

Developing and Introducing a New Course on Building Façade Design

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Developing and Introducing a New Course on Building Façade Design

Abstract

The School of Architecture at Oklahoma State University currently offers accredited programs in Architecture and Architectural Engineering. These programs share several courses that include engineering, management, and studio-based courses. In the past few years, several new courses have been added to these programs that will enable students to be equipped with advanced knowledge, to work in the architecture, engineering, and construction (AEC) industry, and to serve society. Like other areas, such as manufacturing and software, the construction industry has experienced a tremendous amount of change in the last decade. In particular, the design of facades that are made up of materials, such as aluminum, glass, stone, and sheet metal, has grown. Traditionally, most courses in civil and architectural engineering across the United States and other parts of the world, focus primarily on structural design of steel, concrete, and timber, which are largely used in constructing main frame load-bearing members (also called ‘primary structural system’). A façade, which is sometimes referred to as a ‘secondary structural system’, typically forms part of a building’s exterior that is exposed to environmental loads such as wind, seismic, thermal, rain and snow loads. Furthermore, facades such as curtain walls, are aesthetically pleasing and if properly designed, can prevent heat losses, leading to energy efficient buildings. Therefore, the subject of façade design incorporates aspects of structural engineering and building science. Due to the absence of any formal ‘course’ at universities and lack of textbooks in this subject area, most engineers in the industry find it rather difficult to design building facades. To close this ‘knowledge gap’, the program decided to develop a new course titled “façade design”. As part of this endeavor, students from the three programs were asked to fill out a questionnaire to obtain their views about a prospective course in façade design. Furthermore, this paper includes a detailed literature review of coursework within various architecture and architectural engineering programs across North America. It is anticipated that the introduction of the façade design course could potentially see future students from the programs serve the industry with enhanced knowledge in façade design. This article presents the content and structure of the course, besides discussing the contribution of this course to the programs and the architectural engineering community at large.

Keywords: Façade design; Architectural Engineering; Building Science; Survey; New course

Introduction

Although the construction of buildings is a subject of study among architects and civil engineers, this subject is often dealt with differently by each one of them. For instance, architecture typically involves courses in art, science, and engineering, besides studio-based courses applied to building construction. Similarly, civil engineering courses in design around the world have mostly focused on timber, masonry, reinforced concrete, and steel structures. However, increased global warming in recent years due to greenhouse gas emissions, coupled with the need for energy efficient buildings, has resulted in several architecture programs including at Oklahoma State University to offer courses on sustainable building design, covering topics on building energy modeling.

The growing interest in energy efficient buildings has resulted in building facades being constructed of different materials, such as wood, sheet metal, glass, aluminum, and vinyl [1]. A façade is considered a ‘secondary structural member’ that separates the building’s exterior from the interior and is typically attached to the slab. In general, any façade experiences environmental loads, such as wind, seismic, rain, snow, and thermal loads. Thus, a façade must be designed to sustain environmental loads, and to ensure thermal comfort to the building’s occupants [2]. In the construction industry, the last decade has seen a growing trend of the use of different façade systems, particularly curtain walls. One unique aspect of façade design is that it encompasses the subjects of structural engineering and building science. From the author’s own experience, due to the lack of any formal course at a university or textbook, engineers often find it difficult to work on façade design projects in the industry. To address this issue, the authors decided to develop a course titled ‘façade design’ that would incorporate various topics, namely: structural design of aluminum curtain walls and cold formed steel facades using relevant standards and codes, estimating heat transfer through various façade systems and, assessing air and water leakage through facades using relevant ASTM standards. Furthermore, to enhance student learning and future employment opportunities, the course will involve a visit to a nearby industry specializing in façade design, besides having a guest speaker from the industry to share their experience and knowledge. Prior to developing the course, a detailed literature review was conducted to find out about the various programs in architectural engineering offered at U.S. universities, with particular emphasis on façade design courses. This was followed by a survey conducted within the School of Architecture to assess the interest among students and their general understanding of the field of façade engineering. Results from the survey show student interest in a course on façade design as an elective. The initial offering of the course occurred this year and received positive feedback from students through an end of semester survey.

This paper presents a detailed overview and discussion on steps taken by the authors to develop the course on façade design. It is expected that this course will generate sufficient interest for increased student enrollment and future employment opportunities. Furthermore, an increased demand of façade engineers in the industry should see the subject of façade design becoming part of several architectural engineering programs in other U.S. universities in the future.

Façade engineering in the industry and academia

A façade typically separates a building’s exterior from its interior. Some of the earlier building facades built in the early seventeenth century were constructed of stone and brick masonry.



a) Aerial view of the Royal Palace in Madrid, Spain [3]
Figure 1. Examples of stone and brick facades



b) Electricity Museum in Lisbon, Portugal [4]

For instance, the Royal Palace in Madrid (Figure 1) was constructed of stone between 1738 and 1764 [3], while the electricity museum in Lisbon Portugal is made of brick masonry [4]. In more recent times, facades are constructed of multiple materials, such as aluminum, glass, wood, cold formed steel, stone, vinyl, and brick, to name a few. Curtain walls, which are glass infills in aluminum frames, have become quite well known due to their aesthetic appeal, leading to an increase in their use in hospitals, university, and mixed-use buildings [5].

