Utilization of Freeware SMATH and Industry Based Softwares in Teaching Computer Based Concrete Building Design and Earthquake Engineering

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Highlights

- Majority of civil engineering students will likely practice structural engineering thus the need to make sure that they are capable of validating software result while understanding theory and concept of Earthquake Engineering and Concrete Design.
- SMATH and MS Excel are free softwares that can be used for validating the result of Industry Based softwares like STAAD and RCDC
- Online mode of learning for courses PCS1 and PCS2 are proven effective since these courses requires engineering simulation softwares

Abstract

The new curriculum for K–12 graduates offers several professional courses in the final year of study, as indicated on the curriculum map. Both earthquake engineering (PCS1) and computer-based concrete building design (PCS2) are included in the BSCE curriculum at TUP Manila in accordance with the 2017 CHED CMO-92 series requirements (18). These are main courses for Structural Engineering specialization track of BSCE Program. Additionally, these courses teaches students in creating building permit drawings and designing low-rise concrete structures that take into account earthquake and gravity forces using industry-standard software like STAAD and RCDC. As it influences the design and construction of low-rise concrete buildings, earthquake consideration is crucial for a seismic country like the Philippines. To further grasp the concept and how the commercial software functions, students are instructed to validate software results using spreadsheets. This study examines the effectiveness of using free and open source programs like SMATH and MS Excel to teach the first batch of TUP Manila BSCE students in the new curriculum's computer-based concrete building design (PCS1) and earthquake engineering (PCS2) courses in an online mode of learning.

Key Words: earthquake engineering; student learning; STAAD; SMATH, concrete design, online learning, COVID 19

1. Introduction

The new curriculum of BSCE Program was implemented AY 2018-2019 in compliance to CHED CMO-92 series 2017(18). Figure 1 shows majority of Introductory and Enabling courses for the BSCE Curriculum while Figure 2 below shows that PCS1 (Computer Based Concrete Design) and PCS2 (Earthquake

Engineering) are considered Demonstrative subjects to the Program outcomes ”m” in Figure 3. That is, these are required for structural engineering specialization track of BSCE Program in TUP Manila

			Curriculum Map												
Code	**Mathematics**	**Units**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**
MathEng1-M	Calculus 1	3	I												
MathEng2-M	Calculus 2	3	I												
MathEng3-M	Engineering Data Analysis	3	I	I											
MathEng4-M	Differential Equations	3	I												
MathEng5-M	Numerical Solutions to CE Problems (Lec)	2	E				D		E		E		E		
MathEng5L-M	Numerical Solutions to CE Problems (Lab)	1	E				D		E		E		E		
Code	**Natural/Physical Sciences**	**Units**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**
ChemEng-M	Chemistry for Engineers (Lec)	3	I	I									I		
ChemEngL-M	Chemistry for Engineers (Lab)	1	I	I									I		
PhysEng-M	Physics for Engineers (Lec)	3	I	I									I		
PhysEngL-M	Physics for Engineers (Lab)	1	I	I									I		
Geo-M	Geology for Engineers	2					E	E		D	E	E	I		
Code	**Basic Engineering Sciences**	**Units**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**
BES11-M	Civil Engineering Orientation	2						I		I		I			
BES12-M	Engineering Drawing and Plans	1				E		I	I				E		
BES1-M	Computer-Aided Drafting	1	I										D		

Figure 1. Curriculum Map

Code	Professional Courses - Specialized	Units	a	b	c	d	e	f	g	h	i	j	k	l	m
Professional Course (Option 1)															
PCS1-M	Civil Programs in Structural Engineering (Computer Software in Structural Analysis and Design)	3											D		D
PCS2-M	Earthquake Engineering	3	E		E				E				E		D
PCS3-M	Structural Design of Building (Structural Design of Towers and other Vertical Structures)	3	E		E		E		E				E		D
PCS4-M	Foundation and Retaining Wall Design	3	E		E		E		E				E		D
PCS5-M	Plastic Analysis and Design of Steel	3	E		E		E		E				E		D

Figure 2. Professional Courses in Curriculum Map

Program Outcomes	
By the time of graduation, the students of the program shall be able to:	
a	An ability to apply knowledge of mathematics and science to solve engineering problem.
b	Design and conduct experiments, as well as to analyze and interpret data;
c	Design a system, component, or process to meet desired needs within realistic constraints, in accordance with standards;
d	Function in multidisciplinary and multi-cultural teams;
e	Identify, formulate, and solve complex civil engineering problems;
f	Understand professional and ethical responsibility;
g	Communicate effectively civil engineering activities with the engineering community and with society at large;
h	Understand the impact of civil engineering solutions in a global, economic, environmental, and societal context;
i	Recognize the need for, and engage in life-long learning;
j	Know contemporary issues;
k	Use techniques, skills, and modern engineering tools necessary for civil engineering practice;
l	Know and understand engineering and management principles as a member and leader of a team in a multidisciplinary environment;
m	Understand at least one specialized field of civil engineering practice.

Figure 3. Program Outcomes for BSCE

Since the COVID 19 pandemic prohibited students from attending classes, PCS1 and PCS2 courses are taught online. Study by (García-Alberti et al., 2021) noted the challenges of online education and one of which is the unavailability of gadgets and slow internet connections for students especially those with low income families. This paper recommends utilizing free and open source software like SMATH and MS Excel in teaching PCS1 and PCS2 courses to avoid further burden to students of acquiring otherwise expensive softwares.

Although STAAD and RCDC are commercial softwares, they are accesible to students using the academic license of TUP Manila which is only effective for 1 year. To date however, the Bentley Education subscription enables the students to use the commercial software for institutional use so long as school emails are used. This paper also addressed the recommendation of (Ayadat et al., 2021) to use efficient delivery of computer modeling or simulated based engineering tools in the conduct of online learning during this pandemic. To evaluate the effectiveness of combining industry software with free and open source software, an end of course evaluation survey is done.

Survey last year in Figure 4 and 5 show that most civil engineers are practicing structural engineering and graduating students are likely to practice this specialization. And among the softwares available as shown in Figure 6, STAAD is the most used industry based softwares for building analysis and design. Thus, theres a need to make sure students can understand output of software and can validate result.

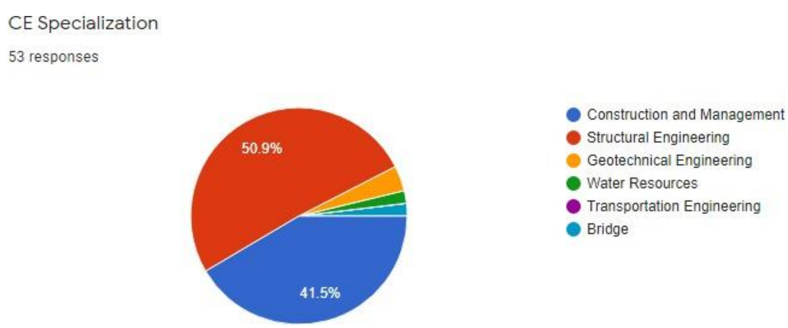


Figure 4. Specializations among CE Profession

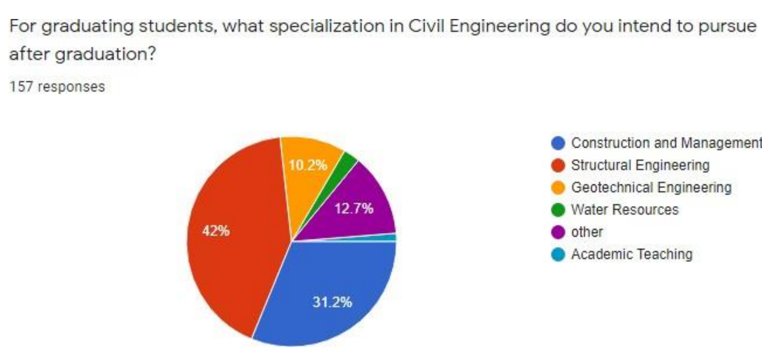


Figure 5. Specialization after graduation

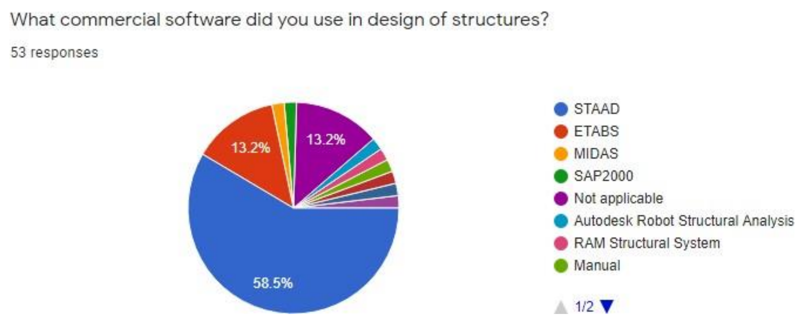


Figure 6. Commercial softwares used in the structural engineering specialization

(Ishack et al., 2021) used STAAD to do 3D response spectrum anaysis of reinforced concrete buildings especially irregular buildings and study the seismic responses. (Markandeya Raju et al., 2021) created mathematical model to determine natural frequency of prestressed concrete beam and compare with non prestressed beam. According to (Ayadat et al., 2021) it still recommended to use general mathematical software since it enhances the competencies included in engineering curriculum.

Many literatures have also shown using mathematical software like MS Excel in aid of teaching civil engineering courses. (Bermúdez et al., 2020) used MS Excel with industry software like EPANET to enhance students understanding of basic concepts in numerical simulation in hydraulic engineering. Responses of students in the survey have shown that these teaching learning strategy resulted in greater participation of students and higher motivation for learning. (Navaee, 2003) utilized excel in solving structural analysis problem and noted that it is better to use than commercial softwares since you can quickly generate and analyze variety of problems easily during lecture.

MATHCAD and MATLAB are both another famous mathematical softwares were used in many literature in teaching engineering courses. (Uziak & Gandure, 2015) compared analysis of spreadsheet and MATLAB in beam bending calculation and noted that MATLAB is faster and has better user interface than MS Excel spreadsheet. However, Mathcad and MATLAB are both expensive thus limiting the use for students especially those in the low income family.

(Estrada & Lee, 2009) recommended the use of MS Excel and MATHCAD in earthquake engineering courses to validate RISA 3D results because the latter does not give equivalent storey forces important for student to verify how member forces are obtained. This paper will instead use STAAD and RCDC both commercial software by Bentley Inc as an aid in teaching Earthquake engineering course and computer based concrete design course.

(Gallardo-Pastor et al., 2021) have used SMATH in teaching thickening design for chemical engineering students. SMATH is similar to MATHCAD and it is entirely free for personal and commercial use.

Moreover, no literatures yet have shown implementing SMATH in earthquake engineering and concrete design courses for civil engineering education. This paper will show the effectiveness of using free and open source software SMATH and MS Excel in teaching Computer Based Concrete Building Design and Earthquake Engineering for the first batch of graduating BSCE students under new curriculum in an online learning mode setup.

Computer Based Concrete Building Design and Earthquake Engineering

Curriculum in BSCE Program

These two subjects PCS1 and PCS2 are offered to the first batch of graduating students under new curriculum this AY 2021-2022 shown in Figure 7.

FOURTH YEAR - FIRST SEMESTER

PCE14-M	Principles of Reinforced/ Prestressed Concrete, Lec	5	5	0	PCE5-M, PCE5D-M	PCE14D-M
PCE14D-M	Principles of Reinforced/ Prestressed Concrete, Des	1	0	3	PCE5-M, PCE5D-M	PCE14-M
PCE15-M	Principles of Transportation Engineering	3	3	0	PCE6-M	None
PCE16-M	Civil Engineering Project 1, Lec	1	1	0	PCE10-M, PCE11-M, PCE13-M	PCE14-M, PCE16D-M
PCE16D-M	Civil Engineering Project 1, Des	1	0	3	PCE10-M, PCE11-M, PCE13-M	PCE14-M, PCE16-M
PCS1-M	Professional Course – Specialized 1	3	3	0	PCE10-M, PCE11-M, PCE13-M	PCE14-M
PCS2-M	Professional Course – Specialized 2	3	3	0	PCE10-M, PCE11-M, PCE13-M	PCE14-M
	Total	17	21			

Figure 7. Fourth Year First Semester Curriculum of BSCE in TUP Manila

Course Learning Outcomes of PCS1 include 1. Demonstrating knowledge of analyzing indeterminate structures using direct stiffness method 2. Recognizing the possible solution to instability warnings and erros in structural analysis of softwares by understanding stiffness matrix formula- tions, 3. Developing their own solver for structural analysis of 2D Problems and 4. Developing complete structural design of multistory concrete building using STAAD and RCDC software.

