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*Full Length Research Paper*

# Misconceptions of civil engineering students on structural modeling

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**Student misconceptions have recently been an important area of research in many branches of science. However, the research work on the misconceptions of engineering students has remained of limited extent. Although the most important task of a structural engineer is structural analysis, structural modeling and interpretation of analysis results have come into prominence due to emerging computer technology. This study is concerned with the levels of perception of structural modeling among eighth-semester civil engineering students. For this purpose, the students were given pier structures and asked to draw structural models for the analysis of these structures. Misconceptions developed by the students regarding structural modeling were then determined by investigating the drawings. It was observed that the students have major misconceptions, especially about boundary conditions. Beside the fact that these misconceptions stem from a large number of factors, one of the most significant consequences is the misconceptions about structural stability. Possible means to mitigate the misconceptions of engineering students are suggested in the conclusion.**

**Key words:** Structural engineering, student misconceptions, structural modeling, drawings.

## INTRODUCTION

Misconceptions are one of the obstacles that prevent the students from learning and applying the desired concepts properly. The thoughts of a student which he builds up or develops aside from scientifically accepted facts are referred to as misconceptions. In order to maintain the efficiency of learning process, it is of vital importance to determine the misconceptions or alternative conceptions developed by students and make necessary changes in the curricula such that these changes can help students to develop acceptable concepts (Taber, 1998).

Many methods exist in the literature that has been proposed to identify misconceptions. Word association (Bahar et al., 1999; Maskill and Cachapuz, 1989), interviews (Osborne and Cosgrove, 1983; Abdullah and Scaife, 1997), open-ended questions (Eisen and Stavy, 1988), concept mapping (Hazel and Prosser, 1994), two-tier diagnostic test (Tuysuz, 2009; Haslam and Treagust, 1987), prediction-observa-tion-explanation (Liew and Treagust, 1995) and drawings (Martlew and Connolly, 1996; Kose, 2008) are the most frequently used methods in the identification of miscon-ceptions. Among these methods, drawing is the one that opens a window to the minds of students. In this method, the probability of misunderstanding the answers due to factors like ambiguities is also at considerably lower levels compared to other methods. The fact that topics which are difficult to explain verbally can be easily illustrated via drawings is a remarkable advantage of this method. For this reason, the drawing method has been widely deployed in studies about misconceptions of students (White and Gunstone, 1992; Rennie and Jarvis, 1995).

One of the most important tasks of a civil engineer is structural design. The design, in the first place, begins by developing a structural model. The engineer builds a numerical model of the structure to be constructed, taking into account the geometry, boundary conditions, loads and material properties of the structure. Later, the behavior of the structure under the design loads is analyzed. After the design forces are determined, the engineer finalizes the design by detailing the sections and connections. If any of the components fails, this design process continues iteratively until the final design is arrived at. Today, with the emergence of computer-aided design technology, the analysis stage and the detailing of

