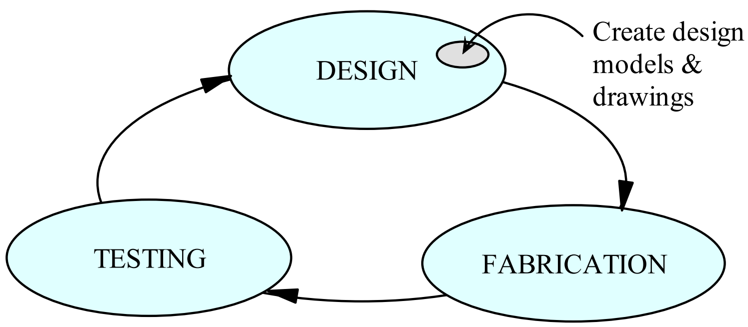
***** WEEK 3 *****

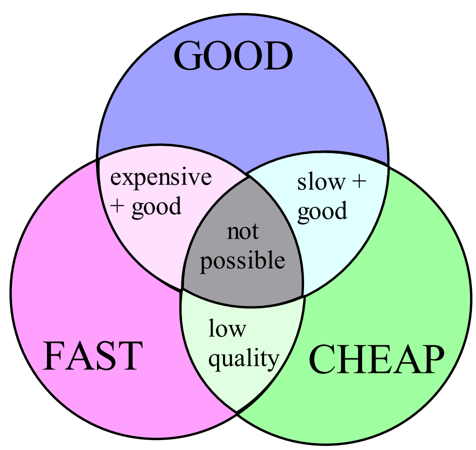
WEEK 3 - DESIGN & CAD (.7h)
3.1 ENGINEERING DESIGN PROCESS

Engineered products are usually designed conceptually before they are built. Before BOARD DRAFTING was used, and it involved the use of pencil, paper, and many drafting tools. Nowadays, most companies use **CAD**, or **computer-aided drafting/design**, software.



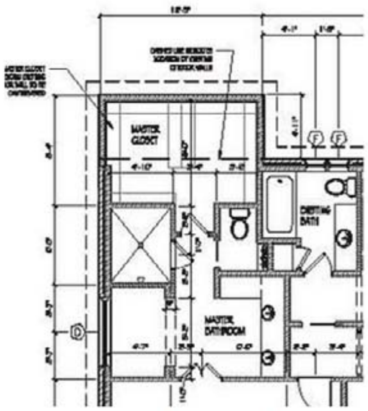
THE ENGINEERING DESIGN CYCLE

Managers of engineering design projects must often make decisions given constraints of resources and time. It follows that one corner of the "design triangle" (below right) must always be sacrificed.

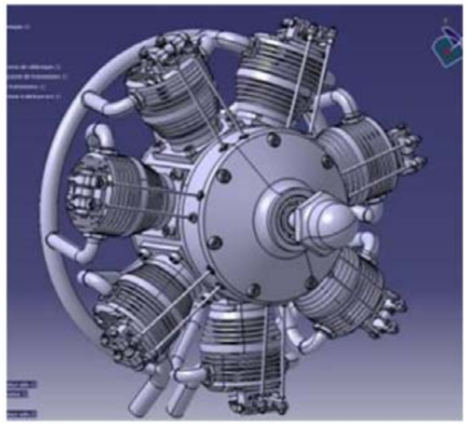


3.2 TYPES OF CAD PROGRAMS

The earliest CAD programs were 2-dimensional (2D). Three-dimensional (3D) work could be done, but it was generally "wire frame". Later, more advanced parametric 3D solid modeling CAD programs became available. These programs use "design intent" and **CHANGEABLE** models. These programs also include "free form" surface modeling (using NURBS, non-uniform rational basis splines) which is hard to model.



AUTOCAD



(3D PARAMETRIC (CATIA)

SURFACE MODELING

3.3 EXAMPLES OF CAD PROGRAMS

There are many CAD programs and they are becoming increasingly specialized to specific engineering areas.

