TOBBLERONZ

BUILDING CONSTRUCTION 2 [ARC 2513]

PROJECT 1: UNDERSTANDING FORCES IN SKELETAL STRUCTURE

HOO ZHI XIN WONG JIA XIN LIM YEE ZHING LEE MIN MUHAMMAD HAZIQ BIN ARIFFIN

OBJECTIVE

THE MAIN AIM OF THIS PROJECT IS TO ENABLE US TO MANUALLY EXPLORE AND EXPERIENCE STRUCTURAL SYSTEMS IN CONSTRUCTION TECHNOLOGY - SPECIFICALLY SKELETAL CONSTRUCTION. WE WERE RESTRICTED TO USING LESS THAN 100 STICKS, WITH A MINIMUM HEIGHT OF 30CM. THE MATERIALS WE WERE ALLOWED TO USE WERE POPSICLE STICKS, TOOTHPICS, PINS AND THREAD.

AN ANALYSIS OF THE WAY LOAD AND FORCES ACT UPON A STRUCTURE FURTHER ENHANCES OUR UNDERSTANDING.

FOR IT TO BE A SUCCESSFUL DESIGN, IT MUST HAVE A HIGH EFFIENCY.

E = HEIGHT X (LOAD / MASS OF TOWER)

THEREFORE OUR AIM WHEN APPROACHING THE DESIGN WAS:

MIN STICKS

MAX HEIGHT

MAX LOAD/FORCES

SUMMARY

160 GRAMS (99 STICKS)

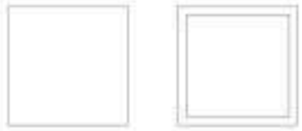
32 CM HEIGHT

55 KG LOAD/FORCES

E = 11

DESIGN STRATEGY

BASE



SQUARE

WE THOUGHT OF USING A SQUARE BASE - ONE WHICH IS REGULAR AND ONE WHICH IS WIDER THAN THE TOP. ULTIMATELY, WE DECIDED NOT TO AS WE THINK A TRIANGULAR SURFACE WOULD BE MORE REIGID AND WOULD ENABLE US TO USE MORE STICKS PER COLUMN/BEAM, MAKING IT MORE RIGID.

TRIANGLE

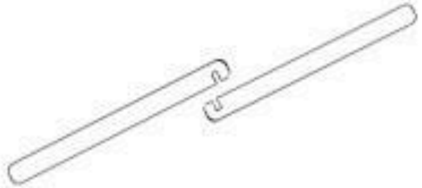
UPON DECIDING ON USING A TRIANGULAR BASE, WE STILL HAD TO CHOOSE BETWEEN A REGULAR TRIANGULAR TOWER OR A BASE WHICH IS WIDER THAN THE TOP. WE DECIDED TO DO EXPLORATION MODELS WITH BOTH TO TEST OUT WHICH WOULD BE STRONGER. WE ALSO HAD TO THINK ABOUT GAINING THE MAXIMUM HEIGHT.

FACADE

THREAD

WE DECIDED TO JOIN THE THREE SIDES TOGETHER USING THREAD, TYING A CROSS KNOT AT ALL MAJOR CONNECTION POINTS.

JOINT METHOD



SLOTTING

WE DECIDED NOT TO JOIN THE STICKS TOGETHER THROUGH SLOTTING AS IT IS QUITE DIFFICULT TO CUT THE SLOTS MANUALLY, AND IT COULD CAUSE CRACKS ON THE EDGES.

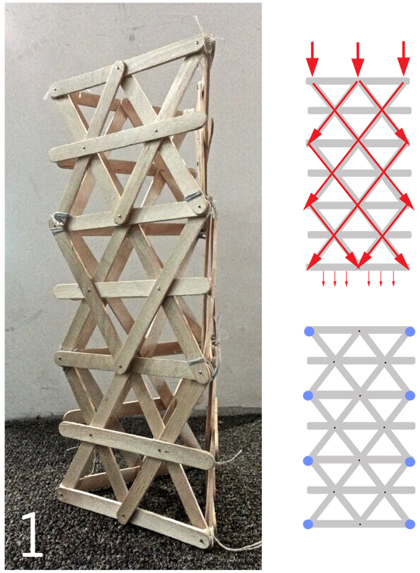
TOOTHPICK DOWEL

ANOTHER OPTION WE HAD WAS USING TOOTHPICKS AS DOWELS. TO DO THIS, WE MUST FIRST DRILL HOLES WHICH ARE JUST RIGHT TO HOLD THE TOOTHPICK TIGHT. THIS IS HARD TO EXECUTE AGAIN AS IT COULD CAUSE CRACKS AND WEAKEN THE STICKS.