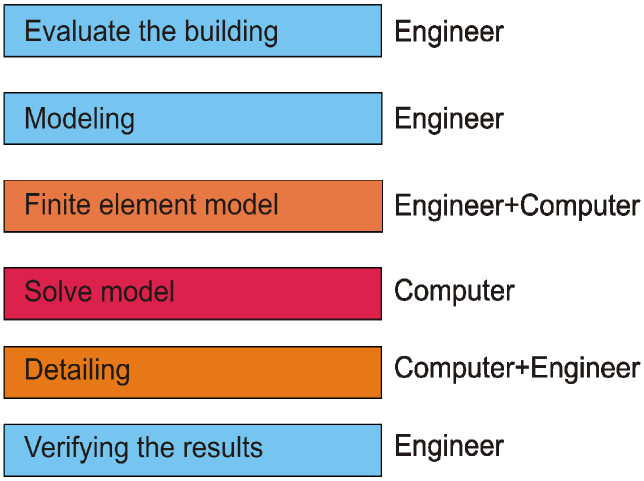


**Figure 1.** Design stages and roles of engineer and computer.

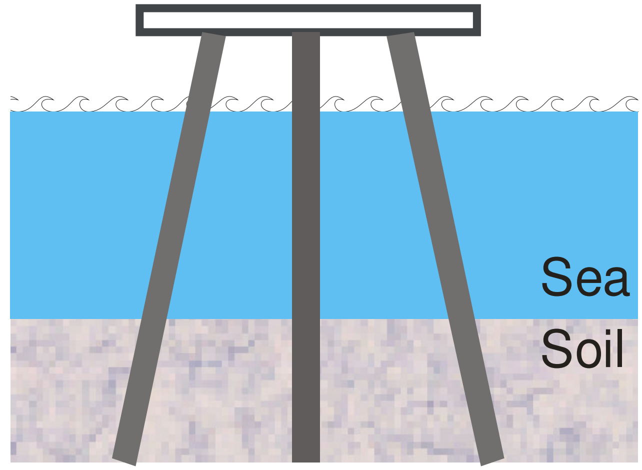


**Figure 2.** The pier structure to be modeled.

**Table 1.** Basic and Structural Mechanics courses in CEDPU curriculum.

| Course name | Semester | Lecture hours |
|---|---|---|
| Engineering mechanics I | 2 | 56 |
| Engineering mechanics II | 3 | 42 |
| Strength of materials I | 3 | 56 |
| Strength of materials II | 4 | 56 |
| Structural mechanics I | 5 | 56 |
| Structural mechanics II | 6 | 56 |

the sections and connections can be accomplished by means of design software programs. Therefore, the most important responsibility of an engineer in the design process is building the structural model as accurate as possible. The consistency of the analysis and design outcomes of the accurate model should, in turn, be examined by the engineer. Figure 1 shows the design stages and the roles of the computer and the engineer in a computer based design process

A significant portion of the structural design process is covered by structural mechanics and structural analysis courses. Although the function of civil engineers today is concentrated on building structural models and examining the consistency of results, such courses are more concerned with the analysis of structural models. The present study examined the structural modeling misconceptions of the eighth-semester graduating senior students at the Civil Engineering Department. The misconceptions developed by the students were identified and suggestions were made to eliminate these misconceptions.

## MATERIALS AND METHODS

This study investigated the structural modeling misconceptions of the 8$^{th}$ semester undergraduate students at the Civil Engineering Department of Pamukkale University (CEDPU). In addition to basic mechanics courses, the participants had also taken 112 hours of Structural Analysis courses. The study was conducted in March 2009 among the senior students who were taking the Reinforced Concrete Design course. The curriculum applied by the CEDPU is of equivalent level with those applied by other civil engineering departments in Turkey. Table 1 presents basic and structural mechanics course load of the curriculum of the CEDPU. The curriculum teaches the individual steps involved in problem solution in separate courses, rather than providing an overall integrated framework on how to solve a problem. For instance, the analysis of a system with a given structural model is taught in mechanics and structural analysis courses, whereas the detailing of a reinforced concrete section with given section details is taught in a separate course; and it is the student who is supposed to make a connection between the two courses.

The first step in the solution of a structural engineering design problem is to build a structural model of the anticipated structure. The design forces are then calculated by analyzing this model under the design loads. The final step is the detailing of sections and connections according to these design forces. These steps may be performed more than once if the dimensions chosen in the pre-design phase are not suitable for the internal forces.

Considering the fact that the students might have had insufficient knowledge about this process, they were instructed on the design process. After that, the meaning of structural modeling was explained. The students participating in the study were also shown how to model certain structural forms.

After the presentation of the general instructions, the students were given a pier structure and were asked to build a structural model. Figure 2 depicts the pier structure, of which the students were asked to construct a structural model.

The structural modeling misconceptions of the students were identified by inspection of the drawings. The drawings exhibiting the levels of perception of structural modeling among the students were classified into five levels: No model, completely wrong drawings, Models with numerous flaws, incomplete structural models and complete models. The details of these levels are as follows:

### Level 1 (No model)

This level comprises the cases of no answer or the answers like “I do not know”.