For instance, the Willis Tower in Chicago and the Burj Khalifa in UAE (Figure 2) are examples of curtain wall systems [6]. More recently, the use of sunshades attached to curtain walls (Figure 2(c)) have been used, which can reduce the glare of the sun and provide occupant comfort.

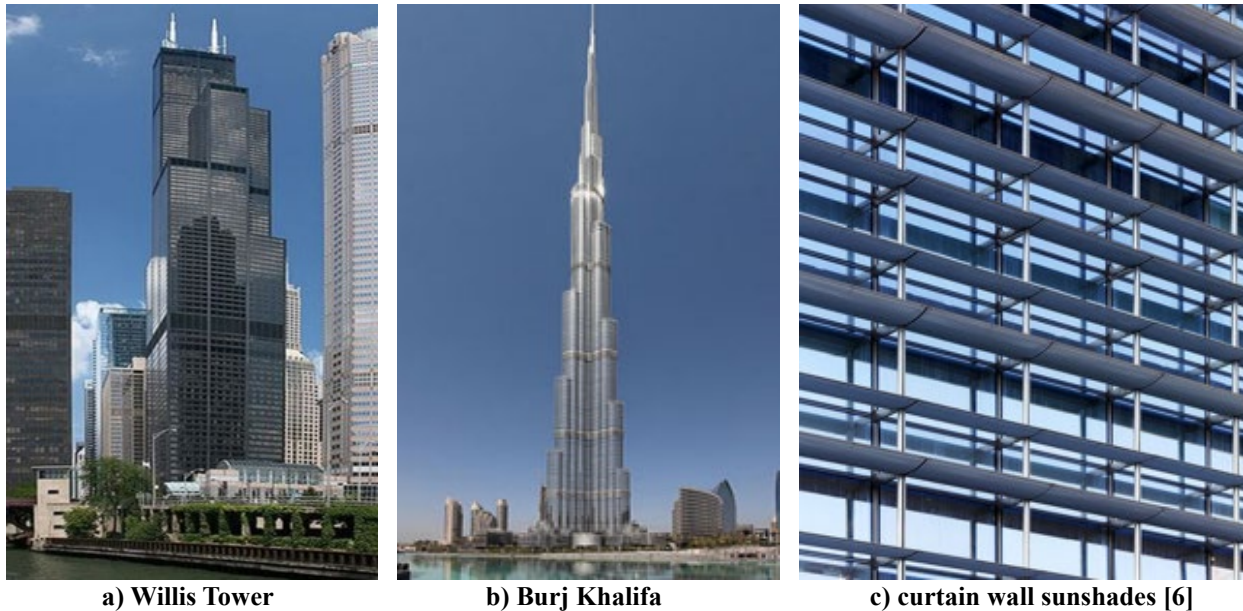


Figure 2. Examples of Curtain Walls

The subject of façade engineering involves structural engineers, architects, applied physicists and mechanical engineers with a background in acoustics, energy, and thermal modeling. Several construction companies specifically work on façade engineering projects, as listed in Table 1. Although some of these firms have office locations outside of North America, this list primarily focuses on locations in US and Canada. There are 26 ABET accredited architectural engineering programs in the U.S. that offer undergraduate degrees, as listed in Table 2, with some of those universities offering graduate programs as well.

A major challenge facing façade engineering consultants is finding hires with knowledge in this area of design. Most engineers graduate with a degree in civil or architectural engineering, where the design courses are mostly focused on concrete, timber, steel, and masonry. However, most façade materials are made up of glass, aluminum, vinyl, stone, cold formed steel, and wood. Although literature in the form of codes and standards exists for materials such as cold formed steel (AISI S-10, 2016) [7], glass (ASTM E-1300, 2016) [8] and aluminum (Aluminum design manual, 2020) [9], lack of any formal coursework or a textbook that compiles the design of these façade materials, makes it more challenging for engineers working in façade design consulting.

Table 1. Design and construction companies working on facade engineering projects.

#	Name of company	Webpage
1	ARUP	https://www.arup.com/
2	RDH Building Science	https://www.rdh.com/
3	Thornton Tomasetti	https://www.thorntontomasetti.com/
4	Buro Happold	https://www.burohappold.com/
5	WJE Associates	https://www.wje.com/
6	AECOM	https://aecom.com/
7	WSP	https://www.wsp.com/
8	McLaren Engineering Group	https://www.mgmclaren.com/
9	Morrison Hershfield	https://morrisonhershfield.com/
10	Mott Macdonald	https://www.mottmac.co

Table 2. List of ABET Accredited Architectural Engineering Programs in the United States.

#	Name of University	Location
1	University of Alabama	Tuscaloosa, AL
2	University of Arizona	Tucson, AZ
3	California Polytechnic State University	San Luis Obispo, CA
4	University of Cincinnati	Cincinnati, OH
5	University of Colorado - Boulder	Boulder, CO
6	University of Detroit Mercy	Detroit, MI
7	Drexel University	Philadelphia, PA
8	Illinois Institute of Technology	Chicago, IL
9	Kansas State University	Manhattan, KS
10	University of Kansas	Lawrence, KS
11	Lawrence Technological University	Southfield, MI
12	University of Miami	Coral Gables, FL
13	Milwaukee School of Engineering	Milwaukee, WI
14	Missouri University of Science & Technology	Rolla, MO
15	University of Nebraska - Lincoln	Omaha, NB
16	North Carolina A&T State University	Greensboro, NC
17	Oklahoma State University	Stillwater, OK
18	University of Oklahoma	Norman, OK
19	Pennsylvania State University	University Park, PA
20	Tennessee State University	Nashville, TN
21	Texas A&M University	College Station, TX
22	Texas A&M University - Kingsville	Kingsville, TX
23	University of Texas at Arlington	Arlington, TX
24	University of Texas	Austin, TX
25	Worcester Polytechnic Institute	Worcester, MA
26	University of Wyoming	Laramie, WY

Furthermore, façade engineering also includes topics on building science, such as condensation problems, thermal and acoustic comfort, besides, air and water leakage through facades. To reduce these knowledge gaps, the authors decided to develop a course titled “Façade Design”, as described further.

