Integrating Earthquake Engineering into Community College Student Educational Experience through a Summer Internship

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Abstract

Young professional civil engineers are critical for preparing the San Francisco Bay Area for future earthquake events. Many of these future engineers will come from community colleges, which serve as a gateway to higher education for large numbers of students, especially minority and low-income students. Preparing community college students for their future engineering career and engaging them in professional development is one of the major objectives of the NASA CIPAIR (Curriculum Improvements and Partnership Award for the Integration of Research) program. In the San Francisco Bay Area, a collaborative NASA CIPAIR program between Cañada College, a federally designated Hispanic-serving community college, and San Francisco State University, a large urban university, has developed a summer internship program that provides freshmen and sophomore community college students an opportunity to participate in a ten-week study of earthquake engineering. For the summer 2012 internship program, students designed a five-story steel special moment-resisting frame, and evaluated its performance under four selected ground motions. The students optimized the structural design through iterative computer-based dynamic time history analysis. Structural analysis program SAP2000 was incorporated into the design process for students to examine story drift, and the capacity of the structural members. The ten-week program was found to be successful in engaging community college students in the civil engineering career thereby helping train future American workforce for seismic hazard mitigation.

Introduction

Earthquake engineering is concerned with design and analysis of structures to withstand earthquakes at specific locations. Steel structure design is one of the main approaches to this mission. Starting in the late 1800's, steel became readily available for applications in large-scale engineering structures. This triggered a tide of tall buildings, including the Home Insurance Building in Chicago and the Manhattan Building in New York[1]. Steel frame buildings began to rise all across the nation without any major changes in their connections or design for nearly a century after the 1880's. But after the structural failures during the 1994 Northridge Earthquake, there was a fundamental rethinking in the design of seismic resistant steel moment connections. This led to the SAC Steel Project research funded by FEMA[2]. The San Francisco Bay Region experienced large and destructive earthquakes in 1838, 1868, 1906, and 1989. In a recent study, scientists and engineers released a new earthquake forecast for the earthquake forecast made for the greater San Francisco Bay Area as shown in Figure 1. The research predicts that the probability of earthquakes of magnitude 6.7 or greater in the next 30 years is 63%[3]. 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.

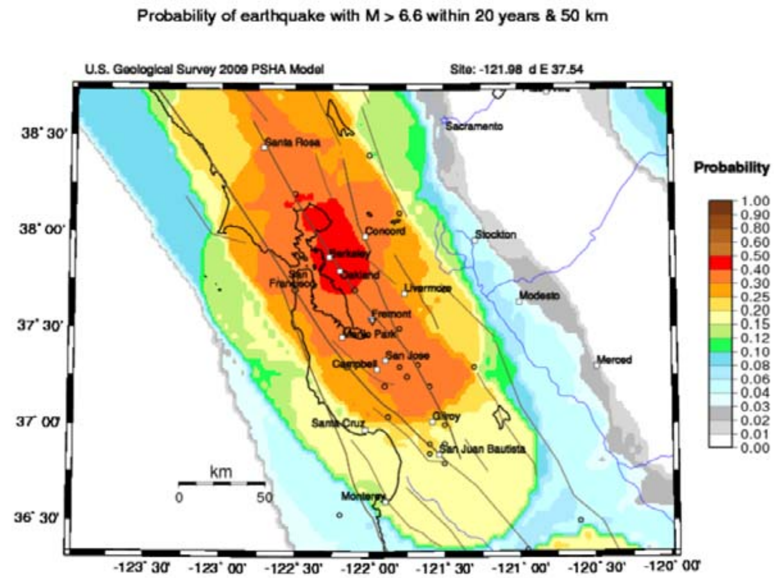

Figure 1. Probability of Earthquakes in the San Francisco Bay Region

Community colleges such as Cañada College serve as the gateway to higher education for large numbers of students especially in California. However, for science and engineering fields, lower success and retention rates are observed at both community college and university levels resulting in underrepresentation of minority groups in these fields. The NASA CiPair program between SFSU and Cañada College addresses some of these 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.

