PLTW Science Frameworks

PLTW Course: Civil Engineering and Architecture (CEA)

Science Strand being addressed: The Nature of Science and Engineering
Sub-strand being addressed: Motion

Science Standard being addressed: 9.2.2.2

Overview:

Science Standard and Benchmarks: 9.2.2.2.3

Standard: 9.2.2.2: An object's mass and the forces on it affect the motion of an object.

Benchmark: 9.2.2.2.3: Demonstrate that whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted by the second object back on the first object.
(Minnesota Department of Education, 2010)

Correlation to AAAS Atlas:

4F/H1*, 4F/H2, 4F/H4, 4F/H7** (SFAA, 4F/H8** (SFAA))

4. The Physical Setting
F. Motion

- The change in motion (direction or speed) of an object is proportional to the applied force and inversely proportional to the mass. 4F/H1*
- All motion is relative to whatever frame of reference is chosen, for there is no motionless frame from which to judge all motion. 4F/H2
- Whenever one thing exerts a force on another, an equal amount of force is exerted back on it. 4F/H4
- In most familiar situations, frictional forces complicate the description of motion, although the basic principles still apply. 4F/H7** (SFAA)
- Any object maintains a constant speed and direction of motion unless an unbalanced outside force acts on it. 4F/H8** (SFAA)

(American Association for the Advancement of Science, 2009)

References:

American Association for the Advancement of Science. (2009). *Benchmarks Online*. Retrieved July 1, 2011, from AAAS-Project 2061: http://www.project2061.org/publications/bsl/online/index.php

Minnesota Department of Education. (2010, 05 24). *Academic Excellence: Academic Standards: Science.* Retrieved July 1, 2011, from Minnesota Department of Education:

http://education.state.mn.us/mdeprod/groups/Standards/documents/Publication/013906.pdf

Essential Understandings/Big Ideas:

* In Civil Engineering and Architecture, the stability of a structure is critical to its longevity and safety of its occupants.
* Engineers must look at what the structure will be made of, how it is made, and what type of ground it will be built on. The concept is called Statics. Statics is "the branch of physics that deals with physical systems in equilibrium, in which no bodies are in motion, and all forces are offset or counterbalanced by other forces." (Statics)
- Various loads/forces are applied to a structure.
- There are live, dead, snow, wind, seismic, and soil pressure loads. Each creates an action of movement on the structure.
- The task for the engineer is to design the structure to withstand these movements.
- Students will work on calculating and designing trusses, beams, columns, and footings. These are the main structural components of a structure.

References:

Statics. (n.d.). *The American Heritage® Science Dictionary*. Retrieved July 17, 2011, from Dictionary.com website: http://dictionary.reference.com/browse/statics

What should students know and be able to do [at a mastery level] related to these benchmarks?

Students will be able to:

- Understand the different types of loads placed on a structure.
- Calculate moment on trusses and beams.
- Determine the load bearing capacity of trusses, beams, and columns.
- Determine the spread of a footing and its load capacity.
- Ensure a structure is in static equilibrium.

Misconceptions:

Student Misconceptions:

- Why calculate the statics when you can just add more columns or increase the size of the beams, columns, and footings.
- Same size trusses can replace the same size beams.
- Same size beams can replace the same size trusses.
- The structure does not change if you build on different soils.

Teacher Resources:

Teacher Notes

Students will explore and gain an understanding of:

- Where does this fit?
- Statics is an integral part of building structures. Without understanding it, structures will fail, possibly causing injury.

- This concept touches upon structure failure during roof designs. But, it is covered in depth in the lesson on commercial structures.
- Students will analyze roofs, floors, trusses, beams, columns, and footings.

How to best introduce the concept?

1. Define key terminology related to statics through vocabulary and picture.
2. Spend more time on each structural member to ensure understanding.
3. Create extra examples, if necessary, for students to practice.
4. Follow the activities and PowerPoints.
5. Use the software MDSolids to model the students' designs.
6. If needed, coordinate with your district's physics teacher to aid in explanation of the scientific terms.

What students struggle with the most?

The students tend to struggle with the terminology and the mathematics.
For some students, it is the first time they may have been introduced to this content. These students tend to be more visual learners.
To aid in their learning, use demonstrations and physical or computer generated models.
Be sure to describe the connection between the model and the concept.
It is best to create more practice problems that will enforce the concepts, functions, and formulas.
Use formative assessments to see where the students still struggle and re-teaching may be required.

New Vocabulary

Load: Forces or other actions that result from the weight of building materials, occupants and their possessions, and environmental effects.
These are the vector forces that are applied to structures.
They are used to calculate the strength of the structure.

Vignette:

This concept will span several weeks. It is important that you provide time for the students to complete this work.