Initial stages of development of the façade design course

Prior to the development of the façade design course, a literature survey was conducted on the number of design firms involved in façade engineering practice, with prominent firms listed in Table 1, followed by the school’s offering degrees in architectural engineering listed in Table 2.

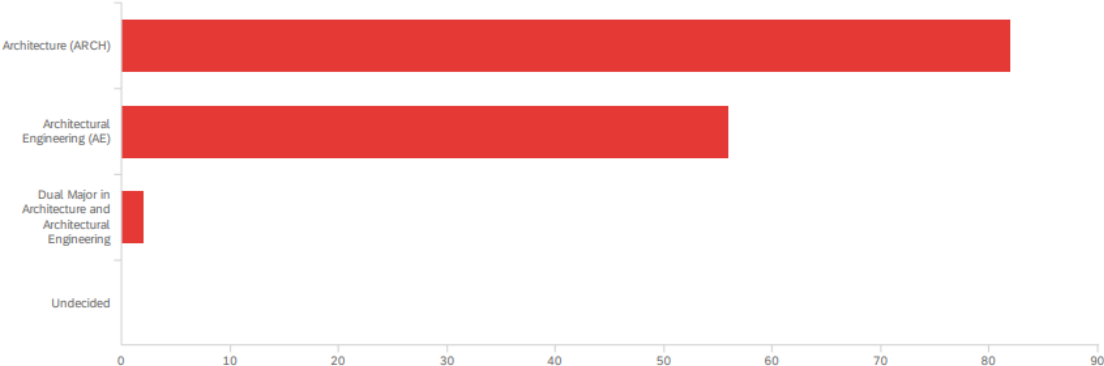
Most of the firms mentioned in Table 1 have been involved with façade engineering projects for several years. The discipline of façade design includes aspects of structural engineering and building physics, requiring architects and engineers to be formally trained in these areas. Although various universities listed in Table 2 provide formal education in architectural engineering, based on the author’s experience of working in the industry, a complete knowledge of façade design is lacking among young graduates. This requires a firm to provide additional training and other resources to its employees, thus making it rather difficult to accomplish façade design projects. Based on these observations, it was understood that a course incorporating structural engineering and building science applied to façade design, would greatly help bridge the knowledge gap described earlier. As a first step, an anonymous survey was developed consisting of ten questions, and distributed among students, with an overview of the questions presented in Table 3.

Table 3. Questionnaire sent to students, prior to developing the façade design course.

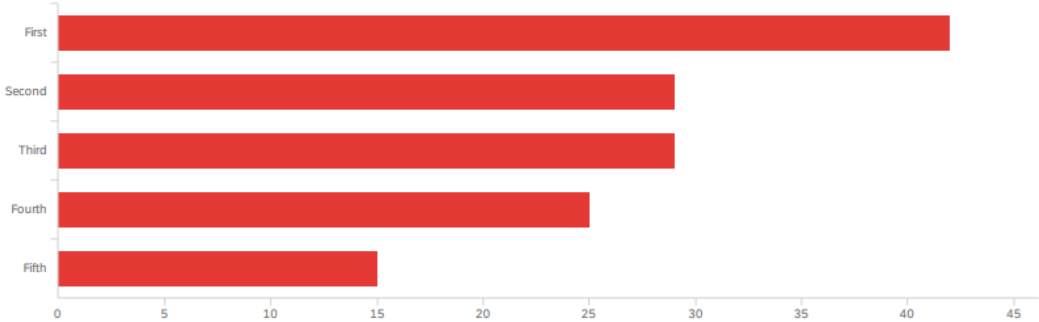
Question	Question	Options for each question
1	What is your major within the School of Architecture?	<ul style="list-style-type: none"> •Architecture •Architectural Engineering •Dual Major in Architecture and Architectural Engineering •Undecided
2	What curriculum year are you within the program at the School of Architecture?	<ul style="list-style-type: none"> • First • Second • Third • Fourth • Fifth
3	Select from below which best describes your understanding of the term ‘façade design’.	<ul style="list-style-type: none"> •Have never heard of this term •Have limited knowledge of this term •Have advanced knowledge of this term
4	Do you think a course on ‘façade design’ would be worthwhile to add to the curriculum of the School of Architecture?	<ul style="list-style-type: none"> • Yes • No • Not sure
5	Are you aware that the demand for façade engineers in the industry has increased over the years?	<ul style="list-style-type: none"> • Yes • No
6	Do you think this course should be offered to both architecture and architectural engineering programs at the SOA?	<ul style="list-style-type: none"> • Yes. The course should be offered to both the programs at SOA. • No. The course should be offered only to one of the two programs. • Not sure
7	Do you think the course should include tools such as ‘Mathcad’ and ‘Bluebeam’ which are commonly utilized in the professions?	<ul style="list-style-type: none"> • Yes • No • Not sure
8	Which of the following course formats should be utilized for the course?	<ul style="list-style-type: none"> • Classroom lectures • Fieldtrips to a facade manufacturing facility • Project and/or presentation by students • Assignments • Exams
9	Would you like to see this course being offered as an ‘elective’ or a ‘required course’?	<ul style="list-style-type: none"> • Required course • Elective course • Not sure
10	If a course on façade engineering is offered, do you think it would increase student employment in the industry?	<ul style="list-style-type: none"> • Yes • No • Not sure

The Qualtrics™ survey, consisting of 10 questions, was sent out to 388 students, with 140 responses. Survey results are presented below in the form of a histogram for each question.