1. AutoCAD - the most **ubiquitous** (used across many fields), esp. **in civil/architecture**.
2. Solidworks - the most used by **mechanical** engineers.
3. CATIA - specialty program used in aerospace, automotive, and boat designs.
4. Creo (formerly Pro/E) - mechanical CAD program (see it a lot in biomedical, industrial, etc)

3.4 TECHNICAL ACTIVITY

Play on AutoCAD.

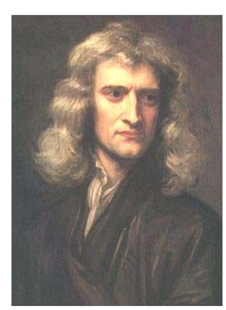
EXAM 1

******* WEEK 4 *******

WEEK 4 - BRIDGE CALCULATIONS (0.5h)

4.1 PRELIMINARIES

Go over Exam 1.



4.2 NEWTONIAN PHYSICS

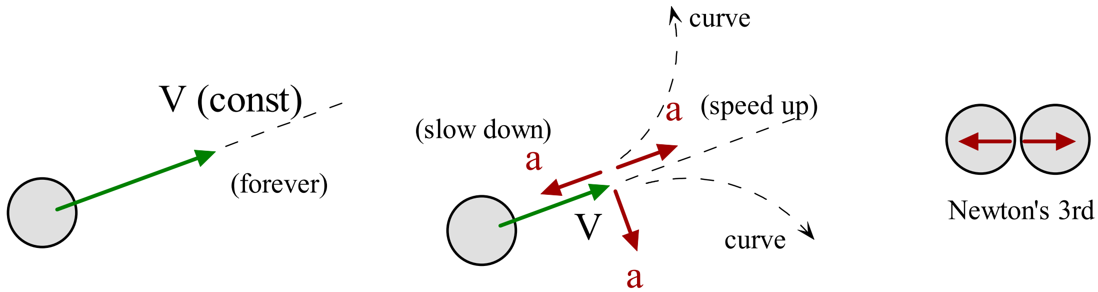
Sir Isaac Newton (1643 – 1717)

Mechanics (relate force & movement), calculus, optics,

NEWTONS EQUATIONS

$$F = ma$$

1. Force - a push or pull that causes a body to accelerate (draw forces as arrows)
2. Mass - an object's resistance to acceleration (different than weight)
3. Acceleration – change the body's motion (speed up slow down, or change direction)



IMPLICATIONS

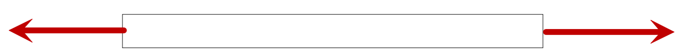
"Static" Objects – are objects that don't move (bridges). Forces are BALANCED on them.

4.3 LOADING OF SLENDER BEAM

There are different ways to "load" (to load means to apply force to...) a slender beam (sometimes called a "member").

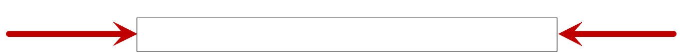
4.3.1 Tension

For 1/8" x 1/8" basswood, the strength is 160 lb.



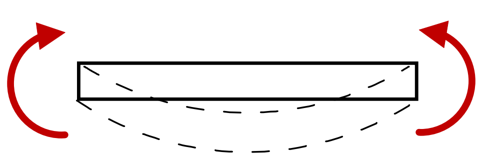
4.3.2 Compression

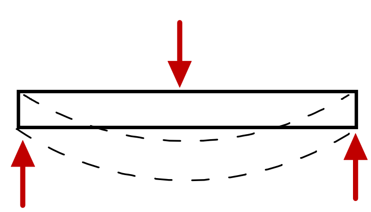
For 1/8" x 1/8" basswood, the compressive strength is ~ 74 lb.



