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# The Role of Superplasticizers on the Workability Consistency *of* ECC Mortar Fresh Mortar Due to an Increase in the Percentage of Palm Shell Ash

**Agussalim Lubis, Muhammad Aswin, Gina Cynthia Raphita Hasibuan**
Universitas Sumatera Utara, Medan, Indonesia
Email: agussalim.lubiss@gmail.com
Correspondence: agussalim.lubiss@gmail.com*

**KEYWORDS**
ECC; Palm Shell Ash; Superplasticizer; Workability; Slumpflow

**ABSTRACT**
Engineered cementitious composites (ECCs) are composites that have better attraction properties and behavior than concrete. ECCs are usually formed from cement, water, silica sand, cementitious materials, fibers, and other additives with a certain proportion. In this study, there are three types of ECC mortars (types AME, EM, and TEM) where these types are differentiated by the amount of cement used, the quantity of water, and the number of sand used. Each type uses ashes of palm shells with the same proportions of 0%, 5%, 10%, and 15% of the weight of cement. According to trial and error during the workability test, the number of superplasticizers used also increased according to the increase in the percentage of ash in the palm shell, where the variation of superplasticizers achieved was 0.70%, 1.59%, 2.49%, and 3.40% of the weight of cement. Based on the results of the slumpflow test, the average diameter of the ECC freshly mixed mortar was between 88 cm and 106.5 cm, and the T500 slump flow was between 0.28 seconds and 1.39 seconds. The test results show a fairly good workability consistency of all ECC fresh mortars, although there has been an increase in the percentage of palm shell ash used. Superplasticizer turns out to be very important in maintaining consistent workability of fresh ECC mortar mix.



## 1. Introduction

The development of building construction in various countries is increasingly rapid. Researchers have made innovations in building materials, including concrete, composites (engineered cementitious composite / ECC), and so on. ECC mortar is a composite that generally does not use gravel, which consists of the main materials, namely cement, silica sand, water, cementitious materials, and other additives such as microfibers and superplasticizers (Faqihuddin et al., 2021). ECC has been widely used in various countries, which include: the USA, Japan, South Africa, and European countries (Shoji et al., 2022). Some of the advantages of ECC are being able to withstand high bending and shear loads in structural applications (Shanour et al., 2018), also being able to withstand monotonic bending loads and cyclic shear loads (Şahmaran & Li, 2010). In addition, ECC is also able to withstand damage due to fluctuating stress and can provide environmentally friendly products related to the use of ECC as a rigid pavement layer (Lepech et al., 2008).

Palm kernel shell ash can be used as an added material to a composite mortar because this material can be pozzolanic. The results of Mulyono's research(2007) showed that the silica oxide content of palm kernel shell ash reached 31.45%. Handayani et al. (2023) reported that the use of palm kernel shell ash material, which is waste, is expected to overcome the problem of environmental pollution. It is seen that palm kernel shell waste is produced, amounting to 9.375 million tons/year. However, the opportunity to utilize palm kernel shell ash waste in Indonesia is quite large. The Director General of Plantations (Perkebunan, 2021) stated that palm oil production in Indonesia in 2023 will be 45.121 million tons with a land area of 16.833 ha. Meanwhile, Harmiansyah et al. (2023) reported that based on a review of the thermochemical characteristics of palm kernel shells, a fairly small value of palm kernel shell ash content was obtained, which was around 6.7% on burning to 400 $^0$C for 2 hours.

The use of palm kernel shell ash in concrete mortar or composites may reduce the workability of fresh mortar due to its water absorption. Zakaria et al. (2023) reported that the workability of ECC mortar due to the addition of rice husk ash will decrease as the amount of rice husk ash increases in the mixture because this rice husk ash material absorbs water.

