1.0 OBJECTIVES

1. The CE405 design project requires each team to demonstrate a good knowledge of structural design.

2. Additionally, each team must demonstrate good report writing and presentation skills.

2.0 APPROACH

It is anticipated that each team will work at least 3 hours per week on the project. The expected timeline for activities, goals achieved, and submissions for the project will be as follows:

<table>
<thead>
<tr>
<th>Week</th>
<th>Dates</th>
<th>Activities and Goals</th>
<th>Submission</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>09/01 - 09/8</td>
<td>Estimate dead, live, roof, snow loads on structure</td>
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<tr>
<td>II</td>
<td>09/8 – 09/15</td>
<td>Estimate wind loads on structure</td>
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<tr>
<td>III</td>
<td>09/15 – 09/22</td>
<td>Calculate loads on the frame to be designed</td>
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<tr>
<td>IV</td>
<td>09/22 – 09/29</td>
<td>Develop structural analysis model – (assume)</td>
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<td>V</td>
<td>09/29 – 10/06</td>
<td>Conduct analysis and determine design forces</td>
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<tr>
<td>VI</td>
<td>10/06 – 10/13</td>
<td>Write and review preliminary report</td>
<td>Preliminary report</td>
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<tr>
<td>VII</td>
<td>10/13 - 10/20</td>
<td>Design beams members</td>
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<tr>
<td>VIII</td>
<td>10/20 – 10/27</td>
<td>Design columns and bracing members</td>
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<tr>
<td>IX</td>
<td>10/27 - 11/03</td>
<td>Design roof truss members</td>
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<td></td>
<td></td>
<td>Verify design forces using designed frame</td>
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<tr>
<td>X</td>
<td>11/03 - 11/10</td>
<td>Design assigned roof truss connections</td>
<td></td>
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<tr>
<td>XI</td>
<td>11/10 - 11/17</td>
<td>Design assigned bracing connection</td>
<td></td>
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<tr>
<td>XII</td>
<td>11/17 - 11/24</td>
<td>Write and Review Final report</td>
<td>Final report</td>
</tr>
<tr>
<td>XIII</td>
<td>11/24 – 12/01</td>
<td>Develop presentation</td>
<td>Presentation</td>
</tr>
<tr>
<td>XIII</td>
<td>12/03 – 12/05</td>
<td>Make presentation + celebrate!</td>
<td></td>
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</tbody>
</table>
3.0 PROJECT TEAMS

The design project teams are as follows:

<table>
<thead>
<tr>
<th>Team</th>
<th>Chief Engineer</th>
<th>Project Manager</th>
<th>A&amp;D Engineer</th>
<th>A&amp;D Engineer</th>
<th>A&amp;D Engineer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mark Gipson</td>
<td>Joshua Dudicz</td>
<td>Bethany Enbright</td>
<td>Mike Kenon</td>
<td>Clinton Loe</td>
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<tr>
<td>2</td>
<td>Andrew Pauly</td>
<td>Brian Mcierney</td>
<td>Steven Siklich</td>
<td>David Stolcenberg</td>
<td>Justin Wing</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Dan Beauchamp</td>
</tr>
<tr>
<td>3</td>
<td>Michelle Powell</td>
<td>Michael Pluger</td>
<td>Derrick Dielman</td>
<td>Matthew Junak</td>
<td>Lin Yu-Chen</td>
</tr>
<tr>
<td>4</td>
<td>Luelseged</td>
<td>Jill Beardslee</td>
<td>Kevin Wheeler</td>
<td>Todd Stelma</td>
<td>Dan Remondino</td>
</tr>
<tr>
<td></td>
<td>Mengistu</td>
<td></td>
<td></td>
<td></td>
<td>Kie-Cung Liong</td>
</tr>
<tr>
<td>5</td>
<td>Eunai Lee</td>
<td>David Schroeder</td>
<td>Jason Makowski</td>
<td>Dan Kehoe</td>
<td>Gregory Heim</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Helen Ferede</td>
</tr>
</tbody>
</table>

As such all team members are expected to contribute equally to the overall project. Please keep track of your individual contributions and those of other members in your group. At the end you will be required to grade your team members efforts and contributions. If possible, briefly indicate individual efforts and contributions in the preliminary and final project reports.
4.0 ROLE DEFINITIONS

4.1 Project Manager:

- The project manager is responsible for the planning, scheduling, coordination, and completion of the overall design project.