4.3.3 Bending

This is the EASIEST way to break it. There are 2 ways to load in bending



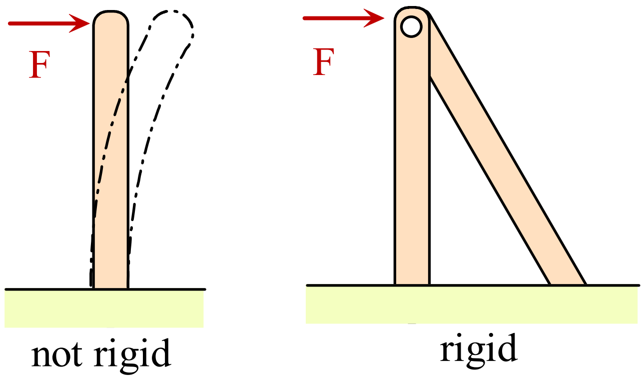


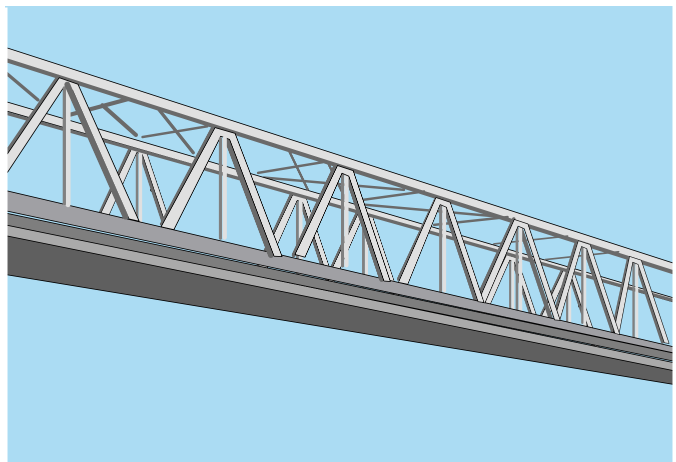
4.4 TRUSS BRIDGE DESIGN

Trusses work very well. They are STRONG and RIGID.

A truss is a structure composed of straight slender "members" connected at their ends with hinged joints. Forces may only be applied at the joints. **Rigid** trusses are formed from **triangular** units.

WHY TRIANGLES
1. Triangles are strong.
2. Why are triangle trusses strong? They protect members from being loaded in BENDING.



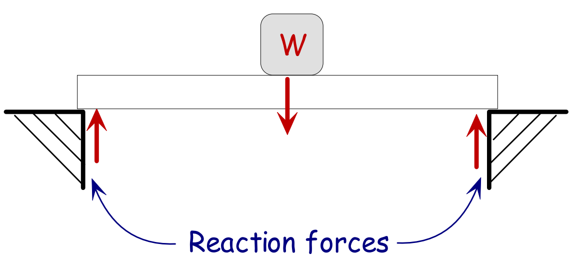


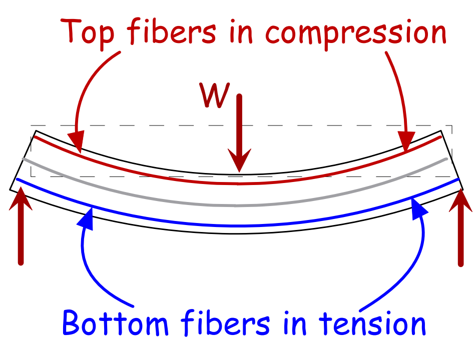
4.5 WHAT HAPPENS WITH BRIDGE-TYPE LOADING?

When we load a bridge **internal** forces will develop in the bridge. Let's investigate these internal forces.

4.5.1 Simple Beam Bridge

A simple beam bridge is like just laying a straight piece of material across the span (e.g., a tree)

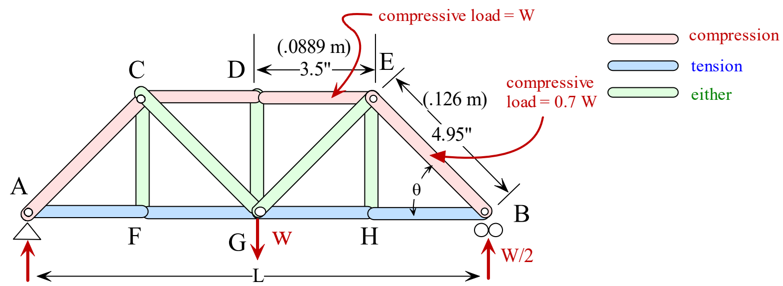




Note the pattern of internal forces on the beam. Imagine the beam is made up of fibers running the length of the beam. The top fibers are compressed; the bottom fibers pulled in tension.

