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Board 21: Representation of Engineering Concepts in Academic and Engineering Workplace Settings: How Situated are Engineering Concepts in These Contexts?

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Representation of Engineering Concepts in Academic and Engineering Workplace Settings: How situated are engineering concepts in these contexts?

Abstract:

Background: Concepts are a nebulous research subject without focus on a specific context. The notion of a concept implies an abstract chunk of information that is ubiquitous across contexts. However, situated cognition theory within education research suggests that conceptual understanding is nuanced and shaped by the contexts wherein conceptual knowledge is learned and applied.

Purpose/Hypothesis: The purpose of this research is to explore the similarities and differences between contexts in engineering education and practice. Through exploration of these contexts, we can understand how contexts manifest similar and different ways of conceptual representations amongst engineering students and professionals. By representations we mean the ways in which conceptual knowledge is demonstrated within social and material contexts.

Design/Methods: This research implemented ethnographic methods within education and practice settings to explore the influence of context on conceptual representations. To narrow our scope on context, the ethnographic research focused on structural engineering concepts represented by structural engineering students, instructors, and professionals within upper-level structural engineering courses and on real-world structural engineering projects.

Results: Early results indicate that students, instructors, and professionals generally agree on common definitions of structural engineering concepts. However, the ways in which these three groups represent those concepts varies based on their contexts. These contexts and subsequent representations have their purposes suited for the academic or workplace settings where they occur, but there exists avenues to simulate workplace contexts in academic settings to help bridge the education-practice gap.

Conclusion: While most engineering students, instructors, and professionals would agree that the purpose of engineering education is to prepare future engineers for the workplace; contexts of the workplace can vary from company to company and position to position. Through more focused in-depth explorations of these contexts within specific engineering disciplines, we can enhance our understanding of which engineering concepts are more or less ubiquitous.

Introduction:

Engineering concepts are often taught in abstract and ubiquitous ways with the goal of transmitting fundamental conceptual knowledge to students. Students are then expected to transfer their fundamental understanding of certain concepts to unique problems in their future courses and careers that may require a more nuanced conceptual understanding. Therefore, it is important to understand the similarities and differences between how engineering concepts are represented in the contexts of professional practice and academic settings and how these contexts influence engineering students' and practitioners' conceptual learning [1]. How concepts are represented is influenced by the social and material contexts wherein concepts and conceptual knowledge is demonstrated. One example of a material context influence on conceptual representations is in a structural engineering workplace, the creation and use of structural drawings influencing conceptual representations such as: tributary area, loads, and load path. The research presented in this paper highlights the ethnographic methods used to study the contexts of professional practice and academic settings. Results from these settings indicate that engineering concepts are represented in disjointed, isolated design efforts in academic settings; whereas similar concepts are integrated within and throughout design efforts in a workplace setting. Some suggestions for engineering education and curriculum based on these results are presented at the end of this paper.

Activities and Findings:

Activity 1: Ethnography of an Engineering Workplace

A graduate research assistant worked as a part time intern for three months with a medium-sized structural engineering department at a private architecture and engineering firm in the Pacific Northwest. While interning with this company, the graduate research assistant conducted an ethnography within the structures department to explore the engineering concepts frequently represented by practicing structural engineers within the contexts of their daily work and structural design efforts. An ethnography is a qualitative research method aimed at observing and participating within a culture to gain a deeper understanding of that culture's practices. The ethnographer records field-notes, documents artifacts, and interviews other members of the culture while being a participant-observer [2]. In this activity, the graduate research assistant had academic training in structural engineering to be able to participate as an intern, recorded field notes of their daily work and observed meetings, took pictures of artifacts frequently used by structural engineers, and conducted formal and informal interviews with structural engineers.

Findings

Common concepts frequently represented in the structural engineering workplace were loads, load path, and beam and column design. The social and material contexts where these concepts were frequently represented were: design aids, architectural and structural drawings, informal and formal design meetings, product catalogs, and free-body diagrams. Throughout a design effort, the structural engineers often have to make decisions quickly and not waste too much time on any single component of the design. To do this, the structural engineers frequently relied on their peers and mentors and a variety of design aids. For example, Figure 1 and 2 shows multiple different tools that a structural engineer was using simultaneously to design a door jamb for a fire truck bay garage door.

