Incorporation of Writing Assignments into Steel Design Courses

Report to American Institute of Steel Construction

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Abstract

This report shows how assignments based on the written review of articles on buildings and bridges, with back-of-an-envelop calculations, can be used to expand coverage in traditional steel design courses. Through these assignments students have the opportunity to look at how structures behave and to consider alternative designs. The writing assignments give students experience in presenting engineering information to both engineers and non-engineers. These assignments provide an additional opportunity for discussion and interaction with students, both in and outside of class. This report provides steel design educators with the materials needed to introduce short written assignments with back-of-an-envelop calculations into their courses.

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INTRODUCTION

Traditional steel design courses are based primarily on teaching students how to design structural components, i.e. beams, columns, connections, bracing elements, etc. Typically, the design of individual elements in a steel structure must precede the study of the overall behavior. Once the design of the different components is mastered, design projects can introduce students to the behavior and design of the full structure. Design projects commonly form the basis of capstone design courses, providing students with the opportunity to fully assimilate the design process. An approach is developed in this report to provide some of the key benefits obtained from design projects earlier in the steel design course sequence.

Experience at the University of Connecticut has shown that students learn more about design when they explore the overall structural behavior in buildings and bridges. Carefully prepared, short assignments that are directed to the study of overall structural behavior increase the student's interest in structural steel design. These assignments do not require the large amount of time normally needed for design projects. As a consequence, students are able to explore a variety of building and bridge types and learn about the creative concepts needed to solve a wide variety of structural problems.

During the past 18 years, this writer has been using writing assignments combined with 'back-of-an-envelop calculations' as a way to expand opportunities for students to see how structures behave and how design decisions affect the overall structural performance (DeWolf, 2002). These assignments have provided students with the opportunity to look at entire structures, whereas conventional course design assignments generally involve the study of individual members and connections. These assignments provide a format for organizing and communicating specific information about load paths, framing approaches, different design alternatives and construction practices.

A key to these writing assignments is the use of back-of-an-envelop calculations. Computers have *not* eliminated the need for back-of-an-envelop calculations. These calculations are just as important today, and perhaps more so, than they were prior to the development of the powerful computer software now used in engineering design offices. Back-of-an-envelop calculations provide a way to get rapid estimates that are useful during different stages of the design and construction process. Engineers often need to develop preliminary designs using short, simple, approximate estimates for forces and resulting member sizes. In addition, all designs must be checked. Checking should not be done by repeating the full analysis and design process. Errors made in the original design process will likely be made in the repeat of the process. Checking should involve short, simple, approximate calculations. These short approximate calculations are often all that is needed to check full designs. Back-of-an-envelop calculations are also useful in developing alternative structural systems. In addition, they can be helpful when there are last minute alterations or when there are problems during construction.

The intent of the writing assignments proposed in this report is that they combine relatively short written discussions about structural behavior with short back-of-an-envelop calculations. This provides students with the opportunity to explore different structures, expanding on the material that is traditionally covered in the normal steel design curriculum. The process provides students with insight into how structures work. In addition, these efforts expand the interaction between the teacher and the student, resulting in a course that is more interesting and rewarding for both.

Background

Today, there are many efforts underway to introduce writing into student's major areas of study. Freeman, et. al (2000) note that the premise behind 'writing-across-the-curriculum' is that students understand their subject better when they are required to write about it. This is because the writing process requires critical analysis. Writing can only be done correctly when a student fully understands what he or she is writing about. Through presentation of material in their area, students develop new ideas that provide them with the opportunity to be part of the dialogue in their field. The writing process helps them learn the language, formats and ways of reasoning in their field. This helps students prepare for their careers in which they will ultimately need to be able to write and communicate about their expertise to both engineers and non-engineers, notably clients and the general public. Thus, experience with writing is an essential component of the students' learning process.

This need is further explored by Bean (1996). He has written a guide that is a valuable resource for introducing writing into a broad range of courses. As he notes, two recent power movements in higher education have been the writing-across-the-curriculum movement and the critical thinking movement. By combining these two elements, students are transformed from passive to active learners, deepening their understanding of the subject matter. They learn to think in their own discipline, ask questions, conduct inquiries, gather and analyze data, and make arguments. While there is no one right way to integrate writing and critical thinking, the underlying premise is that writing is closely linked with thinking, and by creating an environment that demands good writing, we can promote intellectual growth. Students who struggle with their writing, struggle with the process of thinking about problems. In other words, writing engages students.

Writing-across-the-curriculum typically requires that students write in their upper division courses. Suitable courses include laboratory courses, courses with design projects and senior capstone design project courses. At the University of Connecticut, writing assignments combined with back-of-an-envelop calculations have been used in the senior-level steel design course. The course is the second steel design course in the undergraduate curriculum. The first course, required of all undergraduate students in the department, covers tension members, compression members, rolled steel beams and some simple connections. The second course covers beam-columns, bracing, composite design, plate girders and an extensive section on connections. The writing assignments are spread throughout the second course, and they typically have features related to the current design topic.

The main objections to adding writing assignments to engineering courses have been that the teaching of writing in one's discipline can be demanding and that it should only be done by teachers who are experts in the current theory, pedagogy and evaluation of writing. In other words, writing must be taught in English courses or technical writing courses under the direction of "experts" in writing. This is not true. Writing-across-the-curriculum is based on the premise that writing can and should be done in individual disciplines, typically by instructors in the discipline. The experience at the University of Connecticut and elsewhere has shown that it is not necessary to have experts from the English Department involved in courses in order to introduce writing projects. We need to remember that we have all had to learn how to write as engineers, and with some practical, realistic guidelines, we as engineering instructors can introduce writing assignments into our courses, and we can do this efficiently and effectively.

Lynn Bloom, AETNA Chair and Professor of English at the University of Connecticut, Storrs, CT, proposed a list of principles for writing-across-the-curriculum. These have been discussed by Freeman, et. al. The principles were developed to provide the foundation for the development and evaluation of writing outside of English departments. Bloom's guidelines, with modifications that reflect the approach proposed herein for engineering design assignments, are:

1. Writing should be an integral part of the learning process in all courses.

2. Teaching writing is the responsibility of all faculty members; no single discipline or department owns writing.

3. Writing is a process; writing assignments should include generating ideas and development of drafts.

4. We learn to write by writing.

5. Teachers of writing should write.

6. Writing to learn is different from writing to demonstrate mastery of the subject matter or knowledge of the forms and conventions of writing in a particular discipline.

7. Responses to student writing should be based on the purpose of the assignment, i.e. it should focus on what has been learned.

8. Responding to student writing is different from editing it.

9. Not all writing needs to be graded.

10. There is more than one way to write.

The goal of this report is to present guidelines on the use of writing assignments with back-of-an-envelop calculations in steel design courses. It is hoped that steel educators will use these guidelines to explore how writing assignments can be introduced into their own courses. There are four sections, guidelines for developing writing assignments, guidelines for evaluating assignments, basic information on assessment techniques and reasons why steel design educators should include writing assignments in their steel design courses.

GUIDELINES FOR DEVELOPING WRITING ASSIGNMENTS

This section describes what is needed by instructors to develop their own writing assignments. It includes a review of general requirements for the assignments, guidelines that can be used to select assignment topics, suggestions for designing an effective assignment, some suggestions for suitable source materials, and guidelines on how to avoid plagiarism. Sample assignments are given at the end of this report.

Assignment Basis

There are different approaches that can be used to develop writing assignments. The focus of this guideline is the development of relatively short engineering writing assignments that can expand on what is covered in a traditional steel design course. The intent is to enhance the course material. Faculty should not approach writing assignments with the idea that they take course time away from the subject, but instead, faculty should view the assignments as a way to broaden course material. This writer believes strongly that writing assignments should be a part of the normal structural design curriculum.

The essential goal is to provide students with the opportunity to learn more about how structures behave. To do this, the writing assignment can focus on explaining the structural approach used, such as the bracing scheme, or it can be directed at understanding how different components contribute to the overall structural scheme. These goals can be met with relatively short written assignments combined with some simple, approximate calculations. Longer written assignments are more suited to project reports and theses, and these are outside the focus of this report.

The assignment consists of giving students an article about an existing structure, either a building or bridge. The first part of the assignment requires that students write approximately a page about basic structural design features. This part uses a series of questions on the basic design aspects. The written response requires that students explore how structural systems work. The second part of the writing assignments requires that students perform short, approximate calculations, involving either analysis or design aspects. These calculations reinforce the written material. The assignments are carefully explained so that students can focus their efforts on the essential structural elements. The assignments provide an opportunity to supplement the normal course material with discussions of different structural systems, such as the bracing approach or frame type. When the assignment is returned, further class discussion addresses concerns raised by the assignments.

All assignments include what are commonly referred to as ‘back-of-an-envelop’ calculations. The term ‘back-of-an-envelop calculation’ has been used by engineers and others as a label to indicate short, approximate calculations, that can fit on the back of an envelope. The goal is to get a reasonable estimation of some quantity, often using approximations for different variables and simple calculations. The calculations should be neither involved nor lengthy. The effort involved should be on the overall aspects and not on details. This approach often leads to a better understanding of how a structure behaves because the student avoids getting bogged down with details.

The back-of-an-envelop calculations are intended to show students how to make simple approximations that are similar to those made during the preliminary layout of a structure or those made during the checking process. Anton Tedesko wrote that, "*The use of computers has not diminished the value of back-of-an-envelop calculations. Intuition and experience guide a quick calculation, which may reveal the reasonableness or ridiculousness of a design before it gets too far*." (Tedesko, 1994, p. 6). A short article "Hand Calculations Rescue Lift" in Engineering News Record (1997, March 31) showed how back-of-an-envelop calculations allowed a large lift to proceed in a timely manner, farm more rapidly than would have been possible had the engineers resorted to a lengthy computer analysis.

Experience at the University of Connecticut has shown that back-of-an-envelop calculations provide students with an opportunity to focus on the overall behavior, rather than concentrating on details. A typical steel design course has many homework assignments that focus on the details. As an example, back-of-an-envelop calculations can be used by students to estimate the size of a major bracing member that must resist both wind and gravity loads. Through this process, students also learn how to check final designs. It is rarely correct to check either analysis or designs by repeating the full process used to obtain the original results. This would require more time than normally available, and the likelihood is that the same mistake is repeated. In addition, the back-of-an-envelop calculations can be used to provide an opportunity to emphasize that the design process requires both an understanding of specification requirements and the construction process.

Selection of Assignment Topics

Bean (1996) states that in preparation for designing specific writing assignments, teachers should first respond to a series of questions. The following questions have been modified from his list to fit the goals of the assignments proposed in this report.

1. What are the main modules in the course, i.e. what steel members and connections are covered in the course?

2. What are the main learning objectives? Should students concentrate on specific applications of design specifications? Should students explore how steel frames behave? How should the construction be included with design topics?

3. Based on the experiences of former students taking the course, what parts of the course create the greatest difficulty for students? How might specific writing assignments address these problems?

4. What are the final goals that students need to achieve in the course?

The following are suggestions for areas that might be explored in the writing assignments in structural steel courses:

- Structural systems, such as the bracing system.
- The determination of forces acting on individual members, such as the maximum moment that must be carried by a plate girder or the force in one of the key bracing members.
- The determination of load paths for gravity and lateral loads due to wind or earthquakes.
- The determination of approximate members sizes, or the checking of an existing member size. To do this, it is not always necessary to conduct a lengthy, or rigorous, analysis. Through use of approximate analyses, students learn how to estimate member sizes for preliminary design discussions and more importantly, they learn how to check final designs.
- Comparison of two different approaches for the structural system. As an example, should the building use a braced or un-braced frame? What are alternative approaches to placing bracing in a frame?
- Bridges with similar design components or systems. While bridges are designed with a different specification, the overall design approaches are similar.

The assignment selection should be based on an article that provides an opportunity to conduct back-of-an-envelop calculations. These calculations typically require assumptions about the overall structural behavior. This requires that students focus on the design concepts, as opposed to detailed design requirements. As an example, students might be asked to determine the maximum force in the chord of a truss and determine if the size is adequate. Or they might be asked to estimate the size of one of the bracing members.

Assignments should provide students with sufficient information about the structure so that they can estimate member forces and member sizes. Generally, the article should have one or more structural drawings that can be used to do this. It is not always necessary to have all details, precise dimensions or actual loads. Some of these can be estimated and given to the students in the assignment statement. As an example, students might be asked to determine the maximum force in a bracing member, based on an assumed wind load that is provided by the instructor.

Suggestions for Designing an Effective Assignment

The guide by Freeman, et. al. (2000), notes that a writing assignment is analogous to a computer program. The expression "garbage in, garbage out" pertains to equally to both. A paper's quality begins with the assignment. Making the purposes and expectations of the assignment clear will greatly improve the quality of the final product.

The assignments proposed in this report are distinctive in that they combine writing with back-of-an-envelop calculations. Students should apply knowledge from the course content to the structure they are writing about. Requirements that are needed for longer papers, such as introductions and conclusions, are not needed. Since the student is expected to write about an assigned article, additional research with its need for citations is not necessary.

The following are suggested steps for development of the type of assignment discussed in this report. They are based on the need for both a written part and a calculation part.

1. Determine the purpose of the assignment. This defines the reasons for requiring students to write, which should be related to the back-of-an envelop calculations. The purpose might be to explore how a component behaves and to estimate the size of the member. Or it might be to suggest alternative approaches for either structural elements or frame systems.

2. Write out the assignment in detail. Identify what the assignment is expected to accomplish, how the assignment addresses issues related to the class, and what the student is expected to do.

3. Define the desired format. Specify the length (the minimum and maximum number of words are preferable to the number of pages), manuscript form, and other organizational details.

4. Define the audience. Where possible, it is desirable to create a genuine writing situation where students actually write for an intended audience. One possibility is to have students write to an audience that is not as knowledgeable about structural engineering, such as a community group of non-engineers.

5. State the process to be followed. Specify the due dates and need for planned revisions, peer review and other requirements related to the process.

6. Provide the criteria that will be used for evaluation of the assignments. Explain how the assignment will be graded.

7. Consider providing examples. Showing students examples of good papers submitted in previous years can be effective. Showing students a corrected copy of a poorer paper is another possibility.

8. Evaluate the assignment. Have colleagues, graduate students or other students at the same level critique the assignment. This is a good way to determine if there are details that are vague.

9. Provide a list of what will be evaluated. This list should address discipline-based elements (what are the main engineering components that the writing is supposed to address?), writing style (is there a clear logical structure, are statements supported with convincing arguments?), and mechanics (spelling, grammar, etc.).

The final product is better when students know fully what is expected when they work on the assignment. Additionally, students need to be encouraged to revise their work as they develop the final document. If students begin papers close to the due date, they will not have an opportunity to rethink and revise their initial drafts. Revision, with time between drafts, leads to better papers. Bean notes that when students write their papers the night before they are due, they insulate themselves from the intellectual struggles that occur with revision, where the true craft of writing is learned. Students should be required to use a word processor as this encourages revisions.

The following guidelines should help with the design of the steel design assignments.

- What structural components and structural systems are covered in the article? What is unique about the structure discussed?

- How is the material in the article related to that in the course? What can be used in the article to expand the course material? What structural applications included in the article are related to the formal course material?

- What items can be used for the back-of-an-envelop calculations? These calculations should focus the students on the important structural aspects and provide them with an opportunity to explore problems that might require more complexity and time if done 'exactly.'

As Bean (1996) notes, a good assignment "deepens students' engagement with course material, promotes critical thinking, and helps them to learn the discipline's discourse – its characteristic methods of inquiry, analysis, and argumentation.

In preparing questions needed for the assignment, it is important to ask questions that require the students to think about what they have read. Students should not be expected to regurgitate the material in the article. In addition, it is not necessary to assign full-length term papers or other longer papers. A single page is often sufficient, both for explanation of the structural concept and for providing the student with an opportunity to write about a real structure. The inclusion of the back-of-an-envelop calculations is useful in insuring that the assignment is not merely a synopsis of the material in the assigned article. Thus, these calculations can be used to expand what is learned, as well as to focus the written response.

As noted, it is important to carefully develop the assignment so that what is expected is clear to the student. A brief discussion when the assignment is given is often helpful. This should include interesting aspects about the structure, both those needed for the assignment and others. Explaining why the assignment was selected is beneficial. This discussion can be relatively short, 5 to 10 minutes.