Course Learning Outcomes of PCS2 include 1. Demonstrating knowledge of analyzing inde- terminate structures subjected to earthquake forces and verified in softwares 2. Recognizing the dynamic property of structure important in design of structure under seismic zone 3. Apply NSCP Seismic Provision in developing complete structural design of multistory building using STAAD and RCDC software.

TUP Manila uses MS Teams as its platform for online delivery, which can be either synchronous or asynchronous, as the school also has a Microsoft Office 365 subscription.

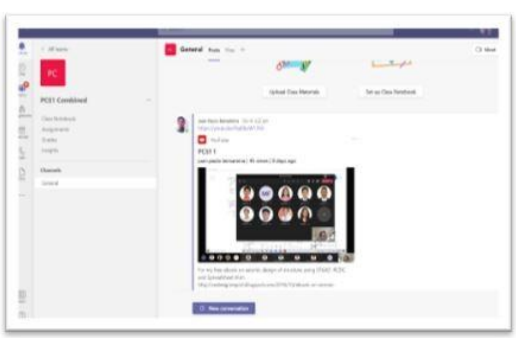


Figure 10. MS Teams for online class

Figure 11. Office 365 for all students

Figure 8. TUP Manila subscription to Office 365 and MS Team as online learning platform

(Rodriguez-Paz et al., 2021) proposed the usage of Youtube channel as crucial component in online learning because it has been successfully used for numerous engineering disciplines even before the pandemic started. Because of this, the majority of recorded lectures are kept in a separate Youtube channel by the instructor so that students can access them online and see or download them whenever and wherever they choose.

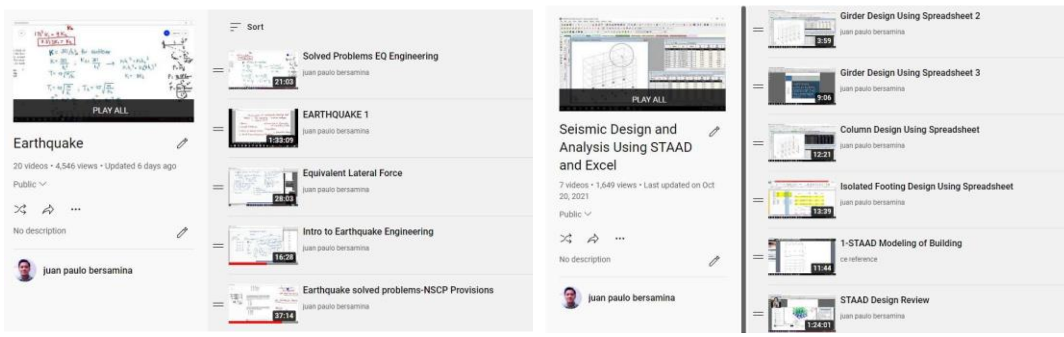


Figure 9. Author's Youtube Channel as repository of online lecture recordings

2. Methods

Utilization of STAAD and RCDC

A Bentley academic license (17) for a year is available to TUP Manila as part of the purchase of structural laboratory equipment. Everyone enrolled in TUP is urged to take use of this open access, particularly graduates who will require software expertise to work in the sector.. Buildings, oil and gas structures, and power plants are all designed using Bentley software (16).

To date however, as long as students and faculty members use their institutional email, softwares are free to use under Bentley education subscription(17). STAAD is used to simulate and analyze the student project, and RCDC is utilized to design the concrete members since it can provide a drawing file that complies with the NSCP Concrete and Seismic Provision Code (19).

Figure 10. Bentley STAAD and RCDC softwares part of Bentley Education Free Usage for Educational Institution

2.1 Geometry Modeling

Sample lowrise concrete building project made by students are shown below.

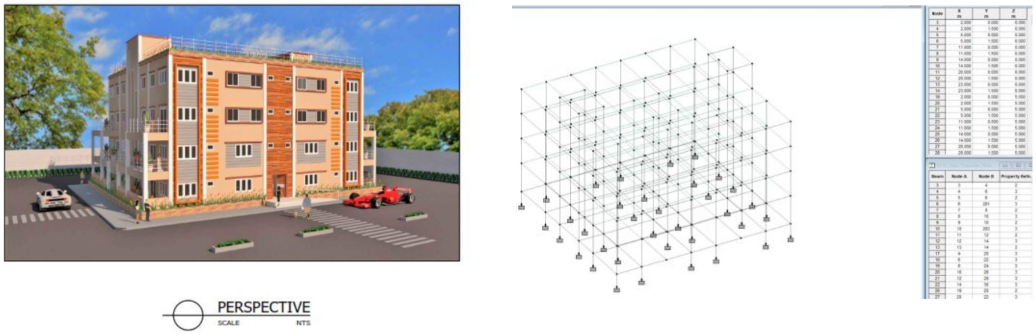


Figure 11. Sample Student Project and Corresponding STAAD Model Geometry

2.2 Property Assignment

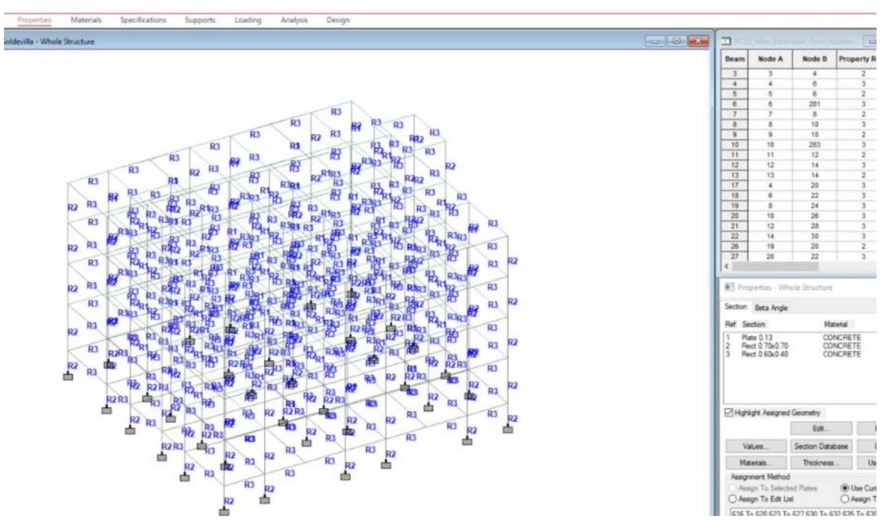


Figure 12. Beams and Column sizes should be consistent with student project drawing

2.3 Supports and Load Application

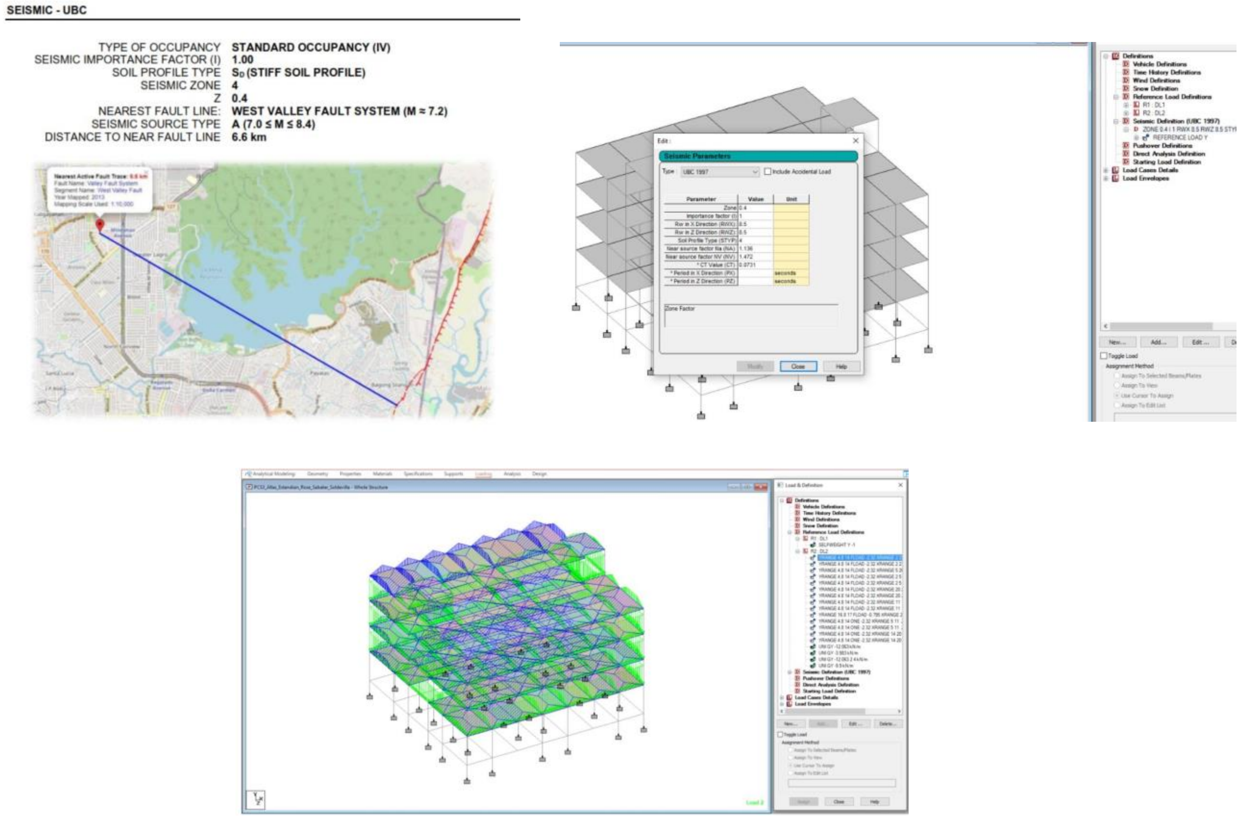


Figure 13. Distance to fault line, STAAD seismic definition and loading combinations from student output

Seismic definitions consistent with the design criteria and NSCP(8) are also defined before applying primary loads and load combinations.

2.4 Other Commands related to Earthquake Engineering Concept

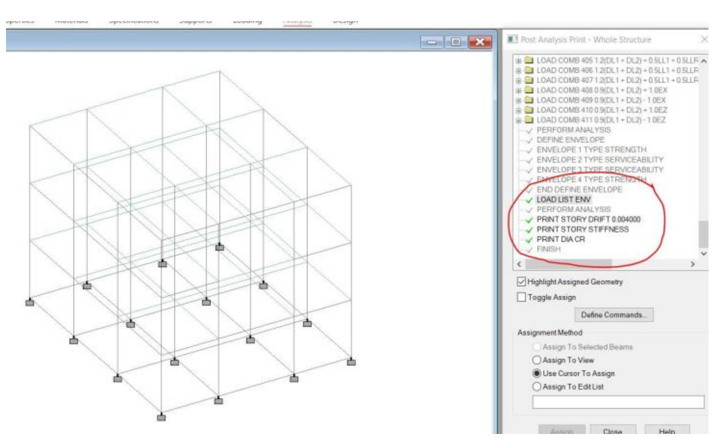


Figure 14. Distance to fault line, STAAD seismic definition and loading combinations from student output

Outputs like Story Drift, Center of Mass, Center of Rigidity and Story Stiffness are required to verify that model does not have torsional shear and in compliance to drift check as per NSCP.

2.5 Perform Analysis and Post Processing

After modeling geometry, assigning properties, load and supports, Analysis shall be performed where possible warning and errors may occur.