The first thing the students will do is learn about loads. They will discover how loads affect a structure. The students will work on an activity that describes how to calculate the spread of a load over a floor or roof with a beam and column system.

The next topic is to calculate beams and columns. The students will learn about moment and shear. They will take a look at how shape and size change the strength of the member. Students begin to mathematically show how a structure meets static equilibrium. Finally, each student gets to design a beam.

Students begin to study different types of foundations. They begin to analyze how the size of spread for the footings supports the load of the structure. The size and shape of the

footing are dependent on the loads but, also the type of soil. Students realize how different types of soils support weight differently.

After the students have been working on these activities, they need to apply these skills in statics to their Keystone Library Project. Any changes to the structure, like a green roof, will affect all structural members to include the footings. These changes must be reflected on their designs and backed with mathematical data.

Additional Instructional Resources

Any Physics books that contain statics would be a great source of information. Your local science department should have those.

Civil Engineering& Architecture Matteson, Kennedy, Baur, ©2012ISBN-13: 978-1-4354-4164-4 Delmar, Cengage Learning PO Box 6904, Florence, Kentucky 41022t: 800-354-9706f: 800-487-8488.

Civil Engineering& Architecture Matteson, Kennedy, Baur, ©2012WorkbookISBN-13: 978-1-4354-4165-1, Instructor Resources, ISBN-13: 978-1-4354-4166-8Architectural Graphic Standards, 11th Ed. The American Institute of Architects, ISBN 13:978-0-471-70091-3 Delmar, Cengage Learning PO Box 6904, Florence, Kentucky 41022t: 800-354-9706f: 800-487-8488.

Revit – 2011 tutorial books – go to www.leadinghighschools.com to receive a complimentary examination copy.

Architectural Drafting and Design – ISBN 13 978-1-4018-6715-7, Alan Jefferis and David Madsen, Thomson, Delmar Learning, Jeanne.Blair@cengage.com is the district rep and can provide information for you about the textbooks and can give you examination copies. Here is the website to get the examination copy: http://cengagesites.com/academic/?site=3243.

Revit Architecture – ISBN-13: 978-1-4390-5715-5, Paul Aubin, cengage.com.

Francis D. K. Ching several books on architecture John Wiley & Sons, Inc. publisher
Architecture: Form, Space and Order, ISBN 978-0-471-75216-5.
Architectural Graphics, ISBN 0471209066.
Building Construction Illustrated, ISBN 0-471-35898-3.

Websites:
http://emweb.unl.edu/negahban/em223/intro.htm
http://www.physicsclassroom.com/class/vectors/u3l3c.cfm
http://www.statics.com/
http://emweb.unl.edu/Mechanics-Pages/Justin-Pflanz-2004/Beam%20analysis.htm
http://structsource.com/analysis/types/beam.htm
http://mechanical-design-handbook.blogspot.com/2007/09/column-design-and-analysis.html
http://www.civilprojectsonline.com/building-construction/guide-to-foundation-design-column-footings/
http://www.asdipsoft.com/Spread.htm

http://www.sciencebuddies.org/science-fair-projects/project_ideas/CE_p006.shtml

Civil Engineering and Architecture activities and/or projects incorporating the standards:

Lesson 3.2 Structures: This lesson contains many activities. Their main focus is Statics, which is the physical study of keeping objects motionless. Since most of the loads are horizontal and vertical, students may not use trigonometry. But, the size, shape and length of span of structural members do have an impact of how the loads are carried. Students will use cross-sectional areas, volumes, material properties, and structural formulas to determine the strength of the structure. Students will design beams and spread of footings. If a student's design has trusses, then that student will need to apply trigonometry functions to determine its load bearing capabilities. All skills acquired in Lesson 3.2 are applied for the Keystone Library Renovation Project at the end of Unit 3.

Lesson 4.1 Commercial Design Problem: If time permits, students are to calculate the size of the structural members in their design solution. This lesson is the capstone project for the course. Students must apply all the concepts learned in the previous units. Then they need to present their plan to a board/owner.

Assessment:

Assessment Methods

Incorporating Explanation, Application and Perspectives:

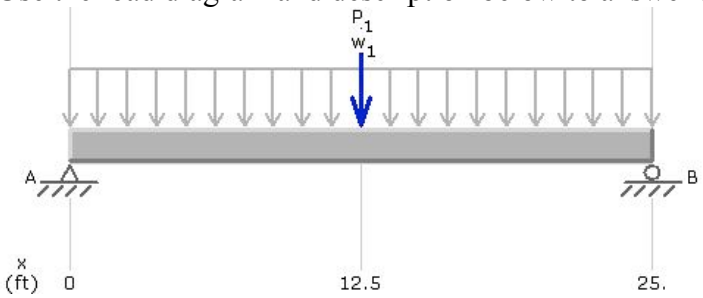
1. Which deflection limit would be the most restrictive for a simple beam?