The assignments can be tailored for use in design courses at any level. The key is to tie the assignment to topics currently being covered in the course. An assignment given in a beginning steel design course might involve a large truss over an arena or stadium; estimation of one of the chord sizes could be tied to the course material on tension or compression members. Assignments in more advance courses could consider the use of plate girders for longer spans. Assignments could also be given to small groups, though this can be problematic with respect to who does the work. Generally, student writing needs to be done be an individual. The back-of-the-envelop calculation could be carried out by the group, with each student doing his or her own writing. As an alternative if there is a series of assignments, the actual writing could be rotated through the group members.

<u>Suggested Assignment Sources</u>

Articles used with the assignments can come from a wide variety of publications. They need to be those that address different structural possibilities, including design, analysis, architecture, construction and failures.

- Modern Steel Construction, American Institute of Steel Construction
- Civil Engineering Magazine, American Society of Civil Engineers
- Structure Magazine
- Engineering News Record
- Case studies provided by engineering and construction companies
- Internet articles on structural steel structures

It is important to be careful with respect to copyright issues when assignments are reproduced for students or placed on web sites. It is suggested that instructors check copyright issues with their educational institution.

Guidelines on How to Avoid Plagiarism

Engineering Codes of Ethics, absolutely critical to the practice of engineering, state that engineers must not be deceptive and that they should not affix their signature to any plan or document that they are not responsible for. Students need to be reminded that plagiarism is unethical, both on a personal level and on a professional level.

Students should be encouraged to discuss the assignments prior to writing, especially with each other. However, each student must write their own response to the questions and perform their own calculations. Group writing ultimately leads to writing by a single group member.

There is much material currently available on plagiarism. Many universities and colleges have developed their own guidelines. The University of Connecticut has been developing a comprehensive approach for application to all areas within the University. There are two aspects to plagiarism that apply to the proposed assignments. The first aspect is obvious, i.e. students must not copy the assignment from other students. The second is that any material used directly from the article must be appropriately referenced.

Plagiarism occurs when a writer uses someone else's language, ideas or other original material without acknowledging the source. Sources of words, ideas, derivations and data must be acknowledged by referencing the source. If verbatim statements are included, they must be included in quotes.

The proposed assignments, combining relatively short written assignments with back-of-an-envelop assignments are less likely to lead to plagiarism, providing that students do not copy another student's assignment. The combination of writing and calculations is somewhat unique, and so solutions are unlikely to exist on the internet. Experience has also shown that when the assignment is not long, students are less likely to search the internet for material. Nevertheless, the following guidelines should reduce, and hopefully eliminate, plagiarism.

- Carefully defined questions assure that students do their own work. The assignment should not require a direct review of what is said in the article, but instead it should be based on the discussion of ideas presented in the article.

- The following statement can be supplied with each assignment: "Students are encouraged to discuss with each other the assignments prior to writing. However, each student must do their own writing and develop their own calculations."

- Students can be told that the best way to approach the assignment is to first read and understand the article, thinking about the assignment requirements. This should be followed by writing about what has been learned, without direct reference to the article. In doing this, students should think about what has been learned, not about the process of writing. This lessons the tendency to just transfer statements from the article to the assignment.

- Bean (1996) suggests that students should be asked to save notes, drafts and other information developed during the assignment and to turn these in with the final assignment. This both encourages students to follow the recommended processes and effectively discourages plagiarism.

- Students can be asked to sign a statement such as "All work submitted is my own work, except where I have given appropriate references."

Example Assignments

Example assignments are included at the end of this document. The first two have been used a number of times at the University of Connecticut. The next two are given to show how assignments can be developed to include both writing and back-of-an-envelop calculations. These examples are followed by two assignments that have been used that follow a different approach. They show how the basic approach can be modified to give students an opportunity to focus on well-known structural problems.

The first assignment also contains the assignment used at the University of Connecticut, an example of the calculations desired, an example of a student's written response with the instructor's corrections, and a list of general comments provided to students when it is returned. Some of the key points pertaining to the assignment are as follows:

- The written portion of the assignment requires a page of writing, which is approximately what is needed to fully describe the structural system. Significantly shorter or longer assignments receive a reduced grade.

- The calculations as shown include some description of what is being done. Normally, one would not include all of the descriptive points, and the calculations could clearly fit on the back of an envelope.

- An example of a student submission, with the instructor's comments, is included to demonstrate the approach used for evaluation. As is shown, there are general comments on organization and style, typically given in the margins. In addition, there are underlined portions with abbreviated notes give to indicate problems (the abbreviations are described in the next section). At times, it is easier to show how something should be changed, as opposed to simply noting that there is a deficiency. Some comments on the example writing assignment show this. However, as noted in the following section, it is often best to require that students reflect on how their writing should be changed and then make the change. The evaluation ends with a general comment that is intended to give the student an overall view of how he or she met the assignment's requirements. Major problems with the written description are noted in this end evaluation.

- A list of general comments, collected with repeated use of this assignment, follows. This list is used with the in-class discussion when the assignment is returned to the students.

RESPONDING TO STUDENT WRITING

The guide by Freeman, et. al. (2000), notes that responding to student papers is undoubtedly the most time consuming part of these assignments. A set of instructions for providing feedback to the students is developed in this section.

With care, the time needed to respond to writing assignments and grade them in upper level university courses can be reduced. Students typically will have had ample opportunity to learn to write by the time they are juniors and seniors. While there is a general feeling that junior and senior students have not learned how to write, instructors of freshmen English courses will state emphatically that students have been provided with good writing instruction. Engineering students need to realize that writing in an engineering course is as important, if not more important, than that in their earlier courses. The ability to write in engineering disciplines is one of the keys to being a successful engineer, regardless of the area of employment. Bean (1996) suggests that faculty members convey the following message to students: "It is socially unacceptable to submit written work with an annoying level of error. You may damage yourself irrevocably in business and professional life if you do so. You might as well learn the habits of careful editing and proofreading now while you are in college."

General Guidelines for Responding to Student's Writing

Experience has shown that the grading of writing assignments in upper level courses does not need to require substantial grading effort. The guide by Freeman, et. al.(2000), emphasizes that responding to student writing is different from editing it. Students should be responsible for identifying and correcting their mistakes in grammar and spelling, not the instructor. Thus, it is only necessary to identify examples of mistakes. This project will outline an approach for the efficient reviewing of the written assignments that can be used so that students take responsibility for their writing. Instructing students how to correct their own work will make them much better writers.

Students learn very little about writing when the instructor, or grader, corrects and rewrites the student's paper. Responding to student's writing falls into two general areas: (a) breadth of the ideas and critical analysis; (b) mechanics and grammar. Experts have noted that it is most important to focus on the breadth of the ideas and critical analysis. Bean states that most writing difficulties involve problems with critical analysis. Typical problems are the lack of a clear, focused thesis, illogical organization and the absence of analytical supporting evidence. Thus the focus in evaluating writing should be aimed primarily at improving students' engagement with the subject matter and not directly at improving student writing. The link between writing and critical thinking should govern the evaluation. As Bean (1996) notes, writing instruction goes sour whenever writing is conceived primarily as a communication skill rather than a process for critical thought.

Bean (1996)strongly recommends that comments on papers should be "revision-orientated" as opposed to "editing-oriented." Marking and commenting strategies should encourage students to spend time doing their own proofreading and editing. This leads to the need for revisions. The revision-orientated approach tells students that the "current draft needs to be dismantled and the ideas thought through again." Students need to be held responsible for fixing their own errors, and this reduces the marking effort needed. One approach is to withhold or lower a grade until a student revises a paper for re-review. As Bean states, "the best advice to give students about a passage is not to edit it for errors but to tell the students that they should rewrite it for clarity and coherence." Thus, put a comment on a paper that merely says "Edit for sentence error." Another comment might be "Rewrite paragraph to improve the flow of ideas."

The following guidelines are presented to help instructors focus their comments on the important elements in the student's writing.

- Emphasize revision during the writing process. Good writing rarely occurs in the first or even second try. Students should be expected to revise their writing before it is submitted. If it is clear that this is not done, the paper should be returned for revision.

- Ask questions as a reader, not as a teacher. Asking questions is preferable to rewriting parts. This approach encourages students to think about how changes should be made.

- Be positive and specific. Offer suggestions that can help students clarify their writing. This can involve asking for better descriptions of processes, or asking students to explain their assumptions.

- Evaluate the assignment with dignity. It never helps to show sarcasm. Bean's advice is to treat the student's work with the same sensitivity that we would use to evaluate the work of one of our colleague's.

- End comments are important. Summary comments provide an overall impression of the paper and emphasize how the paper can best be improved.

- Resubmission is highly beneficial. Writing is a skill that is developed over time, through continual revision. Requiring multiple drafts with revisions leads to improved writing. It is not necessary to grade drafts. Only general comments should be given in the review of drafts. Even if it is not the intent to have students rewrite a paper, feedback should be provided to show students how they could revise the paper.

- It is noted in by Freeman, et. al. (2000), that most writing experts agree that instructors of writing should minimize comments on the mechanical issues of grammar and spelling. As noted above, it is much more important to concentrate on helping students improve the writing process and the substance of their work. Bean notes that research has shown that students will improve more quickly if they are required to find and correct their own errors.

- If the instructor focuses primarily on spelling and mechanics, then so will the students. One way to avoid grammar overkill is to focus on a single paragraph or two, edit it thoroughly, making suggestions on content, organization, style and mechanics. The student should then be asked to make appropriate revisions throughout the rest of the paper.

- One approach is to not make any corrections in spelling and mechanics, simply pointing out to students that there are a number of grammatical errors that they need to correct prior to resubmission. This put the focus of the corrections on the student.

- Requiring students to read their drafts in peer response groups can be effective. Bean says that good writing grows out of good talking. The process of reading aloud forces students to go slowly. In this way, they can often catch mistakes that they overlook when they go through the document more rapidly. Using a group to evaluate drafts is similar to the team approach used to make major decisions during the engineering design process. Discussion of assignments within small groups can lead to better writing.

- Freeman, et. al. (2000), note that learning to critique improves ones own writing. Peer evaluation, where assignments are given to one's peers to evaluate, is the basis for much of our professional writing. Thus it is appropriate to use this approach with writing assignments. The instructor should provide guidelines for all peer exchanges.

    - This writer has prepared the following guidelines for students to use in evaluating each others writing. All evaluation is done anonymously, with evaluators chosen from the opposite side of the classroom. There is no grade for the evaluation; experience has shown that most students learn from the opportunity to do the evaluation of the assignment.

Evaluate the writing assignment for the following:

1. Overall clarity – does the paper have a clear focus? This question should not be answered with a 'yes' or 'no.'
2. Organization - is the paper divided appropriately into paragraphs, with one general idea per paragraph?
3. Awkward phrasing - underline and write 'awk'
4. Redundant statements and phrases - underline and write 'red'
5. Wordy sentences and phrases - underline and write 'wordy'
6. Provide other *helpful* guidelines.

Your contributions are to be helpful, not critical. Keep in mind what would be of help to you if you were asked to rewrite the assignment.

- The guide by Freeman, et. al.(2000), has additional guidelines that can also be used by students to evaluate the writing of their peers. Does the paper have a clear purpose? Is the organization logical? These questions can't be answered with a yes or no. They also recommend use of a check list of errors.

- While the use of computer spell and grammar checkers is generally worthwhile, students still need to proofread carefully. The following has appeared on the internet anonymously, and it demonstrates this point clearly.

> Ode to the Computer Spell Checker
>
> Eye halve a spelling chequer
> It came with my pea sea
> It plainly marques four my revue
> Miss steaks eye kin not sea.

- Checklists can reduce the time spent grading. The following check list, adopted from the document by Freeman, et. al.(2000), covers both general areas, i.e. the breadth of the ideas and critical analysis, and mechanics and grammar.

Content
1. Quality of ideas
2. Quantity of ideas
3. Relevance to topic
4. Development of paper

Structure of Paper
1. Clarity of focus
2. Continuity
3. Arrangement of parts
4. Transition among parts
5. Logical progress of paper

Mechanics
1. Punctuation and grammar
2. Sentence structure
3. Spelling

- Simple corrections, such as those needed for example grammar and spelling errors, are easier to note using a list of abbreviations. An example set of abbreviations that has been used by this writer is shown in the following box.

Awk	Awkward phrasing
Punc	Punctuation error
Red	Redundant; repeating what already said
Sp	Spelling
Sub	Sentence needs subject
Verb	Sentence needs verb
Wordy	Extraneous words, shorten sentence

- Assigning grades requires care. It is important to give the student appropriate feedback, with an appropriate grade. Generally, grades at the top and bottom are relatively easy to determine, i.e. an A or an F. It is those in between that are not always easy to determine. A few subjective guidelines can assist in this process. One way is to tie the grade primarily to the quality of the ideas, the development of the paper, including the outline and continuity, the logical thought process and whether the writer answers the key questions in the assignment. Tying the grade to a grading guide provided to the student helps. This writer has used the following general guidelines, covering both the written portion of the assignment and the back-of-an-envelop calculations, assigning 5 points to the writing and 5 points to the back-of-an-envelop calculations.

The writing will be graded based on your presentation of key ideas. Approach the assignment as if you are writing to describe the material to a student in the course. Organize your paper so that your points are clear to the reader. Normally, you should use a paragraph for each idea or topic. The grade for the written part will be based approximately on the following:

5 - Well done, clear, good writing
4 - Major error in answer to question <u>or</u> writing needs work
3 - Major error <u>and</u> writing needs work
2 - Inadequate length and discussion

The calculation portion of the assignment has a two-fold goal. First, it expands on the material discussed in the written portion. Secondly, it provides a way to explore key design areas in a simplified way. The required calculations are what are often referred to as back-of-an-envelop calculations. They should not require a lot of space or great detail. They are approximate calculations only. This type of calculation is used to get a general idea on the feasibility of a design component, to explore different alternatives or to check more detailed calculations. The grade for the calculation part will be based approximately on the following:

5 - Well done, with correct general approach and no errors which are major (answer within approximately 20% of expected solution)
4 - One substantial error (answer off by more than 20-30% or do not include all aspects in calculation or major error in assumption)
3 - Two errors as described above in 4
2 - Three errors as described above in 4

As Bean (1996) has noted, many teachers across the curriculum believe that because they struggle with their own writing and because they do not know the grammatical terminology and composition theory, they lack the skills needed to help students with their writing. Since the best commentary on a student's writing focuses primarily on ideas and development, we should all be able to evaluate student's writing effectively. As Bean also notes, teachers simply need to be honest readers, making comments like: "I got lost in this part." "You need better evaluation here." "Excellent point."

Determination of the weight of the writing assignments in the total course grade should be related to the portion of the time spent doing the assignments. Bean states that basing 10 to 15 percent of the total course grade on the writing assignment leads to increased student effort in the course and more engaged learning.

When students know what is expected, particularly after they have submitted an initial assignment and have received feedback that is directed at helping them, they do improve in subsequent assignments. If they feel they are a critical part in the process that is needed to improve their writing, they will perform at higher levels. Students need to be convinced of the importance of writing, both while they are students and during their careers.

Ideas for Reducing the Workload

Bean (1996)devotes a chapter to timesaving strategies for coaching students through the process. He emphasizes the need to design good assignments and the need to clarify grading criteria at the onset. In addition, devoting a class to the generation of ideas associated with the assignment can be beneficial. He recommends that students be divided into small groups to discuss the basic ideas, or that they work in pairs where students interview each other about their progress. Submitting something early in the process helps students get underway. He does not recommend outlines as this can distort the process. Also, the word 'outline' carries unfortunate baggage.

There are a variety of options that can be used by the instructor to reduce the amount of time needed to respond to student's writing. These include the following approaches.

- Students can grade each other's assignments, either in small groups or individually.

- Not all assignments need to be graded. Grading only selected assignments, is the same approach used by those who give pop quizzes. Students do not know ahead of time if the assignment will be graded. As Bean notes, students benefit from all writing that they do, no matter how it is evaluated.

- Providing limited, but essential, feedback on the breadth of the ideas and the student's critical evaluation is an effective way to respond to student writing when there are significant time constraints.