Base Shear and Drift Check

Base shear will be manually check with spreadsheet on the succeeding section. This ensures that students knows which base shear formulas govern in their structure. In a typical lowrise building, maximum base shear formula normally governs as observed also in the response spectra and shown in Figure 23.

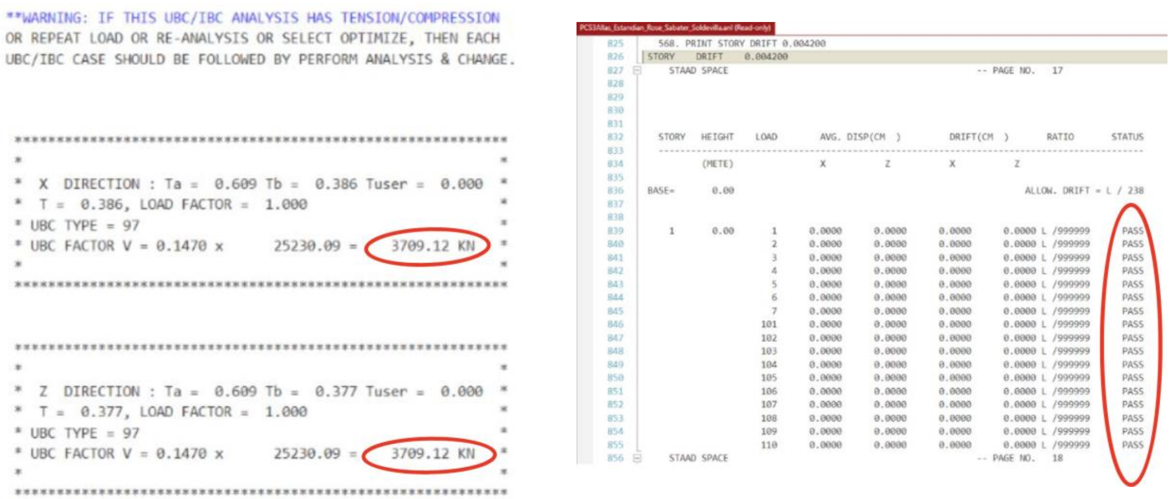


Figure 15. Base shear and drift check output from student project

Center of Mass, Center of Rigidity and Storey Stiffness

Checking the center of mass and center of rigidity verifies that the structure will not induce large accidental torsion during earthquake. This is also manifested by the large rotational stiffness value compared to the stiffness on both X and Z direction.

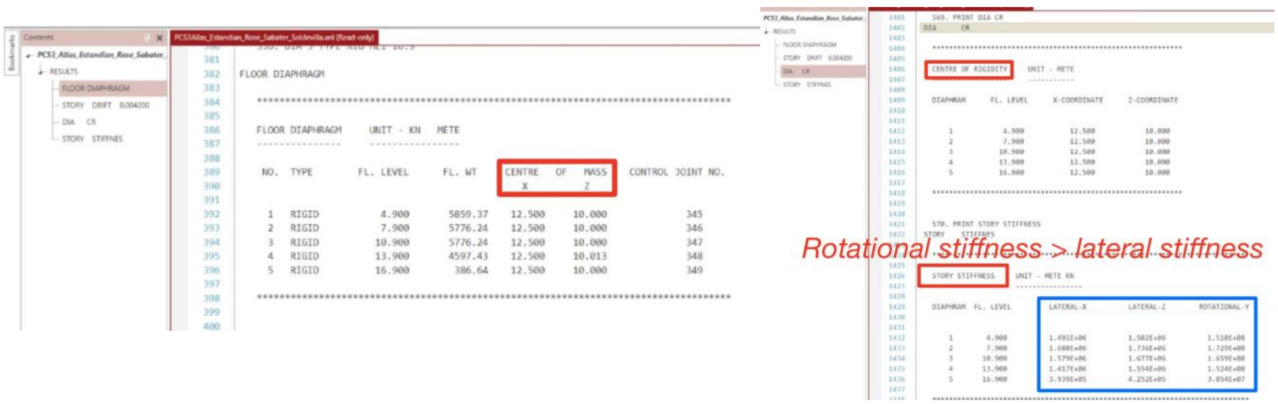


Figure 16. Center of Mass, Rigidity and Storey stiffness from student output

Typical Forces Output for Beam, Column and Footing

After model analysis, postprocessing will be done to obtain the forces of beams, columns and node reactions.

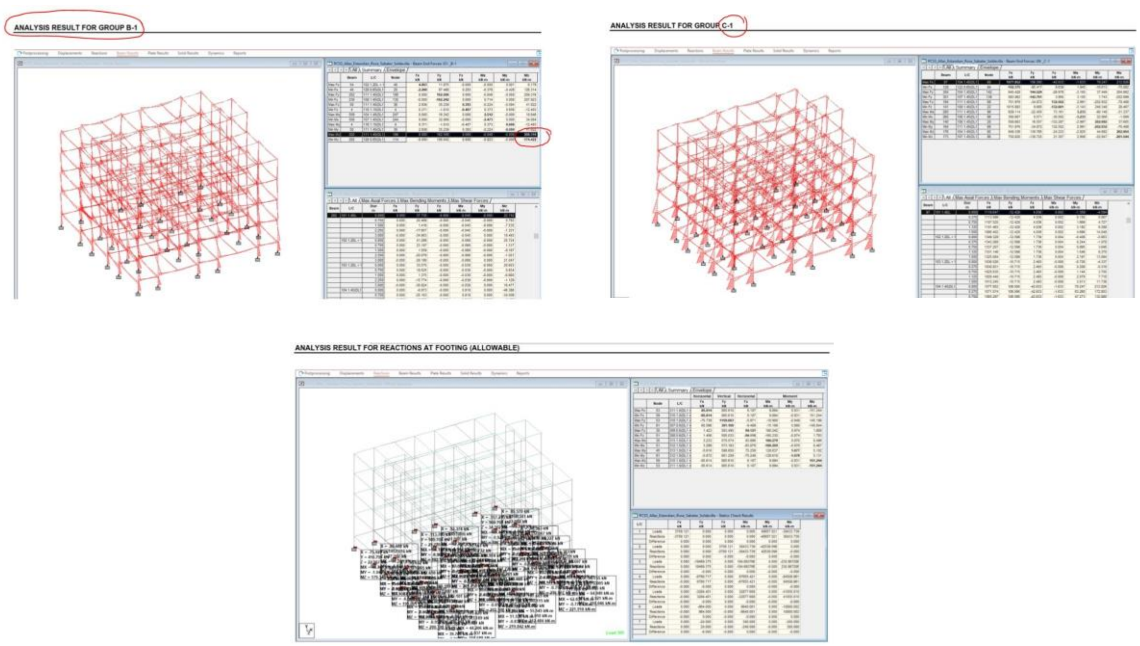


Figure 17. The forces for Beam, Column and Support Reaction will be extracted manually for verification of RCDC Design using spreadsheets created by student

2.6 Design of Girder using RCDC

STAAD Models are imported in RCDC to perform girder design and in compliance to NSCP.

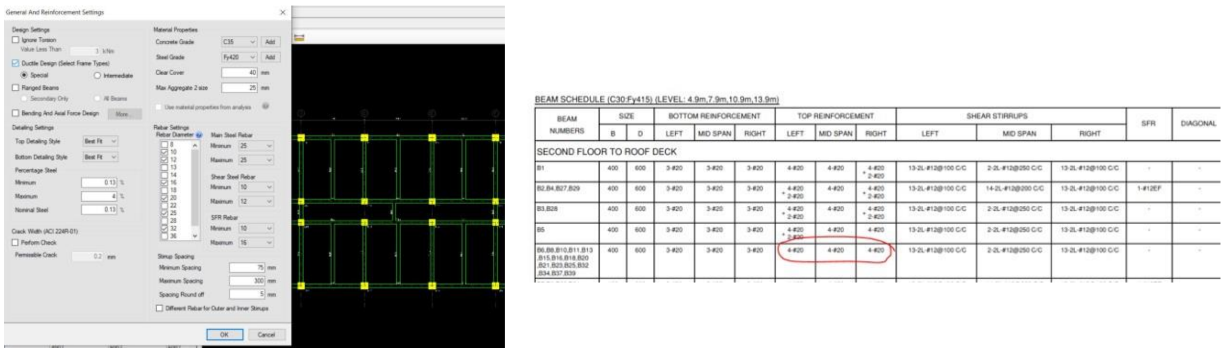


Figure 18. Typical RCDC output and actual student output

2.7 Design of Column using RCDC

STAAD Models are imported in RCDC to perform column design and in compliance to NSCP.

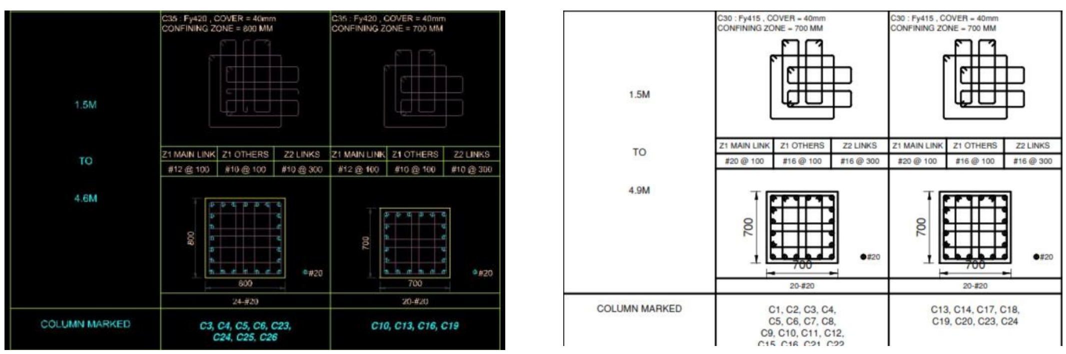


Figure 19. Typical RCDC output and actual student output

2.8 Design of Footing using RCDC

STAAD Models are imported in RCDC to perform isolated footing design and in compliance to NSCP.

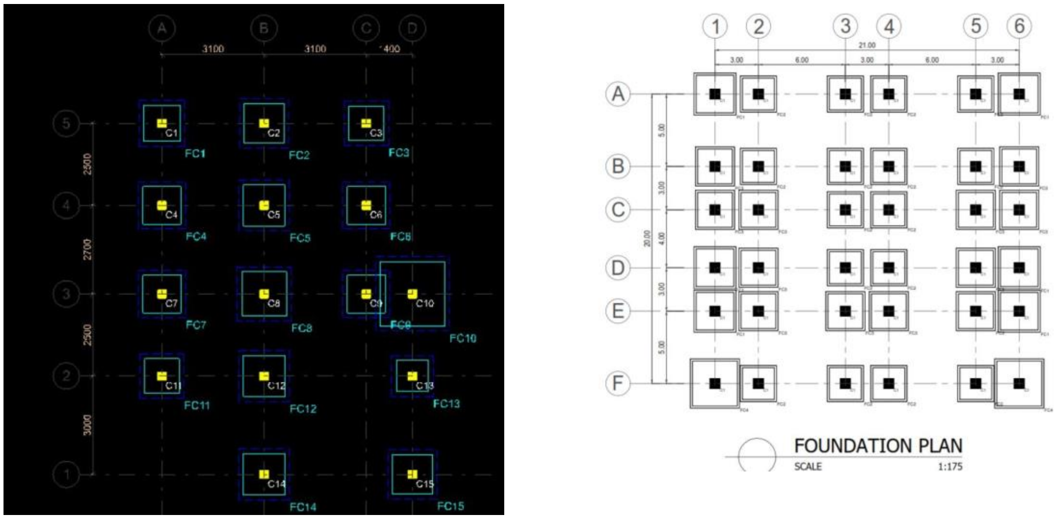


Figure 20. Typical RCDC output and actual student output

Utilization of SMATH and MS Excel in Validating Softwares Result

SMATH

SMATH shown in figure 21 is free software that is available online and was developed by Andrey Ivashov (15). It is an alternative tool to Mathcad and Matlab for creating design calculations for civil engineering design uses such as concrete beams, concrete columns, and other specific template for calculation in a regular design office thanks to its WYSIWYG (what you see is what you get) feature similar to Mathcad (15). The Stiffness Method was also taught using this program, with STAAD and MS Excel serving as the verification tools in (Bersamina, 2021). Additionally, (Gallardo-Pastor et al., 2021) taught chemical engineering students on thickening design using SMATH. Compared to Matlab, its language is more natural and has a smaller learning curve similar to Mathcad.