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 2011-2012 academic year, the College enrolled 10,965 unique students. The student body is genuinely multi-cultural with Hispanic students as the largest single group at 35.5%; white students comprise 32.6%, Asians 8.1%, Filipinos 3.4%, African-Americans 3.9%, Pacific Islanders 1.7%, American Indian/Alaska Natives 0.3%, multi-racial 9.5%, unknown 4.9%. 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 comprise 59.7% of the student body.

The objectives of the NASA CiPair 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.

Summer Intern Project Description

For the second year of the project in summer 2012, 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 5-story office building in an earthquake prone area, where steel moment-resisting frames are used as a 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 for structural design[5] were the main references for their design.

Table 1. Design load for the five-story office building

Building Specifications	Dead load (psf)	Live load (psf)	Height (ft)
Roof	95	20	11
5	90	50	11
4	90	50	11
3	90	50	11
2	92	50	13

The five-story special steel moment frame structure is assumed to be located at 3939 Bidwell Drive, Fremont, CA 94538 and will be an office building designed with large open spaces in the center, and large windows to allow for the most natural light to enter these areas. Table 1 shows the live loads of 50 psf (pounds per square foot) at each floor and 20 psf for the roof. Dead loads (including the weight of the building) were assigned as 95 psf on the roof, 92 psf on the second floor and 90 psf on the third, fourth and fifth floors. The height of the first floor is 13 feet, and 11 feet for the second, third, fourth and fifth floors. Figure 2 shows the dimensions of the entire building. This building is designed according to AISC's code and ASCE's equilateral force procedures. Computer software SAP 2000[6] is required for the students to analyze the structure under given loads.

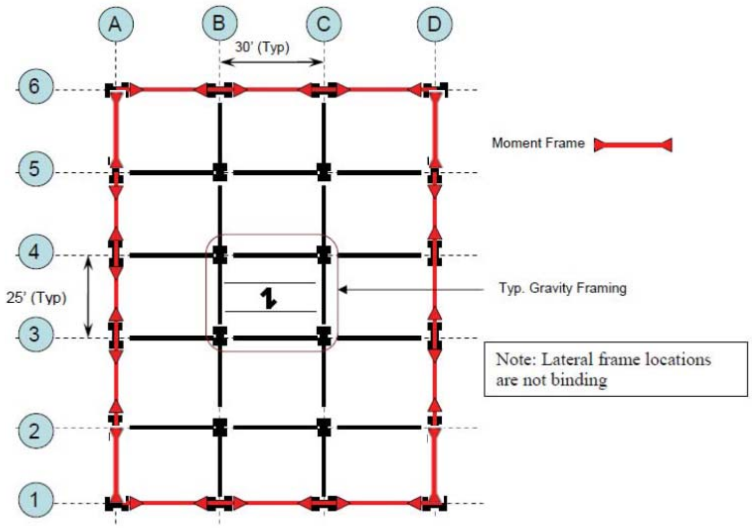

Figure 2- Top view of building

Structural Design Project Outcome

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 backgrounds, the CiPair Program set up a 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.

Table 2 presents the calculation of the horizontal distribution forces and the accidental torsions conducted by the students following the equivalent lateral force procedure. Figures 3 and 4 show the member selection for the first and final design of the moment resisting frame in the E-W and N-S direction, respectively. Tables 3-4 present the check of the selected beam for bending.