Note - the same phenomenon occurs even with a truss bridge (below).

The top members are loaded in COMPRESSION.
The bottom members are loaded in TENSION.

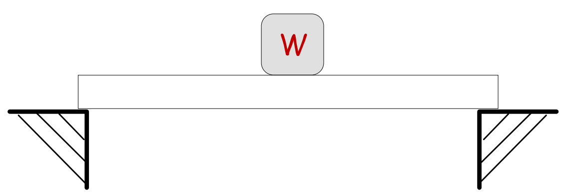


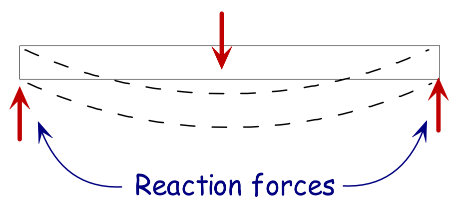
4.6 BRIDGE CALCULATIONS

Now let's use physics and math to compute how strong our bridges can be.
These computations help us predict how different designs affect the strength of our bridges.
(NOT on exam).

4.6.1 Simple Beam Bridge

A bridge is very simple. You just drop a long board across a gap. The board is loaded in bending.

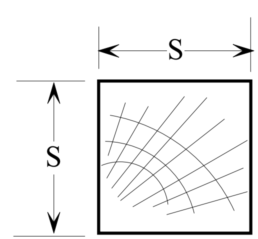




Calculations

$$W = \frac{4I\sigma}{Lc}$$ Equation for maximum load W that can be supported

where
L = beam length
σ = tensile strength of material
I = "moment of inertia" (related to the cross-sectional shape)
c = beam half-thickness (also related to cross-sectional shape)



$$W = \frac{4I\sigma}{Lc} = \frac{4(bh^3/12)\sigma}{Lc}$$ For rectangular beams

$$W = \frac{4(s^4/12)\sigma}{L(s/2)}$$ If the beam is square (side s)

$$W = \frac{2\sigma s^3}{3L}$$ Simplify

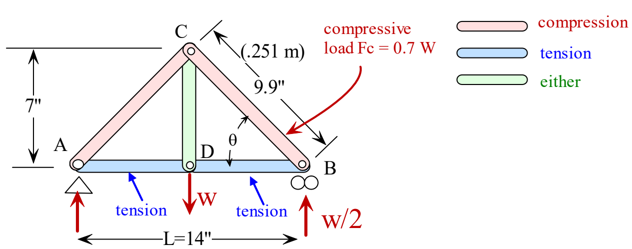
$$W = \frac{2(32.6\,\text{MPa})(.00317\,\text{m})^3}{3(.3556\,\text{m})}$$ Plug in values for 1/8" basswood (L = 14")

$$W = \frac{2(32.6\,\text{MPa})(.00317^3)\text{m}^2}{3(.3556)}$$ Simplify

$$W = 1.95\,\text{N} = \boxed{0.44\,\text{lb}}$$ Accurate result, but NOT strong.

4.6.2 Simple Truss

This truss only has 2 big triangles with LONG members
We assume NO buckling and only tension & compression loading.
Top members are in compression, bottom members in tension (just like beam bridge)



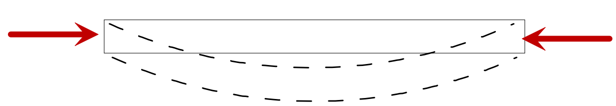
$F = \sigma A = W / \sqrt{2}$	From physics and truss geometry
$W = \sigma A \sqrt{2}$	Solve for W
$W = \sigma\, s^2 \sqrt{2}$	$A = s^2$ (square members)
$W = (32.6\,\text{MPa})(.003175\,\text{m})^2 \sqrt{2}$	Plug in numbers for 1/8" square basswood (σ = 32.6 MPa)
$W = 465\,\text{N} = 104\,\text{lb}$	Result in lb
$W = 930\,\text{N} = \boxed{208\,\text{lb}}$	Double it (there are 2 of these in a bridge)

This value is TOO HIGH (the bridge will not be this strong). Something is wrong!