In this study the modal periods, modal shapes, and mass participation employed in STAAD earthquake engineering results are validated using SMATH. The function by (Urroz, G, 2010) is needed because the Multi Degree OF Freedom problem necessitates numerical method for tackling eigenvalue and eigenvector problem.

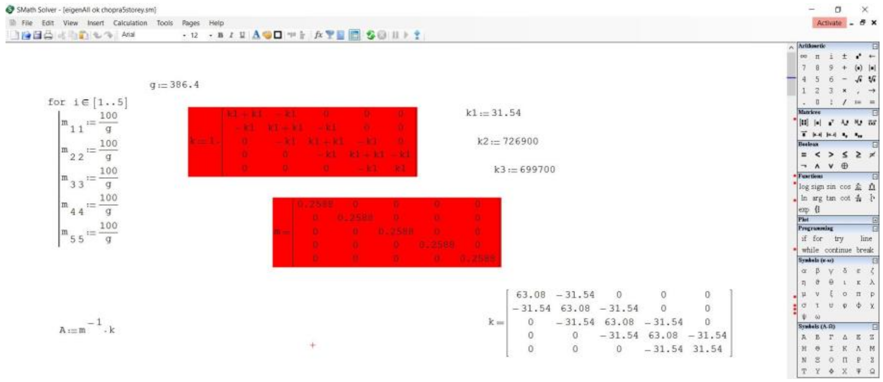


Figure 21. Interface of SMATH

Microsoft Excel

A paper by (El Sawy, K.M. et al.(, 2015) demonstrated the use of MS Excel in teaching structural engineering at UAE University. In this paper, it will be used to verify commercial softwares like STAAD and RCDC to make sure students understand both the concept and how the software works. TUP Manila has Microsoft365 account available for each students enrolled in each semester. Basic programming subject which is supposed to teach them basic MS Excel and computer programming is introduced to first year students in the BSCE Curriculum shown below fig 22. Thus students are expected to create their own solver in MS Excel with consideration of NSCP Code in Concrete and Seismic provision.

FIRST YEAR - SECOND SEMESTER

GEC4-M	Mathematics in the Modern World	3	3	0	None	None
GEC5-M	Purposive Communication	3	3	0	None	None
GEC6-M	Art Appreciation	3	3	0	None	None
CEShop2-M	Engineering Shopwork 2	2	0	6	CEShop1-M	None
MathEng2-M	Calculus 2 (Integral Calculus)	3	3	0	MathEng1-M	None
PhysEng-M	Physics for Engineers, Lec (Calculus Based)	3	3	0	MathEng1-M	PhysEngL-M
PhysEngL-M	Physics for Engineers, Lab (Calculus Based)	1	0	3	MathEng1-M	PhysEng-M
BES12-M	Engineering Drawing and Plans	1	0	3	CEShop1-M	None
BES8-M	Computer Fundamentals and Programming	2	0	6	None	None
PE2-M	Physical Education 2 – Rhythmic Activites	2	2	0	None	None
NSTP2-M	CMT 2 / CWTS 2	3	4	0	NSTP1-M	None
	Total	**26**	**39**			

Figure 22. First Year Second Semester Curriculum of BSCE in TUP Manila

Manual Verification of Base Shear and Vertical Distribution of Earthquake Forces

Spreadsheets was used to manually verify base shear to ensure compliance to NSCP Seismic Provision.

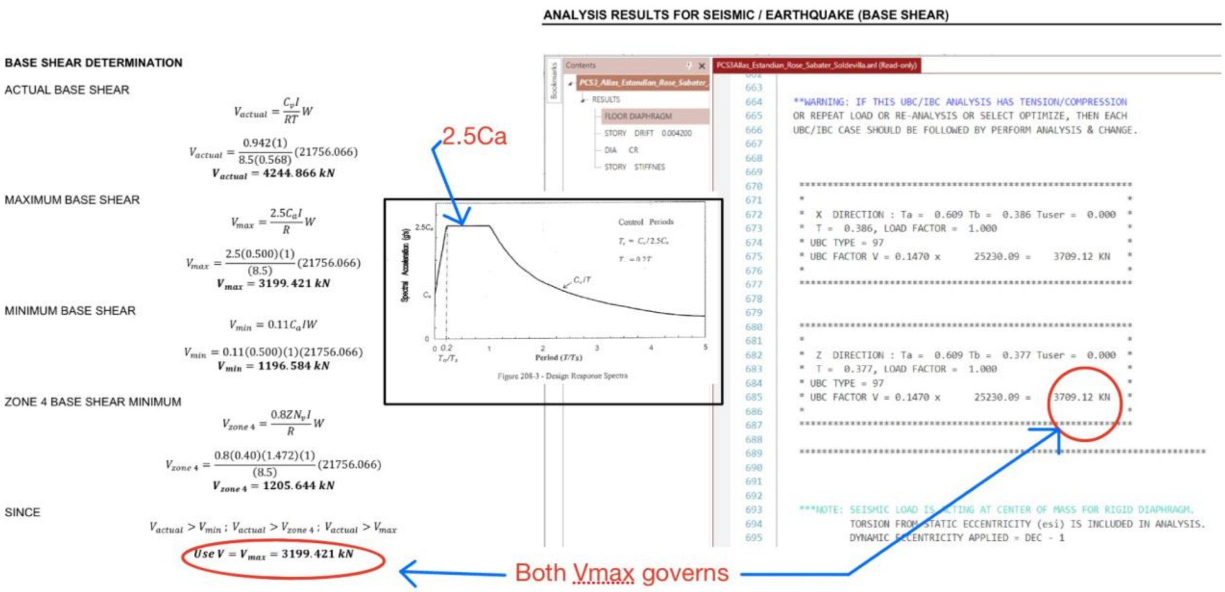


Figure 23. Verification of governing base shear formula by student

Manual Verification of Vertical Distribution of Earthquake Forces

Spreadsheet was used to manually verify vertical distribution of base shear in STAAD.

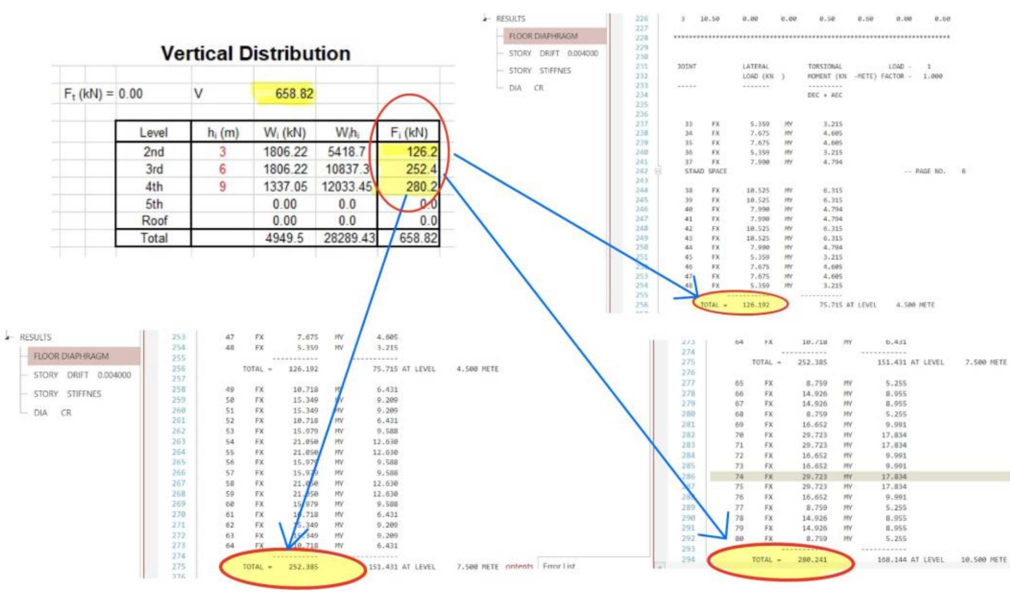


Figure 24. Sample Verification of Vertical Distribution

Manual Verification of Modal Period of Structures in SMATH

SMATH was used to manually verify dynamic property of the structure.

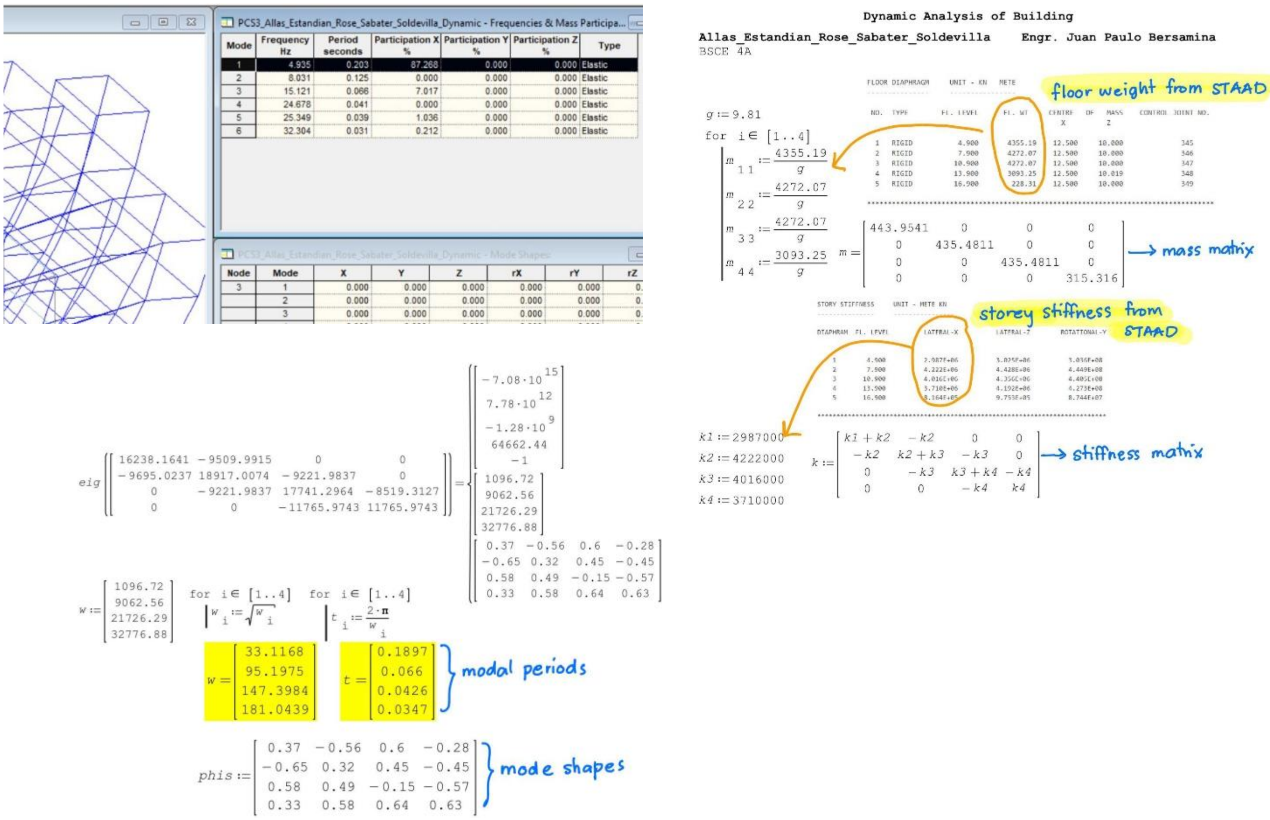


Figure 25. Modal Period verification in SMATH from student output

Manual Verification of Mode Shapes of Structures in SMATH

Mode shapes were manually computed using SMATH code shown in Figure 26. The SMATH code used here can theoretically compute multilevel structure dynamic property which manual solutions by hand cant accomplish.