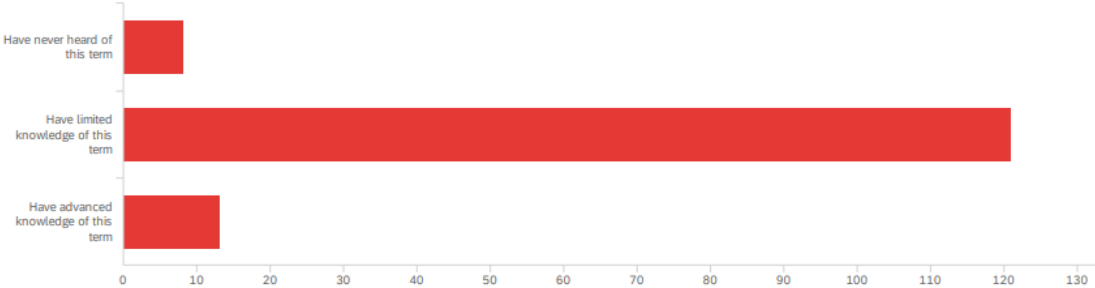
Q1 - What is your major within the School of Architecture?



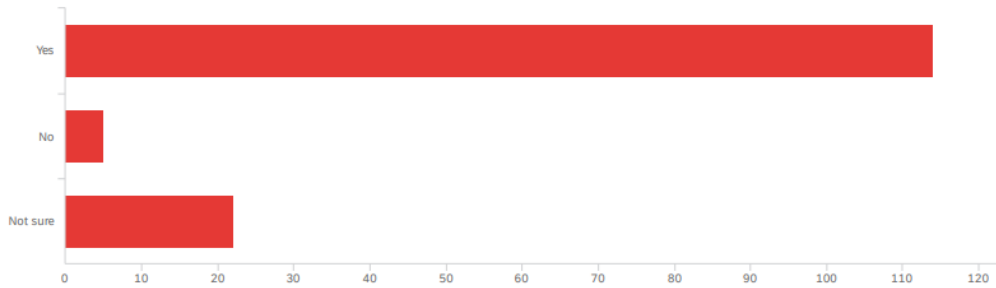
Q2 - What curriculum year are you within the program at the School of Architecture?



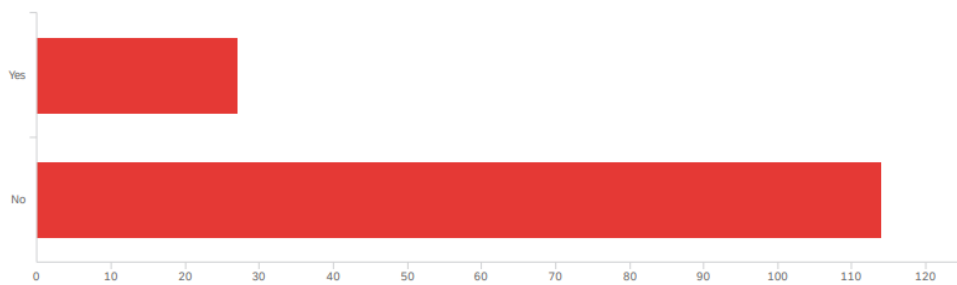
Q3 - Select from below which best describes your understanding of the term 'façade design'.



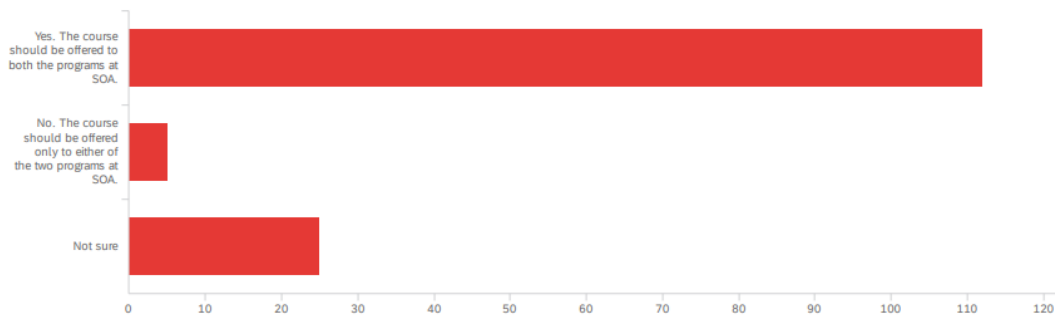
Q4 - Do you think a course on 'façade design' would be worthwhile to add to the curriculum of the School of Architecture?



Q5 - Are you aware that the demand for façade engineers in the industry has increased over the years?

