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PRACTICAL EDUCATION OF MIXTURE DESIGN FOR YOUNG ENGINEERS AT READY-MIXED CONCRETE PLANTS

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The demand for ready-mixed concrete in Japan has decreased in recent decades because various budgets for civil infrastructure have been reduced. Additionally, a large number of skilled engineers will retire in the near future. The numbers of ready-mixed concrete plants and employees have decreased gradually to almost 50 percent of the numbers 15 years ago. The lack of knowledge in mixture design should be a concern, especially to young concrete engineers in Japan. The goals of the present study are to pass on fundamental mixture design methods to young engineers and to develop an effective education program for young engineers. A competition was held between young and skilled engineers to design mixture proportions for a modern concrete and a historically produced concrete made from river aggregate. The educative competition confirmed that skilled engineers are better than young engineers in modifying a concrete design. A questionnaire survey completed after the competition showed that the education of young engineers should include the learning of skills and experiences from skilled engineers.

Keywords: Education, Knowledge management, Young engineer, Mixture proportions.

1 INTRODUCTION

In Yamaguchi prefecture, a typical Japanese region, the numbers of employees and engineers in ready-mixed concrete factories have decreased to 60 percent of the numbers 20 years ago. Although the knowledge of experienced engineers should be appropriately passed on to young engineers, young engineers working at ready-mixed concrete factories have little opportunity to study the mixture design of concrete. The mixture design is the main theme of such education. The goals of the present study are to pass on fundamental knowledge of mixture design through group learning and to develop an effective education program for young engineers in concrete factories.

The Socialization, Externalization, and Combination, and Internalization (SECI) model proposed by Nonaka (1995) is a theory of how knowledge is transferred. In the SECI model, there is a cycling interaction between explicit and tacit knowledge as a knowledge creation process. The present study combines SECI frameworks to establish a model of a learning method that comprises individual learning and group learning (Figure 1).

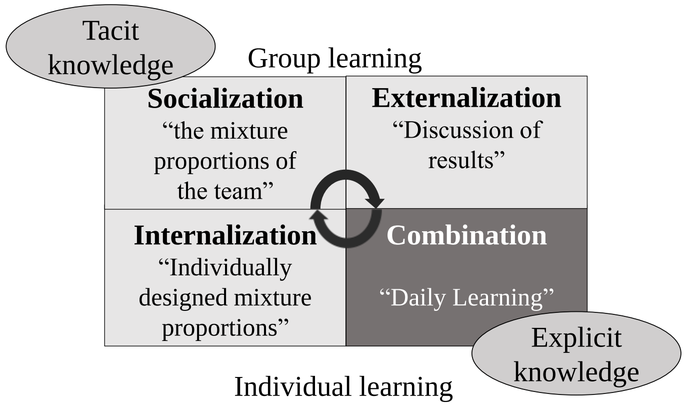
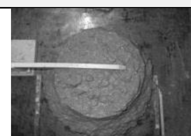


Figure 1. SECI model and process.

Table 1. Criteria of shape evaluation.

Evaluation	Side view	Top view	
A			Good
B			Fair
C			Reexamination Required

2 GROUP LEARNING OF MIXTURE DESIGN

2.1 Objectives

In the context of this paper, group learning aims to improve competence in the design of appropriate mixing proportions for a quality target concrete. The concrete mixture proportions are designed to provide a specified slump (17.5 cm), slump flow/slump (F/S) ratio (1.7), and slump shape of the concrete mass in a slump test of appropriate workability (the property of freshly mixed concrete that determines the ease and homogeneity with which the concrete can be mixed, applied, compacted, spread, or finished) and plasticity (the property of freshly mixed concrete that determines the concrete's resistance to deformation or ease of molding). Table 1 gives the criteria of the shape evaluation.

2.2 Conditions of Mixture Design

The concrete mixture comprises ordinary Portland cement (as defined in JIS R 5210, 2009) and water without the entraining of air or addition of a water-reducing admixture. The concrete was made with a water–cement ratio (***w/cm***) of 60%. Crushed stone (5–20 mm, 2.69 g/cm^3), crushed sand (<5 mm, 2.56 g/cm^3) and limestone sand (<5 mm, 2.65 g/cm^3) were employed for Theme 1, which has been commonly used by ready-mixed concrete plants in Yamaguchi Prefecture (Figure 2(a)). River gravel (5–25 mm, 2.61–2.63 g/cm^3) and river sand (<5 mm, 2.61 g/cm^3) were employed for Theme 2, which has not been used in Yamaguchi since the early 1970s, to study the properties of previously produced concrete. The river gravel and sand were obtained from Fukuchiyama (Kyoto, Japan) for the group learning exercise (Figure 2(b)).

