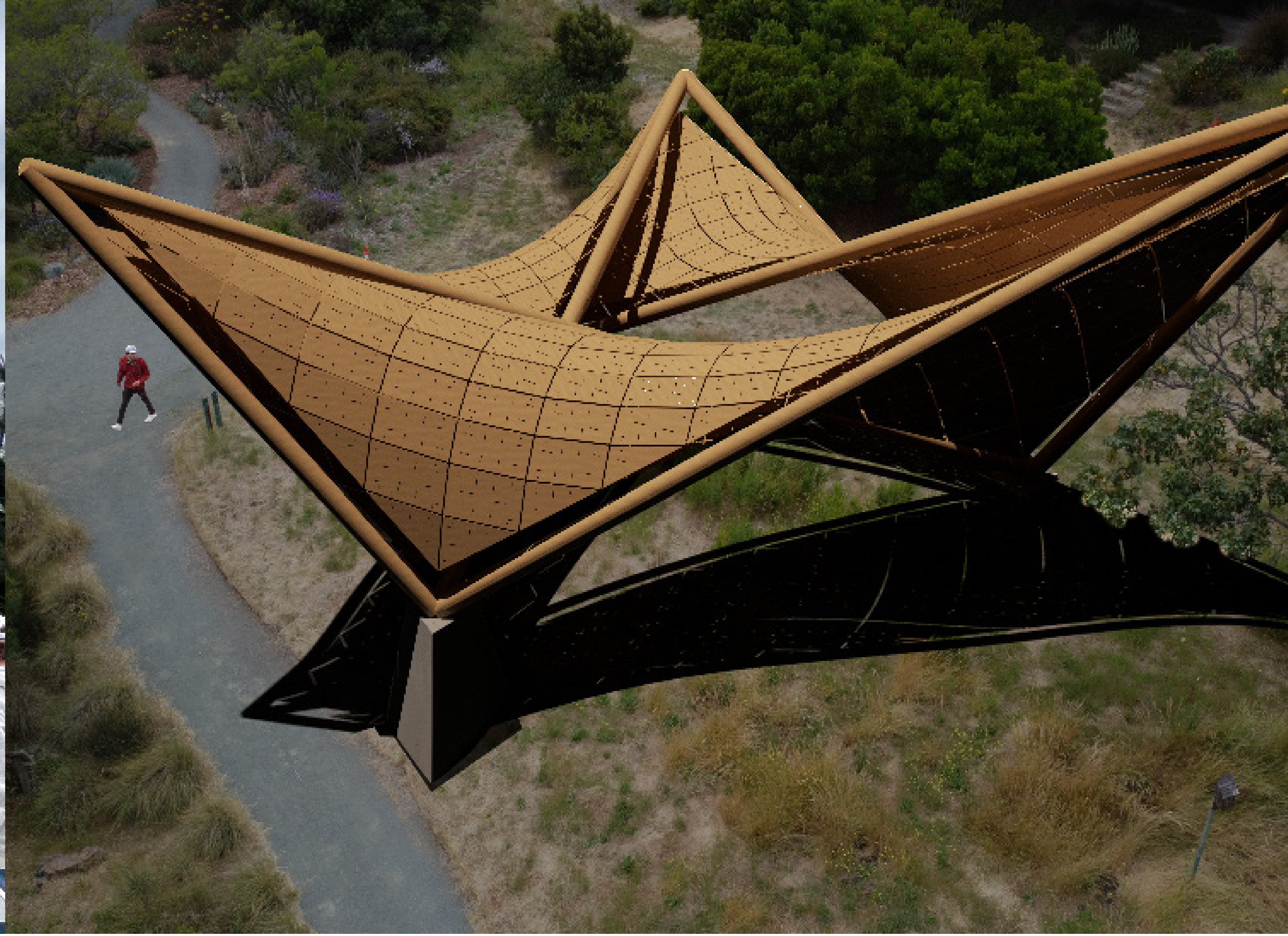
CAST CONNEX® TIMBER END CONNECTORS™ ARE CLEVIS-TYPE FITTINGS DESIGNED TO CONNECT TO THE ENDS OF HEAVY TIMBER OR GLUE-LAMINATED STRUCTURAL ELEMENTS LOADED IN PREDOMINATELY TENSION OR COMPRESSION FOR USE IN ARCHITECTURALLY EXPOSED APPLICATIONS. THE CONNECTORS ARE PURPOSELY PROCESSED WITH A MORE RUGGED AS-CAST SURFACE FINISH TO EVOKE THE APPEARANCE OF CAST IRON FITTINGS OF OLD POST AND BEAM CONSTRUCTION. (FROM CAST CONNEX WEBSITE)