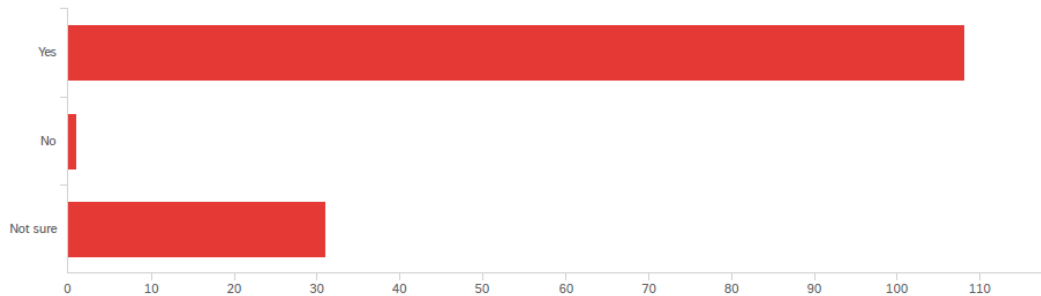


Q6 - Do you think this course should be offered to both architecture and architectural engineering programs at the SOA?



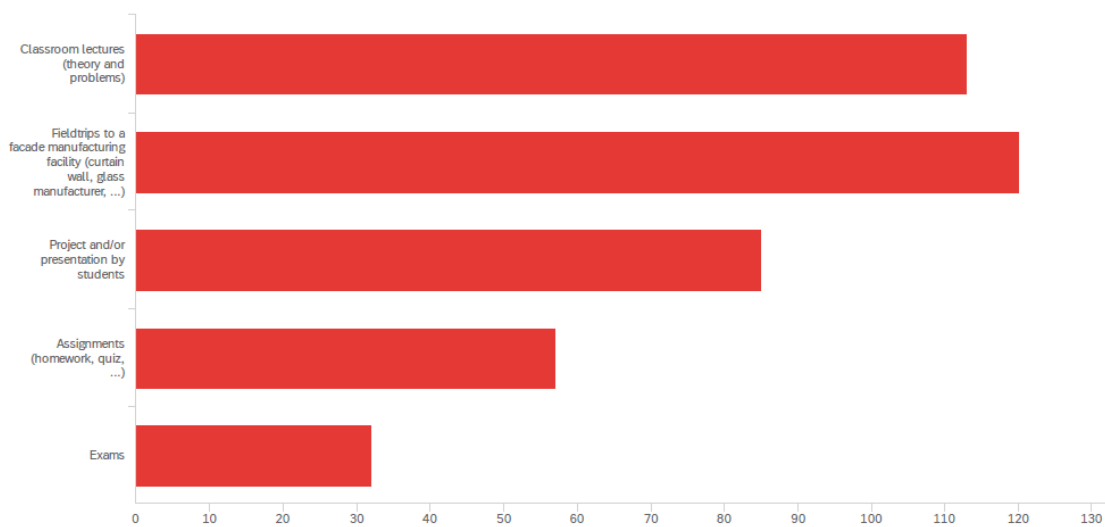
Q7 - Do you think the course should include tools such as 'Mathcad" and "Bluebeam"

which are commonly utilized in the professions?



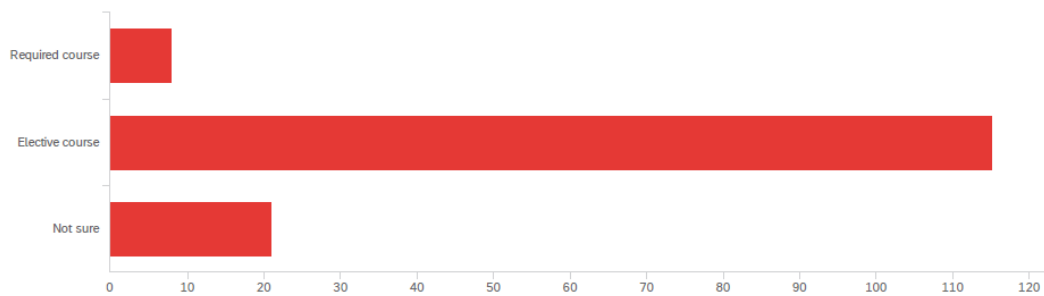
Q8 - Which of the following course formats should be utilized for the course? (multiple

selection is okay)

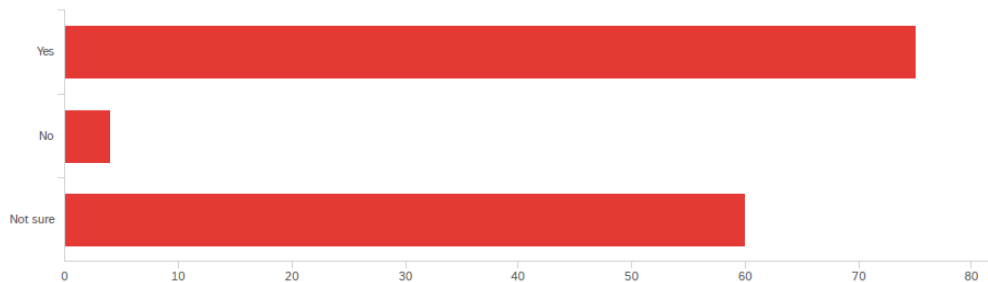


Q9 - Would you like to see this course being offered as an 'elective' or a 'required

course'?