(a) Theme 1 (crushed stone)

(b) Theme 2 (river gravel)

Figure 2. Employed aggregates for group learning.

2.3 Team Formation

The group learning exercise involved members of ready-mixed concrete plants located in central Yamaguchi. The members engage in manufacturing and quality control of products in their daily work. A skilled engineer and a young engineer from each plant in the area participated in the exercise. One team comprised four engineers, and four teams (two skilled-engineer teams and two young-engineer teams) participated in the exercise.

2.4 Learning Process

Figure 3 shows the process of group learning in the present study. Prior to learning, the properties of aggregates were given to the participants. First, the participants individually designed mixture proportions. Participants then got together with their teammates to discuss and determine the mixture proportions of the team. Trial mixing was then performed using each team’s mixture proportions. After analyzing the results of trial mixing, the team discussed and modified the mixture proportions. Test mixing was again performed using the modified proportions. At the end of the exercise, the chairman of the technical committee of the co-operative union decided the best mixture proportions in terms of target quality, judging from the results of test mixing. Figure 4 shows the plan–do–check–act (PDCA) cycle of the group learning. The PDCA cycle was completed twice, once for Theme 1 (crushed stone and sand) and once for Theme 2 (river gravel and sand).

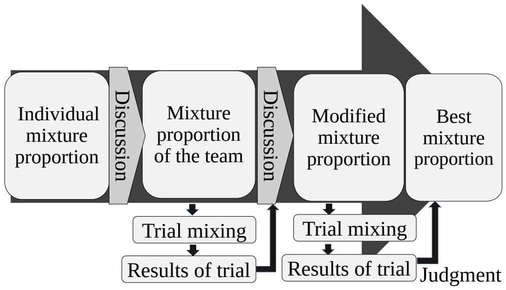


Figure 3. Flow of group learning.

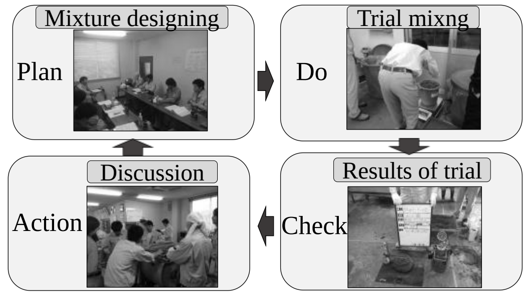


Figure 4. PDCA cycle of group learning.

3 QUESTIONNAIRE

3.1 Objectives

The present study aims to develop an appropriate education system for young engineers. For this purpose, participants were asked to complete a questionnaire survey to reveal differences in knowledge between young and skilled engineers, to confirm the validity of the education system, to investigate the need for education in the future, to assess the degree of achievement of the training objectives, and to provide a training record for follow-up education.

3.2 Questionnaire Subjects

The questionnaire subjects were 16 concrete engineers (all participants). According to the prior discussions, 10 subjects (four young engineers and six skilled engineers) had experience in designing mixture proportions, and six subjects (four young engineers and two skilled engineers) did not.

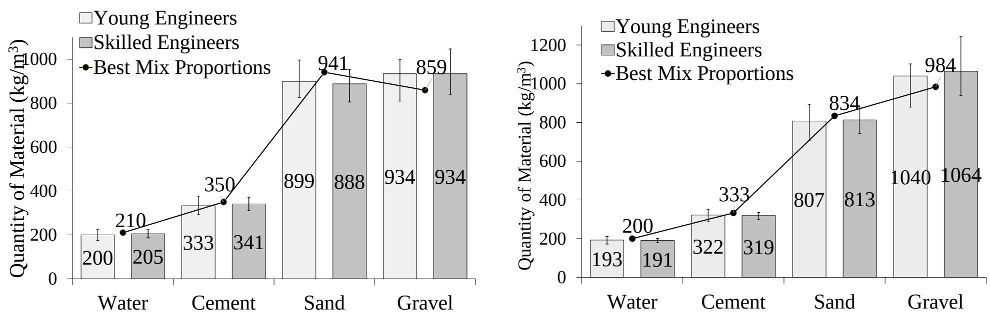
3.3 Questionnaire content

Questionnaires were distributed in advance to the participants. The questionnaires were also used as worksheets for mixture design and scoring forms for the competition among groups. In its role as a worksheet, the questionnaire included questions for participants to answer on the designed mixture proportions and design process, the determination of the mixture proportions of the team and the related decision process, and the modification of mixture proportions of the team and the related decision process. In addition, the questionnaire included questions that allowed subjects to comment on the training, the need for training methods in the future, and the subjects' level of satisfaction with the education offered in the study. Questionnaires were also used as an educational record.