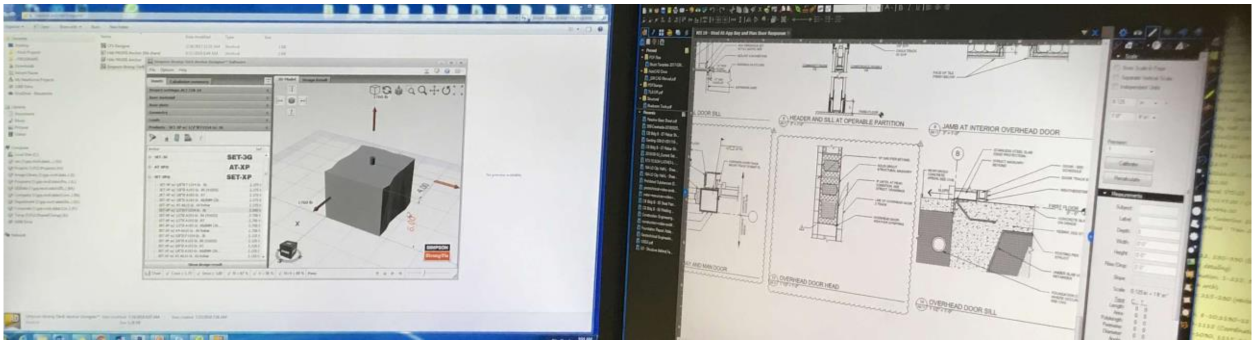


Figure 1: Structural engineer's work station with left monitor running an anchorage design software based on the lateral loads acting on the garage door jamb and the right monitor showing details for a similar anchorage design.

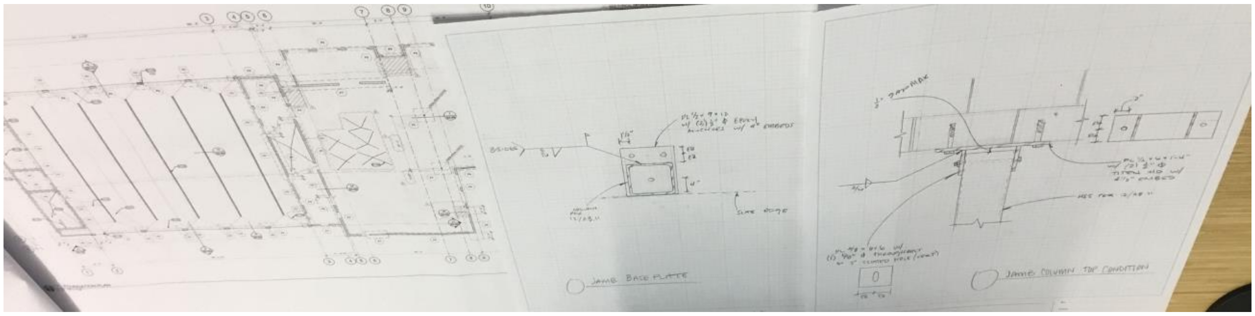


Figure 2: Structural engineer's hand drawn details of the top and base connections of the garage door jamb on the right with printed structural drawings of the buildings being used for reference on the left.

These figures illustrate part of a design effort done by the graduate research assistant as an intern and a structural engineering mentor. The graduate research assistant determined the lateral loads on the door jamb by determining the wind loads acting on the garage door and being distributed to this jamb. The structural engineering mentor then used those loads as input for the anchorage design software (Figure 1, left picture). The structural engineering mentor emphasized that the door jamb need only resist lateral load and none of the gravity load from the existing framing used in the gravity force resisting system. The structural engineer used pre-existing details from a similar project (Figure 1, right picture) to check whether the anchorage software output was reasonable. The structural engineer then used a combination of pre-existing details for door jambs (Figure 1, right picture) and the structural drawings for the existing framing (Figure 2, left picture) to develop a detail that could transfer the lateral loads from wind into the anchorage and foundation without transferring any additional gravity load from the structure (Figure 2, right pictures). This example illustrates the multiple tools that a structural engineer utilizes to aid in the design effort of a door jamb. These tools aided in finding the loads, determining the demand these loads put on the anchorage, determining a desirable load path, and drafting some details of connections to facilitate the desired load path.