Q10 - If a course on façade engineering is offered, do you think it would increase student employment in the industry?



Results from the survey indicated that although most students had limited knowledge about façade design and its applications in the industry [answers to question 3 and 5] they were very interested in having it as an elective course that would include tools used in the industry such as Mathcad, Excel, and Bluebeam [answers to question 4,7 and 9]. This may be a result of lecturers visiting the program over the past several years with presentations focused on building skin systems and the way they are analyzed and designed to be cost efficient initially as well as during the lifespan of the building. Looking for ways to be cost and energy efficient, with a reduced carbon footprint, is a common topic that current students are exposed to during their education, and that is becoming increasingly relevant in the AEC industry.

Furthermore, the survey showed that students wanted the course to be offered to architects and engineers [answer to question 6], to include field trips and classroom lectures as part of the course [answer to question 8], and that the course could make graduates more employable. With more firms including facade design and development departments in their practices, the inclusion of this type of course in their educational career would give students a head start at these firms.

Façade design course - content

According to results from the student survey, the course development commenced in the fall of 2023, and is currently being offered in the spring semester of 2024. Following the receipt of such positive feedback from students, the next step was to decide on the topics to be included within the façade design course. Some of the major topics that are currently covered in this course include:

- a) Design of aluminum framed glass curtain wall systems using ASTM E1300 [8] and Aluminum Design Manual 2020 [9],
- b) Curtain wall testing using various ASTM standards (e.g. ASTM E-1105-15 [10], ASTM E-783-2018 [11]),
- c) Glass fall-out requirement per ASCE 7 [12] / safety glass requirements per IBC 2021 [13],
- d) Estimating U-values, condensation / thermal bridging problems in building facades [14],
- e) Air and water leakage problems in facades and practical solutions [15],
- f) Use of AISI S-100 [7] for design of cold formed steel facades,
- g) Design of standard anchors used in curtain wall construction, and
- h) Design of canopies, skylights, and glass handrails.

The course includes the application of Excel, Bluebeam, Mathcad, and FEM based structural analysis programs that are commonly used in the industry. During the semester, a guest speaker from the industry was invited to share their experience of working in the façade design sector, allowing students to appreciate the course and enhance their base of knowledge. In future, besides traditional classroom teaching, the course will include a visit to a nearby façade consulting firm where the students can interact with architects and engineers to learn about the design process. With this initial offering of the course, it is important to assess the success of the program to ascertain enhancements that can be included in future offerings of the course. To evaluate the relative success of the course, a second survey was given to students to help with the assessment, as discussed further.

Façade design course - Overview and end of semester assessment and future developments

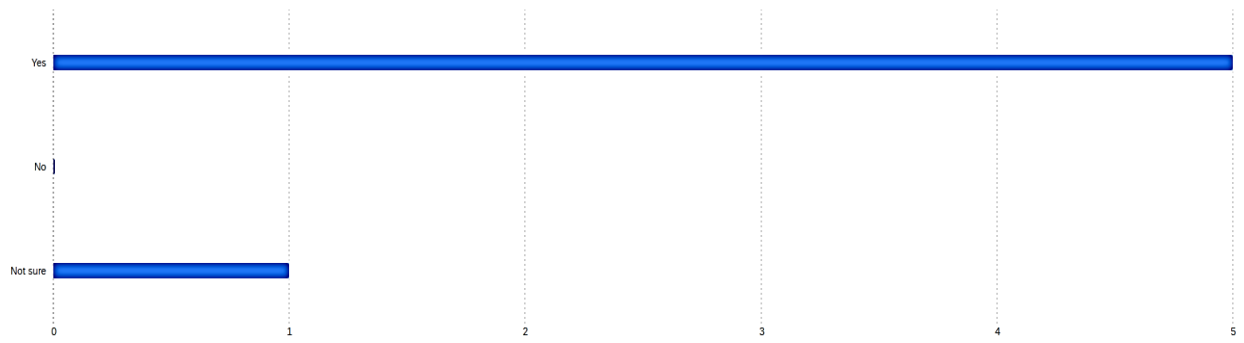
The Façade Design course was offered in the spring 2024 semester, with seven students enrolling in the course. The professor was concerned with the low number of students in the class, but through investigation was able to determine a possible reason. At the time that the course was scheduled, many students had either a required course or an elective course that occurred at the same time. Several students expressed their disappointment that they were unable to take the course due to time conflicts, and requested that the course be offered again, and soon. This is encouraging to the professor, and work has already begun with program administration to schedule the course in the future to minimize conflicts with other courses taken by students in our programs. The response from students unable to take the course in its initial offering is encouraging, and as such, the course is planned to be offered again next year.

To assess the relative success of the course, during the last two weeks of the semester, students enrolled in the course were sent a second survey to assess the topics covered during the semester, and to receive feedback that could improve the course. The professor wanted to know the views of students in the course pertaining to course format, topics covered, delivery methods, and coursework. Students were asked a series of 8 questions about the course, and two additional open-ended questions about future offerings of the course. A Qualtrics™ survey was utilized for this assessment, with 6 of the 7 students enrolled in the course responding, as shown below. Results from this assessment survey will be utilized in further developing the course for future offerings.