- Students can evaluate their own writing assignments. This is similar to requiring successive drafts. It is one way to assure that there are successive drafts. On the due date, the instructor can inform the student that they need to grade their own paper and then revise it accordingly. Students should be asked to turn in the original paper with their comments and the revised paper.

- Students can be asked to turn in a portion of the assignment, prior to the submittal of the final assignment. This helps to assure that the student understands what is needed, and thus it can improve the final submittal. What is submitted should be simple to check, such as a free-body diagram showing the essential features and forces for a building frame.

- Students with significant problems can be referred to the university or college's writing center.

ASSESSMENT TECHNIQUES

At times, it is desirable to evaluate the effectiveness of these assignments to demonstrate the benefits that the assignments bring to student learning and thus convince the instructor that the effort required is worthwhile. The assessment process should be easy to conduct, yet effective, and accomplished with a minimum amount of effort.

The following fundamentals should be considered in the development of any assessment approach used to evaluate these assignments:

- A common approach used for assessment is to give pre- and post-tests to see what has been accomplished. The initial test, given at the beginning of the assignments, establishes a baseline. Then testing at the end demonstrates what has been learned. One approach is to have the first set of assignments evaluated by two or three individuals, dividing them into two piles, those that are acceptable and those that are not acceptable, based on some given parameters. This is then repeated with the last assignment. The percentage of assignments in each pile then forms a rough, but effective basis, for evaluating the student's accomplishments.

- The assessments tool should be narrowly focused to address important concepts only. If too many items are assessed, the process becomes tedious, both for the student and the instructor. A small number of guidelines should be adequate to demonstrate the effectiveness of the assignments.

- A common approach to assessment is to compare students who have done the assignments with those who have not done them. This is not readily applicable for use in most courses, except in courses where only some of the students do the writing assignments. Thus, it is not felt to be an effective technique for what is proposed in this report.

- Assessment is best done by outside evaluators, and not the teacher of the course. Preferably, this should be done by those who either do not know the students, or the names should be removed. One assessment technique is to use peers, i.e. have different groups of students evaluate assignments of another group. Names should be eliminated. This is an effective learning process for all involved, and there is evidence that students write better when they know that their peers are involved in the evaluation process.

- It is important to develop a set of guidelines for use by the assessors. What is most important? A few general guidelines are more readily evaluated than a long list of guidelines. The assessment approach should not be decided by the individual assessors.

- Writing is about conceptualizing ideas, and thus assessment should be based on this. The process should consider the audience that the writing is intended for. Is the writing focused on providing other engineers with information that they can use? Or is the writing intended to show non-engineers how different structural engineering concepts are used in a design? Ideally, assessors should be taken from the intended audience.

With ongoing assessment and review, based on a variety of benchmarking tools, assignments can be modified and refined to provide students with the best strategies for improving their understanding of structural engineering. The assessment techniques should focus on the primary learning objectives. The writing portion of the assignments should be assessed to evaluate the how students are addressing the breadth of ideas and their critical analyses, not the mechanics, i.e. spelling and grammar. The calculation portion is more difficult to assess. Nevertheless, the assessment process should address the students' abilities to conduct short, approximate calculations that show that they have insight into the structural behavior. Tests in steel design courses traditionally focus on details and individual members. The back-of-the-envelop calculations are intended to address the overall behavior, and thus assessment should address how well the students are achieving an understanding of structural behavior.

The results of the assessment process should provide a basis for convincing colleagues, department heads, and deans that the effort to introduce these assignments is worthwhile. The assessment should clearly support faculty who increase the opportunities for their students to expand their learning opportunities in their design course. Faculty rewards should acknowledge good teaching, and the introduction of new, worthwhile concepts in one's courses should be recognized. An assessment process should be useful to achieve this goal.

WHY EDUCATORS SHOULD INCORPORATE WRITING INTO THEIR STEEL DESIGN COURSE

Assigning writing assignments is important because it expands the student's learning process. This is the fundamental reason for using these assignments in steel design courses. Writing assignments should not be given just to provide students with new opportunities to practice writing.

Freeman, et. al. (2000), present what they call "Myths and Realities in Teaching Writing-across-the-Curriculum." These were developed to convince agriculture faculty members to introduce writing assignments into their courses. The myths and realities, with some alterations so that they better apply to steel educators, follow.

> **Myth 1**: I have to be an expert writer to teach writing. **Reality**: Any teacher can use principles developed for writing-across-the-curriculum to give and evaluate writing assignments.
>
> **Myth 2**: I have to like to write in order to teach writing. **Reality**: It is only necessary to believe that writing is important.
>
> **Myth 3**: I can't teach writing **–** it is not my field. **Reality**: We all write a lot, and the principles of teaching writing are not complicated.
>
> **Myth 4**: If I teach writing, it will take away valuable time needed to teach the subject matter. **Reality**: If we incorporate writing as a way to learn course material, we will be teaching both how to write and we will be conveying a deeper understanding of the subject at hand.
>
> **Myth** 5: I am already overworked and stressed out - I can't possibly manage the extra paper load. **Reality**: The guidelines developed for teaching writing-across-the-curriculum in this report have been developed so that the paper load does not become excessive.
>
> **Myth 6**: If I focus on writing-to-learn, it will be at the expense of learning-to-write. **Reality**: The best way to learn to write is to write as often as possible.
>
> **Myth 7**: Writing is elegant and easy for real writers - it is hard and messy for me and thus, how can I teach my students? **Reality**: Writing is hard and messy for nearly everyone - writing to learn is no more difficult than solving problems and conducting experiments to learn.

> **Myth 8**: I've never been trained to teach writing - I can only teach the way I have been taught – with lots of emphasis on grammar, spelling, and rules. **Reality**: Writing to learn, as opposed to focusing on the mechanics of writing, is something we all do.

The presentation of the above myths and realities is intended to help convince engineering educators that they should assign writing assignments in order to expand their students' learning opportunities. Educators should see writing assignments as useful tools that help students achieve the overall goals for the course. As Bean has noted, the reward is seeing students come to class better prepared, more vested in and motivated by problems addressed in the course, more apt to study rigorously, and more likely to submit high-quality work.

Bean (1996) also addresses the concern that emphasizing writing takes time away from course content. Emphasizing writing and critical thinking in a course increases the amount of subject matter that students actually learn and in many cases increases the total content covered in the course. He notes that the primary effect of adding writing and critical thinking components to a course is that it restructures and transforms the students' study time outside of class. This promotes better study habits, and it helps students to see their learning as purposeful and interesting. Based on experiences at the University of Connecticut, improvement in study habits is transferred to other non-writing assignments.

It is the view of this writer that the back-of-an-envelop calculations required for the assignments in this report have become even more important as the use of structural design software has increased. Today, entire floor systems and structural frames are designed using commercial software. The process is automatic, and it often requires very little calculation effort or thought. The danger is that the numbers that are generated by the computer appear to be precise, and thus it is too easy to accept the computer output without thinking about the actual numbers. What students need to understand is that they must view these numbers critically. Using an understanding of the behavior with simplified assumptions and approximations, they can check computer results. The back-of-an-envelop calculations as discussed in this report provide students with an approach that can be readily used to check designs, both those obtained from computer software and those obtained from hand solutions.

Another reason for adding the proposed writing assignments to steel design courses is that the both the writing and calculations strengthen ABET requirements (Engineering Accreditation, 2004). As noted in these requirements, engineering programs must demonstrate that their students can communicate effectively. Writing across the curriculum is based on providing writing opportunities in student's individual majors. The back-of-an-envelop calculations also reinforce the ABET criteria for Civil Engineering Programs that states the students must demonstrate "the ability to perform civil engineering design by means of design experiences." While students do not explore the full design process in these assignments, they do have the opportunity to evaluate and criticize designs. The incorporation of the proposed writing assignments is thus another way to satisfy major ABET objectives.

SUMMARY

Writing assignments with back-of-an-envelop calculations have been proposed to get students to focus on the art of structural engineering, to look beyond the design of specific elements and connections. The writing assignments address the overall behavior of the structure. By using back-of-an-envelop calculations in conjunction with the writing, students learn how the structure behaves using short, easily managed assignments. The assignments typically require consideration of different structural approaches. Examples that have been successfully used have included comparison of the use of bracing versus rigid frames in tall buildings, evaluation of approaches used to cantilever exterior floor areas, and comparisons of cable-stayed bridges with suspension bridges considering suitable span lengths. The writing assignments with back-of-an-envelop calculations also provide a basis for further discussion of structural design in class. The primary goal of these assignments has been to provide an opportunity to explore the major aspects of structural engineering, without detracting from the normal course lectures and assignments that focus on the design of specific elements and connections.

In summary, written assignments provide a format for organizing and communicating information about load paths, framing approaches, different design alternatives and how design influences and is influenced by construction practice. The goal of this report has been to show how writing assignments can be used efficiently in a traditional steel design course in order to help students explore how structures behave and to learn more about the overall design process.

ACKNOWLEDGEMENTS

In 1987, I set out to introduce writing assignments into my steel design course so that I could explore how structures behave, with the goal of expanding what I was doing with the conventional steel design assignments that were focused on learning how do design individual elements, i.e. beams, columns, beam-columns, connections, etc. I have had considerable help along the way. Most of what I have done has been based on what others have done. I have had the privilege of being a member of the AETNA Advisory Board at the University of Connecticut. This board was created by Lynn Bloom, AETNA Chair of Writing and Board of Trustees Distinguished Professor in the English Department, to provide overview to writing efforts across the campus. One of the goals of the AETNA endowment has been to expand student writing in the University. Professor Bloom has presented numerous workshops and has spent considerable time working on the development of writing courses at the University. As a member of the Committee, I have had the opportunity to explore how writing could be used in my steel design course. I continue to be grateful for having had the opportunity to work with Lynn Bloom.

Professor Bloom has also worked with a group of agriculture professors at the University to develop a guide for incorporation of writing assignments into their courses. This guide, “Improving Student Writing in the Agricultural Sciences,” has been invaluable in my teaching of writing. I have liberally quoted from this Guide in this report. Many of the ideas expressed here have been taken from this excellent report, and the authors deserve considerable credit for putting together a clear, comprehensive guide for introducing writing assignments into professional courses.

A comprehensive guide that addresses writing across the curriculum is “Engaging Ideas – The Professor’s Guide to Integrating Writing, Critical Thinking, and active Learning in the Classroom“ by John C. Bean. In the Foreword to this publication, M. Weimer states that the book is analogous to an *owners’ manual* for teaching writing in many different areas. It is a book that every faculty member can turn to when efforts to develop writing and critical thinking skills need support. It has been an excellent resource in developing this report. This author has quoted liberally from Bean’s work, and he has used many of his recommendations to expand the guidelines presented in this report. It is highly recommended as a resource to all who are assigning writing in their courses.

Scott Brown, Professor and Director, Educational Psychology, University of Connecticut, has provided material on assessment techniques that I have adapted to use for the assignments described in this report. Assessment is an important area in education, and many institutions have experts that can assist with this process. True assessment needs to go beyond normal teacher evaluations because these tend be based on more general ideas.

When I first started using writing assignments, I relied heavily on the Bethlehem Steel Building Case Histories that were provided to engineers and educators. These relatively short reports, with excellent photos and design drawings, formed the basis of a number of the earlier writing assignments in my course. The American Institute of Steel Construction *Modern Steel Construction* has also been excellent source for articles. Engineering News Record has had some good supplementary articles. I gratefully acknowledge these sources. Hopefully, the American Institute of Steel Construction will be able to work with designers and contractors to develop additional resources that can be used in steel design courses with the proposed writing assignments.

Most of all, I am appreciative of the many comments from students. While they have never failed to state that an engineering course should be about numerical problems and not writing (some have said that one of the reasons they are in engineering is because they will not need to write), they have generally responded favorably to the assignments. Some of the discussions in my office, both before and after the assignments, as well as during discussions in class after the assignments are returned, have shown the benefits of the assignments. The combination of writing with back-of-an-envelop calculations has given students an opportunity to study real engineering structures. Former students have continued to note that the writing assignments are what they most remember about the course (they have also acknowledged that there is indeed a lot of writing in the practice of engineering).

I am finally grateful to the American Institute of Steel Construction who provided me with a grant do develop this document and who are giving me the opportunity to explain to other educators the benefits of looking beyond the normal design assignments. The writing assignments have greatly added to my enjoyment in the classroom.

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EXAMPLE ASSIGNMENTS

The example assignments that follow demonstrate the approach used to incorporate writing and back-of-an-envelop calculations into steel design courses. Each example includes a brief description of the structure with information pertaining to the assignment, the assignment and the general goals of the assignment.

The first two examples have been used successfully for a number of years at the University of Connecticut. The next two have been not been used, but will be included in future offerings. They are presented here to show how a teacher might construct his or her own assignments. The articles that are used as a basis for these four assignments are included.

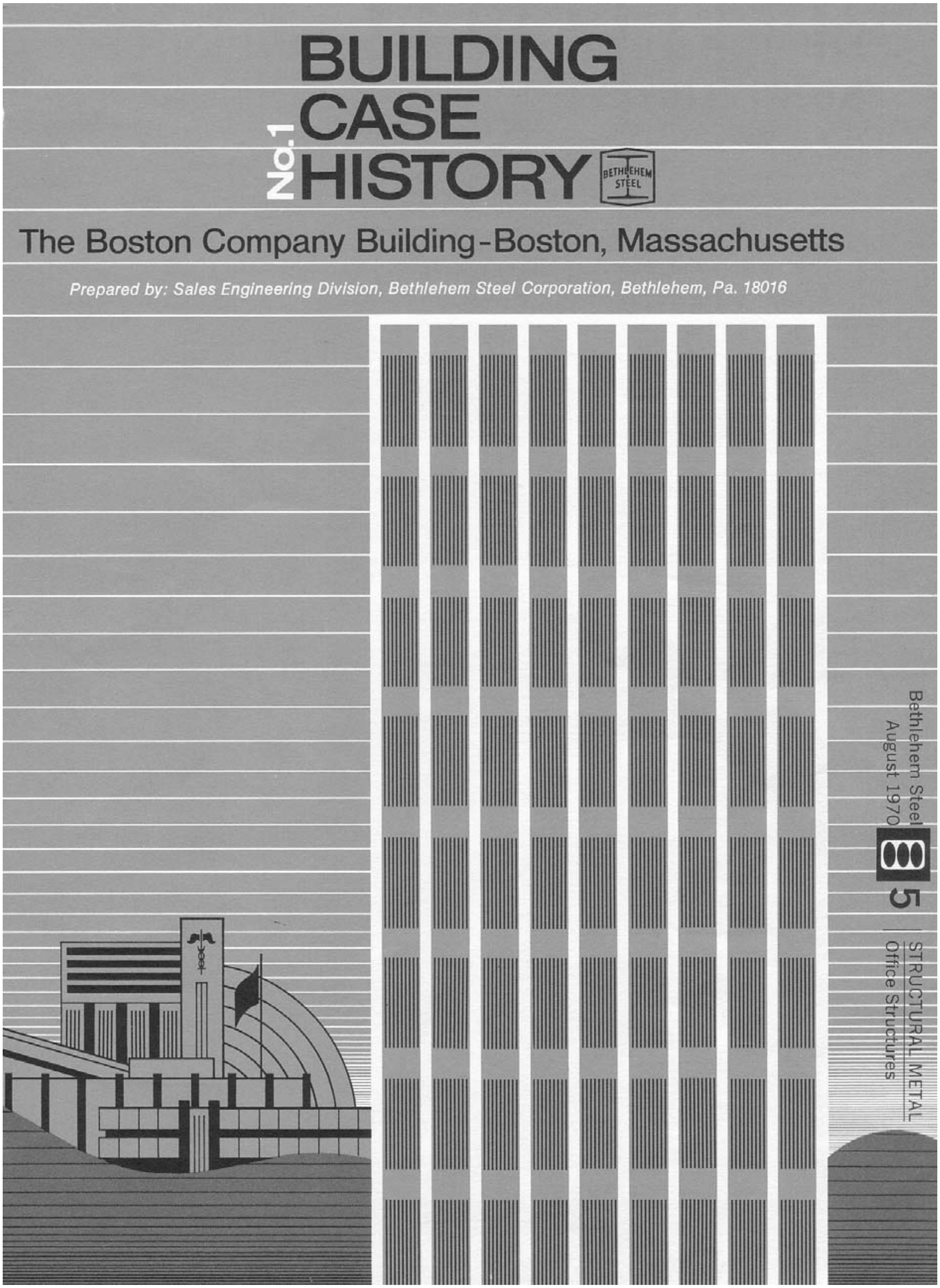
The four example assignments are followed by two additional examples that show how the basic approach can be altered to include articles about structures with real problems. Both of these were developed to include both writing and back-of-an-envelop calculations.