**Table 2.** Frequency of modeling misconceptions.

| Misconception | Number of occurrence |
|---|---|
| No loads were defined | 73 |
| Wrong boundary conditions or support definitions | 44 |
| Unstable structural models | 20 |
| Cantilever ends not modeled | 17 |
| Wrong structural geometry | 13 |
| Wrong loading | 10 |
| Hinged connection between pile and girder | 8 |
| Pile friction forces included into models | 6 |
| Sea water modeled by springs | 5 |
| Hinges on piles at sea bed level | 5 |
| Hinges on piles at sea level | 4 |
| Top girder and piles modeled separately | 2 |
| Additional beams connecting piles at various levels | 2 |
| Springs at top girder level | 1 |
| Only piles modeled as cantilever columns | 1 |
| Restrained top girder against lateral displacement | 1 |

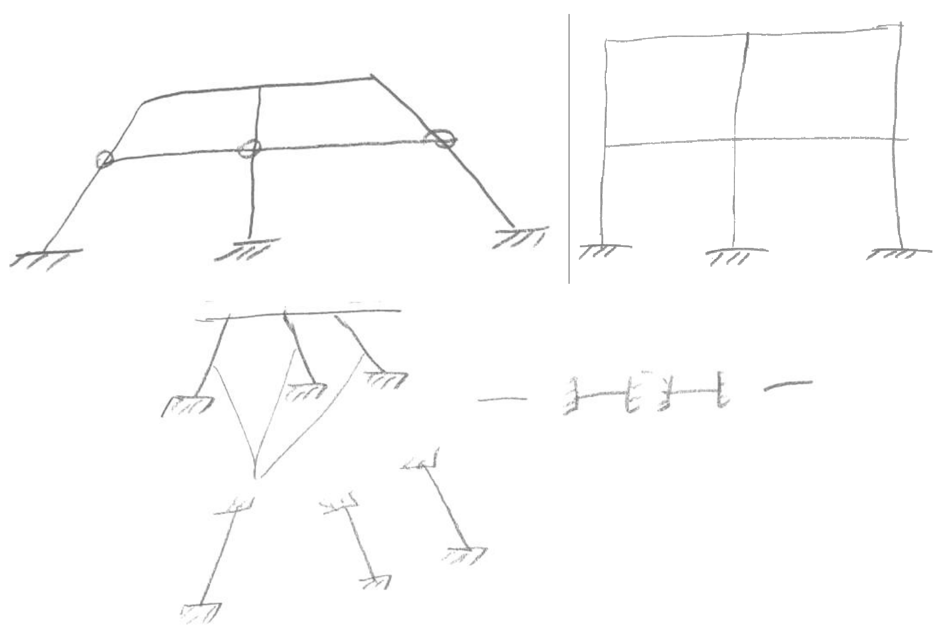

**Figure 3.** Completely wrong drawings (Level 2).

**Level 2 (Completely wrong drawings)**

Models which, in fact, cannot be considered as a structural model or models that are much unrelated to the actual structure were assigned this level. Figure 3 shows sample drawings that belong to this level.

**Level 3 (Models with numerous flaws)**

Models with too many flaws and missing parts were assigned this level. Figure 4 exhibits sample drawings.

**Level 4 (Incomplete structural models)**

If the structural model was built to a large extent, but had a small number of flaws, then the drawing was assigned this level. Figure 5 shows sample drawings representing this level.

**Level 5 (Complete models)**

Acceptable structural models were assigned this level. It is not expected from a structural model to fully represent the true structure no matter how detailed the model is. These models have been referred to as complete because they can lead to the solution within