Another common design aid used by the structural engineers was manufacturers' product catalogs. Figure 3 shows a load table from a steel joist manufacturer's catalog that helps engineers select a joist size and type based on the joists span and allowable load for that span.

ASD

STANDARD LOAD TABLE FOR LONGSPAN STEEL JOISTS, LH-SERIES
Based on a 50 ksi Maximum Yield Strength - Loads Shown In Pounds Per Linear Foot (plf)

Joist Designation	Approx. Wt in Lbs. Per Linear Ft. (Joists only)	Depth in inches	Max Load (plf)	SAFELOAD* in Lbs. Between	SPAN IN FEET														
			< 29	29-33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
24LH03	11	24	401	11620	342 235	339 226	336 218	323 204	307 188	293 175	279 162	267 152	255 141	244 132	234 124	224 116	215 109	207 102	199 96
24LH04	12	24	491	14240	419 288	398 265	379 246	360 227	343 210	327 195	312 182	298 169	285 158	273 148	262 138	251 130	241 122	231 114	222 107
24LH05	13	24	526	15260	449 308	446 297	440 285	419 264	399 244	380 226	363 210	347 196	331 182	317 171	304 160	291 150	280 141	269 132	258 124
24LH06	16	24	708	20520	604 411	579 382	555 356	530 331	504 306	480 284	457 263	437 245	417 228	399 211	381 197	364 184	348 172	334 161	320 152
24LH07	17	24	777	22540	665 452	638 421	613 393	588 367	565 343	541 320	516 297	491 276	468 257	446 239	426 223	407 208	389 195	373 182	357 171
24LH08	18	24	829	24040	707 480	677 447	649 416	622 388	597 362	572 338	545 314	520 292	497 272	475 254	455 238	435 222	417 208	400 196	384 184
24LH09	21	24	976	28300	832 562	808 530	785 501	764 460	731 424	696 393	663 363	632 337	602 313	574 292	548 272	524 254	501 238	480 223	460 209
24LH10	23	24	1031	29900	882 596	856 559	832 528	809 500	788 474	768 439	737 406	702 378	668 351	637 326	608 304	582 285	556 266	533 249	511 234
24LH11	25	24	1087	31520	927 624	900 588	875 555	851 525	829 498	807 472	787 449	768 418	734 388	701 361	671 337	642 315	616 294	590 276	567 259
			< 34	34-41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
28LH05	13	28	415	14120	337 219	323 205	310 192	297 180	286 169	275 159	265 150	255 142	245 133	237 126	228 119	220 113	213 107	206 102	199 97
28LH06	16	28	552	18760	448 289	429 270	412 253	395 238	379 223	364 209	350 197	337 186	324 175	313 166	301 156	291 148	281 140	271 133	262 126
28LH07	17	28	623	21180	505 326	484 305	464 285	445 267	427 251	410 236	394 222	379 209	365 197	352 186	339 176	327 166	316 158	305 150	295 142
28LH08	18	28	667	22680	540 348	517 325	496 305	475 285	456 268	438 252	420 236	403 222	387 209	371 196	357 185	344 175	331 165	319 156	308 148
28LH09	21	28	821	27920	667 428	639 400	612 375	586 351	563 329	540 309	519 291	499 274	481 258	463 243	446 228	430 216	415 204	401 193	387 183
28LH10	23	28	898	30540	729 466	704 439	679 414	651 388	625 364	600 342	576 322	554 303	533 285	513 269	495 255	477 241	460 228	444 215	429 204
28LH11	25	28	964	32760	780 498	762 475	736 448	711 423	682 397	655 373	629 351	605 331	582 312	561 294	540 278	521 263	502 249	485 236	468 223

Figure 3: Load table for steel joists based on their span.

To use this table, the structural engineer needs to determine the span of their joists and their loading to ensure they select a joist with enough capacity. If the framing has already been determined, this information can typically be found on structural drawings, but the structural engineer often has to work with an architect and architectural drawings to see where joists can be placed, spaced, and what type of loads they might support. Figure 4 shows a preliminary sketch of a framing plan for a roof that was traced on wax paper over the architectural drawings for the roof plan.