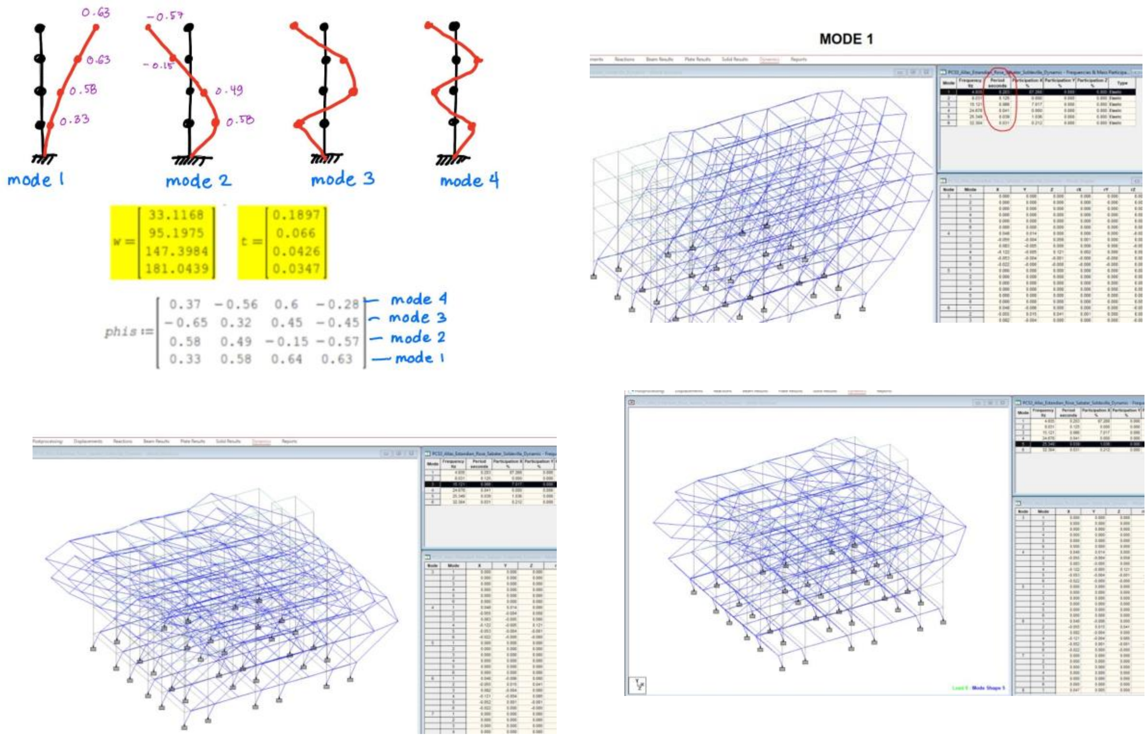


Figure 26. Mode shapes verification from student output

Manual Verification of Mass Participation of Structures in SMATH

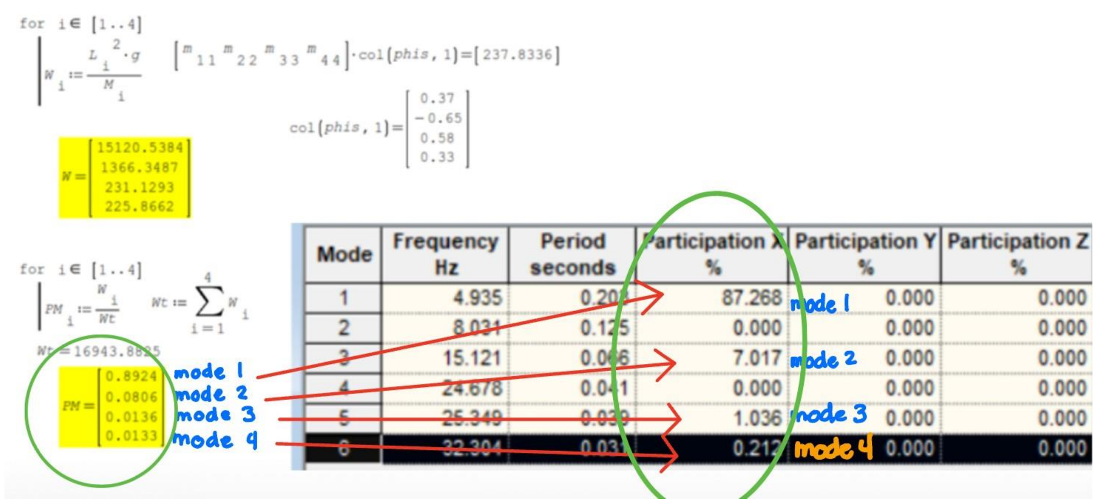


Figure 27. Modal Mass Participation verification from student output

2.9 Manual Verification of Girder Design

Spreadsheets were used to manually verify girder design including seismic detailing output of RCDC to ensure compliance to NSCP Seismic Provision. Figure 28 below shows the equal design result from student spreadsheet and software RCDC output.

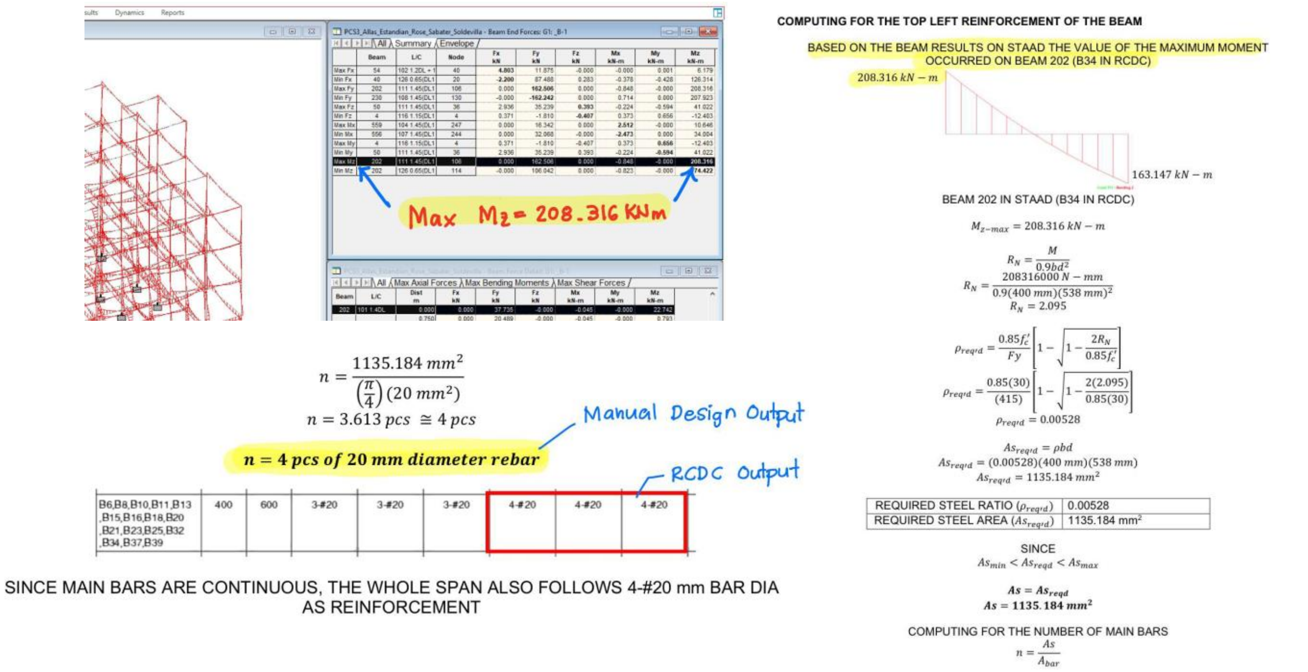
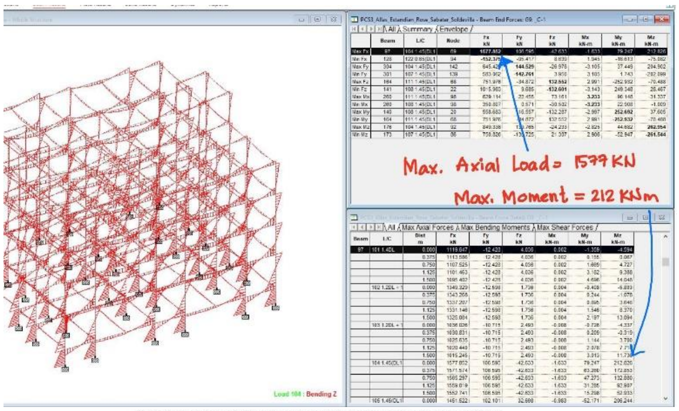


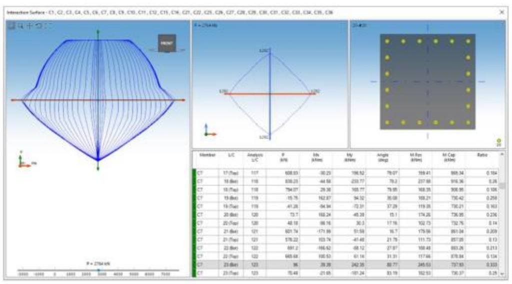
Figure 28. Girder Design using Spreadsheet from student output

2.10 Manual Verification of Column Design

To establish compliance with the NSCP Seismic Provision, spreadsheets were utilized to manually examine the column interaction diagram, including the seismic detailing output of RCDC as shown in Figures 29 and 30. Students may be able to manually change their designs quickly in the event the software produces an insufficient concrete size or reinforcement design or needing reanalysis.

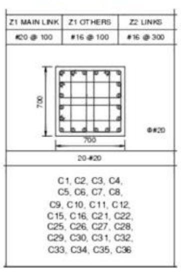


COMPARING THE DIAGRAM TO THE DIAGRAM GENERATED BY RCDC,



THE BALANCED MOMENT AND LOAD FOR BOTH EXCEL AND RCDC GENERATED INTERACTION DIAGRAM IS ALMOST THE SAME.

	EXCEL	RCDC
ULTIMATE LOAD	2414.553 kN	2764 kN
ULTIMATE MOMENT	1171.802 kN-m	1282 kN-m



MANUAL COMPUTATION
(COUNTER CHECK FOR THE COLUMN WITH THE MAXIMUM AXIAL LOAD IN GROUP C1)

BASE (b)	700 mm
OVERALL DEPTH (h)	700 mm
MAIN BAR DIAMETER	20 mm
LATERAL TIES BAR DIAMETER	16 mm
CONCRETE COVER	40 mm
f_c'	30 MPa
Fy	415 MPa

CHECKING FOR THE INTERACTION DIAGRAM OF **BEAM 97** (C1 IN RCDC) GIVEN THIS CROSS SECTION

THERE WILL BE 6 LAYERS OF MAIN BARS RESULTING FOR A 20 PCS 20 mm ø BAR

$$x = 40 + 12 + \frac{20}{2}$$

SURFACE TO CENTER OF MAIN BAR (x)	62 mm

COMPUTING FOR STEEL RATIO

$$\rho = \frac{As}{bh}$$

$$\rho = \frac{\frac{\pi}{4}(20\ mm)^2(20)}{(700\ mm)(700\ mm)} x\ 100\ \%$$

$$\rho = 1.282\ \%$$

BASED ON THE STAAD RESULTS, THE FORCES OF C28 ARE AS FOLLOWS

$$Fx = 1577.852\ kN$$
$$My = 79.247\ kN - m$$
$$Mz = 212.826\ kN - m$$

USING EXCEL, THIS INTERACTION DIAGRAM WAS FORMULATED. UPON CHECKING THE VALUES OF Fx and Mz, THE PLOT SHOWS THAT THE CROSS SECTION AND REINFORCEMENT CAN WITHSTAND THE LOAD.