Boston Company Building

General Description - The Boston Company Building (Sales Engineering, 1970) is a 41-story steel framed office tower. It has a central core area with 9 columns and an exterior framing system, allowing for a column-free floor layout. The building uses vertical k-frame trusses to provide lateral stability and to transfer both the exterior gravity and the lateral loads to the ground. Interesting features include the use of the diagonals to carry the gravity loads in each of the three sub-sections and the fact that the building is open at the base. The result is that half of the entire live load is carried by the four corner columns at the base.

Writing Assignment - Students are asked to explain how the loads are carried by the framing system, with a discussion of both the gravity and wind loads. This discussion must include the function of the diagonals in the frame and note that they carry both gravity and wind loads. Students are told that they need to include a sketch showing the basic framing scheme. To do this, students need to understand how the floors are supported by the interior core and exterior columns and diagonals.

Back-of-an-Envelop Calculation – Students are asked to estimate the force in the lower diagonals at the junction with the corner columns. This reinforces the fact that the diagonals carry the full shear load from the wind and the exterior gravity load in lower portion of the building. To do this, students need to understand the floor framing scheme and be able to determine how the gravity loads are transmitted to the diagonals. They also need to understand how wind is transferred from the building's facade to the diagonals.



BUILDING CASE HISTORY
No. 1

The Boston Company Building - Boston, Massachusetts

Prepared by: Sales Engineering Division, Bethlehem Steel Corporation, Bethlehem, Pa. 18016

Bethlehem Steel
August 1970
5
STRUCTURAL METAL
Office Structures

Design innovations cut weight of steel frame

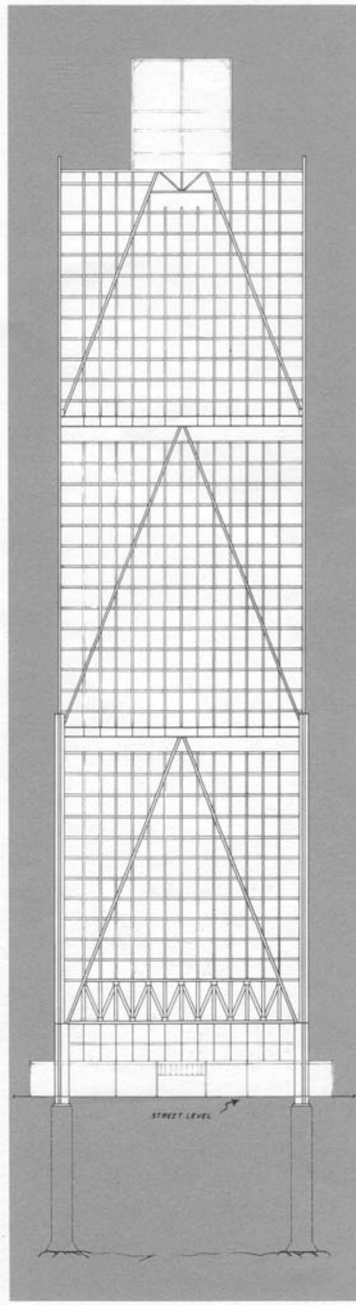
Boston—It's unusual when the steel framing for a 41-story office tower with column-free rental areas checks out at less than 21 psf. In fact, the engineers for the Boston Company Building believe it to be one of the lightest-weight structures of its type and size ever built. They estimate a steel requirement in the range of 24/25 psf to achieve comparable column-free floor areas with a more conventionally designed, rigid-frame structure.

Much has been published about the Boston Company Building's innovative wind bracing system. To fully comprehend the *significance* of the system, however, you should study a typical floor layout. Note that all floors are column-free between the core area and the outer walls, with spans of 42 ft minimum.

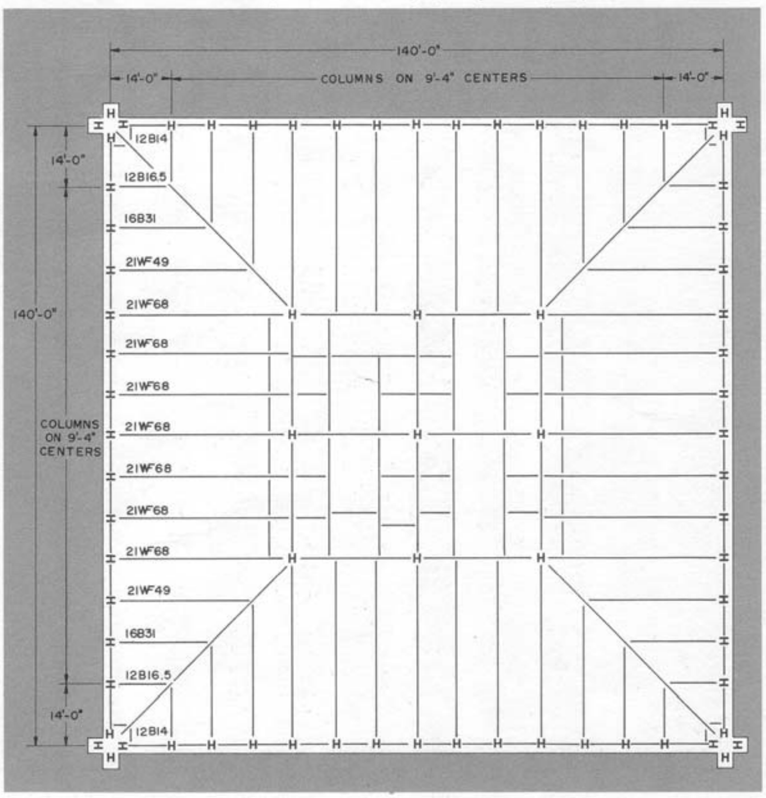
The service core and its tributary floor areas account for about one-half of the total gravity load. These loadings are carried by nine core columns. The remaining 50 percent, plus wind forces, is picked up by the diagonal members and then transmitted to the four corner columns. As explained later, the diagonal members also are components of the structure's wind-bracing system. The core carries wind loads from the fourth floor level downward.

Because the floor framing carries gravity loads only (including 80 lb live load and 24 lb for partitions), the framing is both simple in design and repetitive for almost all floors.

Wall framing elevation sketch, indicating the three wind bracing units described in the text.



Typical floor framing for the full height of the building. Some 42-ft-long 21 WF members are ASTM A572 Grade 50 steel (Bethlehem's V50, 50,000 psi min yield).



Use of lightweight composite cellular steel decking served a number of functions: it provided safe working platforms during construction; it minimizes dead load; it provides complete flexibility in locating power and communications outlets within the office areas; and it imparted rigidity during steel erection.

Three "stacked" structures

Insofar as the "external" loadings are concerned (50 percent of the total gravity loads, and all wind loads), the framing comprises, in effect, three separate structures sharing the same four columns. For example, loadings distributed by the exterior framing system of the topmost (12-story) unit are transmitted to the corner columns at the thirty-first floor level and thence down to the footings. The center (15-story) and lower (17-story) units function in a similar manner. There is, however, some additional transmittal of loadings downward between units through the diagonals.

Note that the intermediate vertical members within each unit (13 to a side, on 9 ft 4 in. centers) are not continuous vertically; they terminate at the base of each unit. The more closely spaced vertical members shown in the architectural rendering are actually non-load-bearing mullions.

In a sense there is yet a *fourth* structure. This is the two-story unit that is suspended from the massive trusses, 24 ft deep and 140 ft long, that form the base of the bottom exterior bracing system. This hanging unit has the dramatic effect of "floating" above the lobby.

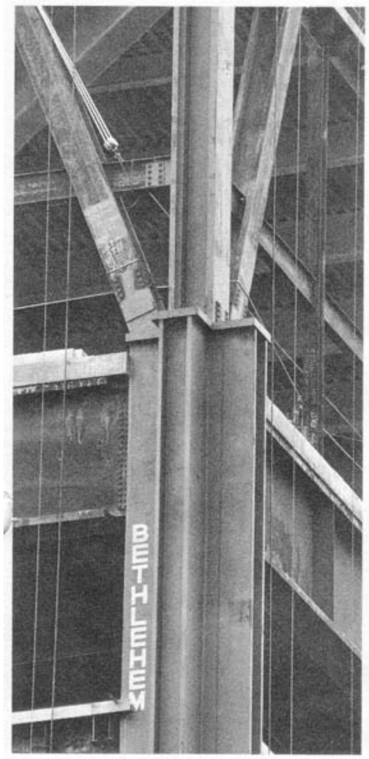
Triangular wind bracing

The lateral-load-resisting system has been described as a K-frame vertical cantilever truss. It is more easily understood, however, in terms of isosceles triangles with diagonals extending the full height of each wind unit, and tied at the base. The base ties for the upper two units are plate girders, while the truss serves this function for the bottom unit.

Gravity loads for the areas tributary to the exterior framing are carried to the corner columns by the floor framing and the diagonals. Wind loads are transmitted to the corner columns primarily by the diagonals. Some wind load, however, is taken by vertical members (thence via the ties to corner columns) to reduce bending forces on the diagonals.

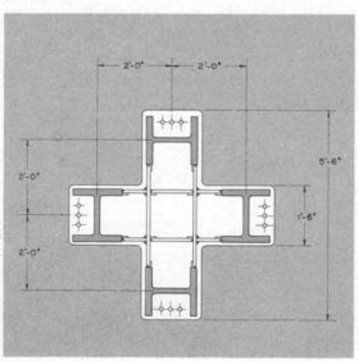
The vertical exterior members located above the diagonals in each unit are basically in compression, as are the bottom sections of those located under the diagonals, and the entire column which bisects the triangle. Those members immediately under the diagonals are hangers functioning in tension. A number of intermediate members may function in compression or in tension under varying loading conditions. The complexities of the system required exhaustive analysis by computer; indeed, the design would not have been feasible otherwise.

With the exception of twenty floor beams at each level and the core columns, for which consideration of economy dictated ASTM A572 Grade 50 steel, the entire structure called for A36 structural steel. Most field connections were high-strength bolted.

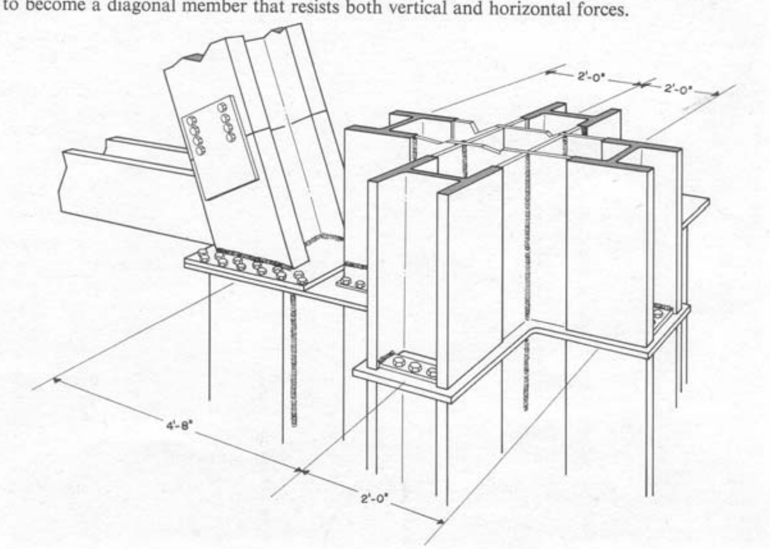


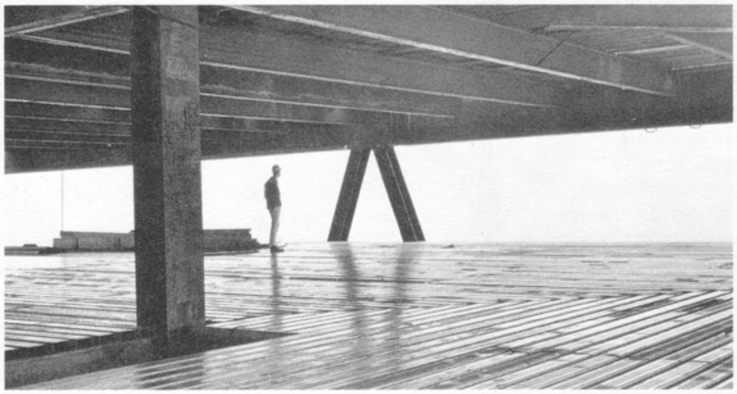
Column connection above the 17th floor, at transition from cruciform box columns to cover-plated H-columns.

Typical cruciform box-column section with 1-in. cap plate. The sections were erected in 2-story tiers, with simple high-strength-bolted splices 1½ ft above finished floor level.



Perspective sketch of a truss-bottom-chord-to-corner-column connection. The truss diagonal, spliced to a stub on the column cap plate, continues beyond the upper truss chord to become a diagonal member that resists both vertical and horizontal forces.





Floors are column-free between core columns (left) and the exterior. Note the absence of intermediate exterior columns at this level, which is immediately below the apex of a wind bracing triangle. Here the floor beams (top) frame into plate girders.

Steel erection

The structural design imposed a number of unusual problems on the erection engineers and work crews.

First, it was necessary to hold dimensions within close tolerances until the first braced unit had been completed. This was accomplished by providing an adjustable temporary falsework support at the midpoint of the 140-ft-long truss on each face of the structure. It remained in place until the diagonals were joined at the apex (see sketch of keystone section), thus permitting the falsework to be released and the entire system to function as designed.

Second, the base columns, rising 45 ft from their footings to the level of the truss bottom chords, were too

The massive lower sections of the corner columns support 2-story trusses, the end members of which extend upward to form the wind-bracing diagonals. Two levels of framing are suspended below the trusses.

large to be erected in one piece. They were erected in two segments, each measuring full height, the largest weighing 43-½ tons. The segments were joined with vertical welds. These base columns are unsymmetrically cross-shaped in section. One extended arm in each of two axes was required to receive the truss bottom chords and diagonals.

Above the truss connection at the fifth floor, and extending to the eighteenth floor level, the corner columns are of regular cruciform configuration (see sketch). Above the eighteenth floor 14-in. WF column sections are used.

Third, erection tolerances were extremely tight, both as a matter of specified tolerances and from the practical standpoint of making connections. The box-type columns, for example, had to be positioned within a 1 ½-in. (± ¾-in.) envelope.

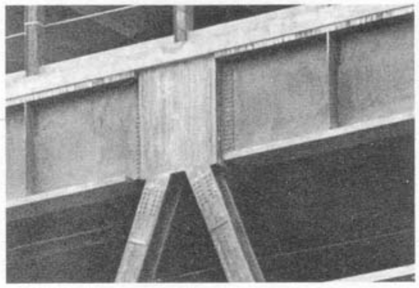
Fourth, design of floor framing made it necessary that erection guy derricks be positioned in the core area. They therefore had to be capable of handling loads at an extended reach. Except for some lower floors handled by crawler crane, steel was hoisted by AAA derricks with double guys, supported directly by seven large jumping beams.

Architectural features

The building's distinguished architectural treatment is worthy of the high quality of the structural engineering. Its skin will be a deep bronze tone, with solar-bronze windows. The closely spaced mullions will, to a large extent, obscure the diagonal braces.

