FSEA PROJECT PLANS

April 8, 1997

EARTHQUAKE TOWER
TW2

Applicable Grades	9^{th}-12^{th}
Number of Members Per Team	Two
Number of Towers Per Team	One
Number of Sessions	Eight to Twelve

SKILLS AND ENGINEERING CONCEPTS DEVELOPED:

Design and fabricate a tower to a given set of specifications which can withstand severe shaking while loaded. Develop engineering layout drawing skills and translation from this drawing to a model. Familiarization with the scientific concepts of tension and compression, rigidity of forms, torsion and bending. Working with a predetermined budget to develop a cost effective design.

PROJECT REQUIRES EARTHQUAKE SIMULATORS WHICH MAY BE IN SHORT SUPPLY. PLEASE ALLOW FOR THIS WHEN ORDERING.

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Opinions expressed are those of the authors and not necessarily those of the foundation

INTRODUCTION

If you look up the definition of a tower, you will find the following; "An exceptionally tall building or part of a building or an exceptionally tall structure used for some functional purpose. In the past, towers were usually used to house bells (bell towers), for observation (watch towers) or for signaling (light houses).

Perhaps the earliest record of a tower comes from the bible where the story of the tower of Babel is told. Other notable towers include the Tower of Pisa and Eiffel Tower, two completely different types of towers.

Today there are many more types of towers which are used for a wide variety of functions. A few examples are transmission line towers, radar towers, radio and TV broadcasting towers, towers for suspension bridges, even the twin towers of the World Trade Center in New York.

In California, as in many other parts of the world, earthquakes are a very real threat to all man made structures. These natural phenomena have the potential of wreaking havoc on cities and surrounding areas as demonstrated in January 1995 in Kobe, Japan and in January 1994 in Northridge, California

As man learns more and more about the forces associated with earthquakes, new and better construction techniques evolve to keep us safe during the events. Presently the major factor in designing for earthquake safety is in the inherent strength of the materials and the design used. Other techniques, such as putting buildings on rollers or shock absorbers are currently being used and evaluated.

OBJECTIVE

The objective of this project is for the students to design and fabricate a cost effective tower which will withstand severe shaking (as experienced in an earthquake) while a load is applied to the top of the tower. The building materials to be used are balsa wood pieces, 36" long of three different cross sectional areas. To be cost effective, the students should try to minimize the cost of the materials used for the fabrication and under no circumstances exceed a predetermined maximum budget

After completion of the towers, a competition will be held to determine the most cost effective tower.

PROJECT DESCRIPTION

This project should be introduced to the students by presenting some background information on towers. (See Introduction) The concept of structural integrity should be demonstrated by using plastic straws fixed into the shape of triangles, squares and polygons. The rigidity of the triangular shape can be emphasized.

The specification for the tower should be passed out to the student teams. (See Appendix B) The mentor should show the class a sample top and base for the tower. Working with the students, the dimensions presented in the specification should be converted into the dimensions for the tower to be built.

The mentor should introduce and explain the concept of cost effectiveness, that is obtaining maximum results for each dollar spent. After this has been accomplished, the mentor should describe the competition and explain how points are awarded and how the cost effectiveness factor is arrived at for each tower. (See Competition)

Students should be broken up into teams of 2 to 3 and instructed to conceptually develop their tower. It may be necessary for them to use straws and paper clips to evaluate certain configurations. At this point, they must determine how much material of each cross section is required. Each team has a total three buy budget of $10,000 to spend for wood and glue and they must remain within that budget. NO EXCEPTIONS FOR EXCEEDING THE BUDGET ARE ALLOWED.

Each team will have three opportunities to purchase materials; however, the cost of materials on the second buy is 25% higher than the first buy and likewise the third buy is 50% higher than the original buy. It is-typical of real projects where material purchased in large bulk quantities receive a substantial price break. For this reason, teams should calculate the amount of material they will require as accurately as possible. Once material has been procured, no returns for credit are allowed. This discourages teams from overbuying the first time and returning the unused material.