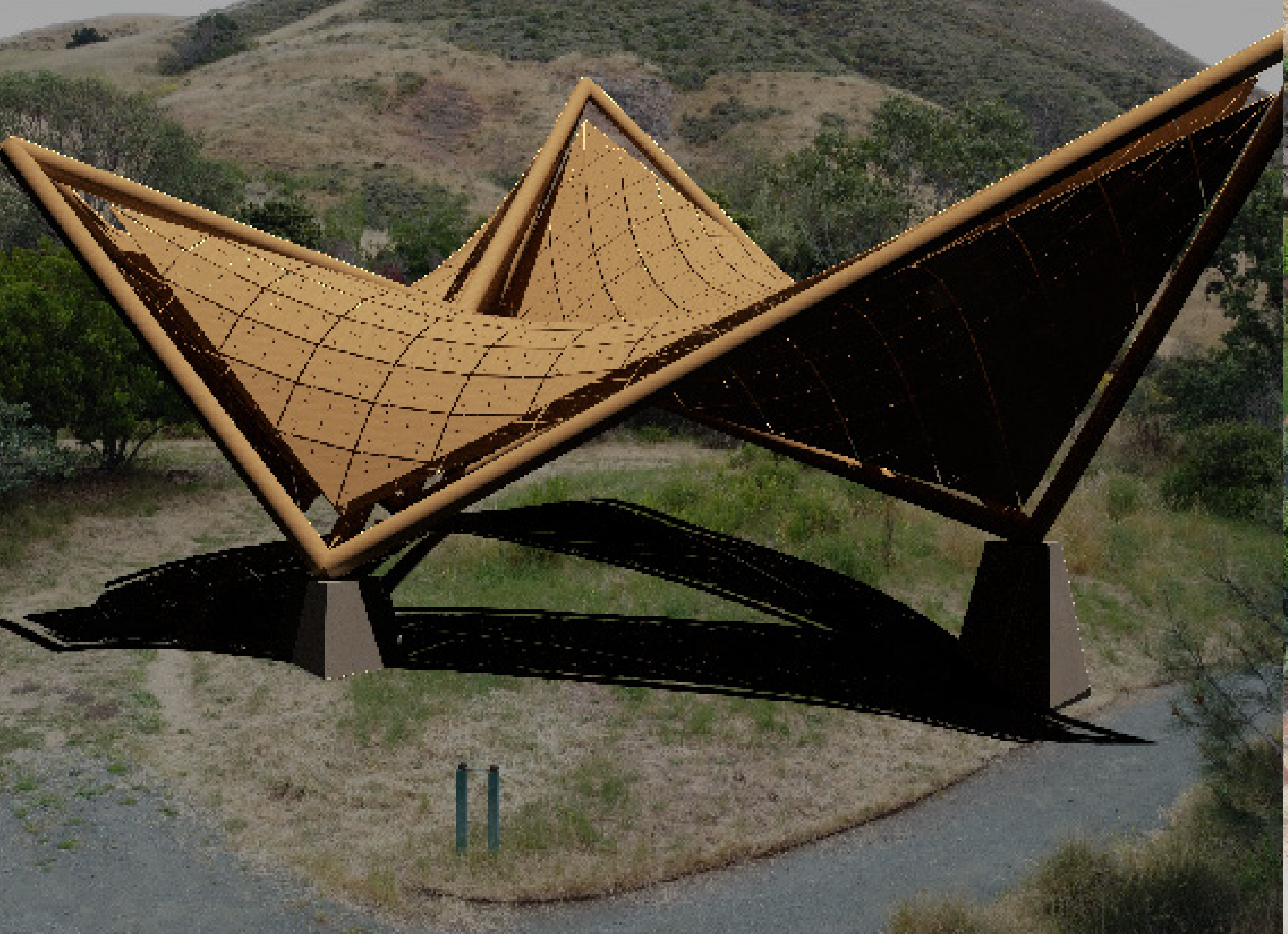





RENDERS



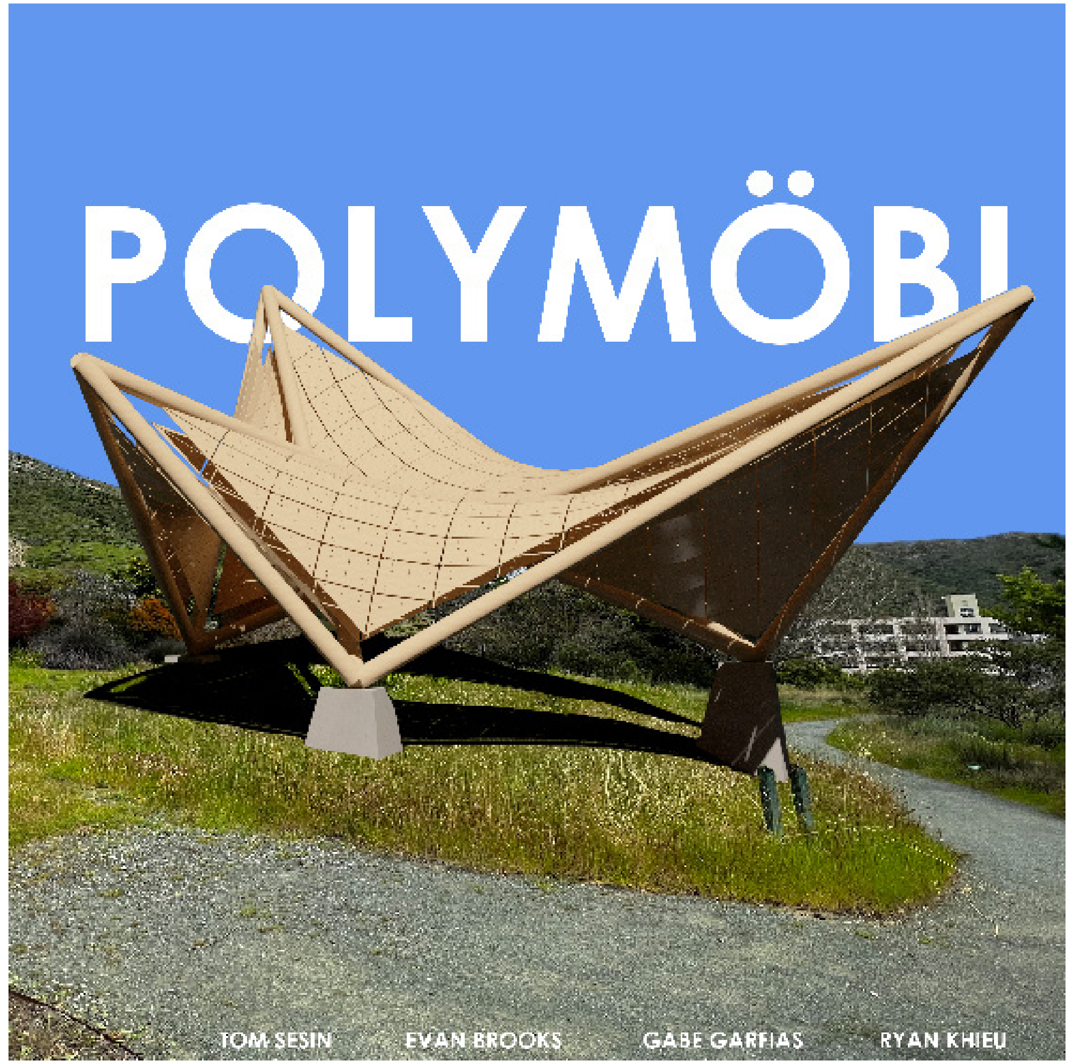




GLOBAL CONSIDERATIONS

THE POLYMÖBI SUNSHADE ENCOMPASSES A RANGE OF GLOBAL CONSIDERATIONS THAT EXTEND BEYOND ITS IMMEDIATE PURPOSE. FIRSTLY, THE DESIGN EMBODIES PRINCIPLES OF SUSTAINABILITY THROUGH ITS SIMPLICITY AND MATERIALITY. THIS NOT ONLY PROMOTES EFFICIENT RESOURCE UTILIZATION BUT ALSO MINIMIZES WASTE. HOWEVER, WHAT TRULY SETS THIS STRUCTURE APART IS ITS REMARKABLE VERSATILITY AND ADAPTABILITY. THE POLYMÖBI DESIGN ALLOWS FOR EASY MODIFICATION AND SCALING, ENABLING IT TO SERVE VARIOUS DESIGN INTENTS BEYOND