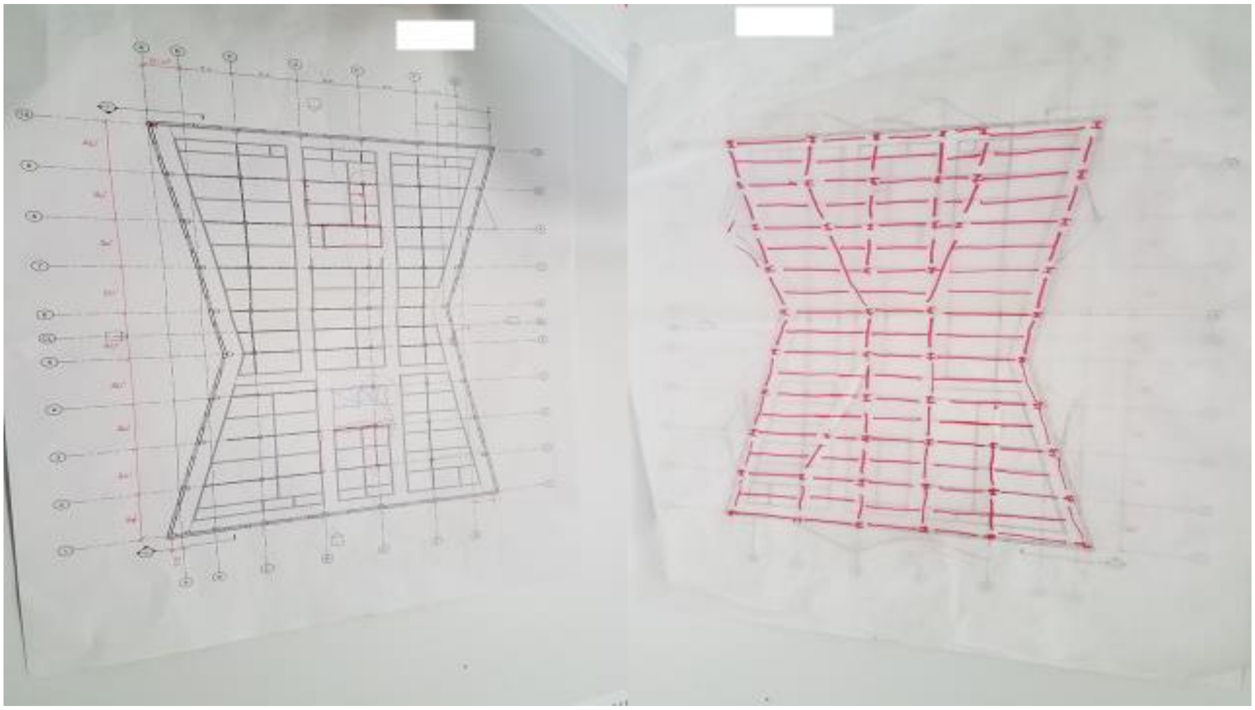


Figure 4: Tracing potential framing layout over architectural drawings.

Tracing framing layouts over the architectural drawings allows the structural engineer to place their structural elements (beams, joists, girders, and columns) while ensuring they do not conflict with any architectural features, such as skylights. This exercise also allows the structural engineer to derive a good estimate of a structural elements span and the tributary area for that element to determine the load it supports. With the span and load determined, the structural engineer can readily use the manufacturer's table in Figure 3 to select a preliminary joist and move forward to other design efforts.

These examples illustrate how a structural engineer may use multiple different tools in a design effort. They may rely on load calculations and previous drawings/details from other engineers, architectural drawings from architects, and/or manufacturers' data of their tested products. These are all examples of social and material contexts that influence how the structural engineer interacts with and represents fundamental structural engineering concepts, such as loads, load path, and member and connection design. Furthermore, these design effort examples illustrate how these concepts are interrelated and influence each other. For example, the loads and load path for the garage door jamb influenced the subsequent member and connection design to resist those loads with the desirable load path.

Activity 2: Ethnography of an Academic Setting

The same graduate research assistant from the previous activity enrolled in fundamental structural engineering courses at a large, public university in the Pacific Northwest. While in these classes, the graduate research assistant used ethnographic methods to explore the ways structural engineering concepts were being represented in common structural engineering courses. The courses that the graduate student enrolled in were an introductory structural theory course and a steel design course. Both these courses are 300 level and required for all civil engineering majors in order to graduate from the university.