Each team should be given a Tower Materials Cost Sheet for their use in ordering materials. (See Appendix C) The mentors should retain these sheets for future use, either for additional material and/or for determining the cost of each tower. The material ordered by each team shall be obtained from the mentor and given to the teams along with a work board for use when cutting or gluing the wood.

Note: Mentor will be provided with bulk material when doing this project.

Each team constructs their tower. Arrangements must be made to store the material safely while the glue dries. After all teams have completed their towers, a competition will be held to determine the most cost effective tower.

COMPETITION

Each team will be checked to verify that the tower meets the height specification. (30” $\pm$ 1/2” from the top of the base to the bottom of the top piece), and that no materials other than the glue and wood provided was used. The total cost of material for each tower must be available prior to competition. Any towers not meeting these specifications will be disqualified.

FSEA will provide an earthquake simulator to which the tower to be tested will be attached. **Simulators may be in short supply and not available when needed. Mentor should give sufficient notice to FSEA for their use.** The simulator will then be operated at different levels of vibration (from mild to severe) for a duration of 15 seconds at each level. After the 3rd level, the simulator will be turned off and a 2.5 LB load will be attached to the top of the tower. After supporting the load for a minimum of 15 seconds, the simulator shall be tuned on and stepped through the three

levels of vibration as before (15 seconds for each level)-The simulator is then turned off and the procedure repeated with a 5 LB load.

The test continues with a 7.5 LB load attached as previously described; however. with 7.5 LBs. the time at each level of vibration is increased to 20 seconds.

Testing of each tower continues until the tower fails or passes all load levels of testing.

Points are then awarded to each team based upon the highest combination of weight and vibration levels which it successfully passed. (The level immediately preceding the level at which it fails.)

A suggested point scoring system is presented in Appendix D and a suggested form to use for recording the various teams results is also shown in Appendix D.

Each teams score is then divided by the cost of the materials used to obtain the tower's Figure of Merit. The team with the highest Figure of Merit shall be declared the winner.

LESSON PLAN BY SESSIONS

This is a guide only.

Session #1

- Introductory Material
  - Background and types of towers
  - Demonstration of rigidity of triangular shapes vs. squares with drinking straws and paper clips.
- Description of project
  - Specification - Handout
  - Conversion of specification dimensions
  - Cost Effectiveness
  - Have samples of the wood to be used (3 sizes) and samples of the top, base and size of glue container.
  - Show Video
- Formation of teams
- Mentor should suggest students look at various towers.

Session #2

- Review project.
- Pass out paper for students to use for their design.
- Start conceptual design.

Session #3

- Complete conceptual and begin working on full scale drawings.
- Work on designs and drawings.
- Handout Tower Materials / Cost Sheets (Appendix B)
- Review importance of determining the proper amount of wood to order (See cost penalty for late orders)

Teams which complete their design should turn in their first buy order forms.

Session #4

Issue material and start construction
Late teams should finish full scale drawings and order material.

Session #5 to xx

Continue construction of tower.

Session #??

Conduct Competition
Simulators may be in short supply and not available when needed. Mentor should give sufficient notice to FSEA for their use..

DESIGN CONSTRAINTS

Only wood and glue furnished by FSEA will be used. (See Appendix C)

COMPETITION

Winners will be based on the following;

Points Scored / $ Cost of Tower = Figure of Merit

Points scored are those points gained by the tower under test prior to failure. These points are shown on the scoring Sheet. (Appendix D)

The highest Figure of Merit is the winner.