A SUNSHADE STRUCTURE. IT CAN BE TRANSFORMED INTO A BANDSHELL, AN INTERACTIVE ART INSTALLATION, OR EVEN A VENUE FOR OUTDOOR EVENTS. THIS INHERENT SCALABILITY ENSURES FUTURE-PROOFING OF THE POLYMÖBI DESIGN, ACCOMMODATING POTENTIAL EXPANSION AND CHANGING NEEDS. BY EXEMPLIFYING THE GLOBAL TREND TOWARDS SUSTAINABLE AND MULTIFUNCTIONAL DESIGN SOLUTIONS, THE POLYMÖBI SUNSHADE STRUCTURE NOT ONLY ENHANCES FUNCTIONALITY AND AESTHETIC APPEAL BUT ALSO REINFORCES THE IMPORTANCE OF MINIMIZING ENVIRONMENTAL IMPACT.

CULTURAL CONSIDERATIONS



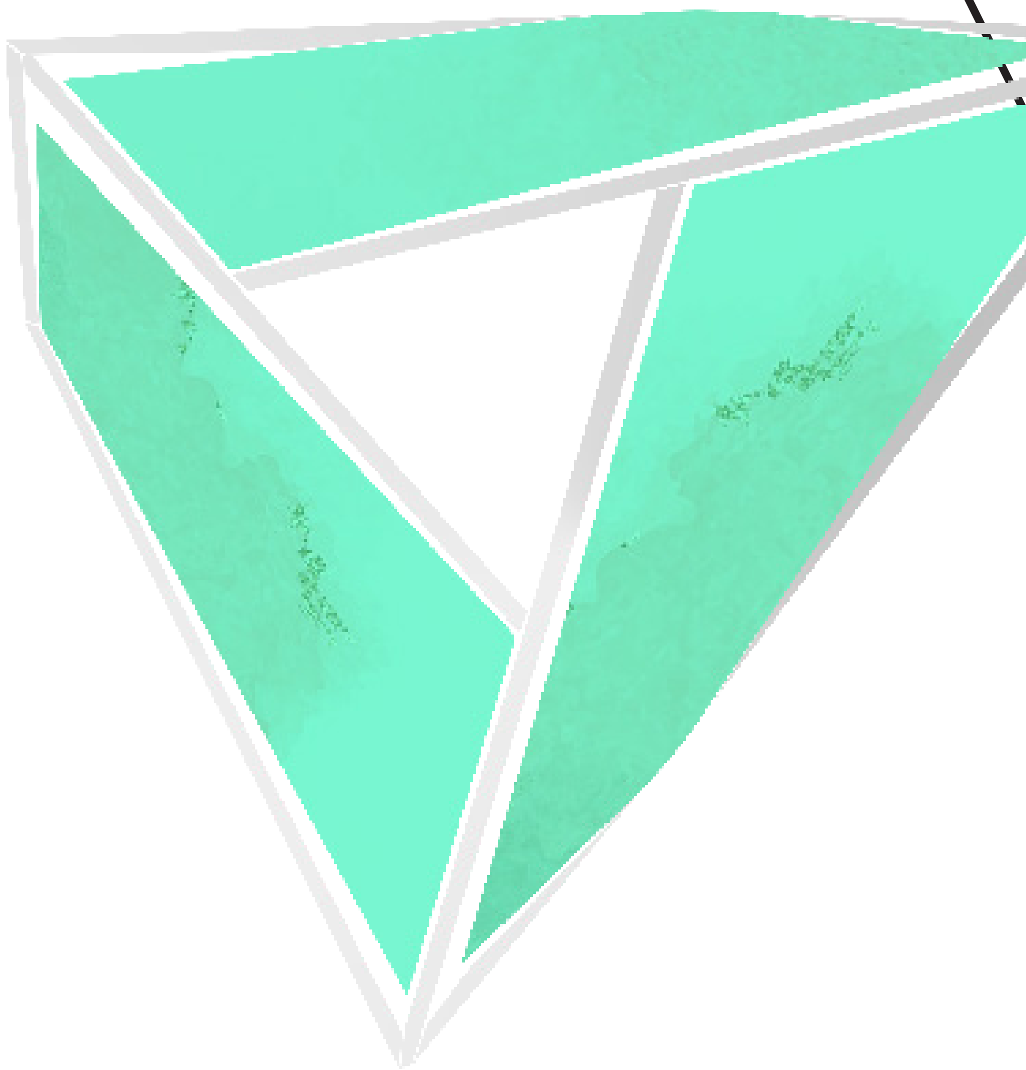
POLYMÖBI'S SINGLE SURFACE AND LACK OF BOUNDARIES CAN SYMBOLIZE UNITY, INTERCONNECTEDNESS, AND THE INTERDEPENDENCE OF ELEMENTS WITHIN A CULTURAL CONTEXT. IT CAN REPRESENT THE CONCEPT OF ONENESS OR THE IDEA THAT SEEMINGLY SEPARATE ENTITIES ARE FUNDAMENTALLY CONNECTED. ADDITIONALLY, POLYMÖBI'S LOOPED NATURE CAN SYMBOLIZE THE CONTINUITY OF CULTURAL TRADITIONS AND THE PASSING DOWN OF KNOWLEDGE FROM ONE GENERATION TO THE NEXT. IT REPRESENTS THE IDEA THAT CULTURAL HERITAGE IS NOT STATIC BUT RATHER AN ONGOING PROCESS THAT EVOLVES WHILE MAINTAINING A CONNECTION TO ITS ROOTS. ON A LARGER SCALE, POLYMÖBI CAN SERVE TO BE A VENUE OF CELEBRATION FOR THESE IDEALS.