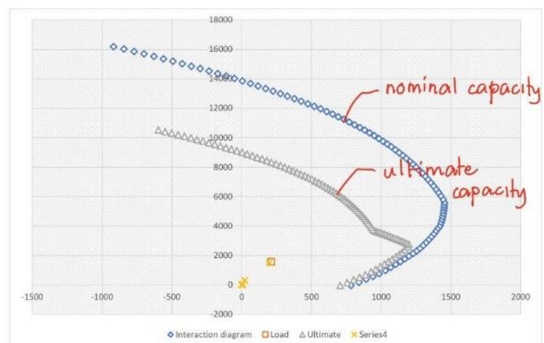
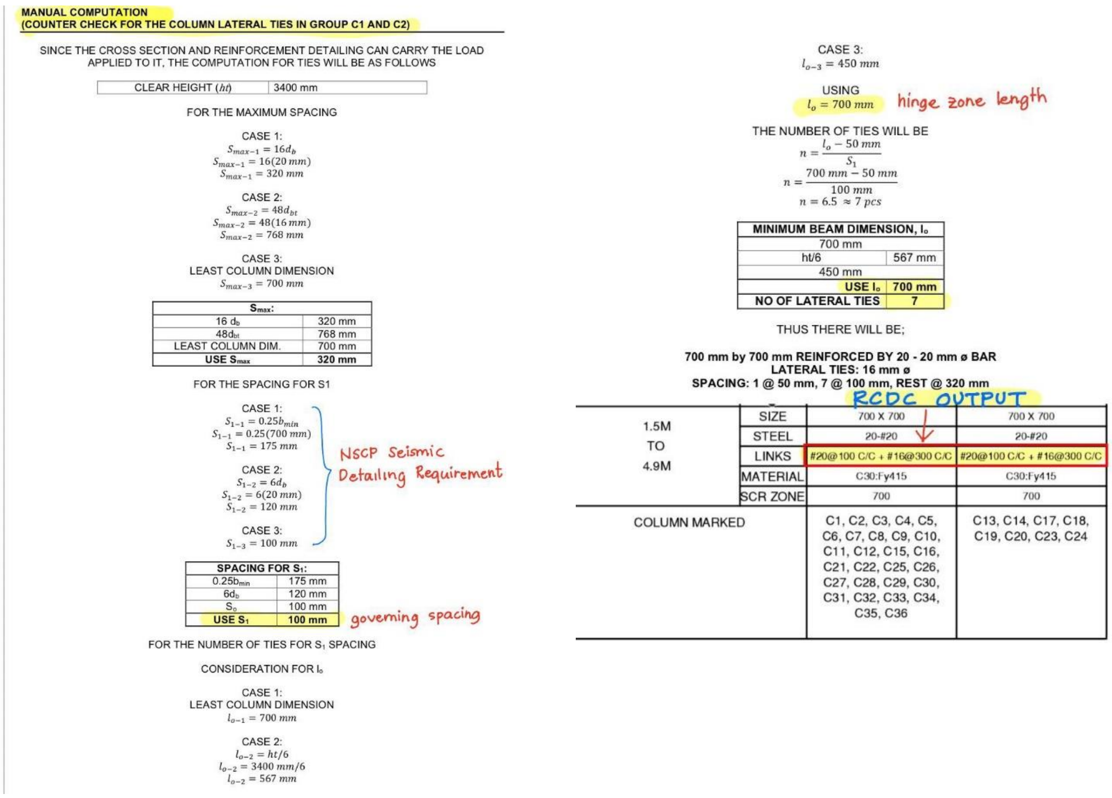


Figure 29. Reinforcement Design of Column using Interaction Diagram from Excel spreadsheet provided to student by instructor



MANUAL COMPUTATION
(COUNTER CHECK FOR THE COLUMN LATERAL TIES IN GROUP C1 AND C2)

SINCE THE CROSS SECTION AND REINFORCEMENT DETAILING CAN CARRY THE LOAD APPLIED TO IT, THE COMPUTATION FOR TIES WILL BE AS FOLLOWS

CLEAR HEIGHT (*ht*)	3400 mm

FOR THE MAXIMUM SPACING

CASE 1:
$S_{max-1} = 16d_b$
$S_{max-1} = 16(20\,mm)$
$S_{max-1} = 320\,mm$

CASE 2:
$S_{max-2} = 48d_{bt}$
$S_{max-2} = 48(16\,mm)$
$S_{max-2} = 768\,mm$

CASE 3:
LEAST COLUMN DIMENSION
$S_{max-3} = 700\,mm$

S_{max}:	
16 d_b	320 mm
48d_{bt}	768 mm
LEAST COLUMN DIM.	700 mm
USE S_{max}	**320 mm**

FOR THE SPACING FOR S1

CASE 1:
$S_{1-1} = 0.25b_{min}$
$S_{1-1} = 0.25(700\,mm)$
$S_{1-1} = 175\,mm$

CASE 2:
$S_{1-2} = 6d_b$
$S_{1-2} = 6(20\,mm)$
$S_{1-2} = 120\,mm$

CASE 3:
$S_{1-3} = 100\,mm$

SPACING FOR S_1:	
0.25b_{min}	175 mm
6d_b	120 mm
S_o	100 mm
USE S_1	**100 mm**

FOR THE NUMBER OF TIES FOR S_1 SPACING

CONSIDERATION FOR l_o

CASE 1:
LEAST COLUMN DIMENSION
$l_{o-1} = 700\,mm$

CASE 2:
$l_{o-2} = ht/6$
$l_{o-2} = 3400\,mm/6$
$l_{o-2} = 567\,mm$

CASE 3:
$l_{o-3} = 450\,mm$

USING
$l_o = 700\,mm$

THE NUMBER OF TIES WILL BE
$n = \frac{l_o - 50\,mm}{S_1}$
$n = \frac{700\,mm - 50\,mm}{100\,mm}$
$n = 6.5 \approx 7\,pcs$

MINIMUM BEAM DIMENSION, l_o	
700 mm	
ht/6	567 mm
450 mm	
USE l_o	**700 mm**
NO OF LATERAL TIES	**7**

THUS THERE WILL BE;

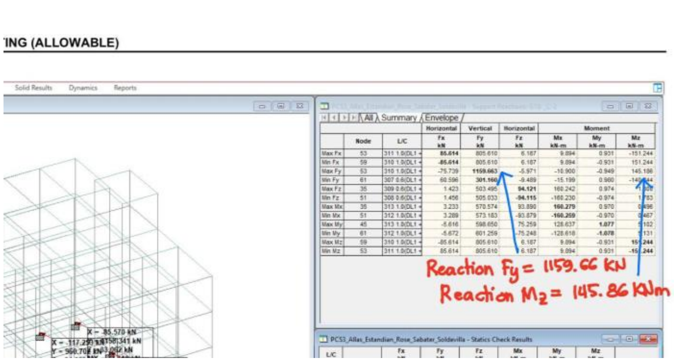
700 mm by 700 mm REINFORCED BY 20 - 20 mm ø BAR
LATERAL TIES: 16 mm ø
SPACING: 1 @ 50 mm, 7 @ 100 mm, REST @ 320 mm

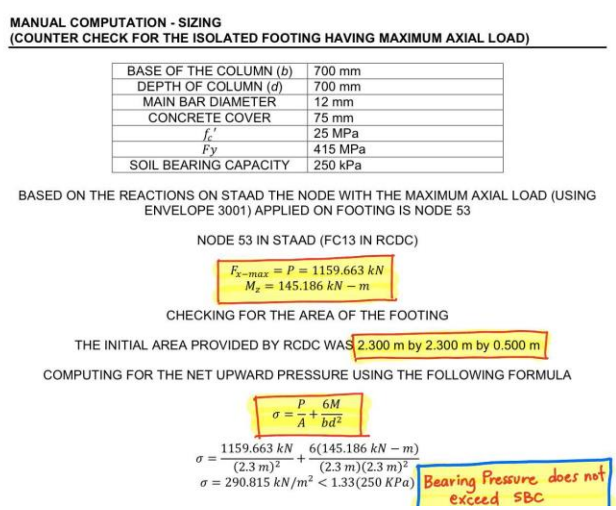
1.5M TO 4.9M	SIZE	700 X 700	700 X 700
	STEEL	20-#20	20-#20
	LINKS	#20@100 C/C + #16@300 C/C	#20@100 C/C + #16@300 C/C
	MATERIAL	C30:Fy415	C30:Fy415
	SCR ZONE	700	700
COLUMN MARKED		C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C15, C16, C21, C22, C25, C26, C27, C28, C29, C30, C31, C32, C33, C34, C35, C36	C13, C14, C17, C18, C19, C20, C23, C24

Figure 30. Seismic Detailing of Column Ties verification using spreadsheet from student output

2.11 Manual Verification of Footing Design

Spreadsheets were used to manually verify footing output of RCDC including size and reinforcement spacing shown in Fig 31-33.





MANUAL COMPUTATION - SIZING
(COUNTER CHECK FOR THE ISOLATED FOOTING HAVING MAXIMUM AXIAL LOAD)

BASE OF THE COLUMN (*b*)	700 mm
DEPTH OF COLUMN (*d*)	700 mm
MAIN BAR DIAMETER	12 mm
CONCRETE COVER	75 mm
f_c'	25 MPa
Fy	415 MPa
SOIL BEARING CAPACITY	250 kPa

BASED ON THE REACTIONS ON STAAD THE NODE WITH THE MAXIMUM AXIAL LOAD (USING ENVELOPE 3001) APPLIED ON FOOTING IS NODE 53

NODE 53 IN STAAD (FC13 IN RCDC)

$F_{x-max} = P = 1159.663\,kN$
$M_z = 145.186\,kN-m$

CHECKING FOR THE AREA OF THE FOOTING

THE INITIAL AREA PROVIDED BY RCDC WAS 2.300 m by 2.300 m by 0.500 m

COMPUTING FOR THE NET UPWARD PRESSURE USING THE FOLLOWING FORMULA

$$\sigma = \frac{P}{A} + \frac{6M}{bd^2}$$

$$\sigma = \frac{1159.663\,kN}{(2.3\,m)^2} + \frac{6(145.186\,kN-m)}{(2.3\,m)(2.3\,m)^2}$$

$$\sigma = 290.815\,kN/m^2 < 1.33(250\,KPa)$$

Figure 31. Footing size calculation from student output

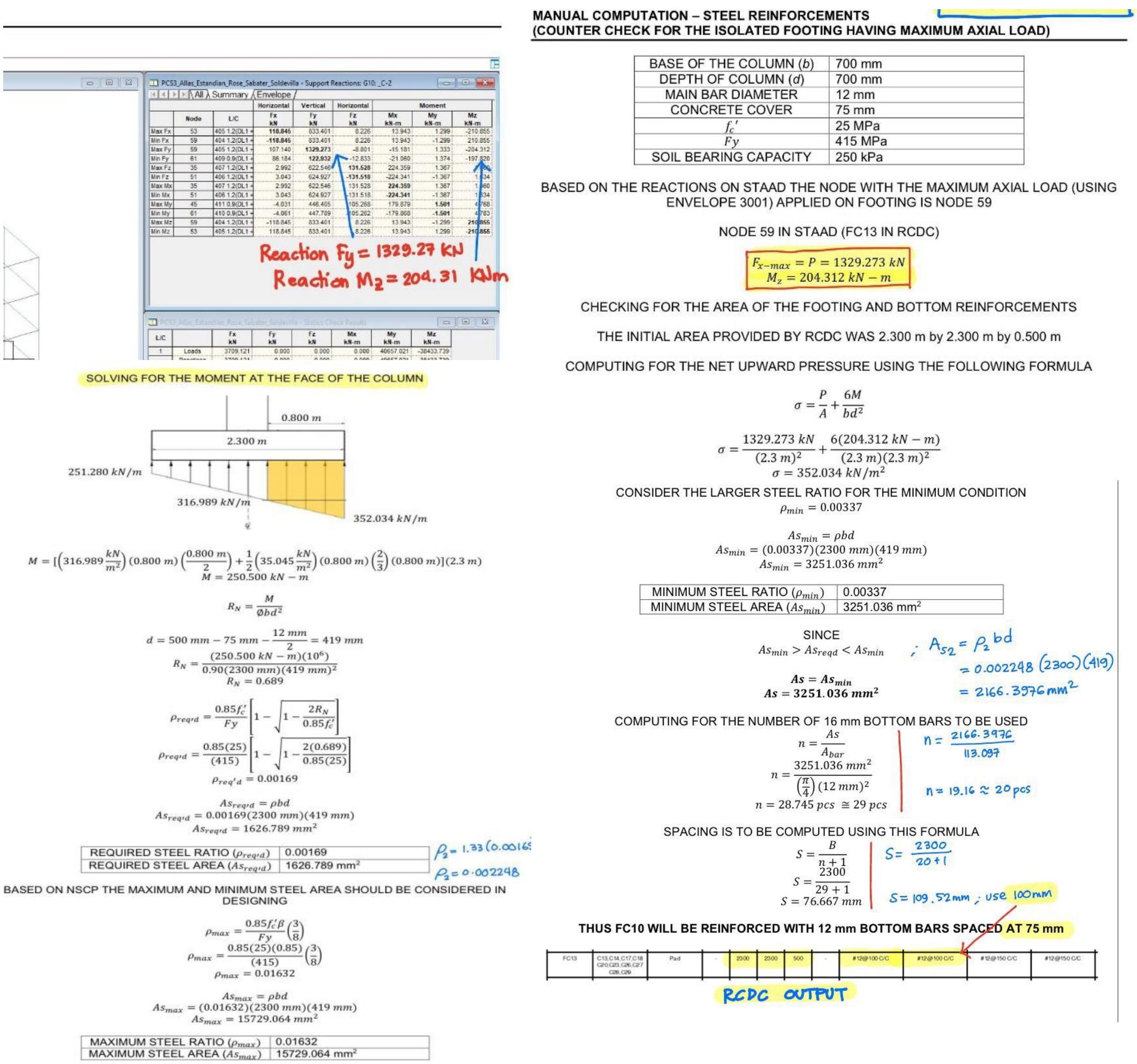


Figure 32. Footing Reinforcement calculation from student output with mark ups from author instructor