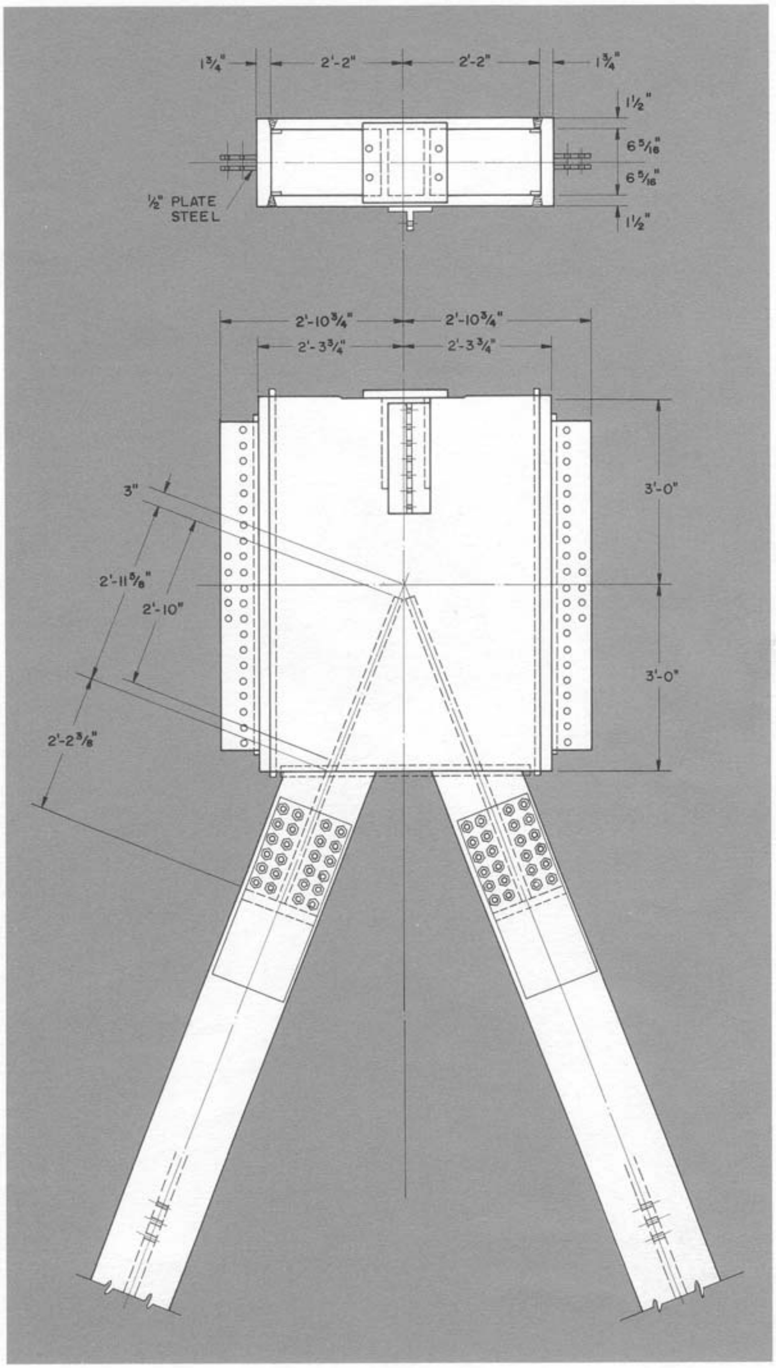
The tower is located on a street-corner plot measuring 37,000 sq ft at street level. An attractive octagon-shaped plaza, its supports sheathed in granite, rises above grade. At plaza level the lobby is enclosed in floor-to-ceiling glass. The 600-ft-high building offers a gross rentable area of 819,000 sq ft. It is planned for occupancy in mid-1970.

Owner/developer/manager: Cabot, Cabot & Forbes; *associated architects:* Pietro Belluschi and Emery Roth & Sons; *structural engineer:* The Office of James Ruderman; *mechanical engineer:* W. A. Digiacomo Associates; *general contractor:* Aberthaw Construction Co.; *steelwork:* Bethlehem Steel Corporation.



Exterior view of a keystone section more fully described below.

Sketch of typical keystone section. This prefabricated box-type section completes the apex of a wind bracing triangle and links the two plate girders which then act as a continuous tie (horizontal leg) of the upper triangular bracing system. Some vertical load is transferred from the girders downward through the diagonals.



Example Assignment:

Assignment: Boston Company Building

1. Describe (minimum of one page, 250 words) (a) how gravity loads for the main portion of the building (above the lobby area) are transmitted to the ground; (b) how wind loading is resisted by the frame. This should be done in your own words, not by copying sections from the article. You also should include one or more sketches with your description.

2. Estimate the total force in the lower diagonal where it intersects with the corner column (it is not necessary to include load factors). This should not involve detailed calculations, nor very precise numbers. This type of calculation is useful in laying out the structure to see if the framing system is feasible and in checking the final design. Assume that wind loading on the structure is 25 psf and that the gravity load in addition to the live load and partitions is 45 psf.

Example Student Submission:

The Boston Company Building behaves like three separate structures stacked atop one another. The lower most unit is comprised of floors four through seventeen while the other two units consist of floors eighteen through thirty-one and floors thirty-two through forty-one. The separation of the building into three separate structures determines the way the building transmits loads to the ground. At the bottom of each section, all exterior loads are assumed to be in the corner columns, which allows for a floor that has very few vertical structural elements along the exterior.

Gravity loads are carried both by interior columns and by four exterior columns which are located at the four corners of the building. About 50 percent of all gravity loads are transmitted from the floor system to plate girders which run along the outside edge of the structure via steel beams, while the rest of the gravity load is transmitted to the interior columns. After the gravity load has been transmitted to the outer edge plate girders, it is then picked up by either the diagonal members or the corner columns. Any load carried by the diagonal members is transferred to the corner columns where the diagonals and the columns intersect. A small portion of the gravity load is transferred from the flooring system to the diagonals via the relatively small vertical columns which are spaced 9'-4'' center to center. These columns are in compression above the diagonals while the columns below the diagonals are basically in tension.

Wind loads above the fourth floor are transferred to the corner columns primarily by the diagonal members. The diagonal system behaves like a K-truss, with most of the wind loading being taken at the intersection points of the truss. The load is then transferred from the truss via the diagonals, which will be either in compression or tension, to the corner columns. The corner columns then transfer the loading to the ground, and can experience either compression or tension as a result of the wind loading.

acting in

red

Instructor: Your description of the overall load patterns is good. You could eliminate some of the wordiness in some phrases. There is some repetition as noted.

General Comments Developed from Evaluations:

- The written portion should clearly separate the description of how the gravity and wind loads are carried by the structure.

- In describing how loads are resisted, it is best to follow the load paths. As an example, start with the gravity load on the floor system, describe how it is transferred to the core and the exterior and then follow it down to the diagonals and then to the corner columns.

- Poorly organized written descriptions are indicative of not fully understanding the load paths and way in which the loads are carried.

- Writing style problems include wordy descriptions, not breaking into separate paragraphs each with a separate idea, repetition of material and the need to use more direct sentences in technical writing.

- Students are reminded that use of simple free-body diagrams will help them organize their calculations.

Buffalo Academic Tower

General Description - The Buffalo Academic Tower is a steel-framed building on the Canisius College campus in Buffalo (Sales Engineering, 1972). It has a nine-story circular tower with offices that sits atop a larger two story structure with class rooms. The design had to deal with significant site, floor-to-floor and height limitations. Additionally, it was not possible to use columns on the exterior of the office tower since these would have extended through the interiors of the classrooms in the lower two levels. Thus a framing scheme was adopted that had columns only in the interior of the office tower, with diagonal tension members supporting the outer floor area. Interesting features include the fact that the tower is round, the use of a rigid frame in the interior core area combined with simple connections in the exterior tower areas and the floor framing system.

Writing Assignment - Students are asked to write about the framing scheme used in the tower. They need to address both gravity and wind loads. They also must discuss why the framing scheme was selected, and suggest alternative framing schemes. This needs to include different approaches for resisting the lateral loading and ways to support the exterior, cantilevered areas in the office tower. The discussion also needs to include advantages and disadvantages of the approach used to support the exterior, cantilevered floor areas in the tower, i.e. the use of diagonal supports.

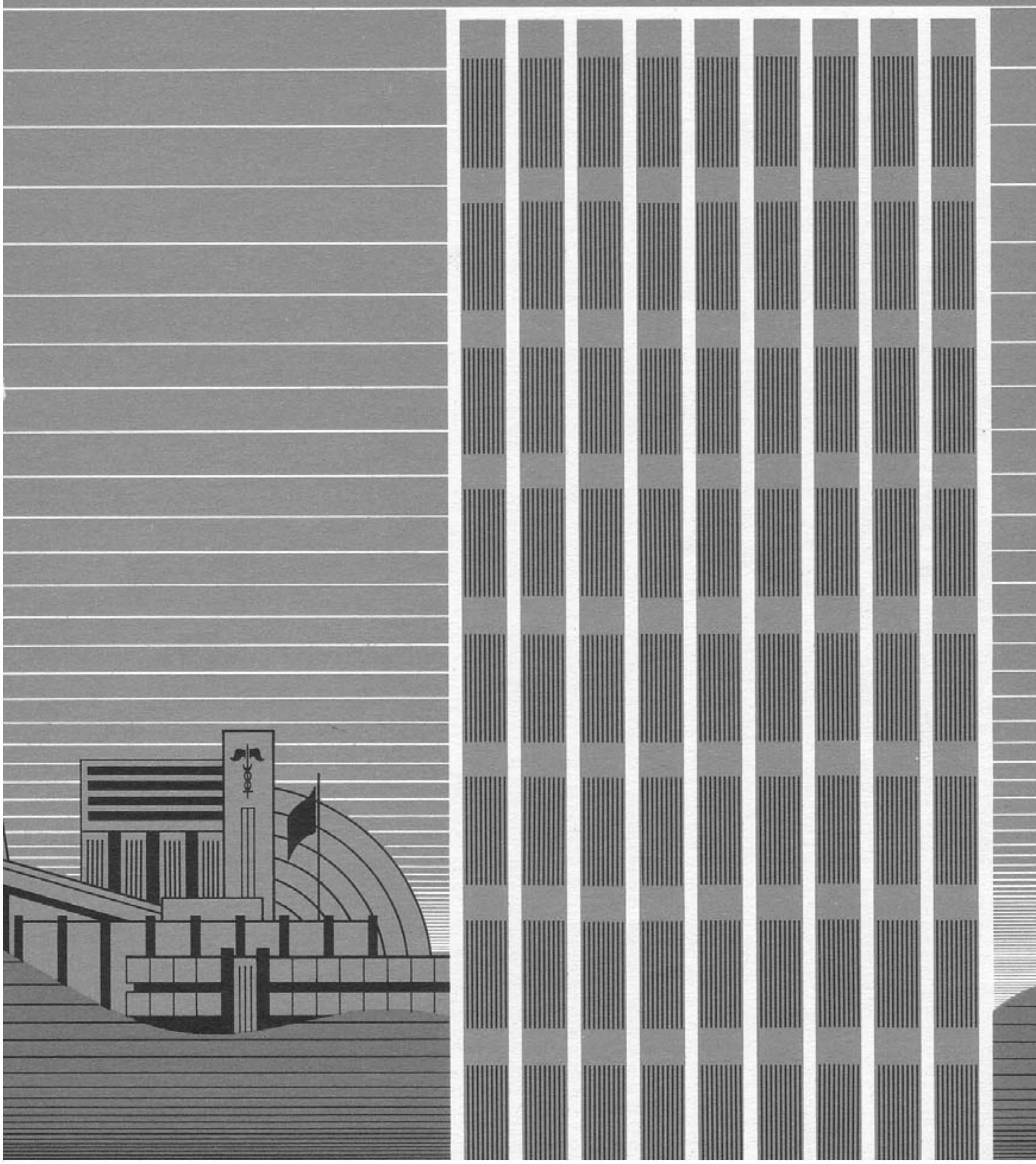
Back-of-an-Envelop Calculation – Students are asked to estimate the forces in the diagonals used in the tower to support the cantilevered areas and the forces in the beam directly supported by the diagonals. This requires tracing the loads through the floor system, with inclusion of the load from the exterior wall. The article does not include a load for the wall, so this is given with the assignment (it is often necessary to supplement material in articles so that students have sufficient information to do the back-of-an-envelop calculations). The solution requires that students understand how the loads in the floor system are transferred to the diagonal supports, using the floor framing plan given with the article. Students should also determine that the beams supported directly by the diagonals are beam-columns (this assignment is given during the unit on beam-columns).

BUILDING CASE HISTORY No. 18

Bethlehem Steel

Churchill Academic Tower, Canisius College, Buffalo, New York

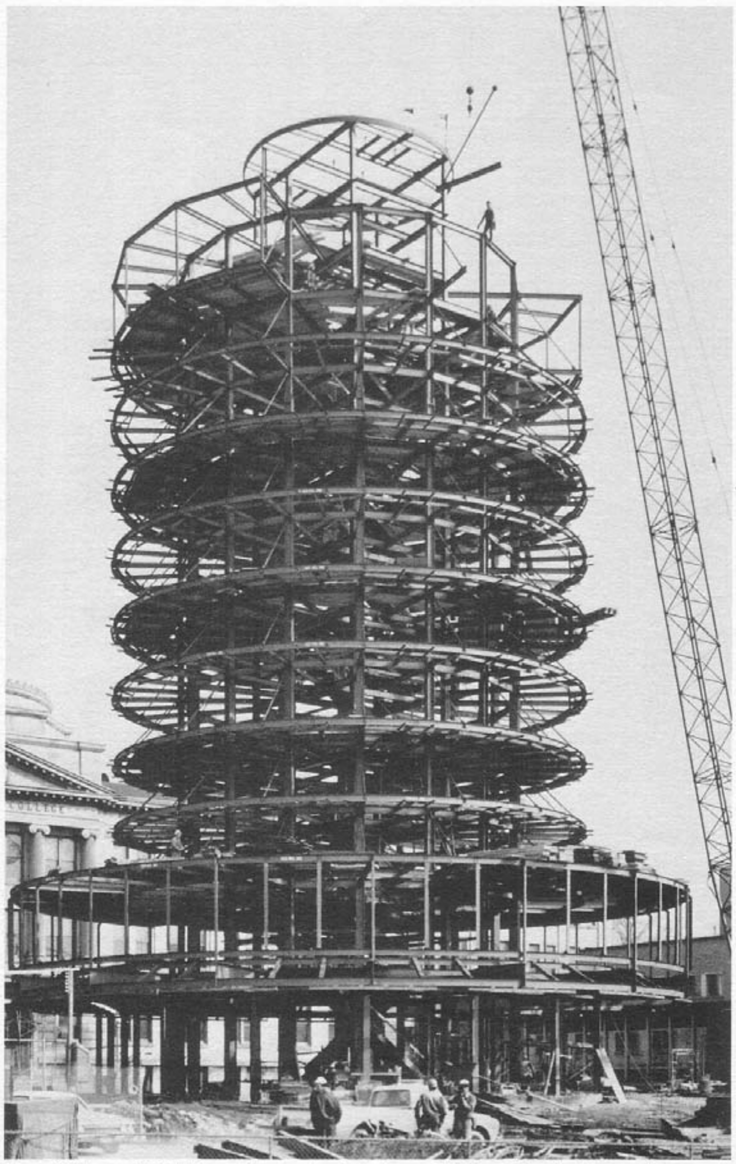
Prepared by: Sales Engineering Division, Bethlehem Steel Corporation, Bethlehem, Pa. 18016



Bethlehem Steel
March 1972

5 GENERAL INFORMATION

Unusual steel framing system overcomes height and site limitations for circular 11-story college office tower



Some 360 tons of Bethlehem A36 structural steel were fabricated for the 11-story framework and erected in only five weeks during winter months.

A steel-framed, circular faculty office tower shoe-horned into a limited site on the campus of Canisius College in Buffalo, New York, has enabled the institution to reclaim urgently needed classroom space from existing structures.

The 11-story structure, Churchill Academic Tower, was built at a cost of $1,783,068. It encompasses almost 49,000 sq ft of classroom and office space.

Site for the tower was limited by existing buildings on three sides and by a parking lot on the fourth side. Building height and floor-to-floor height limitations posed design problems. It was decided that a circular plan housing 144 faculty offices and six classrooms in an 11-story structure would make maximum use of the site.

Tower framework erected in 5 weeks

Steel was chosen as the most practical and economical material for the tower framing. With steel framing, the Churchill Academic Tower was completed within one year, requiring only five weeks for the erection of the tower framework during winter months. In the opinion of the structural engineer, "realistically, the tower couldn't have been framed with anything other than steel."