PIN CONNECTION

ULTIMATELY, WE DECIDED ON USING PINS TO CONNECT THE STICKS TOGETHER. IT ADDS VERY LITTLE TO THE MASS OF THE TOWER BUT DOES ITS JOB OF HOLDING THE STICKS TOGETHER STRONGLY. WE COULD ALSO DRILL THE PINS CAUSING MINIMUM STRESS TO THE STICKS.

EXPLORATIONS



STRENGTH

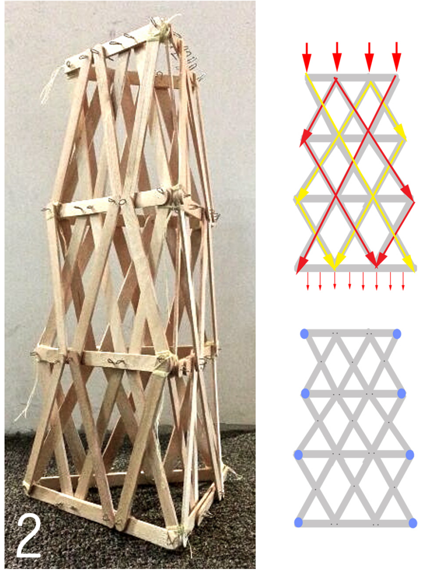
MULTIPLE BRACING
ALLOWS MULTIPLE POINTS
FOR LOAD DISTRIBUTION

WEAKNESSES

LACK OF STRONG COLUMN
AT VERTICES
JOINTS WERE NOT STRONG

IMPROVEMENTS

IMPROVE FACADE DESIGN
TO ENABLE PROPER JOIN-
ING OF THE THREE FA-
CADES



STRENGTH

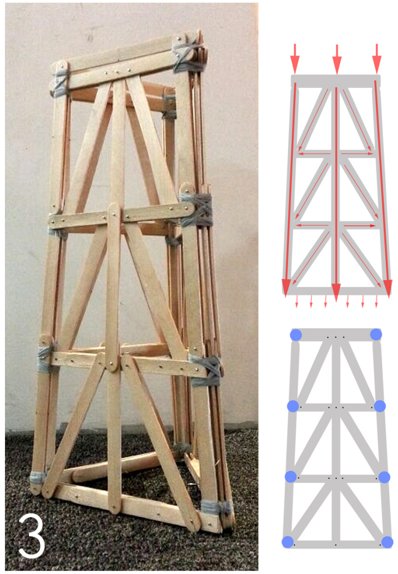
WIDER BASE THAN TOP
SLIGHTLY TALLER THAN
OTHERS

WEAKNESSES

TOO MANY OVERLAPPING
STICKS AT ONE POINT
LACK OF COLUMN AT THE
VERTICES

IMPROVEMENTS

SPREAD OUT STICKS SO
MORE JOINTS AND LESS
C9NCENTRATED LOAD



STRENGTH

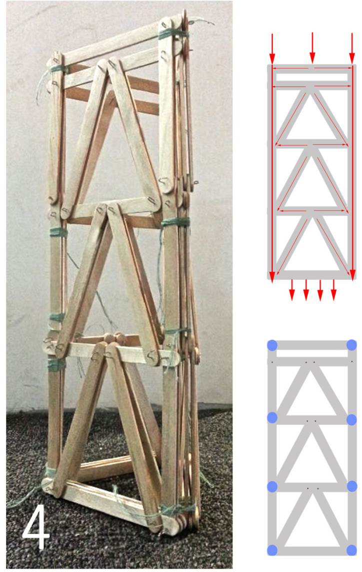
WIDER BASE THAN TOP
COLUMNS ARE STRONG
RIGID SYSTEM

WEAKNESSES

STICKS NOT FLAT ENOUGH
AT BOTTOM AND TOP
BEAMS NOT STRONG

IMPROVEMENTS

REUSE REDUNDANT MIDDLE
COLUMN AS REINFORCEMENT