FOOTING SCHEDULE (C25:Fy415)

FOOTING NUMBERS	COLUMN NUMBERS	FOOTING TYPE	FOOTING DIMENSION					FOOTING REINFORCEMENT				STIRRUPS		SFR	REMARKS
								BOTTOM		TOP					
			STEP	L	B	D1	D2	ALONG B	ALONG L	ALONG B	ALONG L	ALONG B	ALONG L		
FC1	C1,C6,C25,C30	Pad	-	2600	2600	500	-	#12@100 C/C	#12@100 C/C	#12@150 C/C	#12@150 C/C	-	-	-	-
FC2	C2,C3,C4,C8,C9, C10,C11,C15,C16, C21,C22,C32,C33, C34,C35	Pad	-	2200	2200	500	-	#12@100 C/C	#12@100 C/C	#12@150 C/C	#12@150 C/C	-	-	-	-
FC5	C5	Pad	-	2100	2100	500	-	#12@100 C/C	#12@100 C/C	#12@150 C/C	#12@150 C/C	-	-	-	-
FC7	C7,C12	Pad	-	2400	2400	500	-	#12@100 C/C	#12@100 C/C	#12@150 C/C	#12@150 C/C	-	-	-	-
FC13	C13,C14,C17,C18, C20,C23,C26,C27, C28,C29	Pad	-	2300	2300	500	-	#12@100 C/C	#12@100 C/C	#12@150 C/C	#12@150 C/C	-		-	-
FC19	C19,C24	Pad	-	2500	2500	500	-	#12@100 C/C	#12@100 C/C	#12@150 C/C	#12@150 C/C	-		-	-
FC31	C31,C36	Pad	-	3100	3100	500	-	#12@100 C/C	#12@100 C/C	#12@150 C/C	#12@150 C/C	-	-	-	-

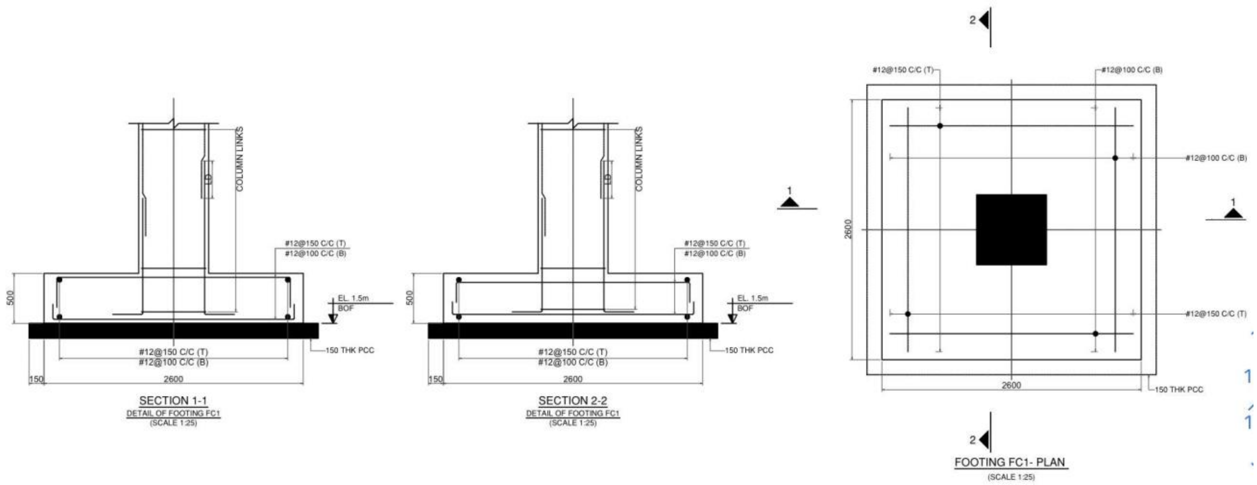


Figure 33. RCDC Output of Footing Schedule from student

End of Course Survey result

The instructor developed a google form to assess the effectiveness of online instruction for PCS1 and PCS2 utilizing free or open source software in conjunction with industry-based software STAAD and RCDC. To preserve the privacy of their answers and remarks, the students can fill out the form anonymously. Students were questioned regarding how well the course was delivered, their learnings, and potential suggestions for the subject matter and instructor. Some questions were derived from (Oreta, 2019) during their implementation of CEORIEN course last AY 2018-2019. More than 90 percent of the population enrolled in the course, or 107 replies, responded in the survey, confirming the authenticity of the results.

3. Results and discussion)

As can be seen in Figures 34 below, students' understanding considerably enhanced after enrolling in PCS1, which was to be expected given that the prior design course learned in their 3rd year covered only steel design.

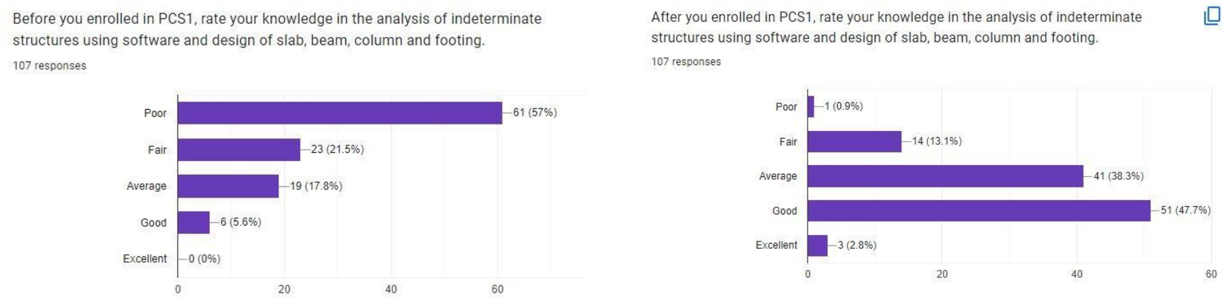


Figure 34. Student Knowledge prior and after enrolling the course PCS1

Following enrollment in PCS2, students' knowledge significantly increased, as shown in Figure 35 below. This is to be expected as the only prerequisite course that 4th year students are aware of is Structural Analysis. The author does, however, think that this considerable rise could also indicate that the instructor performed well in delivering the course, as evidenced by the other survey results and comments made in the survey.

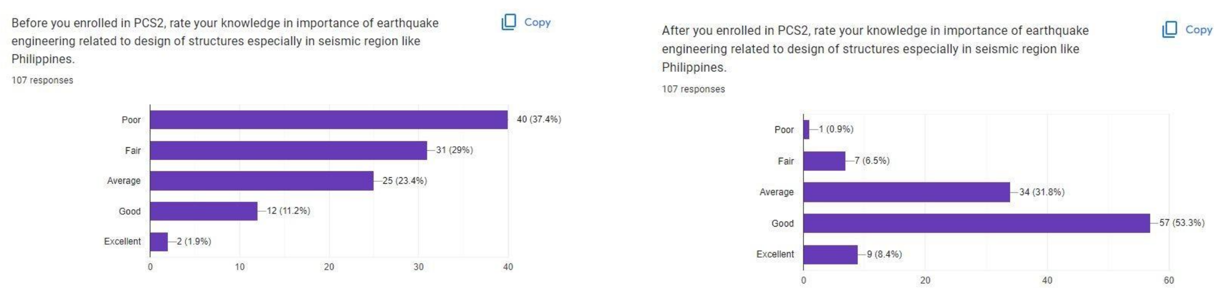


Figure 35. Assessment of student knowledge in PCS2 before and after enrolling course

Asynchronous and Synchronous Lecture Assessment

The majority favors the online way of delivery, as seen in figures 36 and 37. However, as demonstrated in Figure 36, where the highest rating was given by 47.7 percent of respondents, the author notices that asynchronous learning via old recorded lectures preserved on Youtube is not recommended by students. The comments in figure 46 are congruent with this. To solve this issue, the instructor made sure to switch to 100 percent synchronous video in the next semester.

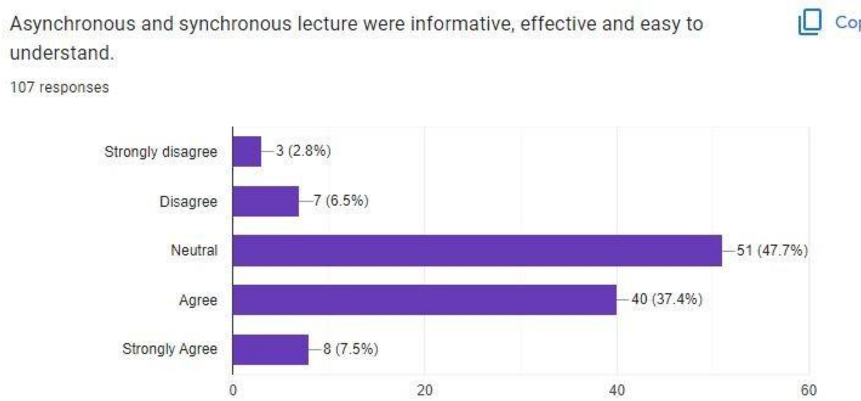


Figure 36. Assessment of Delivery via Asynchronous and Synchronous Lecture

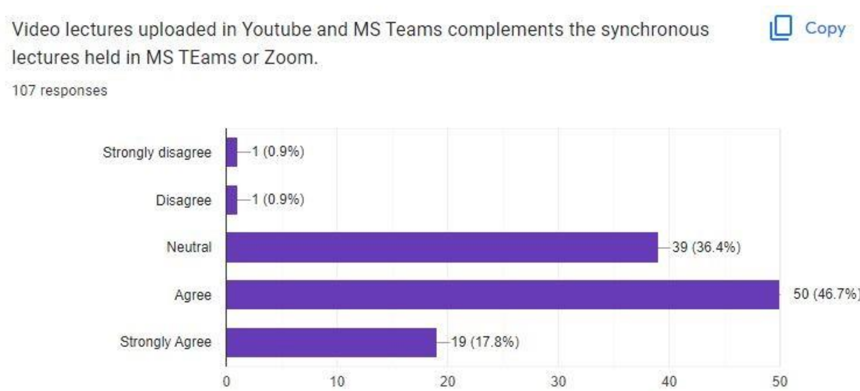


Figure 37. Assessment of Video Lectures

Figure 38. Assessment of manual verification of base shear and dynamic property of structure in STAAD