4.6.3 Simple Truss (with buckling)

The above computation is off because we did not consider **BUCKLING**.

Buckling is a phenomenon where a member collapses when loaded in compression. The equation below computes the compression force needed to cause buckling. Notice that the equation depends on the elasticity of the material (E), but NOT its strength (σ) (weird huh?).



$$F_{MAX} = \frac{\pi^2 EI}{L^2}$$ Buckling equation

where
E = Modulus of Elasticity (stiffness of the material)
I = Moment of Inertia (related to the cross-sectional shape of the member)

L = Length of Member

Notice bigger F means a stronger column. Thicker columns (bigger I) → bigger F.
Longer columns → smaller F.

Computation

$$F_{MAX} = \frac{\pi^2 E(s^4/12)}{L^2} = \frac{\pi^2 E s^4}{12L^2}$$ $I = s^4/12$ for square members

$F_{BC} = W/\sqrt{2}$ Force in member BC (from simulator)

$$\frac{W}{\sqrt{2}} = \frac{\pi^2 E s^4}{12L^2}$$ Set equal to buckling force above

$$W = \frac{\pi^2 E s^4 \sqrt{2}}{6L^2}$$ Solve W. Note, material strength does not matter!

$$W = \frac{1.414\pi^2 (10\,\text{GPa})(.003175\text{m})^4}{6(.251\,\text{m})^2}$$ Plug in for 1/8" square basswood (E = 10 GPa) and the 2-triangle truss above (L = 0.251 m)

$W = 18.8\,\text{N} = 4.2\,\text{lb}$ (must x2 again)

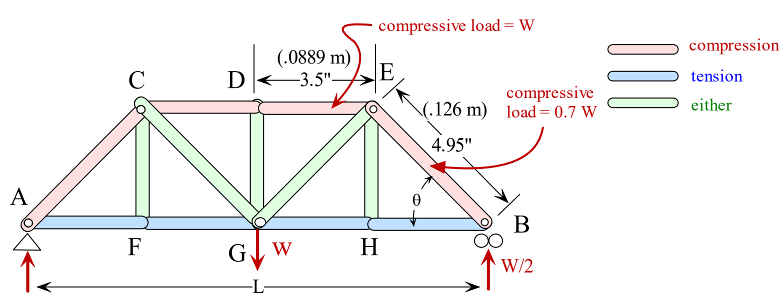
$W = 37.6\,\text{N} = \boxed{8.4\,\text{lb}}$ Accurate, but not very strong. L too long!

If we include buckling, the predicted strength drops from 208 lb to 8.4 lb!!

4.6.4 Truss with Shorter Members (with buckling)

The last truss design is not predicted to do well if we include buckling. Let's re-design and try to shorten the compression members. This should increase the buckling strength.

4 members in compression (AC, CD, DE, BE) may buckle (compute for each one). Due to symmetry, we only need to look at 2 members (say, DE, and EB).



Member DE (or CD, symmetry) – horizontal compression member

$F_{DE} = W$ Calculate or get from simulation

$$W = \frac{\pi^2 E s^4}{12L^2}$$ Set equal to buckling formula

$$W = \frac{\pi^2 (10\,\text{GPa})(.003175\text{ m})^4}{12(.0889\,\text{m})^2} = 105.75\,\text{N}$$ Plug in #s for basswood and length

$$W = 105.75\,\text{N} = 23.8\,\text{lb}$$

$$W = 211.5\,\text{N} = \boxed{47.6\,\text{lb}}$$ (21.6 kg) Weight supportable (x2, pretty accurate)

Member BE (or AC) – diagonal compression member

$$F_{BE} = W/\sqrt{2}$$ Calculate or get from simulation

$$W = F_{BE}\sqrt{2} = \frac{\pi^2 E s^4 \sqrt{2}}{12L^2}$$ Set equal to buckling formula

$$W = \frac{\pi^2 (10\,\text{GPa})(.003175\text{m})^4 (1.414)}{12(.126\text{m})^2}$$ Solve W, plug in #s for basswood & length

$$W = 74.4\,\text{N}$$

$$W = 148.8\,\text{N} = \boxed{33.4\,\text{lb}}$$ (15.2 kg) Weight supportable (x2, pretty accurate)

We now have 2 predictions. Which one is applicable? It is the **SMALLER** one (worst case).