FOR BEAMS
ENSURE FLAT TOP AND
BOTTOM



STRENGTH

REALLY RIGID AND STRONG
SYSTEM
BASE IS REINFORCED

WEAKNESSES

LACK OF STRONG COLUMN
AT VERTICES
JOINTS WERE NOT STRONG

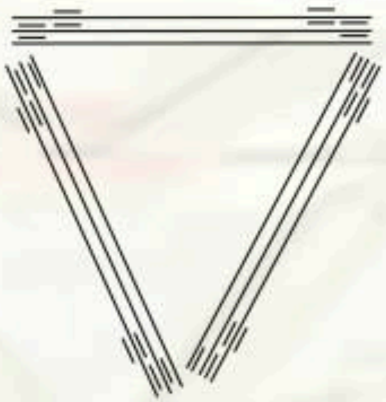
IMPROVEMENTS

CAN STILL IMPROVE ON
THE JOINTS TO SECURE
AND STRENGTHEN JOINTS
REINFORCE THE BEAM

FINAL DESIGN

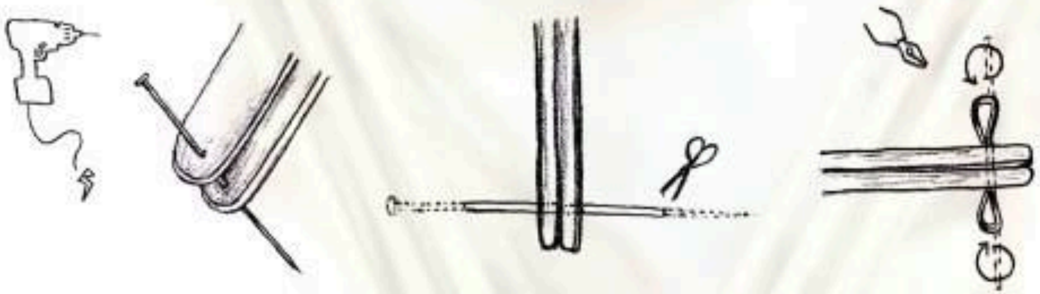
BASE

WE WANTED THE BASE TO BE REALLY STURDY AND FLAT IN ORDER TO SUPPORT AND TRANSFER THE LOAD EXERTED FROM ABOVE. WE USED 3 STICKS FOR EACH SIDE AND ENSURED THAT THE BOTTOM WAS FLAT, SO IT WOULDN'T TOPPLE TO ONE SIDE.



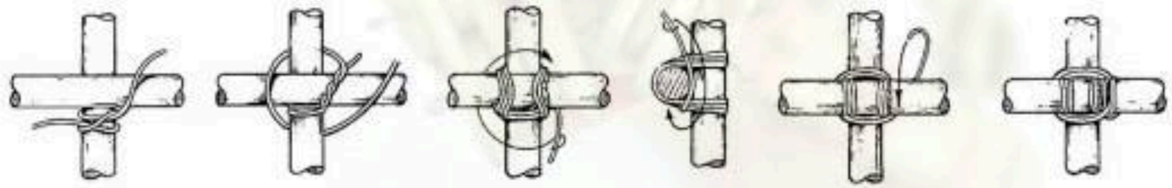
JOINTS - PINS

TO USE THE PIN, WE DECIDED TO DRILL IT INTO THE STICKS IN THE PREDETERMINED CONFIGURATION. WE THEN CUT OFF THE SIDES AND TWISTED IT INTO ITSELF TO ENSURE IT DOES NOT SLIP OUT OF THE STICK.



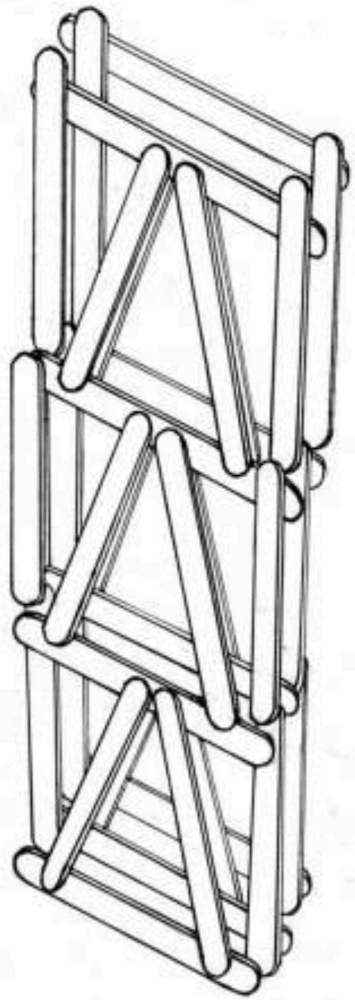
JOINTS - THREAD

TO CONNECT THE THREE FACES TOGETHER, WE USED A CROSS KNOT METHOD USING THREAD. WE ENSURED THAT EACH TIE WAS TIGHT, AND TIED AT ALL THE IMPORTANT POINTS.