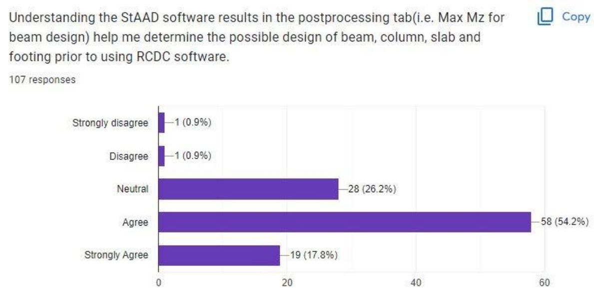


Figure 39. Assessment of Postprocessing Technique in STAAD prior to member design in RCDC

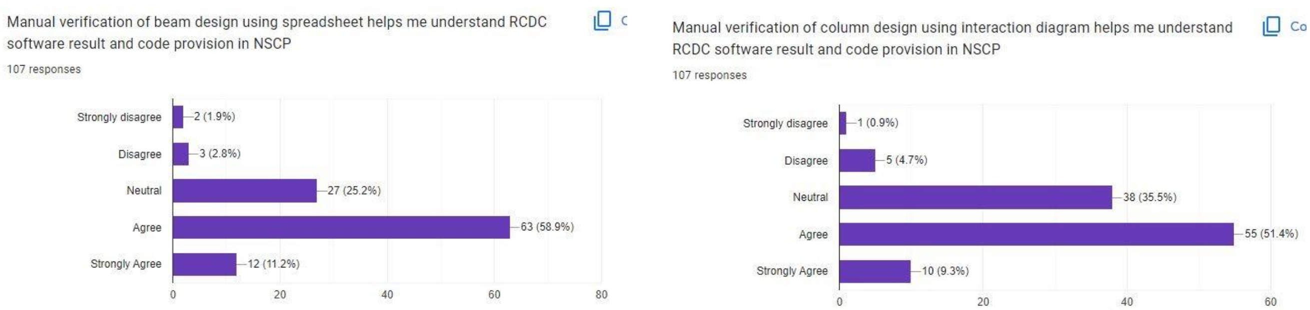


Figure 40. Assessment of manual verification of beam and column design

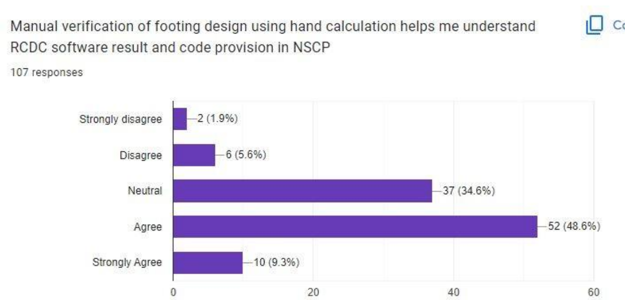


Figure 41. Assessment of manual verification of footing design

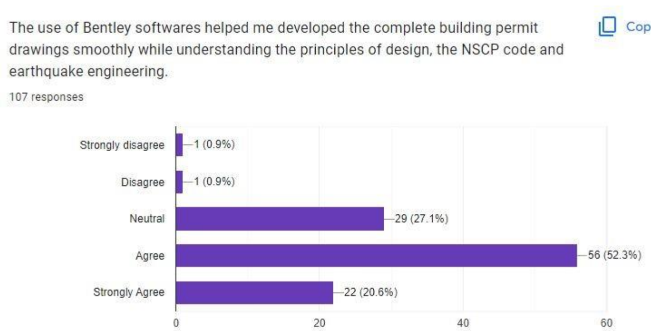


Figure 42. Effectivity of softwares

Figures 38 to 41 demonstrate that using free and open source applications like SMATH and MS Excel to manually check the output of the STAAD and RCDC software has received favorable response from students.

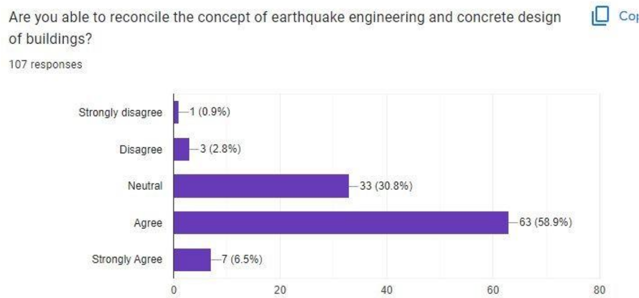


Figure 43. Effectivity of Teaching approach for Earthquake engineering and Concrete Design

Overall, since STAAD and RCDC both has features for earthquake engineering and concrete design concepts in the actual design of concrete buildings and in compliance with NSCP Code shown in Fig 43, the interdependence of two professional courses was achieved in this delivery of courses shown. (Estrada & Lee, 2009) also stated that it is important for engineering student to understand the fundamental concepts despite the availability of software to quickly analyze and design structures subjected to high seismic forces. This is also in line with the expected outcome in the majority of accrediting standards, such as ABET EC2000, which asks students to demonstrate that they can use the methods, abilities, and tools of engineering practice. These approach of using MS Excel and SMATH, the author believes, definitely addressed that requirement.

No.	Comments
1	The most important thing that I learned in this subject is that students must learn how the software works or the manual computation before using the software.
2	Ever since, we only used AutoCAD for designing buildings. So that learning software like Bentley help us to easily verify the structural performance of our building
3	Designing a building manually to understand how the automated design works or calculated with strong compliance with the code provisions.
4	Most thing that I learned using Bentley's application is being futuristic in terms of designing structures and also I learned many tips, tricks and shortcut key in able to perform the application easily
5	Understanding the concept prior on using the software helped me understand where my design fails and revise in response to that failure
6	It's good to know the manual computation or the process of computation of STAAD. To check kung tama yung design. And atleast kahit walang staad alam namin paano icompute
7	For me the most important is knowing how to compute manually the preliminary design of the structure based on it's maximum moment at forces, which I admit that I didn't give too much attention.
8	How the software works and analyze, and software manipulation to check the structural detailing and design
9	I have learned using different computer applications such as STAAD, RCDC and Microsoft Excel which are very helpful in designing structures. It saved a lot of time from doing manual calculations.
10	Concept and theories of structural design to fully understand how the software works

No.	Comments
1	I understand and had a knowledge on designing low rise building considering earthquake forces especially in seismic region like Philippines
2	understanding earthquake engineering helps me to understand how important is the performance of the building to resist earthquake using software can also helps to know the structure performance and to verify it using manual computation as well.
3	Evaluating and Verifying the results of the softwares using manual calculation
4	All manual calculation of plates from building weight to shear an moment are all very useful and important
5	Manual computations, force distributions based on earthquake parameters, load combinations and dynamic analysis of structure.
6	Although the main curriculum for the earthquake engineering is all about the seismic effect of the earthquake to the structure, i think the most important lesson i learned was about the SMATH application because it was easy to use and can be used for checking manual calculations.
7	Everything should be based on NSCP. During exam po kasi halos laht ng problem need ng code. Tska po manual computation is very helpful kapag ichecheck yung staad analysis kung same ba. It's easy to check kung nagpass ba yung design sa pcs2 using staad.
8	Spreadsheet, manual solving, and knowledge in NSCP Code is really a great help in understanding the fundamentals of Earthquake Engineering.
9	In this subject, I've learned that when designing a building it's very important to follow the NSCP codes.
10	Understanding how earthquake affects the building

Figure 44. Comments on Most important learning

Parts of the course which aids in learning

No.	Comments
1	I can say that I've learned a lot on using STAAD software.
2	On how to used the STAAD Pro properly with the application of NSCP codes.
3	Bentley Products, YouTube Tutorials, and lecture discussions
4	The synchronous lectures that i can rewatch
5	I am not really that confident with my knowledge on designing a building by myself. I usually copy what the typical reinforcements or dimensions of structural members in my plates. With this course, I was able to increase my confidence in designing a building as a future engineer. However, I need to study it more.

No.	Comments
1	On how to manually solve the basic parameters of seismic loads in accordance to NSCP codes.
2	SMATH and the discussion about how buildings behave during earthquake
3	Recorded lecture videos
4	Manual computations
5	When we applied what we learned from lec vids to our manual calculations of our plates

Figure 45. Comments on part of the course which aids in learning

While comment number 5 is expected given that students have not received formal instruction in concrete design prior to PCS1, comment number 4 confirms the strategy of releasing recorded lectures to YouTube as suggested by (Rodriguez-Paz et al., 2021). Only building permit plans were needed to be created for their engineering drawings class at lower year level.

Recommendations on Improvement of Delivery

No.	Comments
1	To always provide students a time to absorb the topic, always assess if they actually learn about the subject.
2	I hope we'll have face-to-face class this coming semester.
3	To be honest, i would like to recommend shorter lecture videos because sometimes there are too much information to process. But overall, I learned a lot in this subject.
4	Have the lessons/ video lectures properly labeled, since there are times i need to watch the vid before knowing what content i am watching, this issue is mostly seen on recorded synchronous lessons uploaded to yt
5	Make it groupwork for those that do not have their own laptop

No.	Comments
1	None. I enjoyed the subject. The delivery worked just fine
2	Shorter lecture videos will really be helpful and will personally make me focus more on watching and taking notes compared to longer ones.
3	The videos and lectures provided are are really helpful in understanding on how the software works as well as the manual computations, but it can be better if it will provide a more in-depth explanations on how to do the activities.
4	Nothing po. It was very good
5	Make it groupwork for those that do not have their own laptop

Figure 46. Assessment on Delivery of Lesson

Unfortunately, some students from low-income families lack a laptop for online study, as evidenced by comment number 5 and these will be addressed in a face to face learning where they can access software in the Computer Lab. To ensure that these students have access to online learning, (García-Alberti et al., 2021) advised in his study that institution offer financing services.

As to the instructor's delivery assessment, more than 50% have agreed and strongly agreed to the course delivery. However, it will be observe that on figure 36 majority of the respondents do not prefer the combination of asynchronous and synchronous mode of delivery.

As part of the CQI procedure for faculty rating improvement, a repeat survey was conducted on the end of second semester. Asynchronous lecture were minimized by author instructor and the result is shown in figure 48 with more than 70 percent appreciated the improvement in delivery.

Assessment of Instructor's Delivery and Improvement

Figure 47. Assessment of Instructor's Course Delivery 1st semester

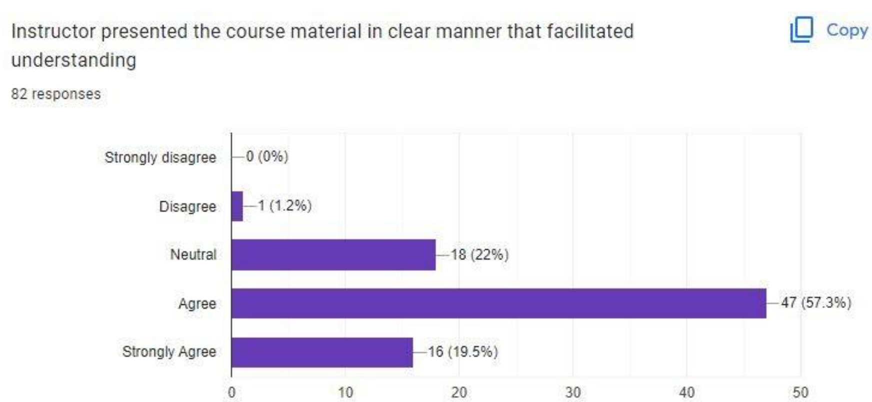


Figure 48. Assessment of Instructor's Course Delivery 2nd semester

4. Conclusion

According to student survey responses, using free and open source software to check software result, such as SMATH and MS Excel, generally receives positive feedback. These aid in their understanding of the concepts and the operation of the software. Most importantly, it's crucial to integrate the NSCP Code's seismic provisions in their own created spreadsheets as these vital for concrete design in a seismic country like the Philippines. The two courses, PCS1 and PCS2, need engineer- ing simulation programs like STAAD and RCDC, which may not always require for full face-to-face interaction. This makes the online mode of teaching particularly beneficial. However, according to survey responses, some students, particularly those without access to a laptop or internet connectivity, may need to participate in a face-to-face setting for a more effective learning environment.

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