Professional Development for Community College Students through Design and Seismic Evaluation of Three-Story Moment Resisting Frame

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Abstract

Earthquake has posed a great danger for the human society especially in the San Francisco Bay Area. Future earthquake disaster prevention and preparation require that young professional civil engineers are trained and recruited into the next generation workforce for the purpose of public safety. For the 2011 NASA CIPAIR (Curriculum Improvements and Partnership Award for the Integration of Research) internship program, four community college students from Cañada College participated in a ten-week study of earthquake engineering design and analysis. Students conducted research on seismic systems, structural design, and time history analysis. Specifically, a three-story steel special moment resisting frame was designed and evaluated under selected ground motions. During the structural design, the students not only utilized building codes to determine appropriate sizes for beam and column members of the building but also conducted research on dynamic time history analysis. Four sets of recorded earthquake ground motion – Landers, Loma Prieta, Kobe, and Northridge Earthquakes – were used to assess the performance of the design steel structure. Structural analysis program SAP2000 was incorporated into the design process for students to examine story drift, and the bending of the structure's members. In addition to learning about the fundamentals of earthquake engineering analysis and design, the interns also delivered an interactive presentation to local high school students to encourage them to pursue careers in math, science and engineering. Lastly, the interns created tutorials and videos to help improve community college and university curriculum. Internship programs such as the NASA CIPAIR help prepare community college students not only for their chosen university, but also for their professional career.

Introduction

Earthquakes have posed significant danger to the human society due to their potential for loss of human lives, structural damage and interruption of function of infrastructure. The 1985 M8.0 Mexico earthquake caused around 10,000 fatalities. The 1995 Kobe earthquake in Japan claimed 6,434 lives and 40% of the 10 to 12 stories buildings were heavily damaged or collapsed. In the 1999 M7.6 Chi-Chi earthquake in Taiwan, 2,415 people were killed, 11,305 injured, and about ten billion dollars worth of damage was estimated. In the recent 2010 M8.8 Chile earthquake, 525 people lost their lives, 25 people went missing and about 9% of the population lost their homes [1]. Earthquakes in the San Francisco Bay Region result from strain energy constantly accumulating across the region because of the relative motion of the Pacific Plate to the North

American Plate (Figure 1) [2]. The region experienced large and destructive earthquakes in 1838, 1868, 1906, and 1989. In April 2008, scientists and engineers released a new earthquake forecast for the State of California to update the earthquake forecast made for the greater San Francisco Bay Area. The research predicts that the probability of earthquakes of magnitude 6.7 or greater in the next 30 years is 63% [2].

Figure 1. Faults and plate motions in the San Francisco Bay Region.

As experienced from recent earthquakes in Northridge, California (**M**6.7, 1994, 20 killed, $20B in direct losses) and Kobe, Japan (**M**6.9, 1995, 5500 killed, $147B in direct losses), earthquakes of magnitude 6.7 or greater can have a profound impact on the social and economic fabric of densely urbanized areas such as the greater San Francisco Bay Area. Future earthquake disaster prevention and preparation require that young professional civil engineers be trained and recruited into the next generation workforce as part of the efforts to mitigate the seismic hazard and improve public safety. In this paper, we will present a collaborative training program between San Francisco State University (SFSU) and Cañada College funded by the **N**ational **A**eronautics and **S**pace **A**dministration (NASA). Four community college students participated in this program in 2011 and were trained to perform seismic design and evaluation of a three story steel moment resisting frame.

COMETS Project Between SFSU and Cañada College

Community colleges serve as the gateway to higher education for large numbers of students in the U.S., especially Hispanic and low-income students. Figure 2(a) illustrates the importance of the community college pathway among California engineering graduates. For the year 2008, approximately 33.0% of all University of California (UC) and California State University (CSU) engineering graduates in 2008 transferred from a community college (individually, 23.4% of UC and 41.1% of CSU graduates). The community college pathway therefore represents a sizeable portion of the engineering pipeline in California. For many students, particularly those from underrepresented groups, this pathway to an engineering career may be the only practical way for them to access higher education.