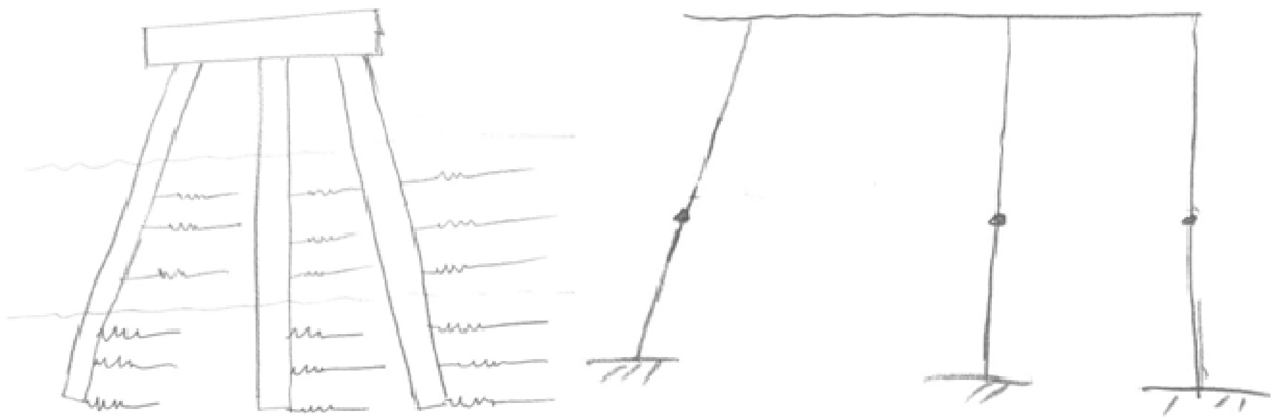

**Figure 4.** Models with numerous flaws (Level 3).

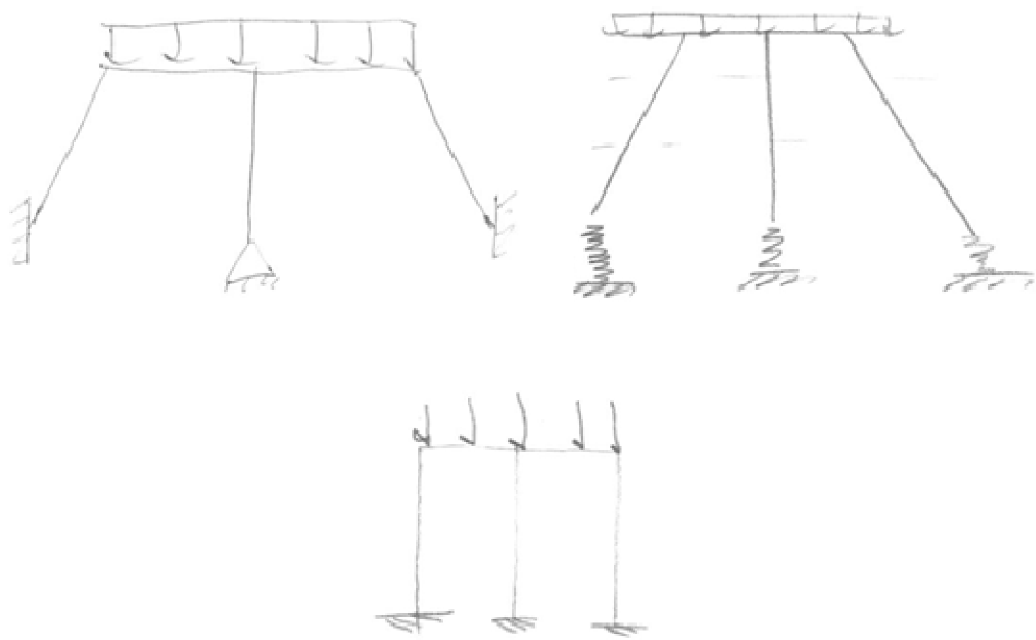

**Figure 5.** Incomplete models (Level 4).

certain error tolerance. Figure 6 depicts a sample drawing from this level.

## RESULTS

As a result of the study conducted among the students, it can be seen that the structural modeling skills of students concentrated on Levels 3 and 4 (Figure 7). This implies that the vast majority of the students had at least one misconception. Table 2 lists the misconceptions observed in the structural models developed by the students.

The most frequently encountered misconception in the models is that the structural models do not contain any loads. Even though the analysis of a structure cannot be performed without loadings, the author considers this mistake to be caused by carelessness rather than as a misconception.

According to the frequencies of misconceptions listed in Table 2, the fact that more than half of the students failed to define the boundary conditions correctly is a remarkable point. Figure 8 shows sample structural models with incorrect definitions of the boundary conditions.