FACILITIES AND EQUIPMENT REQUIRED

Supplied by FSEA

- Wood and Glue
- Cutting Tools (Supplied by mentors to students based on school policy)
- Top and Base of tower
- Layout board for each team (32'x16')
- Pins for holding glued joints
- Paper (for conceptual design and full scale layout drawing)
- Zip lock plastic bags
- Safety Glasses
- Sandpaper
- Wax paper

Supplied by School

- Storage area for towers under construction
- Rulers/Yardsticks

FOR COMPETITION

Earthquake Simulator
2.5 LB. and 5 LB. Weights

SAFETY PROCEDURES

The usual safety precautions should be adhered to by students and especially when using cutting tools on the wood. Special precautions should be taken during the competition. Towers, under load, may fail suddenly and with significant force, especially under high vibration. Be cautious of flying pieces of wood and splinters. (i.e. keep students from crowding around the simulator and keep at least 10 ft. away.

Safety glasses must be worn by the team whose tower is being tested.

APPENDIX A

The following material is for mentors only.

1. Encourage teams to build by sections to allow glue to dry properly-
2 No one person teams. It is too difficult to hold wood properly and glue without two sets of hands at a minimum.
3 There may be teams with nothing to do while waiting for their glue to set-up. If an alternate activity is available, activate it.
4. Check wood issued for the following faults;
   A. Excessive warping
   B. Dimensions incorrect or inconsistent.
   C. Pieces extremely soft and / or flexible.

APPENDIX B

SPECIFICATION

Scale 1 ft = 1/4 inch .
Height 120 ft tall $\pm$2 ft excluding base and top plate.
Tower base 36 ft x 36 ft.
Tower top 14 ft x 14 ft .

Total dollar allocation $10,000 per team.
1st procurement of parts - 100% of price list.
2nd procurement of parts -125% of price list.
3rd procurement of parts -150% of price list.

NO REFUNDS - NO CREDIT

Only wood and glue provided may be used

APPENDIX C

FSEA TOWER MATERIAL COST

Team _____

	ITEM	SIZE	MODEL SIZE	UNIT COST	QUANTITY		ACTUAL COST
1st Buy Inflation Factor 1.0	1 2 3 4	6” x 6” x 144’ 6” x 12” x 144’ 12” x 12” x 144’ Glue	1/8” x 1/8” x 36” 1/4” x 1/8” x 36” 1/4” x 1/4” x 36”	$250.00 $500.00 $1000.00 $100.00			
2nd Buy Inflation Factor 1.25	1 2 3 4	6” x 6” x 144’ 6” x 12” x 144’ 12” x 12” x 144’ Glue	1/8” x 1/8” x 36” 1/4” x 1/8” x 36” 1/4” x 1/4” x 36”	$312.50 $625.00 $1250.00 $125.00			
3rd Buy Inflation Factor 1.5	1 2 3 4	6” x 6” x 144’ 6” x 12” x 144’ 12” x 12” x 144’ Glue	1/8” x 1/8” x 36” 1/4” x 1/8” x 36” 1/4” x 1/4” x 36”	$375 00 $625.00 $1500.00 $150.00			
					TOTAL COST		

APPENDIX D

POINT SCORING

No Load On Tower		
	Vibration Level 1	100 points
	Vibration Level 2	200 points
	Vibration Level 3	300 points
2.5 LB. Load On Tower		400 points
	Vibration Level 1	500 points
	Vibration Level 2	600 points
	Vibration Level 3	700 points
5 LB. Load On Tower		800 points
	Vibration Level 1	900 points
	Vibration Level 2	1000 points
	Vibration Level 3	1100 points
7.5 LB. Load On Tower		1200 points
	Vibration Level 1	1300 points
	Vibration Level 2	1400 points
	Vibration Level 3	1500 points

Each test will be of 15 seconds duration excepting that tests with a 7.5 LB> load will be of 20 seconds duration.

$$\text{Figure of Merit} = \frac{\text{Number of Points Earned}}{\text{Cost of Materials}} \times 100$$