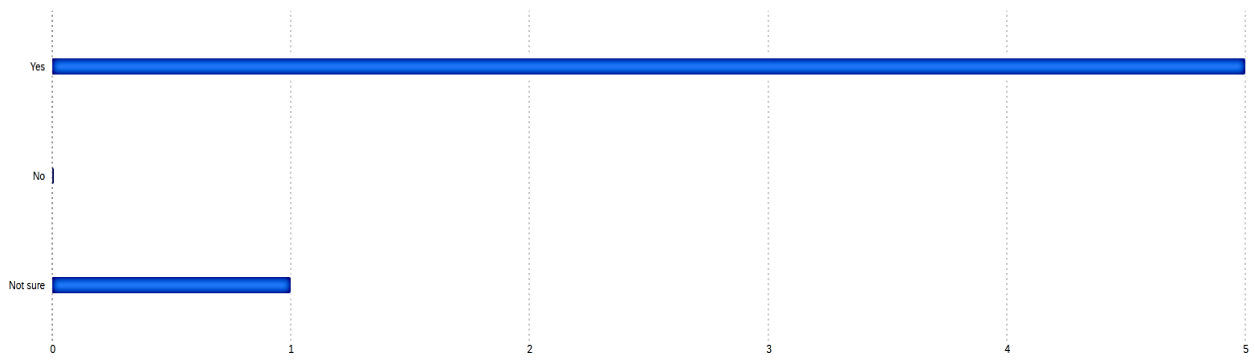
What curriculum year are you in within the program at the SOA? 6 ①



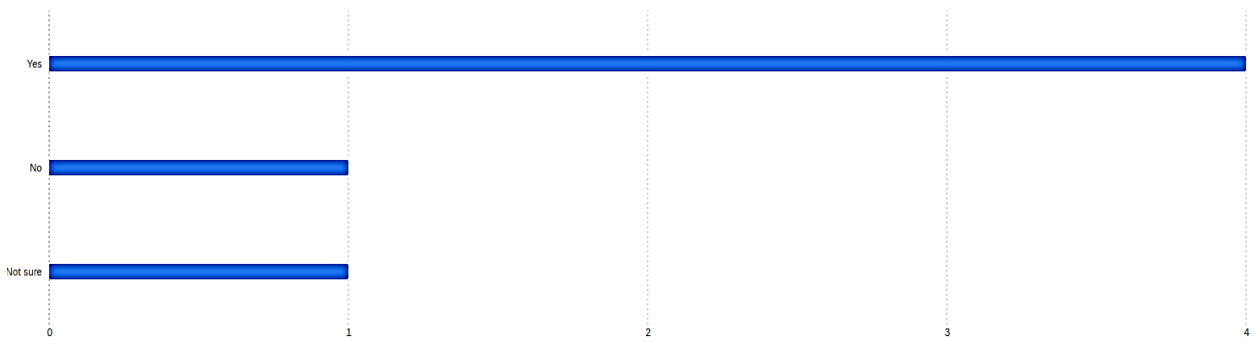
Do you feel that you have gained sufficient theoretical and practical knowledge about structural engineering and building science aspects of façade design? 6 ①



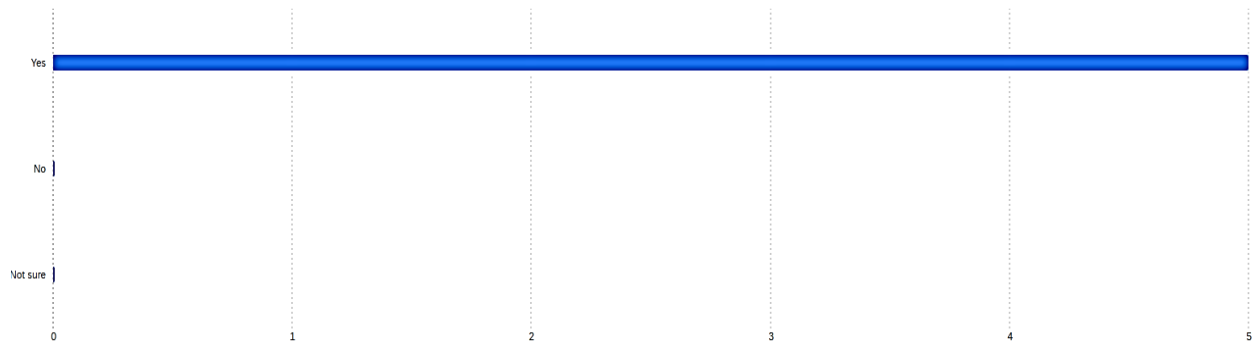
Do you think the knowledge gained from this course will be helpful should you get hired by a façade design consulting firm? 6 ①



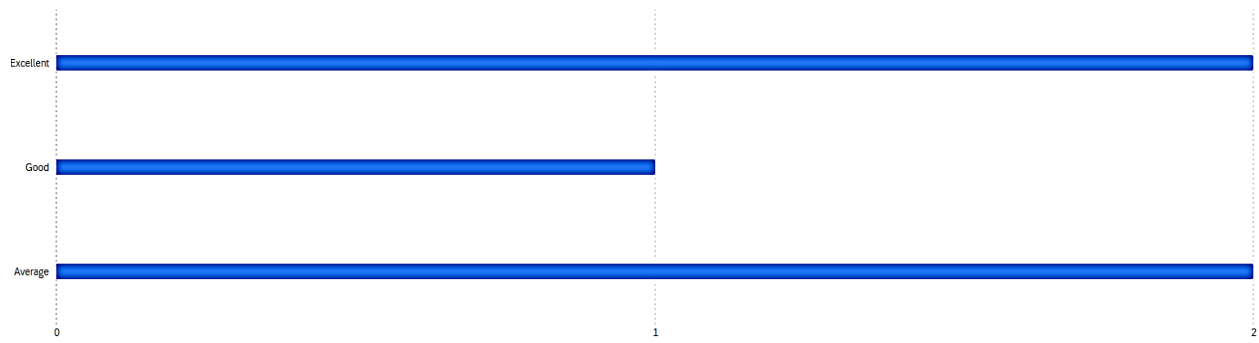
Do you think that the introduction of tools such as 'Mathcad' and 'Excel' was helpful, given they are commonly used in the industry? 5 ①