Findings

Similar concepts, such as loads, load path, and beam and column design were emphasized in both structural engineering courses. The social and material contexts where these concepts were frequently represented were textbooks, lecture handouts/notes, lab exercises, group projects, and in homework. These contexts are often intended to introduce and present simplified representations of concepts while also simulating aspects of contexts in the workplace. For example, Figure 5 shows a table in the textbook used in the introductory structures course that comes from a standard, ASCE 7-16, that is a common resource used by practicing structural engineers.

1.3 LOADS 13

TABLE 1.4 Minimum Live Loads*

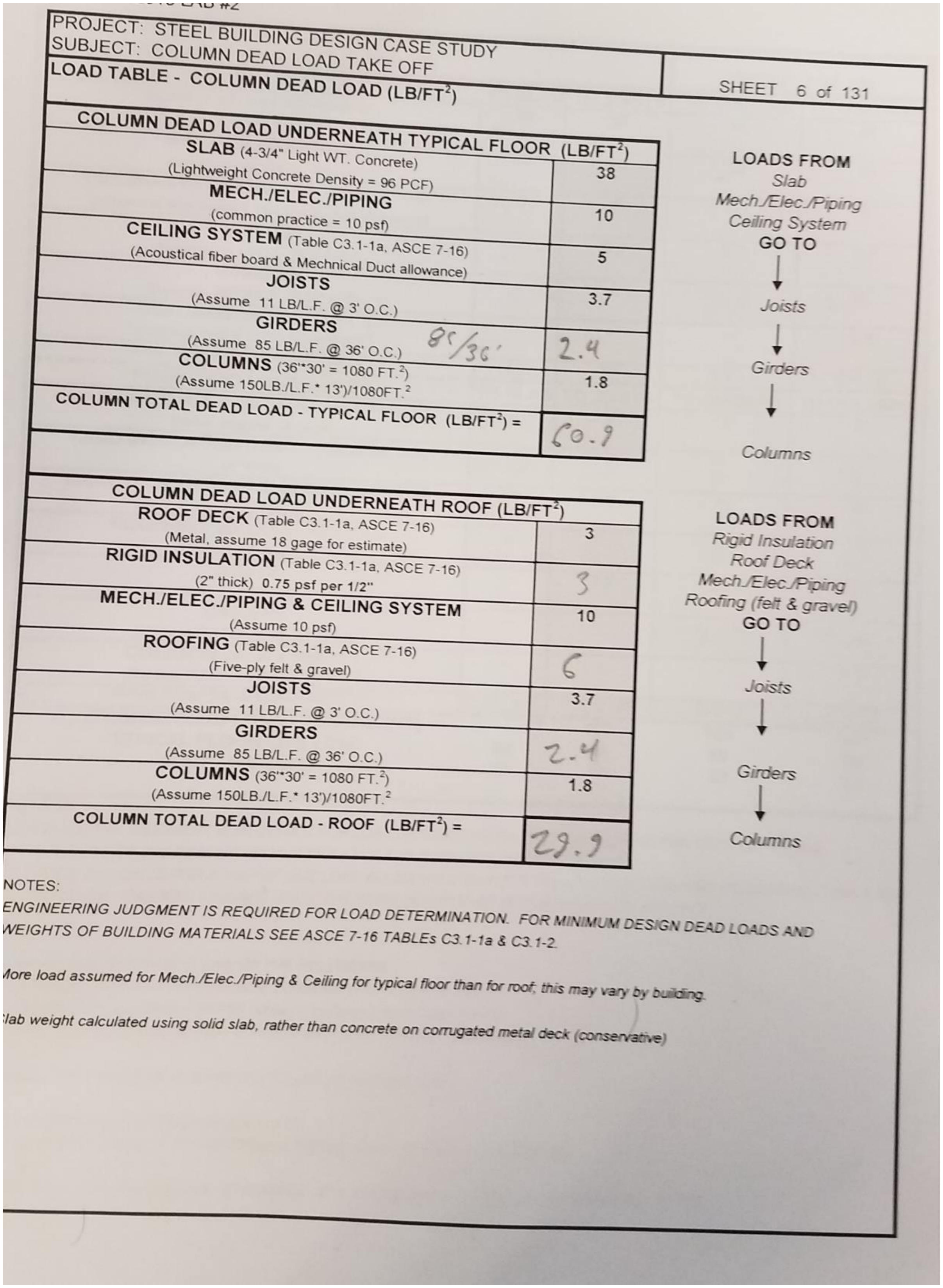
Occupancy or Use	Live Load lb/ft^2	Live Load kN/m^2	Occupancy or Use	Live Load lb/ft^2	Live Load kN/m^2
Assembly areas and theaters			Residential		
Fixed seats	60	2.87	Dwellings (one- and two-family)	40	1.92
Movable seats	100	4.79	Hotels and multifamily houses		
Garages (passenger cars only)	40	1.92	Private rooms and corridors	40	1.92
Office buildings			Public rooms and corridors	100	4.79
Lobbies	100	4.79	Schools		
Offices	50	2.40	Classrooms	40	1.92
Storage warehouse			First-floor corridors	100	4.79
Light	125	6.00	Corridors above first floor	80	3.83
Heavy	250	11.97			