It was observed that the students made simple but important mistakes about defining the boundary conditions, and that they had misconceptions about some basic

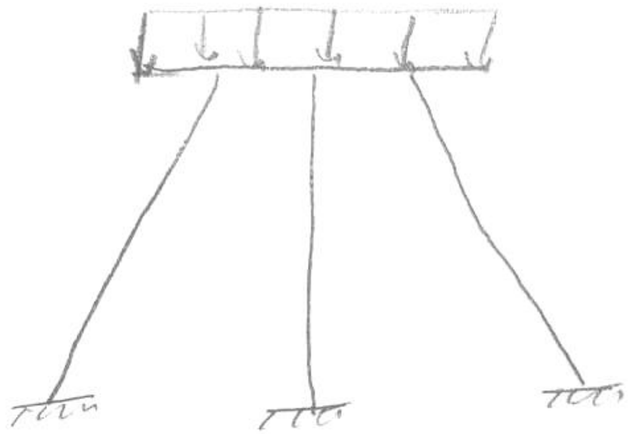

**Figure 6.** A complete model (Level 5).

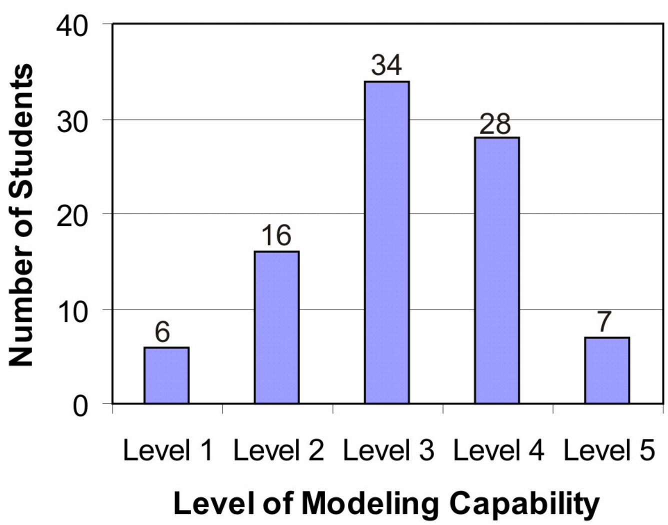


**Figure 7.** Distribution of number of students for different levels of modeling capability.

topics such as simple, fixed and roller supports. Due to the fact that the students failed to define the boundary conditions correctly, 14 of the models had stability problems. The stability problems of the other 6 models were caused by the hinges placed on structural elements. In 12 of the 44 models with misconceptions on boundary conditions, the vertical displacements at the bottom of the side-piles were not prevented. While the number of models in which the vertical or lateral displacements of the piles were not prevented range from 8 to 12, the number of models with at least one of these two types of displacements being not prevented was 17. The number of models with only vertical springs at the bottom of all piles was 8, and all of these models were unstable. Moreover, the facts that 5 models had fixed supports placed right at the sea bed level and that 2 models made use of fixed supports in the sea are worth noting. On the other hand, in another drawing, the free ends of the top girder were illustrated as fixed supports. This reveals the fact that a significant portion of the students did not understand the behavior of fixed supports. Table 3 exhibits all of the misconceptions on boundary conditions that were identified by inspection of the models.

In addition to the flawed boundary conditions, 24% of the models were unstable because of incorrect use of internal hinges in the models. Figure 9 provides examples of such models. It is obvious that the analysis of such models is not possible.

Beside these important mistakes, the geometry of 15% of the models was also incorrect, which is remarkable. Although the side piles in the structure to be modeled were clearly inclined, it was seen that a group of students drew vertical piles. From the interviews with some of these students, it was revealed that they thought the orientation of the piles, inclined or vertical, would not make any difference as far as the analysis was concerned. Figure 10 shows two models with such incorrect geometry.

The fact that a graduating senior civil engineering student can make mistakes that are as simple as the ones mentioned above evidently shows that the curricula should give sufficiently high emphasis, especially to structural modeling and stability.

## DISCUSSION AND CONCLUSION

Since the prominence of computer programs as widely-used tools in the analysis of structural systems, skills in structural modeling and examining the results of structural analysis have become more indispensable for design engineers compared to skills in performing structural analysis. Both modeling skills and the inspection of analysis results require that the engineer have competent knowledge about structural behavior. In this study, a drawing exercise was conducted among 90 eighth-semester civil engineering students in order to identify their modeling skills as well as the misconceptions they had about the topic. The students were given a pier structure and were asked to draw a structural model for that.