So far, we have had one guest lecture. Do you think this course should include more guest lectures and field visits to enhance student learning? 5 ①



How would you rate your experience now that you are nearly finishing the course? 5 ①

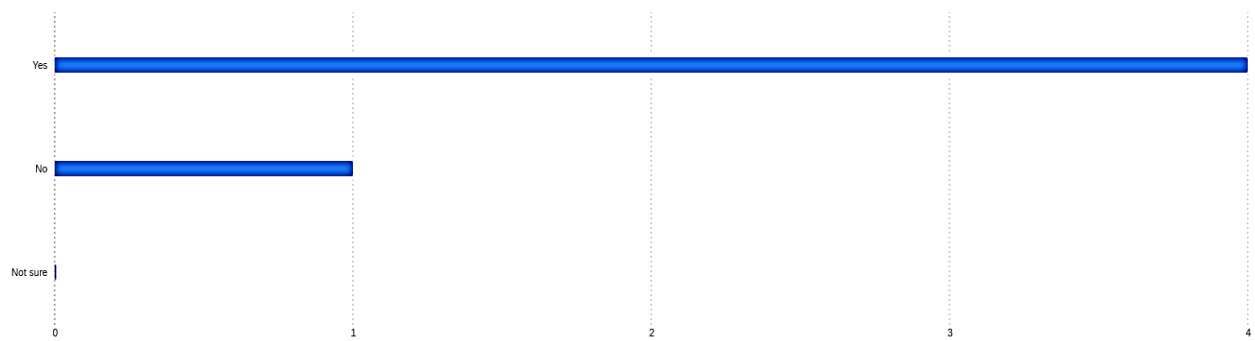


Do you think that the student performance evaluation that currently consists of quizzes, exams, and assignments should be retained? 5 ①



Would you recommend other students at the SOA to take this course? 5 ①

5 ①



Results from this survey show that most students are in the fourth and fifth years of the program and have greatly benefited from façade design course so far. They also believe that tools, such as MATHCAD and Excel, which are widely used in industry, will be extremely helpful for the future. Furthermore, the students approve of the current format of the course that consists of lectures, guest lectures, exams, and quizzes. Based on additional suggestions received from the students, future offerings of this course will include visits to a nearby façade manufacturing plant and construction site undergoing façade installation, to better visualize and understand the processes within the façade design industry. These changes in future will enhance the learning experience, reduce the knowledge gap, and encourage more students to pursue façade design as a career, given the tremendous growth in this area, in recent times.

Conclusions

Façade Engineering is an upcoming field that encompasses multiple disciplines, requiring a formal education at the university, besides relevant textbooks. In the recent decade this field has seen a tremendous amount of growth, especially in construction of high rise, mixed use, university, and hospital buildings. At present, the façade design course offered at Oklahoma State University is being taken by several students studying architecture and architectural engineering. It is hoped that the experiences from this semester will enable the authors to make further improvements to the course content that will enable students graduating from the School of Architecture to better serve the façade engineering industry. In the future, the contents of this course will serve as a basis for writing a textbook that will contribute to the academic and industry fraternity.

This paper presented a detailed overview of a new course titled “façade design” that was recently developed. Facades are made up of different materials, such as aluminum, glass, and cold formed steel. Traditionally, most courses in civil and architectural engineering across the United States and other parts of the world, primarily focus on structural design of steel, concrete and timber, which are mostly used in constructing main frame load-bearing members, while a façade, which is sometimes called as a ‘secondary structural system’, typically forms part of a building’s exterior, exposed to environmental loads such as wind, seismic, thermal, rain and snow loads. The subject of façade design incorporates aspects of structural engineering and building science. Due to the absence of any formal ‘course’ at universities and lack of textbooks in this subject area, most engineers in the industry find it difficult to design building facades. To close this ‘knowledge gap’, the program decided to develop a new course titled “façade design”. As part of this endeavor, students were asked to fill out a questionnaire to obtain their views about a prospective course in façade design. After receiving positive feedback from students, the façade design course was developed incorporating various structural design aspects on glass, aluminum, and cold formed steel members. Towards the end of the semester, students were requested to participate in a second survey to understand any shortcomings and make further improvements. Positive feedback was received from this survey, indicating a strong interest among students within the program. The course currently includes building science topics, such as condensation, sound transmission, thermal bridging, U-values, air, and water leakage problems in facades. The experiences from the ongoing classes at Oklahoma State University will allow the authors to make further improvements in the course content in future. It is anticipated that the introduction of this course could potentially see future students from the programs serve the industry with

enhanced knowledge in façade design. In addition, the contents of this course can be used to develop a textbook that would contribute to industry and academia.

Acknowledgement

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