However, for science and engineering fields, lower success and retention rates for minority students are observed at both community college and university levels resulting in underrepresentation of minority groups in these fields. Figure 2(b) shows that among all non-engineering bachelor's degree recipients in 2008, 46.5% of all UC and CSU graduates were transfer students (individually, 30.1% of UC and 55.8% of CSU graduates). In other words, there is a relatively smaller representation of community college transfers among engineering graduates when compared to other majors. An urgent need therefore exists for improving the successful transfer of engineering students in California community colleges to four-year universities. The NASA CiPair program between SFSU and Cañada College addresses some of the barriers to the successful transfer of community college engineering students to a four-year institution including inadequate preparation for college-level courses, especially in mathematics, low success rates in foundational math courses, lack of practical context in the traditional engineering curriculum, and inadequate relevant internship opportunities for lower-division engineering students.

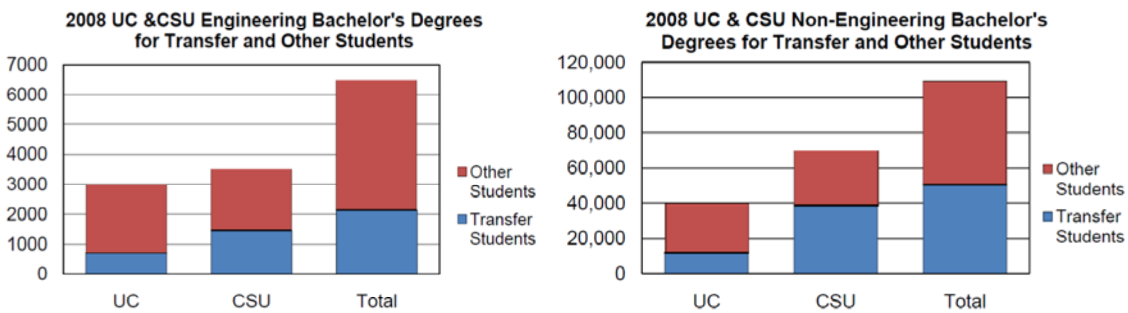

Figure 2. UC and CSU engineering graduates for 2008 showing transfer students from community colleges compared to students who did not transfer from a community college. Data are from California Postsecondary Education Commission [3]

Cañada College is a member of the California Community College System, and is one of three colleges in the San Mateo County Community College District. It is one of only two federally-designated Hispanic Serving Institutions in the San Francisco Bay Area. During the 2008-2009 academic year, the College enrolled 10,865 unique students. The student body is genuinely multi-cultural with Hispanic students as the largest single group at 41.4%; white students comprise 31.7%, Asians 7.2%, Filipinos 3.7%, African-Americans 3.4%, Pacific Islanders 1.7%, American Indian/Alaska Natives 0.4%, other 10.6%. San Francisco State University, is a large, regional, comprehensive university, part of the California State University System. In fall 2009, 30,469 students enrolled at SFSU: 25,001 undergraduates and 5,468 graduate students. Students pursue 115 undergraduate majors, 97 master's degree programs, 27 credential programs, and 37 undergraduate and graduate certificate programs. According to the fall 2009 Undergraduate Student Profile, although white students form the largest racial/ethnic group of undergraduates at 32.8%, 24.9% are Asian, 19.9% are Hispanic, 9.4% are Filipino, 6.0% are African American, 0.9% are Pacific Islander, 0.5% are American Indian or Alaska Native, and 5.6% are "other." Women comprises 59.7% of the student body.