ECONOMIC CONSIDERATIONS

THE MÖBIUS STRIP'S UNIQUE CHARACTERISTIC OF HAVING A SINGLE SURFACE WITHOUT A CLEAR DISTINCTION BETWEEN INSIDE AND OUTSIDE CAN SYMBOLIZE THE PURSUIT OF EFFICIENCY AND OPTIMIZATION IN ECONOMIC SYSTEMS. IT HIGHLIGHTS THE IMPORTANCE OF FINDING INNOVATIVE WAYS TO MAXIMIZE RESOURCES AND MINIMIZE WASTE.

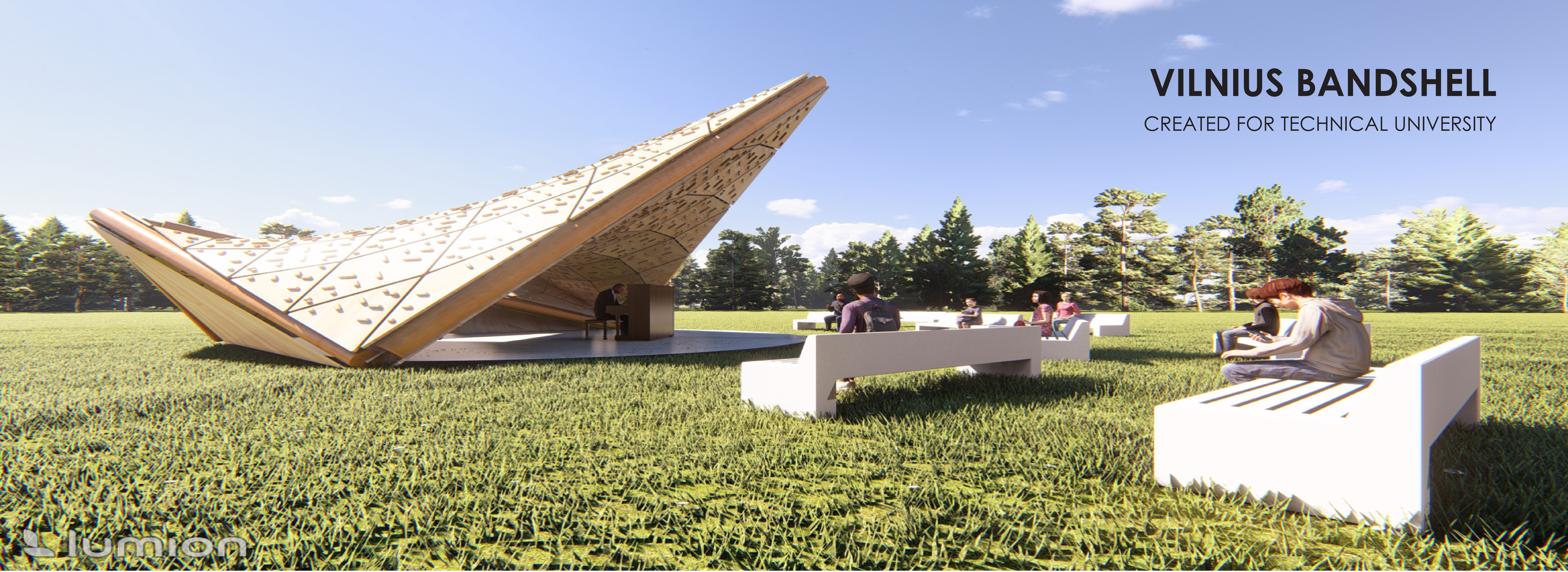
ENVIRONMENTAL CONSIDERATIONS

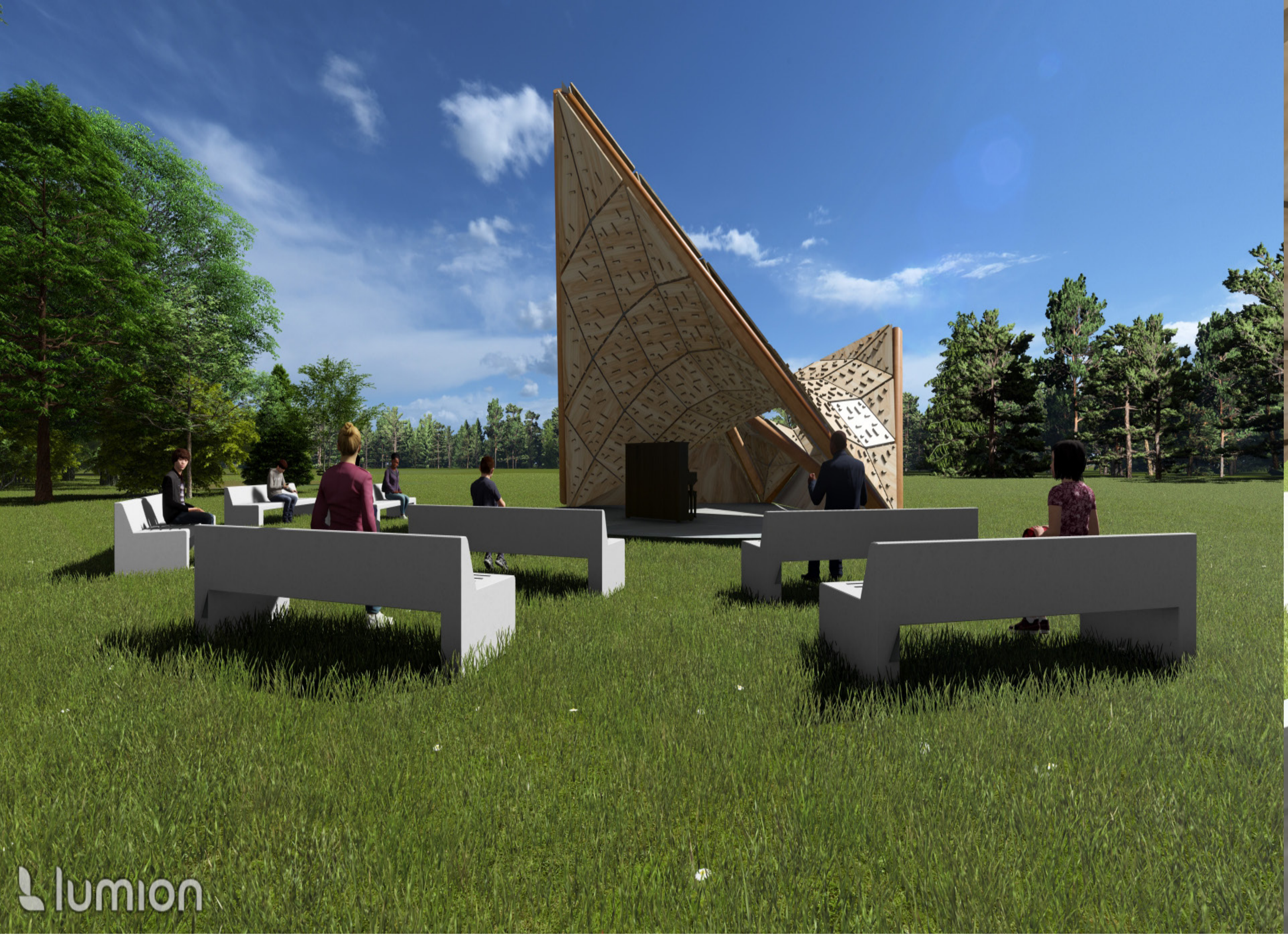
NOT ONLY DOES POLYMÖBI PRIORITIZE THE USE OF A RENEWABLE RESOURCE, SUCH AS TIMBER, BUT IT CELEBRATES IT AS WELL. WITH THE POPULARIZATION OF MASS TIMBER IN RECENT YEARS, POLYMÖBI IS ABLE TO BUILD OFF OF THE MOVEMENT'S NUMBER ONE GOAL: SUSTAINABILITY. BY SIMPLY ADJUSTING THE HEIGHTS OF EACH CROWN, POLYMÖBI CAN ADAPT TO ANY OPEN ENVIRONMENT SO AS TO OPTIMIZE SHADE, SHELTER, AND SITE POTENTIAL. FURTHERMORE, TO REDUCE POLYMÖBI'S CARBON FOOTPRINT, WE HOPE TO REGIONALLY OR COASTALLY SOURCE THE LODGEPOLE PINE, PLYWOOD, AND CEMENT FOR THE CONCRETE FOOTINGS. PURPOSEFULLY LIMITED TO THE CONNECTIONS, RECYCLED STEEL WILL BE UTILIZED. BY FOLLOWING THE OUTLINED MEASURES, POLYMÖBI WILL PROUDFULLY SERVE AS AN AMBASSADOR FOR SUSTAINABLE ENGINEERING --- BRINGING NATURE AND THE STRUCTURE TO THE FOREFRONT OF THE VISITOR'S EXPERIENCE.