ARRANGEMENT OF STICKS

WE ARRANGED THE STICKS IN A SPECIFIC WAY AFTER THE PRELIMINARY TESTING. THE COLUMNS ARE MADE OF 2 STICKS EACH, WHILST BEAMS ARE MADE OF 3, 2, 2 FROM THE BASE UP. FOR THE BRACING, WE USED 2 STICKS EACH. THIS MEANT THAT THE HEIGHT WAS SOMEWHAT LOWER THAN IF WE HAD USED LESS FOR EACH SECTION, BUT THIS METHOD WILL RESULT IN A STRONGER STRUCTURE.



99 STICKS

32 CM HEIGHT

LOAD TESTING

50 KG

0:05 0:50 1:20 2:30 3:00 3:50 3:56

WE WERE GIVEN A TIME LIMIT OF 5 MINS. WE STACKED THE WEIGHTS ONE BY ONE, TRYING AS BEST AS WE CAN TO MAKE SURE IT'S PLACED ACCORDING TO THE CENTRE POINT. THIS IS IMPORTANT TO MAKE SURE IT IS STABLE. HOWEVER, IT WAS QUITE HARD AND THE WRONG CALIBRATION OF THE WEIGHTS CAUSED IT TO BE IMBALANCED. ONCE IT'S PLACED FIRMLY, WE LET IT GO AND TRIED NOT TO ADJUST THE WEIGHTS. WE REACHED THE MAXIMUM AMOUNT OF WEIGHTS THAT WAS AVAILABLE AT THAT TIME - 50KGS. THE MODEL STILL STOOD FIRMLY WITH NO SIGNS OF CRACKS, BENDING OR DEFORMATIONS. WE THEN PLACED PACKS OF SUGAR, HOWEVER THE LOAD EXERTED WAS NOT DISTRIBUTED EQUALLY AND EVENTUALLY CAUSED THE MODEL TO FALL OVER. THERE WERE STILL NO CRACKS OR DEFORMATIONS - ONLY A FEW STRINGS LOOSENED, BUT WE DID NOT RE-TIE IT.

55 KG

0:05 0:25 0:45 1:05 1:25 1:45

WE WENT TO THE GYM AFTER THE INITIAL TEST TO GET MORE WEIGHTS. HOWEVER, AGAIN, THE WEIGHTS WERE NOT PLACED DIRECTLY ACCORDING TO THE CENTER POINT, THUS CAUSING THE LOAD TO BE DISTRIBUTED UNEQUALLY THROUGH THES TRUC-TURE. AFTER PLACING A TOTAL LOAD OF 55KG, THE STRUCTURE COLLAPSED DUE TO CRACKS AND BENDING OF THE STICKS.

THIS TEST WAS RELATIVELY UNFAIR AS WE HAD PREVIOUSLY TESTED UP TO 50KG, THUS WEAKENING THE STRUCTURE DUE TO DEFORMATIONS AND WARPING - THOUGH IT MIGHT NOT HAVE BEEN VISIBLE TO THE EYE. WE DID NOT RE-TIE THE STRINGS THAT LOOSENED DUE TO THE PRIOR TESTING EITHER.

ANALYSIS

EFFICIENCY

THE EFFICIENCY OF THE FINAL DESIGN WAS 11.

IT COULD BE IMPROVED THROUGH 3 APPROACHES.

1. **LOWER THE MASS OF THE STRUCTURE.** THIS WOULD MEAN THAT WE HAVE TO USE LESS STICKS BUT STILL MAINTAIN THE STRENGTH OF THE STRUCTURE. WE COULD POSSIBLY TAKE OUT UNNCESSARY STICKS.

2. **INCREASE THE STRENGTH OF THE STRUCTURE (TO WITHSTAND MORE LOAD).** TO IMPROVE THE STRENGTH OF THE STRUCTURE, PERHAPS WE COULD HAVE DESIGNEDED A MORE STABLE BASE AS WELL AS IMPROVE THE JOINTS.