*Minimum Live Loads. Reproduced with permission from American Society of Civil Engineers *Minimum Design Loads for Buildings and Other Structures*, ASCE/SEI 7-16, American Society of Civil Engineers.

Figure 5: Live load table from a structures textbook representing an abridged table from ASCE 7-16.

The table in Figure 5 provides students with some common live load values needed to solve later textbook problems that they had on a homework assignment.

Similarly, a lab exercise for determining loads in the steel design course, presented a load table for students to use in determining load values and the load path from a slab to column. Figure 6 shows the load table students were asked to complete for the dead loads on a structure and Figure 7 shows the printed handout of a table on dead loads from ASCE 7 that the students need for filling out certain parts of the table.



PROJECT: STEEL BUILDING DESIGN CASE STUDY
SUBJECT: COLUMN DEAD LOAD TAKE OFF
LOAD TABLE - COLUMN DEAD LOAD (LB/FT^2)

SHEET 6 of 131

COLUMN DEAD LOAD UNDERNEATH TYPICAL FLOOR (LB/FT^2)	
SLAB (4-3/4" Light WT. Concrete) (Lightweight Concrete Density = 96 PCF)	38
MECH./ELEC./PIPING (common practice = 10 psf)	10
CEILING SYSTEM (Table C3.1-1a, ASCE 7-16) (Acoustical fiber board & Mechnical Duct allowance)	5
JOISTS (Assume 11 LB/L.F. @ 3' O.C.)	3.7
GIRDERS (Assume 85 LB/L.F. @ 36' O.C.) 85/36'	2.4
COLUMNS (36'*30' = 1080 FT.^{2}) (Assume 150LB./L.F.* 13')/1080FT.^{2}	1.8
COLUMN TOTAL DEAD LOAD - TYPICAL FLOOR (LB/FT^2) =	60.9

LOADS FROM
Slab
Mech./Elec./Piping
Ceiling System
GO TO
Joists
Girders
Columns

COLUMN DEAD LOAD UNDERNEATH ROOF (LB/FT^2)	
ROOF DECK (Table C3.1-1a, ASCE 7-16) (Metal, assume 18 gage for estimate)	3
RIGID INSULATION (Table C3.1-1a, ASCE 7-16) (2" thick) 0.75 psf per 1/2"	3
MECH./ELEC./PIPING & CEILING SYSTEM (Assume 10 psf)	10
ROOFING (Table C3.1-1a, ASCE 7-16) (Five-ply felt & gravel)	6
JOISTS (Assume 11 LB/L.F. @ 3' O.C.)	3.7
GIRDERS (Assume 85 LB/L.F. @ 36' O.C.)	2.4
COLUMNS (36'*30' = 1080 FT.^{2}) (Assume 150LB./L.F.* 13')/1080FT.^{2}	1.8
COLUMN TOTAL DEAD LOAD - ROOF (LB/FT^2) =	29.9

LOADS FROM
Rigid Insulation
Roof Deck
Mech./Elec./Piping
Roofing (felt & gravel)
GO TO
Joists
Girders
Columns

NOTES:
ENGINEERING JUDGMENT IS REQUIRED FOR LOAD DETERMINATION. FOR MINIMUM DESIGN DEAD LOADS AND WEIGHTS OF BUILDING MATERIALS SEE ASCE 7-16 TABLEs C3.1-1a & C3.1-2.

More load assumed for Mech./Elec./Piping & Ceiling for typical floor than for roof; this may vary by building.