Table 2. Horizontal distribution forces and accidental torsions for structural design

Horizontal Distribution Forces and Accidental Torsions							
Floor	h_i	w_i	$w_i h_i^k$	$\frac{w_i h_i^k}{\Sigma(w_i h_i^k)}$	F_x	$.5F_x$	V_x
Units	ft	K			kips	kips	kips
Roof	57	1068.75	93136.06	0.35	327.91	163.95	0
5	46	1012.50	69621.35	0.261	245.12	122.56	327.91
4	35	1012.50	51474.28	0.19	181.23	90.61	573.02
3	24	1012.50	33925.67	0.13	119.44	59.72	754.25
2	13	1035.00	17613.58	0.07	62.01	31.01	873.70
1	0	0.00	0.0000	0.0000	0.0000	0.0000	935.71
	sum	5141.25	265770.93	1.0000	935.71	467.85	935.71

The student interns are guided to develop a preliminary design and then a final design to improve the efficiency of the building. Figure

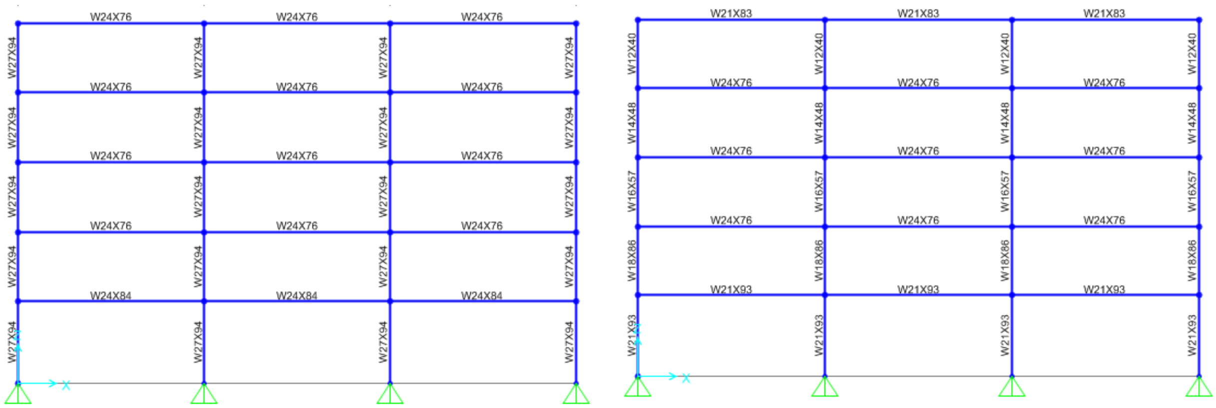

Figure 3. Building design in E-W direction: a) first design; b) final design

Table 3. Details of E-W Beams for final design

E-W beams	Members	Wu (kip)	M_u ($kip \cdot in$)	Calculated Z_x (in^3)	Z_x table (in^3)	Check
Roof	W21X83	9.48	710.93	189.58	196	OK
5	W24X76	9.95	746.29	199.01	200	OK
4	W24X76	9.95	746.29	199.01	200	OK
3	W24X76	9.95	746.29	199.01	200	OK
2	W21X93	10.14	760.27	202.74	221	OK