The faculty office tower incorporates nine circular office floors, 68 ft in diameter, rising from a two-story circular base. The second floor extends fifteen ft beyond the perimeter of the tower itself. Base framing consists of an outer ring of sixteen W10x49 columns on the ground floor supporting W36x135 cantilevered beams carrying the second floor classrooms.

Tower framing above the classroom

level is comprised of 16 interior columns spaced at 22°-30′ intervals on a circle 48½-ft in diameter. On the typical floor, the building perimeter projects 10 ft beyond the columns in order to avoid column penetration in the classroom areas.

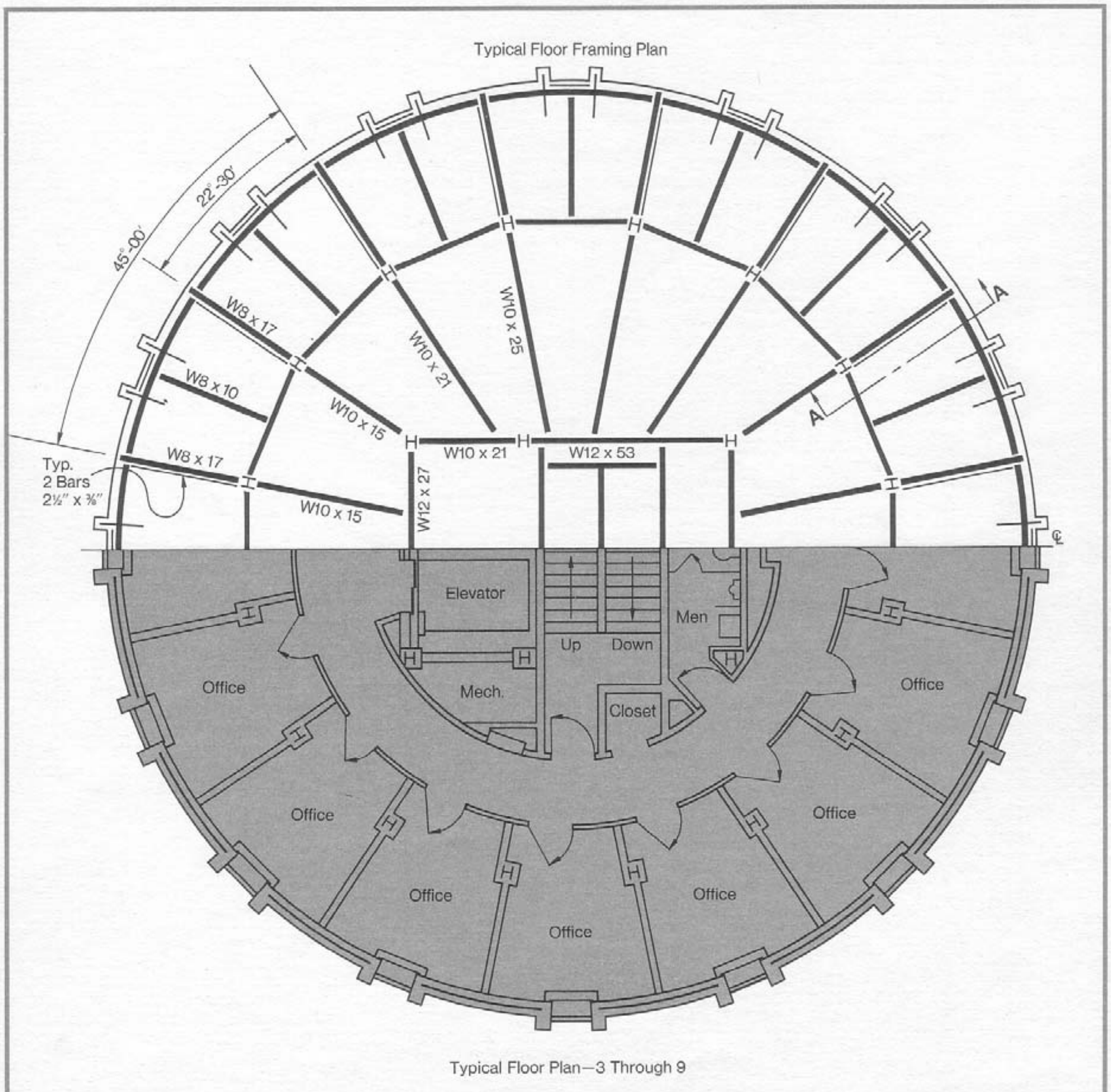
A ring of 10-in.-deep, curved spandrel beams is framed 9 ft, 4 in. outside of the columns, with filler floor beams running back to the interior girders.

Shallow floor height a problem

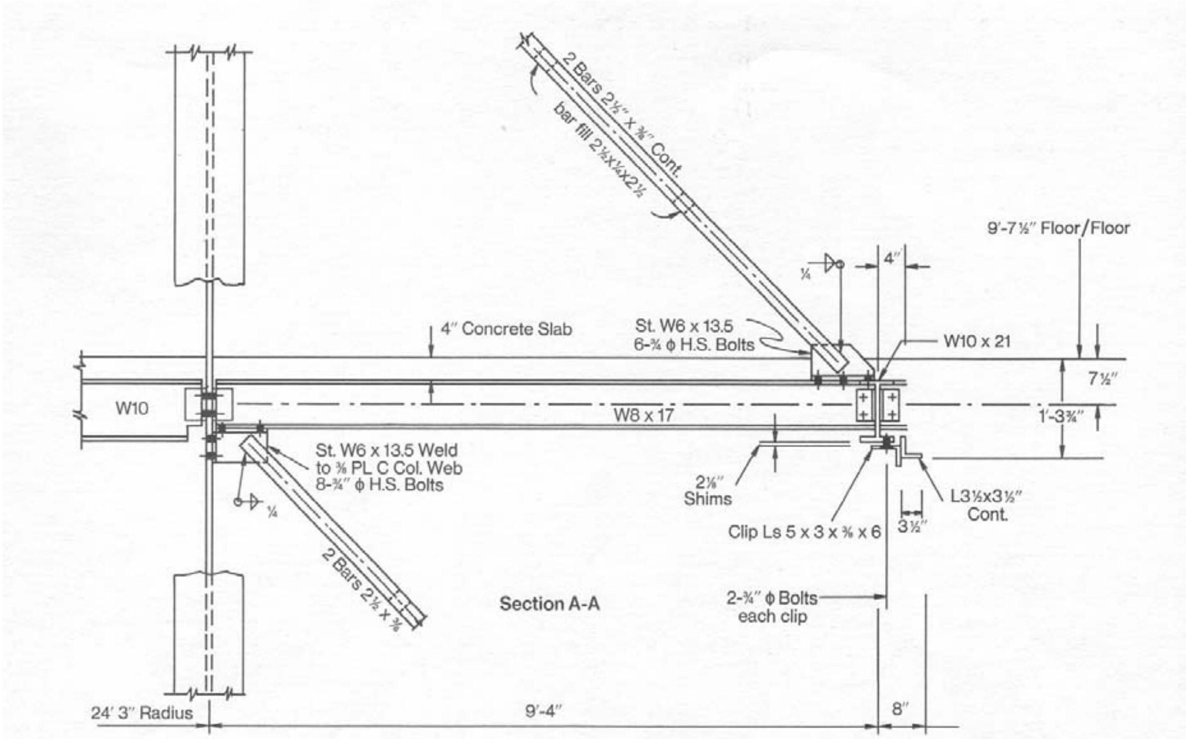
The preliminary design with radial cantilever beams at each column called for W21 sections, but the floor-to-floor height was established at 9 ft, 7½ in., and beam depth could not exceed 12 in. This framing problem was solved by substituting W8x17 sections for the W21 cantilever sections in combination with a pair of diagonal tension bars measuring 2½ by ⅜ in.

These diagonal bars connect to the top flange of the W8 sections at the perimeter and to gusset plates at the joint of the columns and the W8 sections on the floor above. The bars are concealed in a partition between individual faculty offices in the nine office floors.

This unusual method of framing worked well with the architectural plan. It also reduced the tonnage of structural steel required by saving an

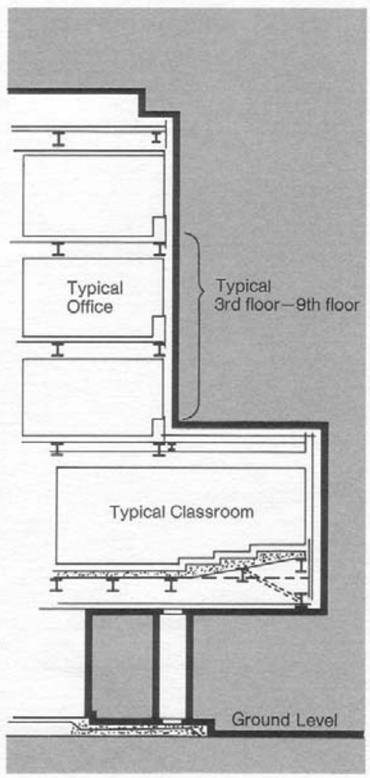


Tower framing above the second floor is comprised of 16 interior columns spaced at 22° - 30′ intervals on a circle 48½-ft in diameter. A ring of 10-in.-deep, curved spandrel beams is framed 9 ft, 4 in. outside of the columns with filler floor beams running back to the interior girders. The framing design provides column-free classrooms on the second floor and an efficient office arrangement on the nine floors above.



A floor-to-floor height limitation problem was solved with W8x17 beams in combination with a pair of diagonal tension bars measuring 2½ by ⅜ in. The bars connect to the top flange of the W8 sections at the perimeter and to gusset plates at the joint of the columns and the W8 sections on the floor above.

outer ring of steel columns. The design provided other savings by eliminating the need for eight ft more of building height, while keeping the overall tower height within limitations imposed by the aesthetics of the surrounding buildings—particularly in relation to the striking gold dome atop "Old Main." The framing system also provided column-free classrooms in the second floor instructional areas.



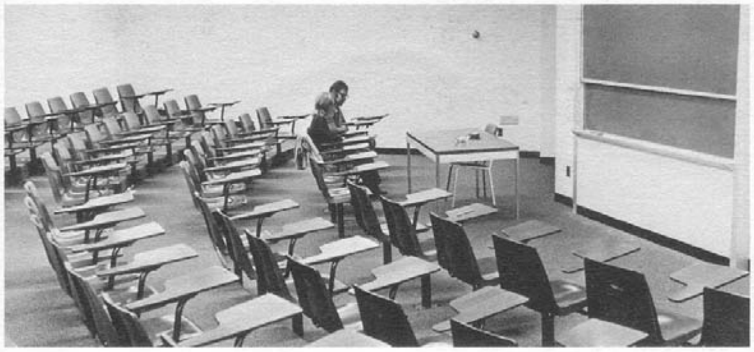
The second floor cantilevers fifteen feet beyond the perimeter of the tower creating an instructional floor 98-ft in diameter which contains six classrooms in a stepped amphitheater arrangement.

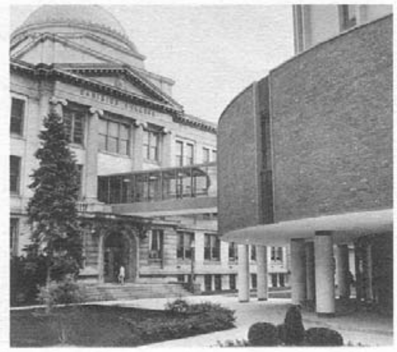
Inner columns are W12x106 members up to the second splice above the third floor line. Two intermediate reductions in column size occur before the inner columns taper off to W10x33 sections above the ninth floor line.

Framework of Bethlehem steel

Bethlehem provided some 360 tons (1941 pieces) of A36 structural steel for the tower's framework. Nineteen tons of Bethlehem concrete reinforcing bars were used in the foundation and another 19 tons of welded wire fabric were placed in the 4-in.-deep, poured-concrete slab floor system. Floor-to-ceiling height in the tower is 8 ft. The total floor-to-ceiling sandwich accounted for 1 ft, 7½ in. The major portion of the tower's ceilings and partitions is drywall construction. A spray-on, three-hour-fire-rated, cementitious coating fire protects the tower framework.

In addition to its adaptability to unusual site conditions, the economical steel framing provided an easy connection of the classroom (second) floor with a bridge to the second floor of the existing "Old Main" classroom structure adjacent. A second connection with "Old Main" is made with a tunnel on the basement level.



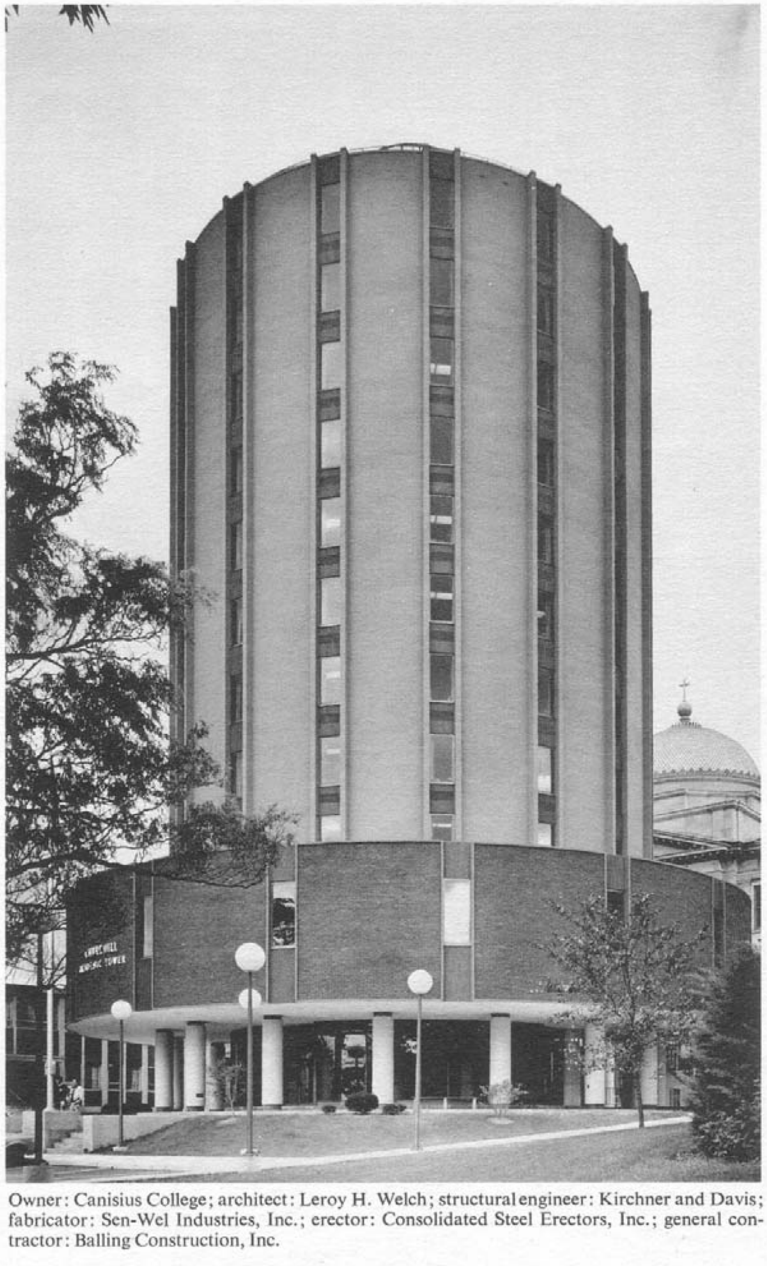


The second floor classroom is designed on an amphitheater plan with stepped-up floors. This level contains six classrooms each with an average capacity of 40 students. Floors in the nine stories above each contain 16 faculty offices.

A statistics laboratory is housed in the basement and an elevator penthouse containing mechanical equipment sits atop the tower structure. The tower core encloses a scissors stairway, lavatories, and two elevators.

Design loads for typical floors in the tower are 50 psf for live loads and 80 psf for dead loads including 20 psf for partitions. Wind loads are designed for 20 psf up to the fifth floor, and 30 psf to the top of the elevator penthouse. High-strength-bolted wind moment connections provide lateral restraint for the rigid frame.

On the exterior of the Churchill Academic Tower, dark brown brick at the classroom level contrasts with the light brown brick enclosing the upper floors. Besides relieving overcrowding, the structure will provide an academic setting for improving student-faculty relationships on this 3,900-student urban campus.