Slab weight calculated using solid slab, rather than concrete on corrugated metal deck (conservative)

Figure 6: Lab exercise for determining dead loads from slab to a column.

Table C3.1-1a Minimum Design Dead Loads (psf)[a]

Component	Load (psf)
CEILINGS	
Acoustical fiberboard	1
Gypsum board (per 1/8-in. thickness)	0.55
Mechanical duct allowance	4
Plaster on tile or concrete	5
Plaster on wood lath	8
Suspended steel channel system	2
Suspended metal lath and cement plaster	15
Suspended metal lath and gypsum plaster	10
Wood furring suspension system	2.5
COVERINGS, ROOF, AND WALL	
Asbestos-cement shingles	4
Asphalt shingles	2
Cement tile	16
Clay tile (for mortar add 10 psf)	
Book tile, 2-in.	12
Book tile, 3-in.	20
Ludowici	10
Roman	12
Spanish	19
Composition:	
Three-ply ready roofing	1
Four-ply felt and gravel	5.5
Five-ply felt and gravel	6
Copper or tin	1
Corrugated asbestos-cement roofing	4
Deck, metal, 20 gauge	2.5
Deck, metal, 18 gauge	3
Decking, 2-in. wood (Douglas fir)	5
Decking, 3-in. wood (Douglas fir)	8
Fiberboard, 1/2-in.	0.75
Gypsum sheathing, 1/2-in.	2
Insulation, roof boards (per inch thickness)	
Cellular glass	0.7
Fibrous glass	1.1
Fiberboard	1.5
Perlite	0.8
Polystyrene foam	0.2
Urethane foam with skin	0.5

Figure 7: Printout of a table with dead load values from ASCE 7-16.

Notice how in Figure 6, the students are provided with some assumptions for material weights, and that some of the values are already given with a reference to the table in Figure 7 for where those values came from.

These examples show that students are being presented with concepts such as loads and load path in their homework, textbooks, lab exercises, and handouts. Both Figures 5 and 6 inform students that the loads are determined from ASCE 7, a commonly used standard by structural engineers for determining loads. Figure 6 even has students look up some values from a table printed out from ASCE 7. These exercises help introduce students to common live and dead load values, a basic load take off and load path, and what ASCE 7 is; however, they do not provide students with much opportunity to navigate and locate these tables within an entire ASCE 7 standard or wrestle with where some of the load assumptions and member spacings in Figure 6 come from.

Another exercise performed by students on a homework assignment in the introductory structures course required them to determine and trace a load path for a floor framing plan of an existing structure by reading and interpreting the existing structural drawings as shown in Figure 8.