The objectives of the COMETS project are: (1) to improve student engagement and success in foundational math courses and core engineering courses; (2) to provide ten participants each summer with research experiences in NASA Ames, which they would not otherwise have in their usual academic environment; (3) to provide current community college students a year-long engineering design experience early in their academic career by participating in capstone design courses for graduating seniors; (4) to strengthen existing faculty relationship with NASA Ames, and establish new collaborative relationships among two-year and four-year engineering faculty, and NASA Ames Research Center; (5) to increase the number of academically prepared community college students transferring to four-year institutions as engineering majors; (6) to improve academic success of engineering students from underrepresented groups by providing academic support and mentoring; and (7) to increase the number of minority students pursuing advanced degrees in STEM fields.

Student Project Description

In Summer 2011, a total of twelve students were selected through an application process and participated in the CiPair Program. Four of these twelve students chose to work on a civil engineering project, which composed of designing a 3-story office building in an earthquake prone area, where steel moment resisting frames are used as major lateral resistant system. Figure 3 shows a schematic of the project office building. The AISC Steel Manual [4] and ASCE 7-05 Minimum Design Loads for Buildings [5] for structural design were the main references for their design.

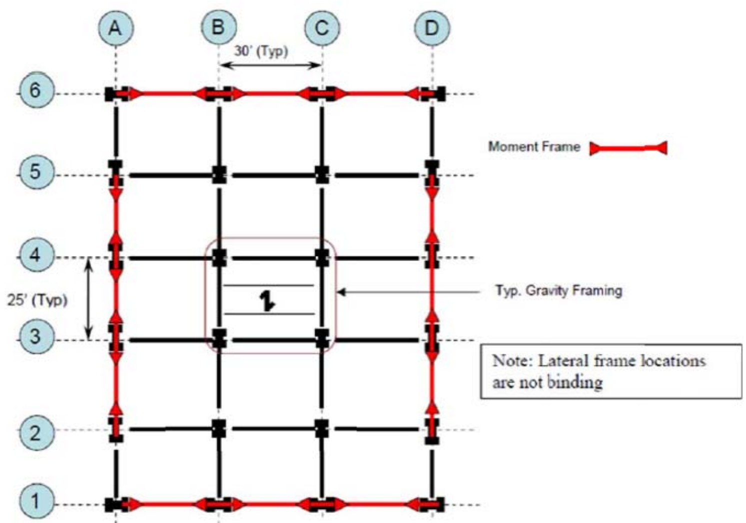

Figure 3 Schematic of the project office building

The students were expected to: 1) understand fundamental concepts such as loads and connections in structural steel design practice; 2) learn to use design manuals (such as ASCE-07 and LRFD Steel Design Manual) to look up required information for their design purpose; 3) follow the basic procedure to determine the equivalent lateral force; 4) learn to use computer software SAP 2000 to analyze the structure under given loads; 5) design the steel members according to AISC codes from the LRFD Steel Design Manual; 6) check if the strength, stability and deflection of the designed building satisfy the code requirements.

Project Outcomes

During the 10-week internship program, the four students were expected to acquire necessary knowledge on structural design and evaluation of a steel moment resisting frame. To accommodate their different educational background, the CiPair Program set up two-level instructional team that includes a faculty advisor and a graduate student. Fundamental concepts in steel design were explained to the intern students by the graduate student and then reinforced by relating the concepts to the equations in the design manual.

Through the program, the students learned how to design the three story steel moment resisting frame under the supervision of the faculty advisor and the graduate student. Tables 1 to 4 present how the students utilized the LRFD Steel Design Manual for the stability, strength and stiffness check of their final design, including the local buckling check, beam nominal moment check, beam deflection check and slenderness check [6].