3. **INCREASE THE HEIGHT OF THE STRUCTURE.** TO FURTHER INCREASE THE HEIGHT OF THE STRUCTURE BUT MAINTAIN THE OVERALL STRUCTURAL DESIGN WE WOULD HAVE TO USE MORE THAN 100 STICKS. OTHERWISE WE WOULD HAVE TO COME UP WITH A NEW APPROACH TO MAKING THE STRUCTURE STRONG USING LESS STICKS. HOWEVER OUR HEIGHT OF 32CM WAS RELATIVELY ABOVE AVERAGE.

STRENGTHS

THERE ARE SEVERAL POINTS WHICH MADE OUR STRUCTURE STRONG.

1. **GOOD WORKMANSHIP.** WE MADE SURE THAT THE JOINTS WERE DONE PROPERLY WHEN DRILLING THE PINS. IF THERE WERE ANY CRACKS, WE WOULD REDO WITH NEW STICKS. ADDITIONALLY, WHEN WE TIED THE THREAD, WE MADE SURE THE KNOTS WERE FIRM AND TIGHT.

2. ONCE THE PINS WERE DRILLED IN, THEY WERE **TWISTED MANUALLY** USING A PLIER, ONE BY ONE. THIS ENSURED THAT IT WOULDN'T SLIP OUT AND A LOT OF CARE WAS TAKEN TO ENSURE THE TWISTING DIDN'T CAUSE ANY CRACKS.

2. THE STICKS WERE CONNECTED SO THAT IT WAS RIGID ALLOWING THE **LOAD TO BE DISTRIBUTED PERPENDICULARLY** TOWARDS THE BASE. HOWEVER, WE FOUND THAT BEING TOO RIGID MIGHT RESULT IN THE WHOLE STRUCTURE SNAPPING IF TOO MUCH LOAD IS EXERTED. THEREFORE IT WAS SLIGHTLY FLEXIBLE TO COMPENSATE.

EVALUATION + CONCLUSION

WHY IT FAILED

DESPITE THE STRENGTHS OF THE STRUCTURE, THE FOLLOWING WEAKNESSES CAUSED IT TO FAIL AND MINIMIZED THE OVERALL EFFICIENCY.

1. **QUALITY OF POPSICLE STICKS.** THE STICKS WERE NOT CONSISTENT. SOME WERE MORE RIGID, SOME WERE SOFTER. TO IMPROVE WE COULD HAVE FILTERED THROUGH THE STICKS, GRADING THEM ACCORDING TO THE FEEL AND ONLY USED THE BEST.

2. **PLACING OF LOAD.** THIS WAS A MAIN FACTOR AS TO WHY OUR STRUCTURE DID NOT WITHSTAND MORE LOAD. THE LOAD WAS NOT PLACED IN THE CENTRE, THEREFORE IT WAS NOT STABLE. IN ADDITION TO THIS, WE HAD TO TEST THE LOADS TWICE - SEPARATELY. AFTER THE FIRST TESTING, OBVIOUSLY THE STRUCTURE HAD WARPED DUE TO THE LOAD, AND THEREFORE THE SECOND TESTING WAS NOT AS RELIABLE.

THROUGH THIS SIMPLE EXERCISE, WE WERE ABLE TO UNDERSTAND HOW

SKELETAL STRUCTURES

ARE DESIGNED AND HOW IT RESPONDS TO

COMPRESSIVE AND **TENSILE**

FORCES IN MORE DEPTH.

WE WERE RESTRICTED TO USING ONLY A

MAXIMUM OF 100 POPSICLE STICKS,
THREAD,
TOOTHPICK/PINS

AND WITH THIS WE WERE TO CREATE A TOWER OF

AT LEAST 30CM

HEIGHT AND WITHSTAND MAXIMUM LOAD.

IT WAS A DAUNTING TASK BUT IT ENABLED US TO USE OUR CREATIVITY IN DESIGNING NOT ONLY THE AESTHETICS, BUT **MORE IMPORTANTLY THE STRUCTURE** AND HOW IT CAN WITHSTAND MAXIMUM LOAD. WE WERE ABLE TO RECOGNISE OUR

STRENGTHS AND **DOWNFALLS**

AND APPRECIATE HOW TO IMPROVE IT TO GAIN A HIGHER EFFICIENCY VALUE.