Winners determined by the greatest Figure of Merit

APPENDIX D

SCORE SHEET

TIME	VIB LEVEL	TEAM	TEAM	TEAM	TEAM	TEAM	TEAM
15 SEC PER LEVEL	NO LOAD						
	1 (100 pts)						
	2 (200 pts)						
	3 (300 pts)						
15 SEC PER LEVEL	2.5 LB. LOAD (400 pts)						
	1 (500 pts)						
	2 (600 pts)						
	3 (700 pts)						
15 SEC PER LEVEL	5 LB. LOAD (800 pts)						
	1 (900 pts)						
	2 (1000 pts)						
	3 (1100 pts)						
20 SEC	7.5 LB. LOAD (1200 pts)						
	1 (1300 pts)						
	2 (1400 pts)						
	3 (1500 pts)						
	SCORE						
	COST						
	FIGURE OF MERIT						

APPENDIX D

EXAMPLE

TIME	VIB LEVEL	TEAM 1	TEAM 2	TEAM 3	TEAM 4	TEAM 5	TEAM 6
		Joe Mike	Ellen Mary	Susan Sam	George Keith	Margaret Karen	Ed Frank
15 SEC PER LEVEL	NO LOAD						
	1 (100 pts)	√	√	√	√	√	√
	2 (200 pts)	√	√	√	√	√	√
	3 (300 pts)	√	√	√	√	√	√
15 SEC PER LEVEL	2.5 LB. LOAD (400 pts)	√	√	√	√	√	√
	1 (500 pts)	√	√	√	Failed	√	√
	2 (600 pts)	√	√	√	(3)	√	√
	3 (700 pts)	√	√	√		√	√
15 SEC PER LEVEL	5 LB. LOAD (800 pts)	√	√	√		√	Failed
	1 (900 pts)	Failed	Failed	√		√	(4)
	2 (1000 pts)	(1)	(1)	√		√	
	3 (1100 pts)			√		√	
20 SEC	7.5 LB. LOAD (1200 pts)			√		√	
	1 (1300 pts)			√		√	
	2 (1400 pts)			√		√	
	3 (1500 pts)			√ (2)		√ (2)	
	SCORE	800	800	1500	400	1500	700
	COST (5)	$6600	$6000	$8200	$7800	$7100	$6100
	FIGURE OF MERIT (6)	12.1	13.3	18.3	5.1	21.1	11.5

NOTES

(1) Teams 1 and 2 passed the no-load and 2.5 LB. load vibration test. Both failed at the lowest vibration level with a 5 LB. load applied. Score for each = 800 points.

(2) Teams 3 and 5 passed all the tests at all load. Maximum score + 1500 points.

(3) Team 4 failed at the first level with a 2.5 LB. load. Score = 400 points.

(4) Team 6 passed the no-load and 2.5 LB. load vibration tests but failed when a 5 LB> load was placed on top of their tower. Score = 700 points.

(5) Cost figures were obtained from the Material Cost sheets for each team.

(6) Figure of Merit calculated - Score/Cost x 100

Result: Team 5 - winner (FOM = 21.1)
Team 3 - 2nd place (FOM = 18.3)
Team 2 - 3rd place (FOM = 13.3)

FAX (714) 229-2228

NAME♦	PHONE♦
ADDRESS♦	
CITY♦	ST♦ ZIP♦
MY SCHOOL IS♦	
TODAY'S DATE♦ / /	DATE NEEDED♦ / /

FILL IN YOUR ORDER BELOW. STEPS 1,2,3 (SEE CATALOG FOR PROJECT INFORMATION)

PROJECT NAME	CODE	NUMBER OF STUDENTS
STEP 1 (EXAMPLE) LAND YACHT	STEP 2 LY1	STEP 3 30

PLEASE, NO MORE THAN TWO PROJECTS PER ORDER FORM

T-shirts	SM	ME D	LG	XLG	
Girls					Total
Boys					

Hats	One size fits all	

Miscellaneous	Sets
Extra Ribbons - One set = One 1st, 2nd, 3rd	
Extra Certificates	
Portfolios	

Membership Cards	Count
Engineer Technician	
Junior Engineer	
Engineer	
Senior Engineer	
Engineer Specialist	

Other (Please Note)	