4.7 TECHNICAL TOPICS/ACTIVITY (Work on CE project!)

******* WEEK 5 *******

WEEK 5 - CIVIL ENGINEERING (.5h)

5.1 PRELIMS

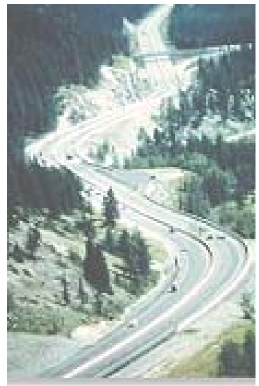
(CT - post this lecture online?)

5.2 CIVIL ENGINEERING

5.2.1 Description

Civil engineering deals with the design, construction, & maintenance of **public works** or **fixed structures** (making our world a more enjoyable place)

Examples – buildings, bridges, roads, dams, water ways, sewage systems

It is possibly the **oldest** engineering field.

5.2.2 Activities of CE's

1. Design & supervise construction projects.
2. Estimate costs, personnel & material needs.
3. Preparing proposals & establishing completion dates.
4. Work with compliance to codes & specifications, permits & approvals.

5.2.3 Sub-disciplines of CE

1. Structural – design & analyze structures (buildings, aircraft, bridges)
2. Geotechnical – foundations, soil properties, compression
3. Transportation – highways (paths), traffic flow
4. Water Resources – manage human water resources.
5. Environmental – waste water treatment & purification, sewage.
6. Material science – esp. construction materials (steel, concrete)
7. Construction management – surveying (measurement of construction site)
8. Seismic design - designing for earthquake resistance

5.2.4 Related Areas

1. Architects – hired by the customer, the project leader, responsible for overall project (look, feel, way in which people use & experience the spaces of the building).
2. Architectural engineering – design building sub-systems (HVAC, electrical, plumbing, etc.).

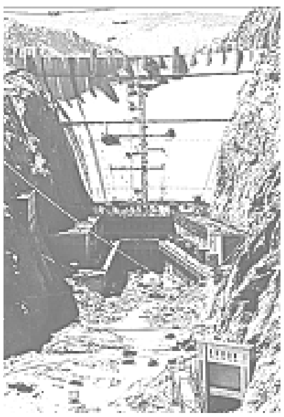
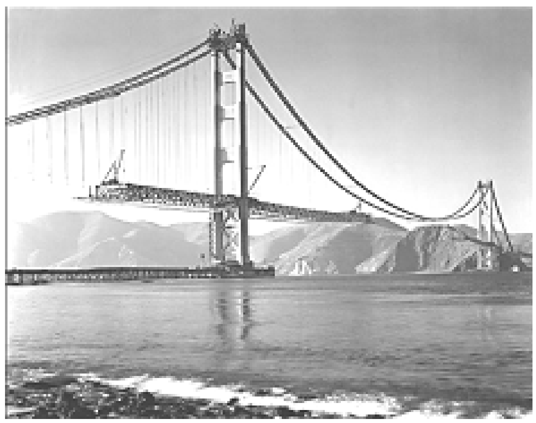
3. Civil engineers – hired by architect to do design & analysis of structure (will it stand?)