It was observed that 7% of the students, who had already taken basic mechanics and structural analysis courses, could not make any drawings. When considered together with the students who made meaningless drawings, it can be seen that almost 25% of the students were considerably inadequate in structural modeling and that they had substantial misconceptions. The percent-age of students who had numerous errors in their drawings was as high as 38%, which is non-negligible. On the other hand, the percentage of students making a small number of errors or building complete (acceptable) models was 39% the fact that the students were rather

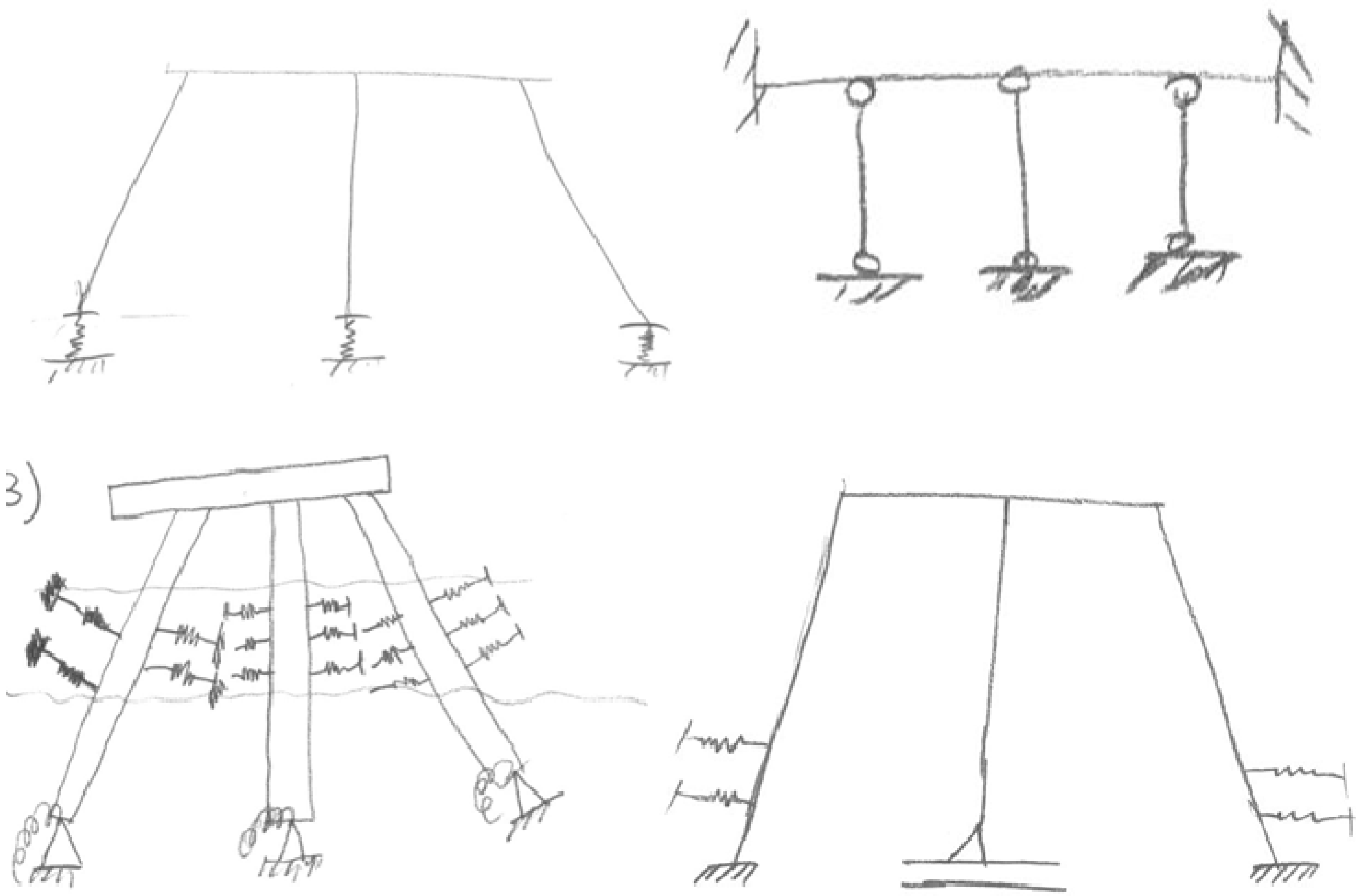


**Figure 8.** Example drawings with incorrect boundary conditions.

**Table 3.** Frequency of misconceptions about boundary conditions.

| Mismodeled boundary condition | Number of occurrence |
|---|---|
| No stability due to boundary conditions | 14 |
| Vertical displacement at bottom of side-piles not prevented | 12 |
| Lateral displacement at bottom of mid-pile walls not prevented | 10 |
| Simple support at side piles without any lateral springs | 10 |
| Simple support at middle pile without any lateral springs | 9 |
| Vertical displacement at bottom of mid-pile walls not prevented | 9 |
| Lateral displacement at bottom of side-piles not prevented | 8 |
| Only vertical springs used at bottom of all piles | 8 |
| Lateral displacements not prevented at all piles | 7 |
| Modeling sea with lateral springs | 5 |
| Fixed supports used at sea bed level | 5 |
| Lateral springs used only at bottom of side piles without preventing vertical displacements | 3 |
| Lateral displacements prevented by springs at sea bed level | 2 |
| Middle pile fixed in sea | 2 |
| Vertical springs used at bottom of side piles only | 1 |
| Lateral springs used at top girder level | 1 |
| Piles modeled as both ends fixed | 1 |