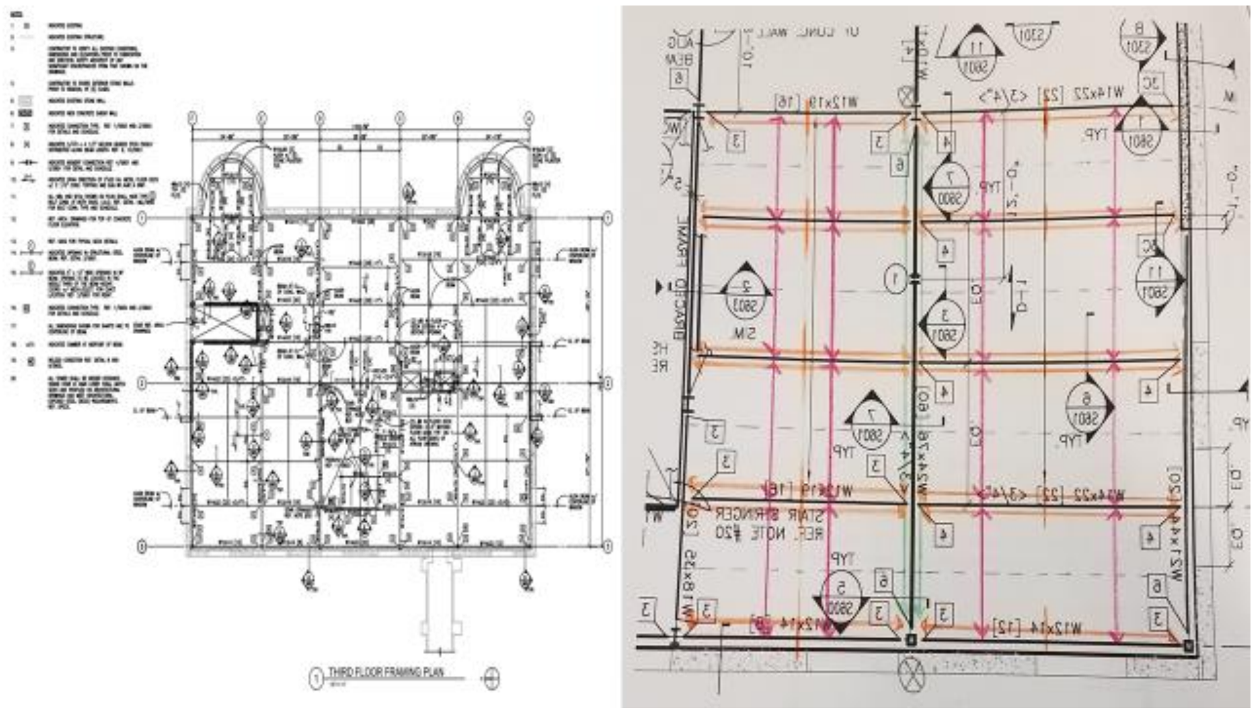


Figure 8: Homework problem asking students to use the floor framing plan structural drawings on the left to determine and trace the load path on an enlarged printout of a portion of the same floor plan.

This exercise exposes students to the concept of load path, while also exposing them to reading and interpreting structural drawings. These types of exercises that provide students with tangible materials (used by practicing structural engineers) to learn new concepts, allow students to become familiar with the contexts of the workplace that influence how structural engineers represent and understand these same concepts.

<u>Discussion:</u>

This project's impact on engineering education is that it allows for a deeper understanding of how concepts are represented in a professional setting, so that best practices and areas of improvement can be identified for how similar concepts are represented in academic settings. Engineering education exposes engineering students to a wealth of concepts with the assumption that if students fundamentally understand these concepts, they will be able to apply them appropriately in their professional careers. Situated cognition theory, however, would argue that the social and material contexts wherein concepts are learned and applied influences our understanding of them and ability to recognize, understand, and apply them in novel contexts. [3].

The authors' do not mean to contend that all concepts be represented in similar social and material contexts as practice. Indeed the contexts of the academic setting have their purpose of introducing new concepts in simplified, isolated ways and scaffolding off of this into more nuanced and integrated representations. However, there are opportunities for curriculum to be more aligned with the social and material contexts of practice so that students are aware and prepared for these contexts. In terms of structural engineering, students could benefit from exercises such as the one presented in Figure 8, where they must read and interpret structural drawings—a common material context of the structural engineering workplace—to represent the load path. Similarly, students might benefit more from engaging with concepts presented in standards and codes common in practice, rather than textbooks or printouts that only reference isolated aspects of these standards and codes.

Conclusion:

This project will provide a more holistic view of how concepts are represented in an authentic workplace setting and how this compares with the ways similar concepts are represented in academic settings. One reason for the education-practice gap in engineering is the differences between the contexts of these settings and how these contexts influence conceptual learning and understanding as posited by situated cognition theory [3]. A descriptive exploration of these settings and their contexts was provided through ethnographic methods of a structural engineering workplace and structural engineering courses. These methods highlighted that concepts are represented across a variety of social and material contexts in the workplace often geared towards expediting design decisions; whereas concepts are represented in simplified and isolated contexts in academic settings that limit the opportunities for students to make broader connections of how these concepts integrate in holistic design efforts. These findings indicate that concepts can be less ubiquitous than they are represented as being in academic settings and by exposing students to some of the ways concepts are represented in professional practice they may become more aware of the tools and resources engineers use to represent these concepts and their role in design efforts.

References:

[1] Bornasal, F., Brown, S., Perova-Mello, N., & Beddoes, K. (2018). Conceptual Growth in Engineering Practice. *Journal of Engineering Education,* 107 (2).

[2] Johri, A. (2014). Conducting Interpretive Research in Engineering Education Using Qualitative and Ethnographic Methods. *Cambridge Handbook of Engineering Education Research*. (pp. 551-570).

[3] Johri, A, Olds, B.M., & O'Connor, K. (2014). Situative frameworks for engineering learning research. *Cambridge Handbook of Engineering Education Research.* (pp. 47-66).