4 RESULTS AND DISCUSSION

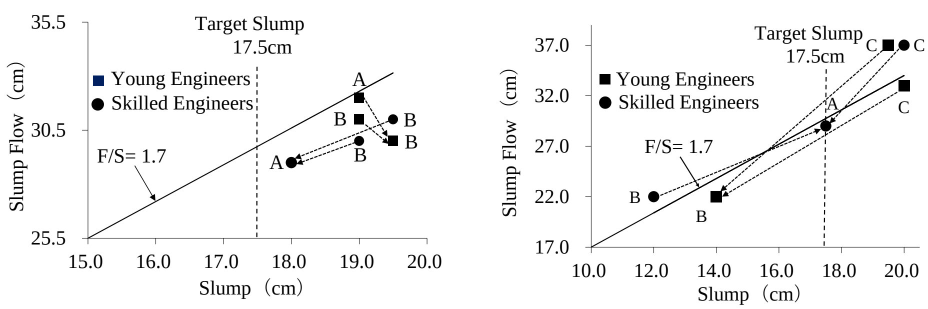
4.1 Results of Group Learning

Figure 5 shows the average quantity of material per unit volume of concrete in the mixture proportions of individuals and the best mixture proportions. There was no great difference in the designed mixture proportions and design process judging from the questionnaires.



(a) Theme 1 (crushed stone). (b) Theme 2 (river gravel).

Figure 5. Results of mixture designs of individuals.



(a) Theme 1 (crushed stone). (b) Theme 2 (river gravel).

Figure 6. Results of trial mixing.

Figure 6 shows the results of trial mixing. Figure 6 (a) shows that the slump value in the case of Theme 1 (using crushed stone and sand) was 1.5–2.0 cm greater than the specified slump value (17.5 cm) for both young-engineer teams and skilled-engineer teams. The shape of the concrete mass after the slump test was given an evaluation grade of A for one young-engineer team and a grade of B for the other three teams. The results of the second trial mixing of the mixture proportions modified after team discussion (by two teams; a team of all the young engineers team and a team of all the skilled engineers) were a slump value of 18.0 cm for the skilled engineers and a slump value of 19.5 cm for the young engineers. The result indicates that skilled engineers were better than young engineers in modifying the mixture proportions. Figure 6 (b) shows that, in the case of Theme 2 (using river gravel and sand), the slump value varied widely for all teams of skilled and young engineers. The shape of concrete mass after the slump test was evaluated as grade B for one of the skilled-engineer teams and grade

C for the other three teams. The slump value for the second trial mixing of the modified mixture proportions was 17.5 cm (consistent with the target) for the skilled engineers and 14.0 cm for the young engineers. Again, the result indicates that the skilled engineers were better than the young engineers in modifying the mixture proportions.

4.2 Results of questionnaire

At the end of the learning process, the participants completed questionnaire items relating to their satisfaction with the practical education offered in the study. The level of satisfaction ranged from 0 to 3 (not satisfied = 0, partially satisfied = 1, satisfied = 2, more than satisfied = 3). Table 2 presents the satisfaction level (by average score). The average values for young engineers, skilled engineers, and all engineers were taken. Scores for items 1, 2, and 5 suggest that internalization, socialization, combination, and externalization in the SECI model were accomplished. In contrast, scores for items 3 and 4 suggest that externalization was not accomplished.

Table 2. Evaluation of learning satisfaction.

Items measuring the educational effect	Satisfaction (average score)*		
	Young engineers	Skilled engineers	Overall
1) Participants can ascertain their own level of understanding of mixture design.	2.3	2.0	2.1
2) Participants can recognize the abilities of others and their own deficiencies through team activities.	2.1	2.0	2.1
3) Young engineers can compare their knowledge with that of skilled engineers.	1.9	1.8	1.8
4) Participants have the chance to communicate their own ideas to other engineers.	1.8	1.4	1.6
5) Participants have the opportunity to develop an interest in the historical development of concrete technology	2.4	2.0	2.2

* scores <2 show dissatisfaction and scores ≥2 show satisfaction

5 Conclusions

The goals of the present study were to pass fundamental mixture-design methods from skilled to young engineers and to develop an effective education program for young engineers. The conclusions of this case study are summarized as follows.

(1) The educative competition confirmed that skilled engineers are better than young engineers in modifying a concrete design.

(2) A questionnaire survey completed after the competition showed that the education of young engineers should involve the passing of skills and experiences from skilled engineers.

References

Nonaka, I, Takeuchi, H, *Knowledge-Creating Company*, Oxford University Press, New York, 1995.