5.2.5 Where do you work?

1. Government – city, state, federal levels (unique to CEs)
2. Architectural, Engineering & Construction Firms – Fluor, CH2M Hill, HDR, Gensler,

5.2.6 Impacts & Landmarks of CE

1. Hoover Dam (completed 1935, 726 ft high)
2. Golden Gate Bridge (1937, 4200 ft long)
3. Empire State Building (1250 ft high)


5.2.7 Licensing

Licensing is particularly important for CE's

1. Professional engineer (PE) – legally recognized by the state as an engineer.
2. State licensing boards: http://www.pels.ca.gov/
3. Boosts salaries – e.g., Caltrans, Level A ($50K) to PE level D ($90K)
4. Where "PE" is required
   - Engineers working for government
   - Expert witnesses, many consulting engineers
   - Only PE's may sign off engineering plans submitted to public authority for approval.
5. Steps
   - Pass EIT exam (Engineer in Training) or FE (Fundamentals of Engineering) (in 3rd yr of BS)
   - Complete the B.S. degree
   - Work 2 more years under a PE
   - Pass the PE exam (Principles and Practices) – 8 hours, 2 sessions, open book, various fields

5.2.8 Professional Society for CE

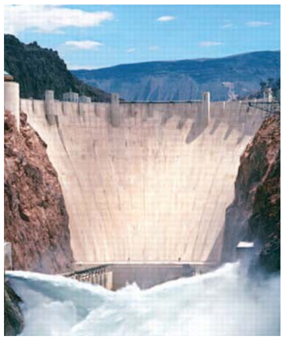
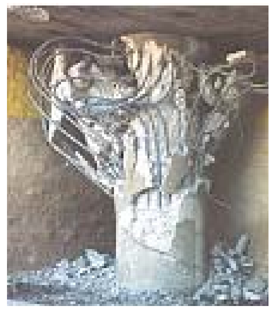
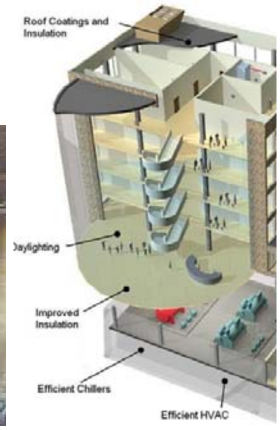
ASCE (American Society of Civil Engineers, founded 1852)

5.2.9 Job Outlook

Job outlook should be good due to the need to rebuild the nation's infrastructure (ASCE report card).

5.2.10 Challenges for CE

1. Infrastructure resilience & monitoring, water resources (managing scarcity),
2. Building energy efficiency, seismic design, alleviate traffic congestion

5.3 CONSTRUCTION

Field related to fabrication of buildings & structures.

Work conditions – physically demanding work (heavy objects, stooping, crawling) & exposure to harmful materials, noise, & dangerous machinery

Job titles & job requirements vary considerably (per US Labor Dept. – www.bls.gov/ooh)

1. Construction manager (general contractors) – plan & direct construction projects
   (BS construction science, $60-70K median)
2. Construction/Bldg inspector – verify compliance to standards/codes (~$40K median)
3. Electricians – install & test electrical systems (HS diploma + training, $20-30/hr)
4. Generic construction laborers – select HS courses (math, blueprint reading), $12-14/hr)
5. And many more...

5.4 LAB/TECHNICAL

Work on CE project

5.4.1 Unit Conversion

Refer to the CT GUIDE (Section 3.2)

EXAM 2 REVIEW

DESIGN & CAD (WK 3)
- Engineering design process – YES.
- CAD stands for what? – YES.
- Drafters do what? - YES.
- 4 CAD Programs listed – YES.

BRIDGE PROJECT (WK 4)
- Newton – what does a force do? static objects – YES.
- Loading a Slender beam (tension, compression, bending) – YES
- Truss Bridge Design (triangle, protect members from bending) - YES.
- What Happens with Bridge-Type Loading (C on top, T on bottom) – YES
- Predict Bridge Strength (all of those calculations), material properties – no.
- BUT know that buckling occurs when member is in compression – YES

CIVIL ENGINEERING (WK 5)
- Where you work – no
- Stuff you'd work on – YES
- Name 3 sub-disciplines of CE – YES
- Licensing – what is EIT, PE? YES
- Branch professional societies – YES
- Branch emerging technologies – no.
- Difference between architect, architectural engineer, & civil engineer – YES

TECH – units, simple unit conversion – YES.