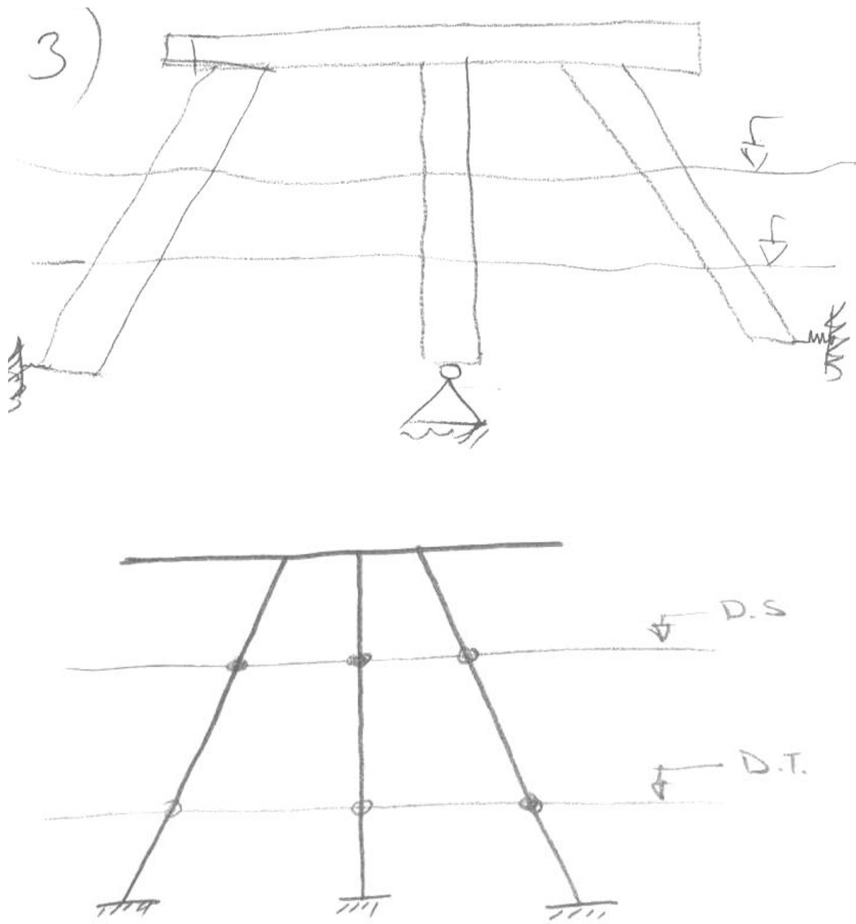


**Figure 9.** Examples of unstable models.

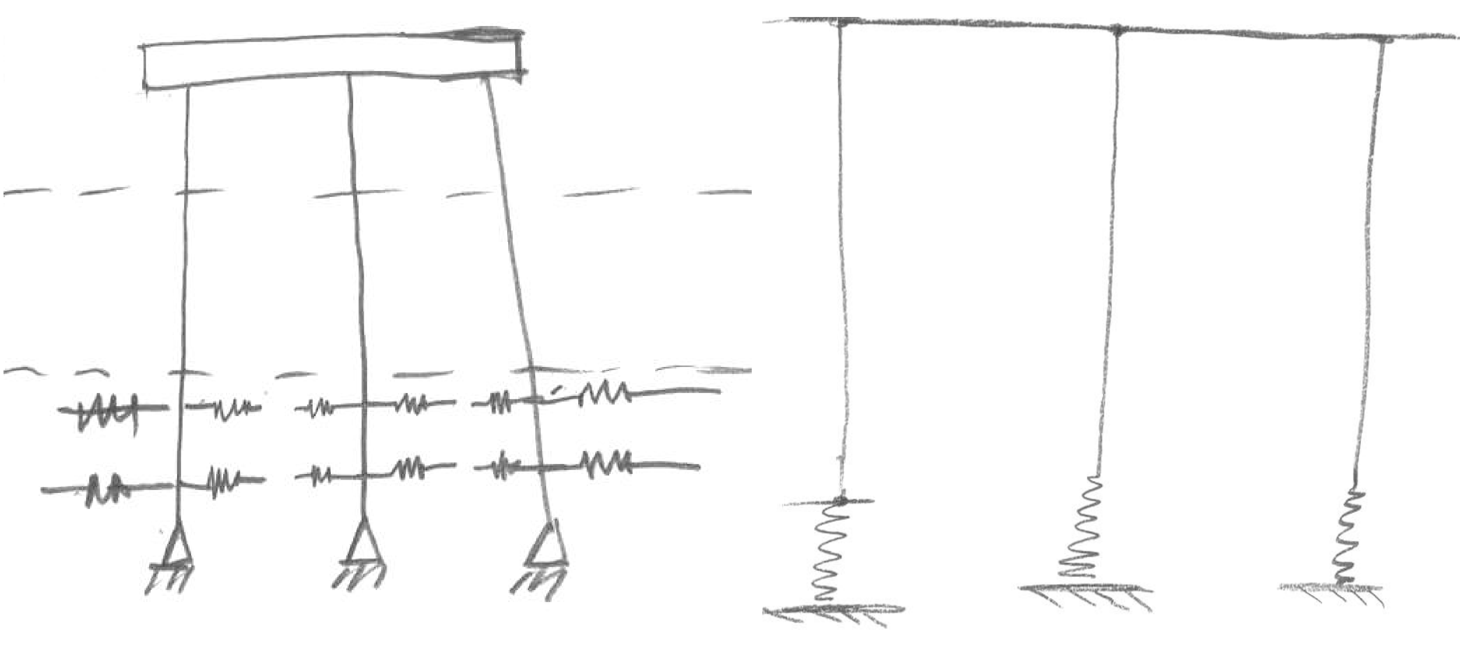

**Figure 10.** Models with incorrect geometry.

Furthermore, it was seen that 24% of the drawn models were unstable, which was mainly caused by the misconceptions of the students about boundary conditions and supports. As a matter of fact, when only the students, who turned in a drawing, were considered, it was observed that more than half of the students had misconceptions about boundary conditions. The misconceptions on boundary conditions, which had been developed by the students, were listed above in Table 3. Consequently, it can be understood that the students had failed to internalize the concept of supports and thus had question marks about stability.

It was observed that, due to the misconceptions they had, the vast majority of the students failed to model a real structure completely. This phenomenon is caused by familiar with problems in which the structural models were already constructed, and which were not concerned with structural modeling and behavior. It is obvious that, even if a flawed structural model is analyzed correctly, the results cannot reflect the reality. For this reason, it is necessary to review the curricula of structural analysis courses and arrive at a problem-focused curriculum. Firstly, problems with already constructed models should be abandoned and the construction of structural models should be incorporated into the problems. In this way, as a result of a long process, the modeling concepts like fixed or basic supports will cease to be imaginary phenomena and will be linked to the real-world problems. Moreover, term projects concerned with real world problems that would improve the modeling skills of students can be suggested as another viable option. It would also be beneficial to monitor the levels of perception of concepts among students after such changes in the curricula.

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