Table 1. Local Buckling Check

Columns	Design Step 1: AISC B4. Classification of Sections for Local Buckling, Flange	Upper limit	Width-Thickness Ratios of Members, Flange	Local Stability Check for Unstiffened Elements, Flange
Members	AISC 13th Ed. LRFD Formula	$\lambda_r = 0.56*(E/F_y)^{1/2}$	$\lambda = b_f/(2*t_f)$	$\lambda_r = 0.56*(E/F_y)^{1/2} > \lambda = b_f/(2*t_f)$
W18X65	Roof	13.49	5.06	Okay
W18X71	3^{rd}	13.49	4.71	Okay
W18X97	2^{nd}	13.49	6.41	Okay

Table 2. Beam Nominal Moment Check

TRANS MEMBER CHECK:	Step 1 & 2, Check for Design Strength	Moment Check [kip-inch]	Check Against [kip-inch]	Check Okay
Floor	AISC Steel Design Requirements	$M_{u\ beam}$	$M_{u\ required}$	$M_{u\ beam}$ vs $M_{u\ required}$
Roof	W21X68	7200	2094.741	Okay
3rd	W21X68	7200	2032.553	Okay
2nd	W21X68	7200	2057.428	Okay

Table 3. Beam Deflection Check

TRANS MEMBER CHECK:	Maximum Permissible Live Load Deflection	Material Property	Formula Constant[inch]	Check
Floor	AISC Steel Design Requirements	Δ = (5/384)*((wL*L4)/(E *Ix))	L/360	$\Delta = (5/384)*((w_L*L^4)/(E*I_x)) < L/360$
Roof	W21X68	0.988	1	Okay
3rd	W21X68	0.959	1	Okay

2nd	W21X68	0.971	1	Okay

Table 4. Check for Slenderness Ratio Limitations

Columns	AISC 13th Ed. LRFD Formula	Slenderness Ratio, Chapter E2.	AISC Chapter E Section E2.	Check Status
Floors	Chapter E2. Slenderness Limitations and Effective Length	(KL/r_y)	Do not exceed 200	$(KL/r_y) < 200$
Roof	W18X65	78.11	200	Okay
3rd	W18X71	77.65	200	Okay
2nd	W18X97	58.87	200	Okay

Structural analysis using computer software is emphasized in the program. In addition to the steel member design, the students were also trained on structural analysis using SAP2000, an integrated software for structural analysis and design [7]. The students were instructed to use SAP 2000 for both equivalent lateral force design in Table 5 and the time history analysis. Table 6 lists the four ground motions used for the SAP 2000 time history analysis by the students. The analysis results is presented in Figure 4.

Table 5.SAP2000 Check for Story Drift

Floors	Deflection by Elastic Test U1 ,δ_{xe}	Deflection of Level x ,δ_x	Max Allowable Drift Δ_a	Drift Check, δ_2 - δ_1	[units]	Check
Roof	1.940	10.669	3.3	1.576	[inch]	Okay
3^{rd}	1.653	9.093	3.3	2.823	[inch]	Okay
2^{nd}	1.140	6.270	3.9	1.140	[inch]	Okay

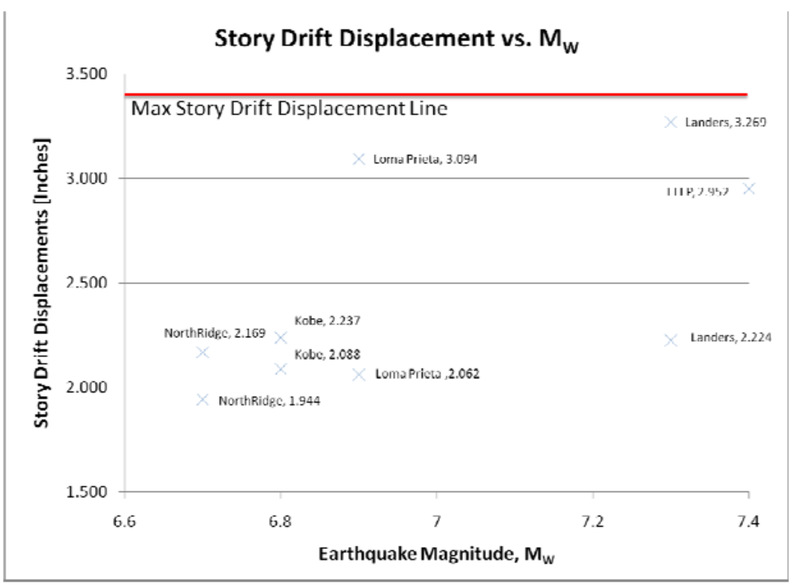

Figure 4. Comparison of SAP 2000 Time History Analysis Results [6]