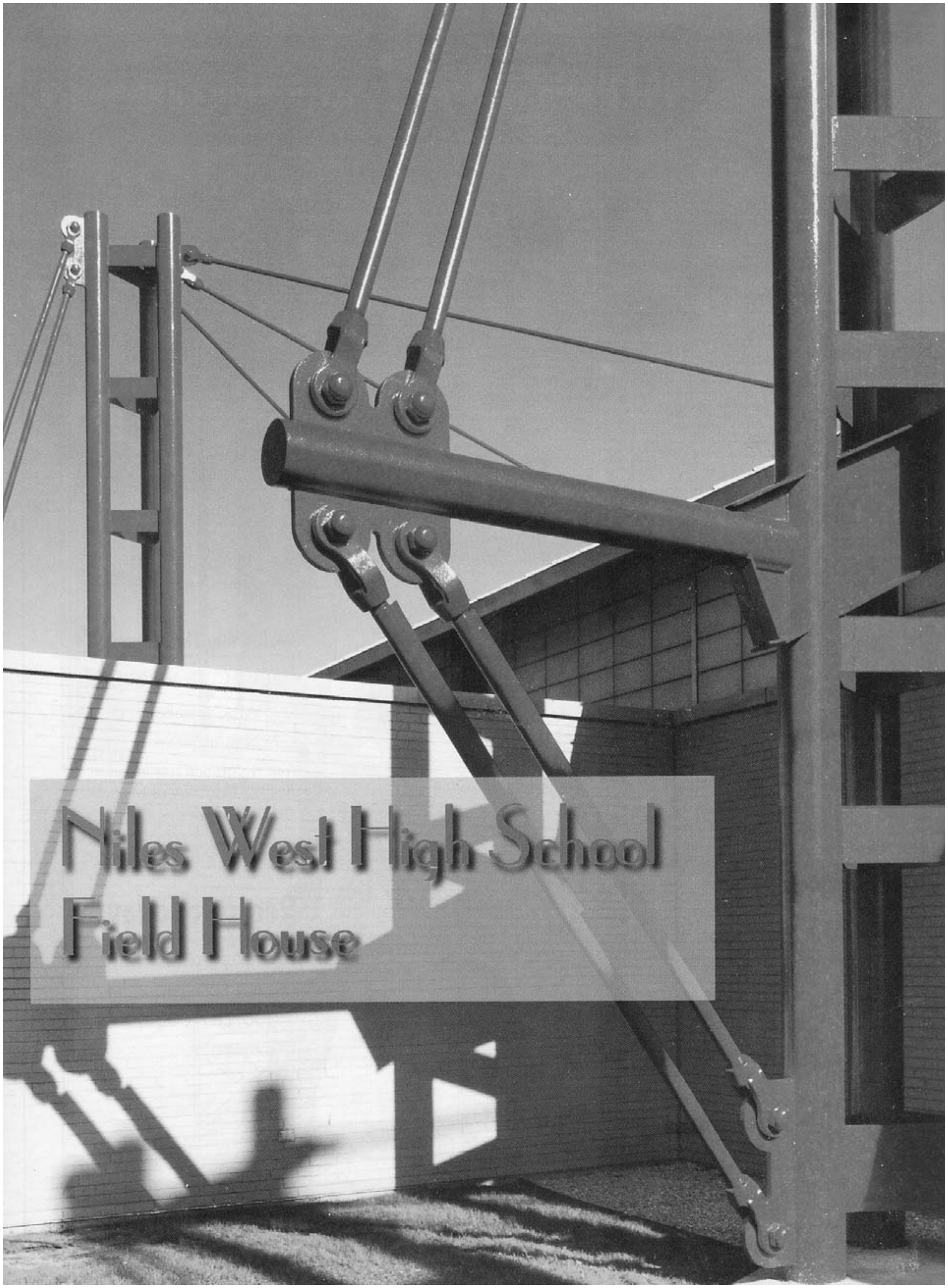
Owner: Canisius College; architect: Leroy H. Welch; structural engineer: Kirchner and Davis; fabricator: Sen-Wel Industries, Inc.; erector: Consolidated Steel Erectors, Inc.; general contractor: Balling Construction, Inc.

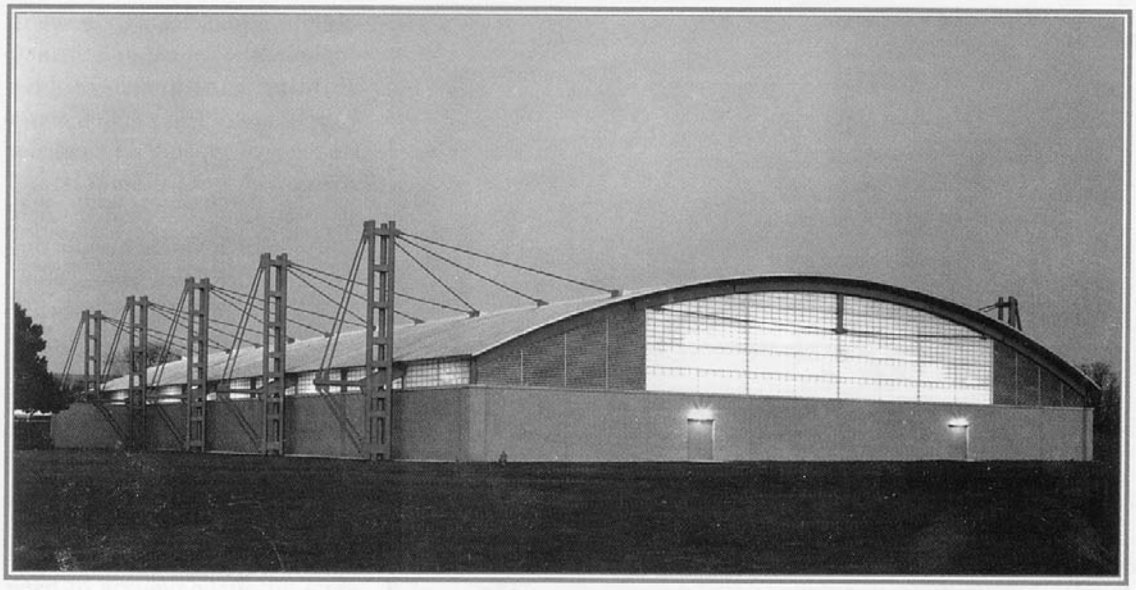
Niles West High School Field House

General Description – The field house was designed to provide an indoor track, four basket ball courts and other athletics facilities (Niles West, 1997). The owners required that the volume of the building be minimized to reduce heating costs. Thus, the designers decided to use a curved roof with lower heights at the sides where acceptable. To do this, they used cable supports to reduce the moments in the beams and thus the required beam sizes. The approach provided the required 170 foot clear span with a minimum height of 12 foot over the track in the central area. The roof structure is supported by wide flange arches with cable supports as shown in the cross-section figure. Interesting features include the position of the cables, on the inside of the building in the central portion and on the exterior adjacent to the columns, the fact that the cables are angled horizontally from the supporting columns and the need for the wide flange members that are encased in concrete in the floor area.

Writing Assignment - Students might be asked to discuss the structural framing scheme. Basically, the frame is similar to a one-bay, one-story rigid frame with fixed supports that are both fixed for rotation and fixed against horizontal displacement. In addition, the frame is made from wide flanges combined with cables, and the combination results in a beam with two pinned points at the junction of the wide flanges and the cables. The writing assignment could ask students to explain the need for the encased wide flange beams in the floor and to explain whether the frame is determinate or indeterminate. The assignment could address the horizontal truss in the plane of the roof, referred to in the last paragraph. The writing assignment could be supplemented with a request to suggest alternatives to the scheme used. One alternative is to use a conventional truss, with the roof at the lower chord level.

Back-of-an-Envelop Calculation – Students could be asked to estimate the forces in both the cable and the wide flanges at the center of the span due to gravity loading. This would require determination the dead and live load on the roof, and this would require addition of the load information to the assignment. Students could also be asked to estimate the areas needed for the wide flange and the cable, though this would require some cable design information and an estimate of cable strength. Students could also be asked to estimate the force in the encased wide flanges. These questions will require some preliminary discussion of the distribution of the roof load to the individual frames.


Niles West High School
Field House

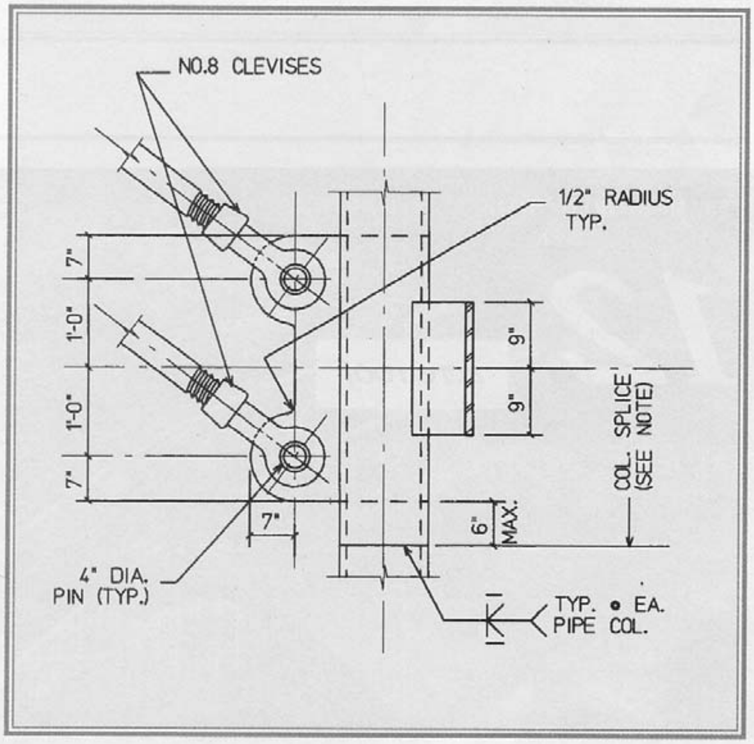


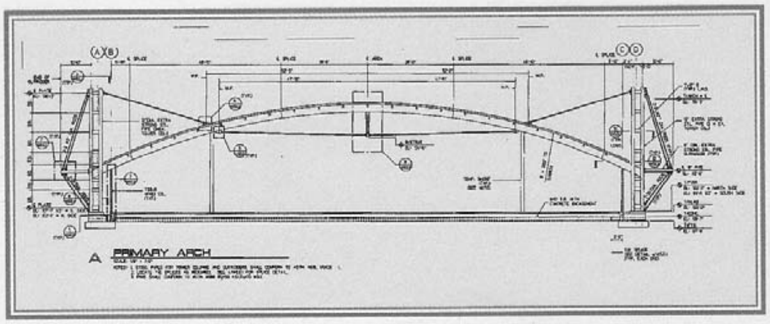
Engineering Awards of Excellence

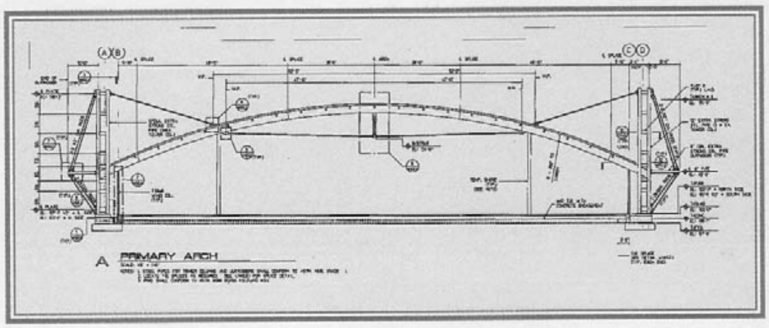
National Winner

Designed to accommodate the physical education and athletic needs of a burgeoning student population, the 40,000-sq.-ft. Niles West High School Field House includes four teaching stations, a competitive 160-meter track and four full-size basketball courts, which allows several sporting events to take place simultaneously.

The design of the building was driven by programmatic and structural requirements. Perhaps the greatest challenge was to sat-



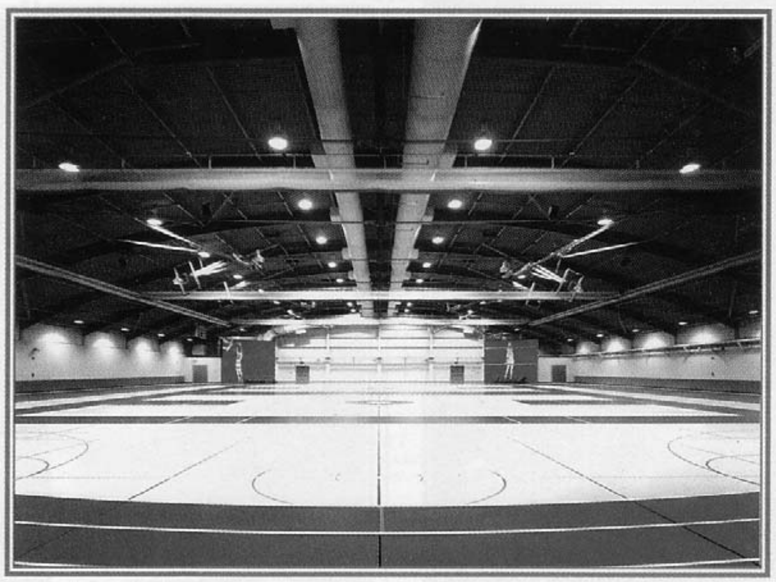


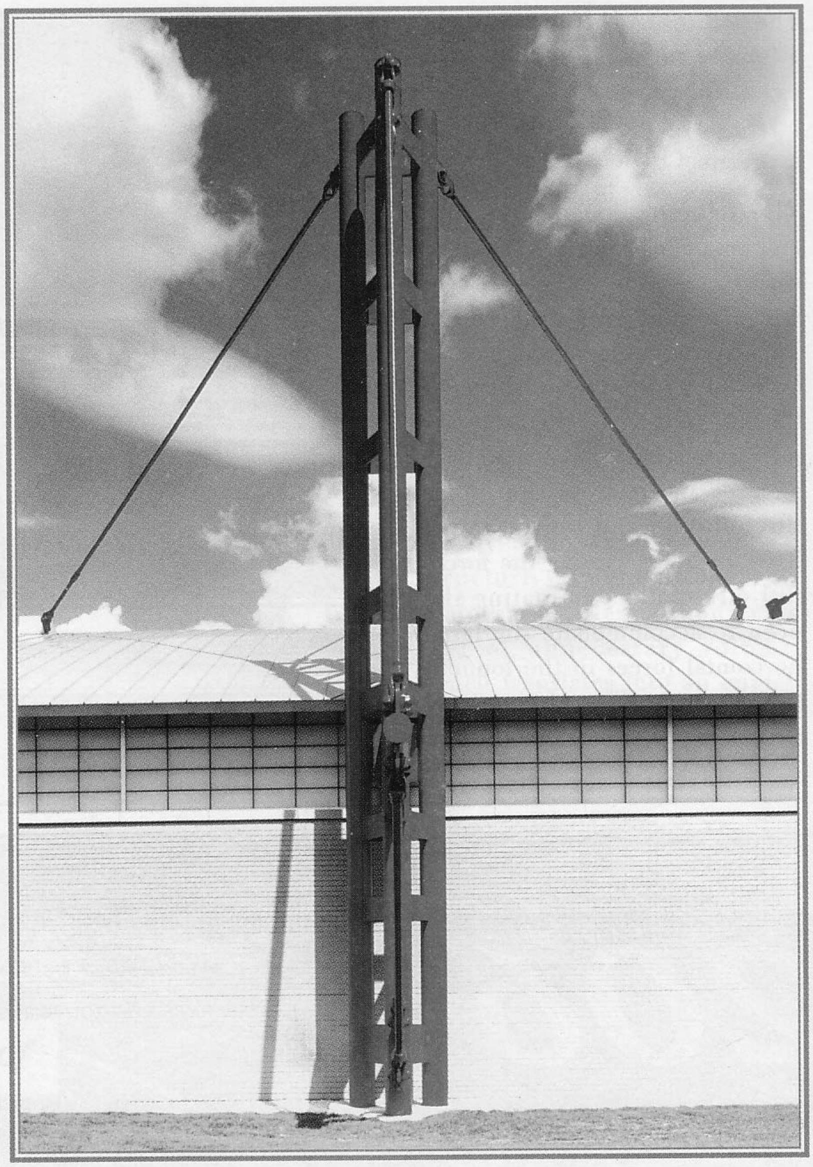


isfy the School Board's desire to minimize the volume and the new building and thereby reduce heating costs. The solution was a curved roof supported by exterior structural steel elements and clear-spanning 170' over the field house's open floor. Supporting the structure from above minimized interior obstructions while a curved long-span arch provided the required vertical clearance of a peak of 35' above the basketball and volleyball activities while providing a minimum height of 12' over the track. The curved structure eliminated approximately a quarter million cubic feet of unnecessary volume, which translates into an annual energy savings of about $27,800.