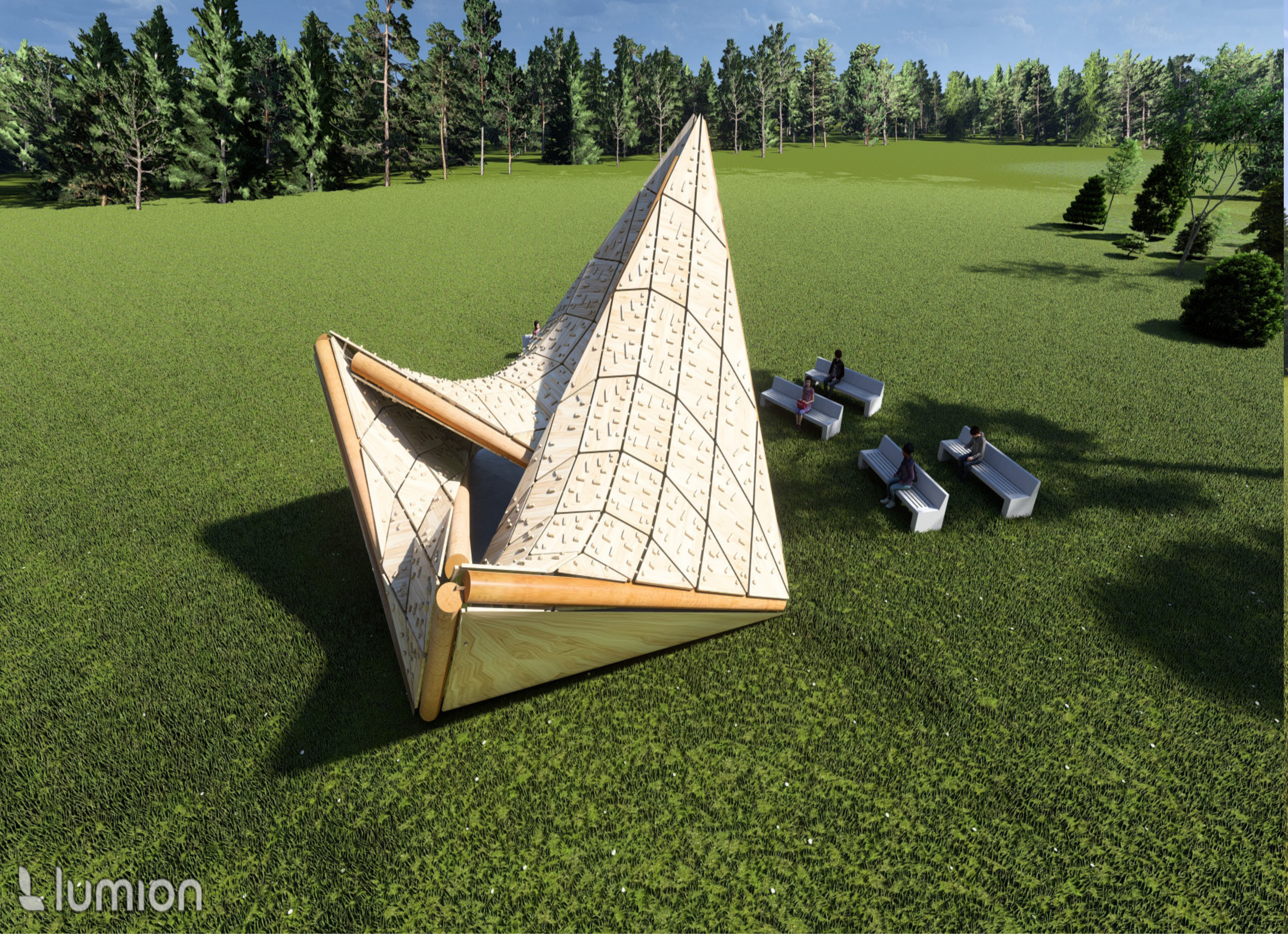


VILNIUS BANDSHELL

CREATED FOR TECHNICAL UNIVERSITY







COMMENCEMENT

WHEN APPROACHING THE END OF A PROJECT, MOST WOULD THINK TO WRITE A CONCLUSION, OR CLOSING STATEMENT. HOWEVER, WE BELIEVE THAT WHILE OUR WORK ON POLYMÖBI IS DONE, THE CONCEPTS WE'VE CREATED AND ADVANCEMENTS MADE TOWARDS POLYSHELL POSSIBILITIES IS THE TORCH THAT WILL BE CARRIED ON TO THE FUTURE. IT IS OUR DREAM TO BRING POLYMÖBI TO LIFE. THIS DREAM WOULD NOT BE POSSIBLE WITHOUT THE CONTINUATION OF INNOVATION AND DEDICATION TO THIS IDEA. AS THE LEANING PINE ARBORETUM WILL SOON GROW IN SIZE AND SPLENDOR, POLYMÖBI OFFERS IT A BEAUTIFUL OPPORTUNITY TO BLOSSOM. ADDITIONALLY, THIS PROJECT IS PART OF THE COMMENCEMENT OF BRINGING BACK THE IDEA OF BEING ARCHITECTURAL DESIGNERS