Figure 4. Building design in N-S direction: a) first design

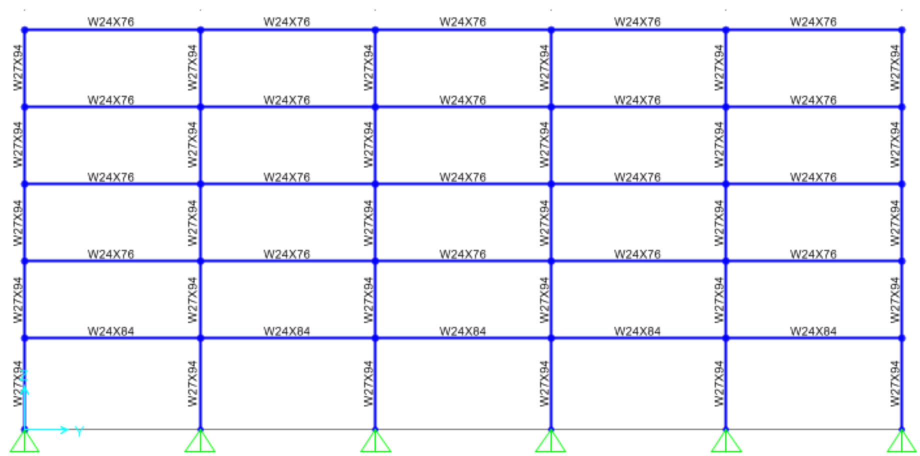

Figure 4. Building design in N-S direction: b) final design

Table 4. Details of N-S beams for final design

N-S beam	Members	Wu (kip)	Mu ($kip \cdot in$)	Calculated Z_x (in^3)	Z_x (in^3)	Check
Roof	W21X68	11.37	592.44	157.98	160	OK
5	W21X73	11.94	621.91	165.84	172	OK
4	W21X73	11.94	621.91	165.84	172	OK
3	W21X73	11.94	621.91	165.84	172	OK
2	W24X68	12.16	633.55	168.95	177	OK

The member columns are checked by tests for effective slenderness and elastic buckling behavior. K, the effective length factor, is used for calculating the column slenderness, KL/r, where L is the laterally unbraced length of the member and r is the governing radius of gyration. The flexural buckling, F_e, stress test and elastic buckling, F_{cr}, test are to confirm if the building can retain its shape after being hit by an earthquake. The nominal strength, P_n, checks for local stability for proper thickness of the column web and strong axis bending strength[7]. These calculations and tests can be seen in Table 5.

Table 5. Strength checks of the columns

Columns		$\frac{KL}{r}$		Fe= $\frac{(\Pi^2 * E)}{(\frac{KL}{r})^2}$	Fcr	$P_n = F_{cr} * A_g$	
	Members	Slenderness ratio	Check	elastic critical buckling (ksi)	Flexural buckling Stress (ksi)	nominal strength (kips)	Local Stability
roof	W12X40	68.0412	OK	61.8235	35.6418	417.0088	stable
5	W14X48	69.1099	OK	59.9262	35.2618	497.192	stable
4	W16X57	82.5	OK	42.0523	30.3977	510.6822	stable
3	W18X86	50.1901	OK	113.6217	41.5891	1052.2032	stable
2	W21X93	84.7826	OK	39.8184	29.5608	807.0101	stable

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, integrated software for structural analysis and design[6]. The students were instructed to use SAP 2000 for both equivalent lateral force design and the time history analysis. Ground motions recorded in four different earthquakes that occurred in California were selected by the students with magnitude between 6.0 and 7.0. Table 6 lists the details of the four ground motions for the SAP 2000 time history analysis by the students. The analysis results are presented in Figure 5, which shows that the final design satisfies the code requirement.

Table 6. Specifications on the four selected earthquakes

Earthquake	Magnitude	Duration (s)	Cost	Loss of Life
Loma Prieta, 1989	6.90	40	$8 Billion	63 killed, 3,757 injured
Morgan Hill 1984	6.19	27	$7 Million	27 injured
Northridge 1994	6.70	60	S20 Billion	57 killed, 8,700+ injured
San Fernando 1971	6.61	70	$505 Million	65 killed, 2,000+ injured