The structure includes five primary arches and six secondary arches. All of the arches consist of curved W30x99 wide flange members.

The primary arches tie into columns consisting of three 12" diameter hollow structural sections in a triangular arrangement. The column design was chosen both for aesthetics and because the design provided the necessary stiffness. Heavy W12 members encased in concrete run under the building and tie the tower bases together, closing the forces full circle and eliminating the need to accommodate the large horizontal forces in the foundation system. The alternative, according to a soil consultant,





would have been to use batter piles, but they would have been much more expensive.

The thrust in the secondary arches is transferred to the tower columns through a truss, consisting of W12x40 members, in the "plane" of the roof. Transferring forces through the truss allowed the designer to cut the number of column towers in half and instead of having columns at each arch they could be at every other arch. Not only did this reduce costs, but it created a more open and attractive design, both light and dynamic in appearance.

Project Team

Architect/Engineer:
OWP&P Architects, Inc., Deerfield, IL

Contractor:
Boller Construction Co., Inc., Waukegan, IL

Judges Comments

The combination of a steel arch, an unusual thrust tie system and the exterior columns yields a very elegant solution. A highly aesthetic yet cost effective response to the need for column free space.

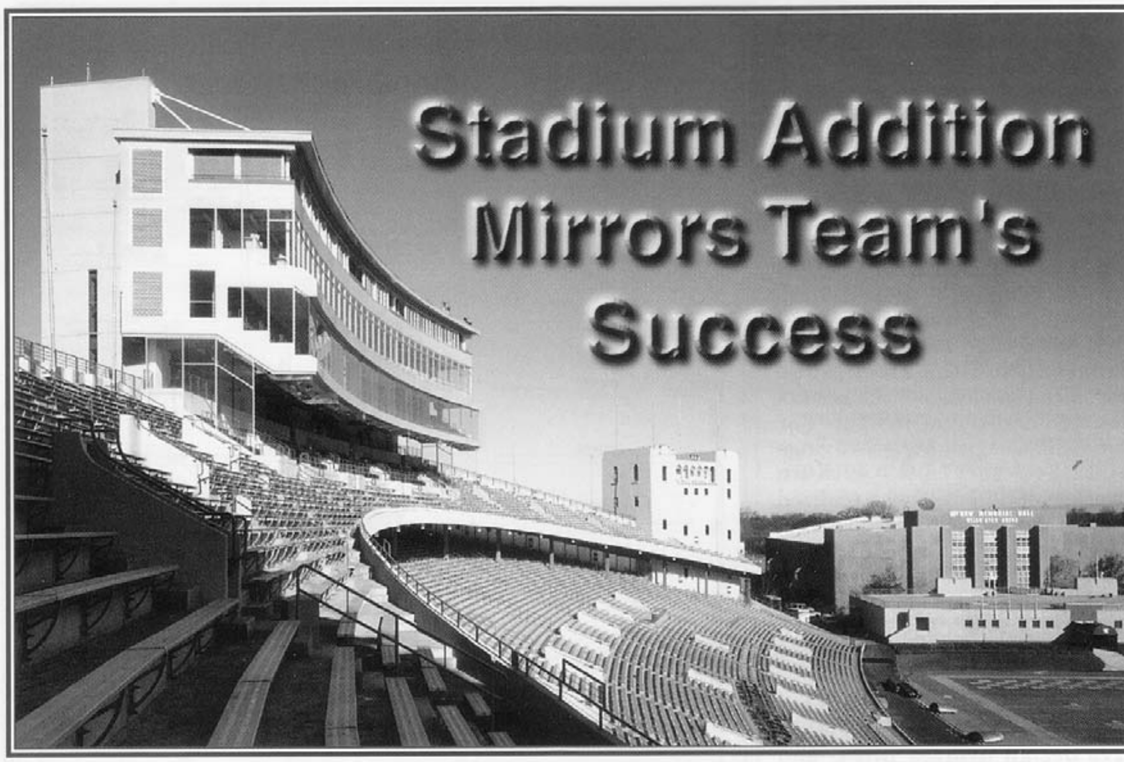
Northwestern University Stadium

General Description - A new pressbox facility has been added to the Northwestern University Stadium (Stadium Addition, 1998). This pressbox sits above the existing stadium, and the design must satisfy specific site requirements. Three floor levels were required, with height limitations specified by the city. The height restriction required tight floor-to-floor heights, and this in turn minimized the beam depths. Thus a cable support system has been used to transfer gravity loads back to the supporting truss. Some of the interesting features include the fact that serviceability governed in the supporting truss design, the limitations on the truss depth, and the use of the cables at the top.

Writing Assignment - Students could be asked to write about the framing scheme selected. This could address both the gravity and wind loads. They also could discuss why the framing scheme was selected, though this is reasonably well covered in the article's short description. A better approach would be to have students discuss alternatives to the framing scheme based on use of the cable supports, with and without the height restrictions. These might include use of a cantilevered truss to support the three floors, though this would place restrictions on the interior layout. Were it not for the height restrictions, the floors could be supported by cantilevered beams. Students could be asked to address how the tower meets both strength and serviceability requirements. They should note that serviceability governed in the design.

Back-of-an-Envelop Calculation – Students could be asked to determine the force in the cables at the junction with the roof of the pressbox. Estimated floor loads would need to be included in the assignment, preferably in terms of dead and live loads. In addition, it would be necessary to include an estimate of the weight of the glass window wall. Also, spacing of the trusses would need to be estimated. Another back-of-the-envelop calculation could be the determination of the axial forces in the two truss chords at the base of the tower. As noted in the article, one chord is in compression and one in tension.

Stadium Addition Mirrors Team's Success

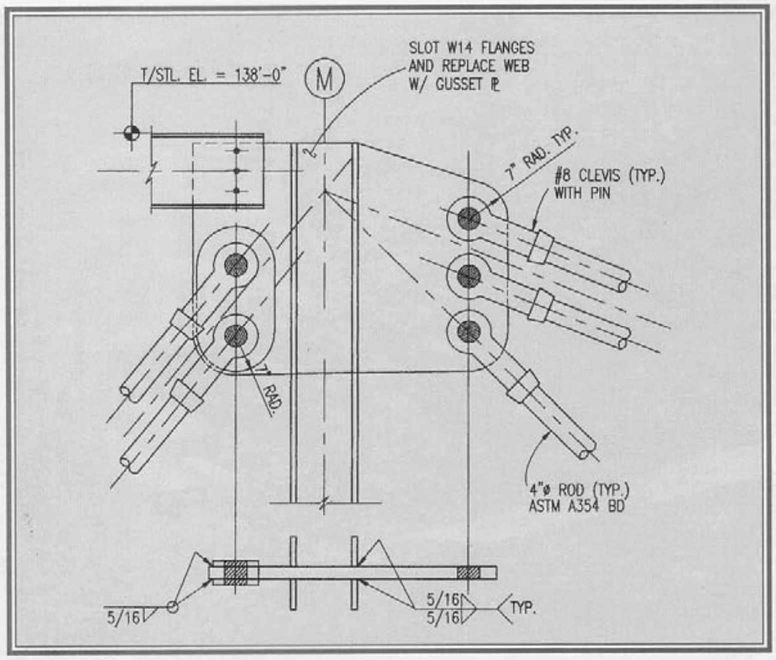


The new pressbox facility, inside (above) and out (top).
Photos by George Lambros Photography

The growing popularity—and success—of Northwestern University's football team led the school to add a new pressbox facility

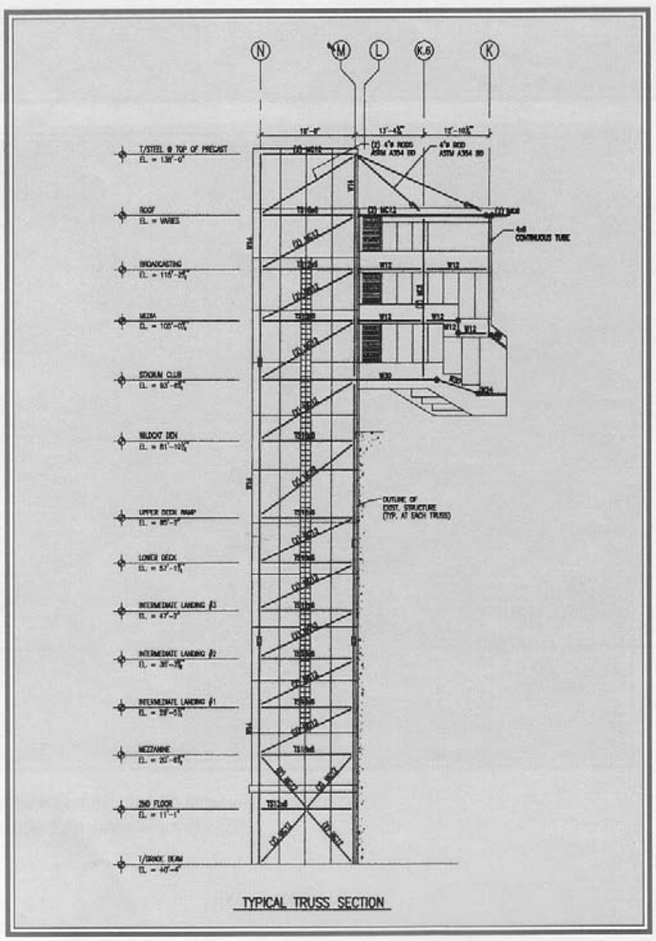
THE NORTHWESTERN UNIVERSITY WILDCATS SOARED ABOVE THE ODDS IN 1996, when they earned only their second trip to the Rose Bowl in the University's long and storied history. Once league-wide doormats, Northwestern has emerged as a competitive team in the nation's toughest conference. While an appearance in the Rose Bowl exceeded everyone's expectations, the athletic department had shown faith in the team a year earlier when they launched a $25 million upgrade of the existing football facilities. The upgrade was sorely needed to help raise the standard of their stadium to that of other Big 10 universities.

The Ryan Field Pressbox was one of the most publicly visible parts of the upgrade. In addition to the pressbox, however, the project included a new locker room facility, a lowered natural grass playing field and rehabilitation of the existing stadium structure. Athletic officials felt



the former pressbox was outdated and undersized; it didn't adequately accommodate the local and national newspaper, television and radio personnel, as well as the athletic department's major supporters.

The pressbox, which today climbs above the stadiums walls and is readily visible from the surrounding blocks, was designed with three main levels: Broadcast, Media and the VIP Stadium Club. There were several challenges to the construction of the pressbox. A height restriction in Evanston, IL—the University's home—limited the building to 1,255' at the main roof level, making floor-to-floor heights tight and the depths of steel support beams shallow. Kevin Wilson, S.E., with Tylk, Gustafson & Associates, struc-



Project:
Ryan Field Pressbox
Evanston, IL

Owner:
Northwestern University

Structural Engineer:
Tylk, Gustafson & Asociates
Chicago

Architect:
Griskelis& Smith Architects
Chicago

AISC Member Fabricator & Detailer:
Zalk Joseph Fabricators
Stoughton, WI

General Contractor:
Turner Construction
Chicago

tural engineers for the project, said that with the top of the stadium at +/- 82', only 43' were available to squeeze in the four levels.

In order to meet these challenges, some modifications to the design had to be made. Six independent vertical steel trusses were designed to extend above the concrete stadium to support the three floor levels, which cantilevered up to 30', and hung over the existing upper deck level of seating. The trusses vary in depth from 10'-6" to 18'-8" to follow the oval contour of the existing stadium and are spaced laterally between the stadium's existing concrete arches. The trusses are made up of wide flange column-chords and double channel/tube web members. Exposed above the main level are 4" diagonal steel rods that carry two rows of double channel and tube verticals that extend down through the structure. These continuous tension hangers support the broadcast, media and stadium club levels. A 10' high, 1-1/8" thick butt-glazed laminated glass wall on the Stadium Club level provides 180' of unobstructed football field and campus view.

At the ground level, the width of the new structure was limited because of an existing right-of-way on the adjacent street to the west. The steel trusses adjacent to the centerline of the pressbox are only 10'-6" deep. Floor beams were designed compositely with the 5¼" lightweight concrete slab-on metal deck to minimize the depth of the steel. The architectural design also sought to minimize visual obstructions, so the size and location of the columns were restricted. W30 girders supporting the stadium club extend out 30' over the Wildcat Den to create a column-free space.

Because of the structure's slenderness, Wilson said that the design of the six vertical trusses was based on lateral stiffness rather than steel strength. "During high winds, we did not want

the swaying of the steel frame to become noticeably perceptible," Wilson added. "We limited our lateral drift criteria for different loading combinations to between H/400 to H/500." Once strength criteria requirements were met, member sizes were adjusted upward to meet the stiffness criteria.

Due to the large cantilever floor lengths, the design dead loads and Building Code prescribed live loads, the "columns" at the west side of the structure are in tension. A vertical camber to the west was intentionally designed and fabricated so that when the dead load was fully applied, the erected steel structure would be plumb. Horizontal expansion joints are present at each level where the new press-box structure abuts the existing stadium.

Citicorp Building

General Description - One of the best articles on what is one of the best discussions of engineering ethics is the article "The Fifty-Nine-Story Crises" that was first printed in the New Yorker magazine (Morgenstern, 1997). Students have found this article both interesting and of value. The article does not present a clear description of the building, so it is supplemented with a photo showing the actual structure and an Engineering News Record article, "Engineers Afterthought Sets Welders to Work Bracing Tower."

Writing Assignment –Students are asked to describe the problem confronted by William LeMessurier when he was asked about the building by a student. They need to include in this a description of how the wind loading is normally resisted, what quartering loads are, and why these quartering loads were critical for this structure when they usually are not a problem in tall buildings. The intent is to get students to look at how the main columns are loaded when wind acts on the structure. Students need to compare column forces due to wind when there are four columns at the corners and when there are four columns are at the centers of the sides, as occurs in the actual structure. Students are also asked to describe what was done to repair the structure and to note how this improved the overall performance.

Back-of-an-Envelop Calculations - It is stated in the article that the wind increased the strain by 40 percent because the columns were at the center of the four sides instead of at the corners. Students are asked to show how this occurs, using a back-of-an-envelop calculations. This requires coverage of the basic ideas in lecture.

Kansas City Walkway Failure

Study of failures provides students with an excellent opportunity to write and conduct back-of-an-envelop calculations. The Kansas City Walkway failure is one of the more notable structural engineering failures (Pfrang, 1982). This failure has been studied at the University of Connecticut using a modified approach to that used in the conventional writing assignments. Students are first given a design problem that asks them to design a hanger for two beams, showing the hanger as a single round bar. The beams are given, along with their reactions. Students are also asked to consider how they would connect the beams to the hanger, and them must develop sketches showing their approach. Numerical design of the connection is not required. The assignment shows that invariably most students make the same error that the original designers made. The actual writing assignment follows this assignment.

Writing Assignment - The written assignment follows discussion of the assignment in class. The Civil Engineering Magazine article on the walkway failure by Pfrang and Marshall (1982) is handed out at this time. Students are asked to describe how the failure occurred, with a discussion of the difference between the original design and the actual constructed design. They are also asked to develop and describe in both words and sketches a revised connection design.

Back-of-an-Envelop Calculations – Students could be asked to replace the bars used for the tension hangers with an alternative that allows them to design a connection. Or they could be asked to suggest a design, with calculations, that they feel is safer. At the University of Connecticut, the initial design prior to the reading of the article is the calculation that is included with this assignment.