Table 6. Ground Motions for Time History Analysis

Earthquake	Magnitude (M_W)	Ground Acceleration (g)	Duration (sec)
Loma Prieta 1989	6.9	0.274	15

Landers 1992	7.3	0.727	120-180
Northridge 1994	6.7	0.511	10-20
Kobe 1995	6.8	0.693	20

Project Assessment and Future Improvement

To obtain a quantitative assessment of the project and further improve the project in the future, an exit survey was conducted for all twelve students participating the CiPair program. Students were asked to rate their level of agreement with each question in a five point scale: 1 – Not at all useful; 2 – A little; 3 – Some; 4 – Quite a bit; 5 – A lot. The tables below present the students' response to the survey questions. The survey was conducted anonymously to help student express their opinions honestly.

Question**:** How useful were each of the following activities during your internship?

Activity	Average Rating
Opening Day on June 6th	4.67
Faculty Adviser Description of Project	4.25
Library Orientation Session	2.67
Meetings with Graduate Student	4.00
Meetings with Faculty Adviser	3.75
Weekly Progress Reports	3.75
Mid-Program Presentations (July 22nd)	4.75
Trip to NASA Ames	4.08
Poster Session (Aug 12)	4.83
Final Presentations (Aug 12)	4.92

Question**:** How satisfied are you with each of the following?

Activity	Average Rating
Opening Day	4.67
The project/topic you worked on	4.33
The results of your project	3.67
Your final poster	4.08
Your final presentation	3.83
How much you learned from the program	4.75
Your group mates	3.83
Your graduate student mentor	3.83
Your faculty adviser	4.00
The Summer Internship Program as a whole	4.58

Question**:** As a result of your participation in the program, how much did you learn about each of the following?

Activity	Average Rating

Performing research	4.67
Designing/performing an experiment	4.67
Creating a work plan	4.5
Working as a part of a team	4.75
Writing a technical report	4.5
Creating a poster presentation	4.67
Making an oral presentation	4.67
Performing research	4.67

Question**:** Tell us how much you agree with each of the following statements.

Activity	Average Rating
The internship program was useful.	4.8
I believe that I have the academic background and skills needed for the project.	4.17
The program has helped me prepare for transfer.	4.33
The program has helped me solidify my choice of major.	4.58
The program has helped me solidify my choice of transfer university.	3.75
As a result of the program, I am more likely to consider graduate school.	4.67
As a result of the program, I am more likely to apply for other internships.	5
As a result of the program, I am more likely to consider SFSU as my transfer institutions, or recommend it to others.	3.08
I am satisfied with the NASA CIPAIR Internship Program.	4.67
I would recommend this internship program to a friend.	4.83

When asked the question "what do you like most about the NASA CIPAIR Internship Program?' Typical response from the civil engineering group students are: "The subject was very interesting. It was a very real world experience of working in a team, meeting deadlines, and not having control over the quality of the deliverables; It was a new experience because I have never worked on something related with my major. It was good because I learned a lot of thing from my other coworkers; I like the opportunity that NASA CIPAIR has given to us to allow us to perform undergraduate research and immerse ourselves on a specific topic and became somewhat of an expert on the topic; I thoroughly enjoyed the work experience with the graduate students and Dr. Chen. Most of Dr. Chen's graduate students were very much helpful and we shared common interests. The challenge of working on something new and unguided was always rewarding."