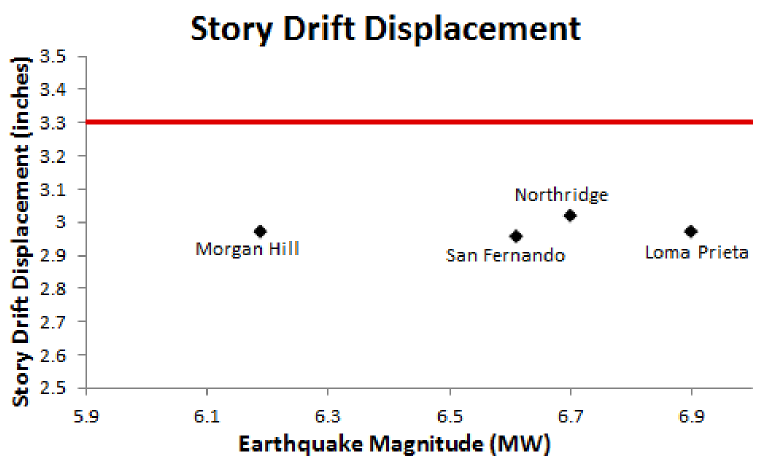

Figure 5. Story Drift Displacement from SAP2000 Analysis

To help propel NASA's goal of human settlement in outer space, the interns also analyzed special moment-resisting frames' behavior on the surface of the moon. They researched the landscape and studied the environment to gain a better understanding of the lunar conditions and determine if the designed structure would endure moon ground shaking. There are four different types of moonquakes, the technical term for seismic activity on the moon, which are deep moonquakes, meteorite impacts, thermal quakes, and shallow quakes. Shallow moonquakes is the most harmful type of moonquake as they are less intense (magnitude of 4 on the Richer scale) but last for a longer duration (up to 10 minutes) in comparison to earthquakes[7]. Shallow moonquakes due to the terrain of the moon being a large dry-rigid chunk of stone, seismic activity of the same magnitude/intensity on the moon would cause more damage than that on Earth where the water and soil dampen seismic vibrations. Low magnitude moonquakes will not cause serious damage to our structure but their extended duration causes issues such as low-cycle fatigue.

Project Assessment and Future Improvement

The internship experience enabled the interns to realize how trained civil engineers in the field will have to collaborate with other members on their team. Trained civil engineers will need to make weekly meetings with their supervisor to discuss their progress on their design and provide feedback on what they can improve. They will need to make a detailed, tentative plan that they must follow until their deadline when the building must be constructed. The research project could not have been completed by one engineer because it takes teamwork and collaboration on everyone's part to get the project done.

To obtain a quantitative assessment of the project and further improve the project in the future, an exit survey was conducted for all twelve student participants. 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 some of the survey questions. The survey was conducted anonymously to help student express their opinions honestly.

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	4.69
Designing/performing an experiment	4.85
Creating a work plan	4.77
Working as a part of a team	4.85
Writing a technical report	4.85
Creating a poster presentation	4.62
Making an oral presentation	4.54

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

Activity	Average Rating
The internship program was useful.	4.92
I believe that I have the academic background and skills needed for the project.	4.08
The program has helped me prepare for transfer.	4.38
The program has helped me solidify my choice of major.	4.38
The program has helped me solidify my choice of transfer university.	3.54
As a result of the program, I am more likely to consider graduate school.	4.46
As a result of the program, I am more likely to apply for other internships.	4.77
As a result of the program, I am more likely to consider SFSU as my transfer institutions, or recommend it to others.	3.77
I am satisfied with the NASA CIPAIR Internship Program.	4.85
I would recommend this internship program to a friend.	4.77

When asked the question "what do you like most about the NASA CIPAIR Internship Program?' Typical response from the civil engineering group students are: “I like the fact that we work in a group on a research project. We gain the experience and knowledge of working as a group.” “The problem that we were given was a graduate level problem for student civil engineers. This project helps us advance our skills in civil engineering.” “I liked how each day i had the chance of learning something new about my major and the principles that goes with Electrical Engineering. “The part I liked the most about this project was the safety inspections that we did at NASA Ames (full-time interns' assignment). I was able to learn a lot about the things NASA does to improve our lives.” “I like the opportunity to conduct research and experience how theoretical concepts learned in class can be applied to real world situations. I like the environment created by adviser, mentor, and group mates. We could work and learn as we have some fun.”

Summary and Conclusion

The NASA CiPair program has been very successful in helping students understand civil engineering topics and the 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.

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