   A. L/180 *C.* L/300
   B. L/240 *D.* L/360

2. Which of the following loads is **not** considered a Dead Load?

   A. roof structure *C.* occupants
   B. floor tile *D.* walls

Use the load diagram and description below to answer the questions.



Note: w1= 100 lb/ft and P1= 500 lb

3. In the beam loading diagram above, what is the reaction at Support A?
   A. 250 lb *C.* 1,250 lb

   B. 500 lb *D.* 1,500 lb

4. A 60,000-pound load from a column is placed on a 4 foot by 4 foot spread footing. What is the soil bearing pressure due to the load?

5.
   A. 16 sf C. 960 ksf

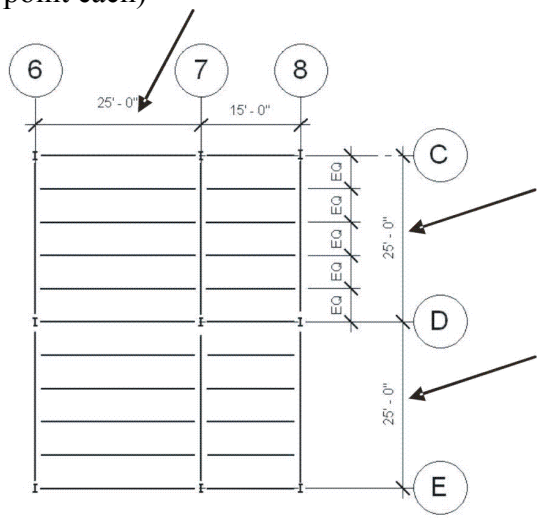
   B. 600 lb D. 3,750 psf

6. Below is the preliminary structural steel layout of building. The owners and the architect have agreed to revise the column spacing, in both the bay between Column 6 and 7 and the bays between Columns C to D and D to E (bays noted for clarity).

   The span length will change from 25 feet to 30 feet. The number of beams in the bays will not change.

   List 5 structural items that will be affected by this design change**.**

   (5 points total: 1 point each)



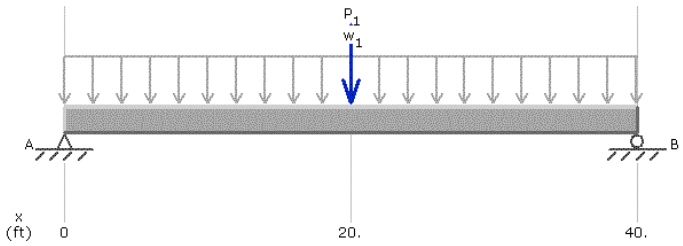
Possible answers:
Tributary width of the beams will change thus increasing the load on that beam
Span length of beam increases
Longer Beams, same load, therefore End Reactions will increase
Moment in beams will increase, therefore increase beam sizes
Footing size will increase, as the tributary floor area has increased for the column/footing

7. Beam Design

a) Calculate the End Beam Reactions and the Maximum Moment for the following beam. All work must be shown.

a. Calculate the required Section Modulus for the beam.

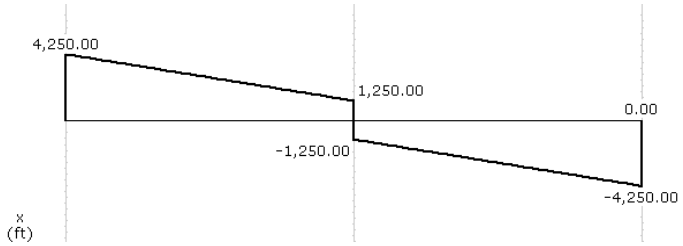
Span = 40 feet
W_1= 150 lb/ft
P_1= 2,500 lbs. at 20 feet from left support
Use an Allowable Bending Stress of $F_b = 24{,}000$ lb/in^2



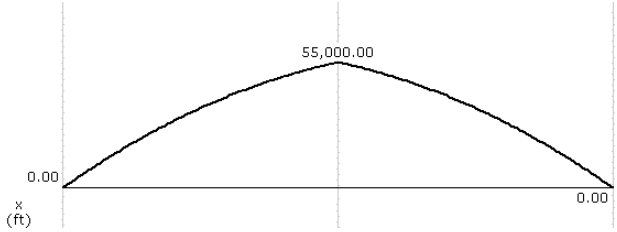
(5 points total: 2 points for R_A and R_B; 2 points for Moment and 1 point for Section Modulus)