Summary and Conclusion

The CiPair program was very successful in helping students understand specific engineering topics and engineering profession. Responses from the student participants are very positive. Among the students who solidified their choice of an engineering career and decided to major in one of the engineering fields, the program has provided context to their study of engineering – a strategy that has been proven to increase student motivation and persistence – especially as they struggle through the first two years of the engineering curriculum.

Acknowledgement

This project is sponsored by NASA Office of Education through the Curriculum Improvement Partnership Award for the Integration of Research (CIPAIR), Grant Number NNX10AU75G

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Biographical Information

Dr. Cheng Chen joined SFSU in 2009 and he is currently an assistant professor in civil engineering at the School of Engineering at SFSU. He has a strong research background in hybrid simulation and earthquake engineering, and he has published more than twenty technical papers in professional journals and conference proceedings. He has served as faculty advisor for the ASCE SFSU chapter since 2009. He is also a technical committee member of ASCE on structural control and seismic effects.

Dr. Amelito Enriquez has been a tenured professor in the Engineering and Mathematics departments at Cañada College since 1995. He has been an active member of the California Engineering Liaison Council since 1997, and has been serving as the Vice Chair, Community College of the ASEE Pacific Southwest (PSW) section since 2008. He has received awards for his accomplishments related to teaching and enhancing student success. He also received the 2010 NSF Presidential Awards for Excellence in Science, Mathematics, and Engineering Mentoring (PAESMEM).

Dr. Wenshen Pong joined the engineering faculty of SFSU in 1998. As a committee chair of over 40 graduate students' culminating experience, Dr. Pong works closely with his students to ensure that they successfully produce and complete quality research work. He was named Faculty of the Year by the engineering societies of the School of Engineering at SFSU in 2000. He also served as Graduate Coordinator from 2001 to 2007. He has been civil engineering program head since 2007 and currently serves as Director of the School of Engineering at SFSU.

Dr. Hamid Shahnasser has been teaching and carrying out research at SFSU for the past 22 years. He has received ten NASA related grants and fellowships, and has been working at NASA Ames Research center since 1990. He has advised and mentored many students and successfully introduced some of them to NASA Ames summer internship programs as well as careers at Ames and other NASA sites.

Dr. Hamid Mahmoodi is currently an assistant professor of electrical and computer engineering in the School of Engineering at San Francisco State University. He was a recipient of the 2008

Semiconductor Research Corporation Inventor Recognition Award, the 2006 IEEE Circuits and Systems Society VLSI Transactions Best Paper Award, 2005 Semiconductor Research Corporation Technical Excellence Award, and the Best Paper Award of the 2004 International Conference on Computer Design. He is a technical program committee member of International Symposium on Low Power Electronics Design and International Symposium on Quality Electronics Design.

Dr. Hao Jiang joined San Francisco State University in 2007. Between 2000 and 2007, Dr. Jiang worked as a radio-frequency modeling engineer and a radio-frequency integrated-circuit (RFIC) design engineer in Conexant Systems, Jazz Semiconductor and Broadcom Corporation. His recent research in the area of developing electronics system for biomedical implants at San Francisco State University, together with his works in leading edge electronics companies, like Conexant Systems and Broadcom, will bring NASA a needed combination of basic sciences driven research in academia and application driven development in industry.

Mr. Qiming Zeng is currently a graduate student in earthquake engineering at SFSU. He has finished advanced engineering classes including advanced steel structure design; fire structural design and advanced seismic design at SFSU. His research topic focuses on push-over analysis for steel structure.

Andrew Chan, John Louie Paulino, Moises Quiroz and Jose Valdovinos were student participants of the CiPair program from Cañada College. Mr. Chan is currently a structural engineering student at University of California at San Diego. Mr. Quiroz is currently a civil engineering student at Cal Poly at San Luis Obispo. Mr. Valdovinos and Mr. Paulino are currently continuing his second year study at Cañada College.