JUST AS MUCH AS BEING STRUCTURAL ENGINEERS. IT IS A COMMENCEMENT TO THE HARMONY OF FORM FINDING, FORM TESTING AND FORM MAKING— WE MUST HOLD TRUE TO THE TITLE OF ARCHITECTURAL ENGINEERS. ULTIMATELY, THIS IS THE ENDING OF OUR TIME WITH POLYMÖBI, BUT LET IT MORE IMPORTANTLY BE THE BEGINNING OF OUR MESSAGE TO THE FORM FINDERS OF THE FUTURE.

ACKNOWLEDGEMENTS

THANK YOU TO EDMOND SALIKLIS FOR CHALLENGING US TO STRIVE FOR GREATNESS WITH POLYMÖBI, PROVIDING THOUGHTFUL INSIGHT AND CREATING AN ENVIRONMENT FOR US TO GROW AS ENGINEERS AND HUMANS.

THANK YOU TO NATHAN LUNDBERG FOR PROVIDING THE GRASSHOPPER SCRIPT THAT WAS THE BACKBONE OF POLYMÖBI'S SHELLS. IT IS WITH YOUR GENIUS THAT WE WERE ABLE TO TURN OUR CONCEPT INTO A PHYSICAL REALITY. WE HOPE THE INFLUENCE OF YOUR CREATION SPREADS FAR