- The project manager will also run intelligence and interference for the group.

- The project manager will help the chief engineer (CE) and the analysis and design (A&D) engineers to complete the design project.

- The project manager will make the final presentation along with his team.

- The CE and the A&D engineers help the project manager to develop the group presentation.

4.2 Chief Engineer:

- The chief engineer is responsible for the overall accuracy of the completed work.

- The chief engineer will provide significant assistance to the A&D engineers to complete the project.

- The chief engineer will also double check the results.

- The chief engineer will write the report with the help of the information and drawings provided by the A&D engineers.

- The chief engineer can communicate with the instructor about design issues.

- The chief engineer will assist the PM to develop the presentation.

4.3 Analysis and Design Engineers:

- The analysis and design engineers are responsible for working on the details of the project.

- They will work together and with the CE and the PM to complete the project accurately and in time.

- The A&D engineers are the backbone of the design firm. They should maintain a close working relationship with the CE.

- They will collaborate with the CE to develop the report and with the PM to develop the presentation.
5.0 DESIGN PROJECT

- Figure 1 shows the structural floor plan and layout of a new office building that will be built in Lansing.

- Figure 2 shows the structural elevation of the interior braced frame A-A. All frames in the north-south direction are similar to the braced frame shown in Figure 2.

- The structural elevation of the perimeter moment resisting frame B-B is shown in Figure 3. All frames in the east-west direction are similar to the moment frame shown in Figure 3.

- **Design all the members of the interior frame A-A.**
  - Note that A-A is not an exterior frame.
  - Design the frame according to the American Institute of Steel Construction (AISC) specifications.

- **Design connections at joints P and C in frame A-A.**

5.1 One Possible Approach

- Step I: Estimate the dead, live, roof, and snow loads
- Step II. Estimate the wind loads
- Step III. Calculate the resultant loads on the interior frame A-A
- Step IV. Assume sections for the members of frame A-A. Develop an analytical model of the structure
- Step VI: Perform the structural analysis with the assumed members to determine the design forces
- Step VII. Submit preliminary report.
- Step VII: Design the members for the design forces determined from Step VI
- Step VIII: Reanalyze the structure using the designed sections to verify the designs.
- Step IX: Design the connections.
- Step X: Write the final report.
- Step XI: Prepare a presentation for the project.
Figure 1. Structural floor plan and layout

Figure 2. Structural elevation of frame A-A
Figure 3. Structural elevation of frame B-B
6.0 PROJECT REPORTS

The project reports should be brief readable document that summarize the relevant results from the analyses and design of the frame. They should include relevant drawings of the designed structure. The report should have enough information to assess the accuracy and the approach used for the design. Relevant AISC Specifications should be cited using their Specification numbers. *The report should not be too verbose*. Attach the analysis results as an appendix to the report. Very briefly summarize the contributions by the individual members of the team.

7.0 PROJECT PRESENTATION

Each group will have eight minutes for the presentation and two minutes for questions and answers. Limit yourself to a total number of 12 - 15 slides. Prepare your presentation using Microsoft Powerpoint. Each group's presentation will be graded by all other groups and the instructor. Save some of your interesting questions for the day of the presentations. Please limit yourself to 12 - 15 slides for each presentation. Prepare your presentations using Microsoft Powerpoint.

9.0 GUIDELINES FOR THE FINAL PROJECT REPORT

The final design project report must be a concise, organized, and easy-to-read document. The exact layout and table of contents of the final design project report is up to the individual teams. However, the report must *at-least* address the following issues:

- Preliminary Analysis
  - Model of the structural system
  - Summary of results from the elastic analysis of the preliminary structural model
- Emphasis on member design forces and corresponding governing load combination.