Accuracy (0)

a. Reactions : Note that the beam is symmetrically loaded:
$R_A = R_B = wL/2 + P/2$
$R_A = R_B = [(150 \text{ lb/ft})(40\text{ft})]/2 + [2500\text{lb}/2]$
R_A= 4,250 pounds = R_B = 4,250 pounds



Moment: Maximum Moment occurs at midspan
$M = wL^2/8 + PL/4$
$M= [(150 \text{ lb/ft})(40\text{ft})^2]/8 + [(2{,}500 \text{ lb})(40\text{ft})/4]$
M= 30,000 lb -ft + 25,000 lb-ft
M= 55,000 lb-ft



b. Section Modulus

$S_x = M/F_b$
$S_x = [(55{,}000 \text{ lb-ft})(12 \text{ in/ft})] / 24{,}000 \text{ lb/in}^2$
$S_x = 28 \text{ in}^3$

8. Footing Design (5 points total)
   Accuracy (0.00)
   Size a Square Footing given the following information:

   - Design Loads
     - Dead Load =35 lb/ft^2
     - Live Load =50 lb/ft^2
   - Tributary Floor Area Carried by Footing = 40 ft x 40ft
   - Allowable Soil Bearing Capacity 2,500 lb/ft^2
   - Assume thickness of footing is equal to 2'-0"
   - Weight of concrete 150 lb/ft^3

SHOW ALL WORK

(DL + LL) Tributary Area= (35 lb/ft^2 +50 lb/ft^2) (1,600ft^2) = 136,000 lb

Pressure = Load /Area q=P/A
Weight of Footing = (2ft) x 150 lb/ft^3 = 300 lb/ft^2
q_{net} = Soil capacity Available= 2,500 lb/ft^2 – 300 lb/ft^2 = 2,200 lb/ft^2

Footing Area Required = P/ q_{net}
A=136,000 lb /2,200 lb/ft^2

A=61.82 ft^2
Use 8 ft X 8 ft square footing

Differentiation:

Gifted and Talented

Since the overall goal of the statics is to conduct the analysis on the Keystone Library Project, the gifted and talented students are working at their level. If the student is truly engaged, their changes or additions to the library will be challenging as it is. The instructor must encourage these students to push themselves and give them the time to follow through.

Special Education

All students typically will work in groups of two or three. This helps as the assignment load is divided out between all the team members. Each special education student should be paired with another student that has or shows ability to master the static concepts. Most work is hands-on with the computer and other tools. This typically aids in student understanding. Additional practice in the statics should be offered for more clarity and understanding. Coordination with the individual's case manager would be extremely helpful for any modifications to assignments and assessments. Formative assessments should be used for planning and the needs of the students.

English Language Learners

The difficulty is the English vocabulary that accompanies the statics. Post lessons, lectures, activities, and vocabulary with definitions on a class website or an online instructional tool such as Moodle. This will allow ELL students the opportunity to review the vocabulary at their convenience. Translations of documents can be formed by the ELL instructor within your school district. There are cases of students who lack a

mathematical foundation. Those students need to be assessed so the proper instruction can be given. Each student is different. Your ELL instructor is your best support.

Parents and Administration:

Administrative/Peer Classroom Observation

Students Are:	Teachers Are:
Receiving presentations on loads, beam analysis, and foundations.	Introducing the concept to statics through presentations and examples.
Calculating load pathways, beams, and footings.	Demonstrating examples with models.
Determining static equilibrium of a structure.	Observing the students working, answering questions, and guiding them through the process.
Analyzing the changes to their Keystone Library Project.	Providing help with the Revit program as students make changes to their library plan.
Creating the mathematical data to support their analysis on equilibrium of their library.	Assessing student work to ensure mastery of concept.

Professional Learning Communities:

Reflection: PLTW instructors should have discussions with Science instructors on the subject of Statics. This will ensure the standard is addressed with the same rigor in both subject areas.

Materials: PLTW instructors should use the above resources within in their discussions.

Parent Resources:

Refer parents to the suggested lists and searches found in Additional Instructional Resources. It would be very helpful to create a website in which the instructor can communicate with parents on assignments, topics, and additional support.

References:

American Association for the Advancement of Science. (2009). *Benchmarks Online*. Retrieved July 1, 2011, from AAAS-Project 2061: http://www.project2061.org/publications/bsl/online/index.php

Minnesota Department of Education. (2010, 05 24). *Academic Excellence: Academic Standards: Science.* Retrieved July 1, 2011, from Minnesota Department of Education:

http://education.state.mn.us/mdeprod/groups/Standards/documents/Publication/013906.pdf

Statics. (n.d.). *The American Heritage® Science Dictionary*. Retrieved July 17, 2011, from Dictionary.com website: http://dictionary.reference.com/browse/statics