- Displaced shapes of the frames for critical load combinations.

- Structural Design - Members
  - Summarize the results of the design process
  - Emphasis on selected material, member, strength (resistance), and controlling limit state.
  - Sample design calculations for some critical roof truss, columns, and bracing members.

- Structural Design - Connections
  - Summary of calculations for the design of connections for Joints S and G.
  - Engineering drawings of the designed connections.

- Final Analysis and Design Verification
  - Comparison of results from analysis of preliminary and designed structural system.
  - Emphasis on deviations in design member forces, and redesign of members (if any).

- Structural Weight, Fabrication Cost, and Design Cost
  - Determine the weight of each member and the total weight of steel in the structure.
  - Assuming a fabricated steel cost of $1.00 per pound, determine the total fabrication cost of the project.
  - Break the project, as your group has conducted it, into several tasks. Identify these tasks.
  - Develop a Table summarizing the number of hours dedicated by each group-member to each task. Identify total number of person-hours for each task and for the complete project.
  - Assuming a cost of $50.00 per person-hour, determine the cost of designing the project.
This handout discusses the design of connections at joints S and G, shown in the figure below. It is similar but not identical to the connection design for the design project.

Working point: The working point for a connection is defined as the point of intersection of the centroidal axes of all members connected at the joint.

The working point (W.P) for all connections should correspond to the joints shown in the line sketches and assumed in the analysis & design.
• Design the connections using either bolts or welds. Note that welds will be much easier. If you have assumed bolted connections during member design, then you will find that they will still be adequate for welded connections.

• Example details of connection S and G are shown in the attached sheets. Additional references include the AISC manual pages 13-11 to 13-17 for truss connections and 13-3 to 13-11 for bracing member connections. See Example 13.2 (case b on page 13-35) for bracing connection examples. See Example 13.3 (page 13-38) for truss connection examples.

• A sample gusset plate design is also shown. Additional reference for gusset plate design can be downloaded from: http://www.aisc.org/documents/dec_98.pdf
- Example of Connection S - Bolted

- Example of Connection S - Welded
• Example of Connection - G (Bolted and Welded options shown together)
Bracing connection design example (very brief, many steps omitted)

Given:

Bracing member, \( L_x = L_y = 34 \, \text{ft} \).

\( K_x = K_y = 1.0 \)

\( P_u = 90 \, \text{kips (tension and compression)} \).

Design member

- Select double angle section 8 x 6 x 1/2 in. with long legs back-to-back, made from 50 ksi material

- See AISC manual page 4-82:
  \( \phi P_n = 113 \, \text{kips for x-axis buckling} \)
  \( \phi P_n = 92 \, \text{kips for y-axis buckling} \)

  y-axis buckling governs, need two connectors along the member length (student design).

Design Connection of member to gusset plate

- If a bolted connection is desired,
  
  No. of bolts required = four 3/4 in. A325 bolts
  
  \( \phi R_n = 127 \, \text{kips} \).
  
  Design, edge distance \( L_e = 1.5 \, \text{in.} \) and spacing \( s = 3.0 \, \text{in.} \).

- If welded connection is required,
  
  Let \( a = 5/16 \, \text{in.} \) (check with \( a_{\text{min}} \) and \( a_{\text{max}} \))
  
  Design with E70XX electrode
  
  \( \phi R_n = 0.75 \times 0.6 \times 70 \times 0.707 \times 5/16 \times L = 6.96 \, L \, \text{kips} > 90 \, \text{kips} \)
  
  Therefore, \( L > 12.93 \, \text{in.} \).
  
  Design, \( L = 16 \, \text{in.} \) - (8 in. on either sides of the gusset plate)
Gusset Plate Design

- Gusset plate design is governed by the length of the critical section subjected to direct tension or compression. The length of the critical section can be estimate using the Whitmore gage-length method, shown in the Figure below.

- The Whitmore gage-length method assumes that the critical section is located at the last fastener long the line of force. The length ($L_{gw}$) of the critical section is estimated assuming $30^\circ$ angles of spread from the length of the plate in direct tension or compression at the first fastener.

- The area of the critical section is equal to $L_{gw}$ multiplied by the thickness ($t_g$) of the gusset.

- The thickness ($t_g$) of the gusset plate must be designed so that the gross yielding and net section fracture strength of the critical section are greater than factored tension force.

- *Usually*, the limit state of gusset plate buckling due to compression forces is also considered in the design process. However, this is beyond the scope of the current course.
Therefore, design the thickness \( t_g \) of the gusset plate so that the gross yield strength in compression, with a \( \phi \) factor of 0.85, is greater than the factored compressive force.

\[ \phi T_n = 0.9 F_y L_{gw} t_g > T_u \]

\[ \phi T_n = 0.9 F_y L_{gw} t_g > T_u \]

\[ \phi T_n = 0.75 F_u (L_{gw} - n (d_b + 1/8)) t_g > T_u \]

Whitmore gage length and design of gusset plates: (a) member with bolts or welds; (b) Whitmore gage length for bolted conn.; (c ) Whitmore gage length for welded conn.

**Design Gusset Plate**

- \( L_{gw} = 3/4 + 2 \times 9 \times \tan30^\circ = 11.14 \) in. - for bolted connection

- \( \phi T_n > T_u \) - gross yielding in tension

\[ 0.9 \times L_{gw} \times t_g \times 50 > 90 \] - gross yielding in tension

Therefore, \( t_g > 0.18 \) in.

- \( \phi T_n > T_u \) - net section fracture in tension

\[ 0.75 \times (11.14 - 0.875) \times t_g \times 65 > 90 \]

Therefore, \( t_g > 0.18 \) in.

- \( \phi T_n > P_u \) - gross yielding in compression (approx.)

\[ 0.85 \times (11.14) \times t_g \times 50 > 90 \]

Therefore, \( t_g > 0.19 \) in.
• Assume $t_g$ = either 3/8 in. or 1/2 in. or 3/4 in. for bolted connection gusset plate. All of these values are greater than that required. The final choice will be based on the designer. The instructor would prefer a 1/2 in. thick gusset plate.

- $L_{gw} = 8 + 2 \times 4 \times \tan 30^\circ = 12.6$ in.

- $\phi_t T_n > T_u$ - gross yielding in tension
  
  $0.9 \times 12.6 \times t_g \times 50 > 90$

  Therefore, $t_g > 0.16$ in.

- $\phi_t T_n > T_u$ - gross yielding in compression.
  
  $0.85 \times 12.6 \times t_g \times 50 > 90$

  Therefore, $t_g > 0.17$ in.

- Design $t_g = 1/2$ in. for the gusset plate.

*Design gusset plate to beam and column connection.*

$T_u$: design force for vertical weld
$T_u\cos\theta$: design force for horizontal weld
$\theta$ – angle between the vertical and the line joining the corners of the gussets at the top and bottom levels
o The weld joining the gusset to the beam must be designed for a design force of $T_u \times \sin\theta$

o The weld joining the gusset to the column must be designed for a design force of $T_u \times \cos\theta$

o These values come from page 11-22 of the AISC Volume II. Note that there are three other methods of designing these connections. However, the recommended method is the simplest.

o $\theta$ is the angle between the vertical and the line joining the corners of the gussets at the top and bottom level. Thus, $\theta$ is not exactly equal to the angle of the diagonal bracing member.

o In order to use the recommended simple design method for the connection, the bracing member centroidal axis should pass through the corners of the gusset plates as shown. Thus, the working point for the bracing member should be located at the corner of the gusset.

o This will cause some additional end moment in the beam due to the eccentricity of the working point with respect to its centroidal axis. This should have to be accounted for in the design process.

*However, it is beyond the scope of this course and design project.*