Superplasticizer (SP) is a type of chemical additive added to the mixture (stirring) of concrete or mortar with the aim of increasing the ability of slump flow so that it is easy to pump, pour, and mold without reducing the final strength (Persson, 2001), and also has a function to reduce pores in concrete so that it can increase compressive strength, and affect the value of modulus of elasticity. Superplasticizers have various types, each of which has a different influence on the mortar of the material (Astm, 1999; Sha et al., 2020). Superplasticizer type sika discrete 3115N has excellent slump flow ability, good self-compacting ability, and high ability in water reduction, and can increase compressive strength (Puspitasari & Uisharmandani, 2023). The use of Superplasticizer as a substitute for water in the concrete mixture was found to increase the abrasion of fresh concrete mortar, with a good level of workability (easy to work) and can reduce the amount of water by up to 20% (Efnarce, 2002).

In this study, the initial goal was to make ECC mortar (without fiber) by utilizing palm kernel shell ash as a cementitious material. Based on the descriptions above, it is estimated that the workability of fresh mortar ECC mortar will be affected by the involvement of palm shell ash, moreover, the percentage is increasing. So it is necessary to conduct a study on the effect of the use of superplasticizers on the workability consistency of ECC mortar.

## 2. Materials and Methods

This research was conducted based on experimental studies with the following stages or procedures of activity:

### Procurement of Materials and Equipment

The procurement preparation of materials and equipment used to make fresh mortar ECC mortar is cement, water, sand, palm kernel shell ash (ACS), and superplasticizer (SP). The cement used is OPC Type-1 cement. Palm kernel shell ash (ACS) is obtained from the plantation of Serdang Bedagai District, North Sumatra province, which is produced from the burning process and only uses palm kernel shell ash by passing filter no. 30 or 0.6 mm diameter. Furthermore, the procurement of equipment used in making ECC mortar is scales, mixer drills, slump test equipment, flowability test equipment, length measuring instruments, and so on.

### Mix design

Mix design is the process of determining the right proportions (composition) to achieve the desired properties in a mixture or mortar in order to produce a mixture that meets the desired technical requirements. In this study, a mix design was carried out for fresh mortar ECC mortar with 3 types, namely Type-I AME specimen code, Type-II EM specimen code, and Type-III TEM specimen code. Each type is carried out variations in the addition of the same palm kernel shell ash, namely 0%, 5%, 10%, and 15% of the weight of cement. Superplasticizer is added to the fresh mortar of ECC mortar so that the fuss (ductility) can be fulfilled properly. The increase in the number of superplasticizers (SP) is adjusted to the increase in palm shell ash. The percentage of superplasticizers taken from experimental testing in trial and error laboratories is for ACS 0% used SP = 0.70%, ACS 5% with SP 1.59%, ACS 10% used SP 2.49% and ACS 15% used SP 3.40%. Type-I composition with specimen code AME, using cement of 250 kg per cubic meter, cement water factor = 0.415, sand weight = 1.1 times cement weight, the percentage weight of palm shell ash is taken from the weight of cement. Type-II with EM specimen code also uses cement at 250 kg per cubic meter, cement water factor = 0.42, but sand weight = 1-time cement weight. While the composition of Type-III with the specimen code TEM, the weight of cement is taken at 260 kg of cement per cubic meter, the water factor of cement = 0.45, and the weight of sand = 1 time the weight of cement. The mixed proportion of fresh mortar ECC can be seen in Table 1.

**Table 1 Mix Proportion Mortar ECC**

| **Type** | **Code** specific | **Water** | **Sand** | **Cement** | **Palm Shell Ash** | | **Superplasticizer** | |
|---|---|---|---|---|---|---|---|---|
| | | **(kg)** | **(kg)** | **(kg)** | **(kg)** | **(%)** | **(kg)** | **(%)** |
| I | AME 0% | 4.449 | 11.792 | 10.72 | - | - | 0.075 | 0,70 |
| | AME 5% | 4.344 | 11.513 | 10.467 | 0.523 | 5 | 0.167 | 1,59 |
| | AME 10% | 4.249 | 11.263 | 10.239 | 1.024 | 10 | 0.256 | 2,49 |
| | AME 15% | 4.155 | 11.012 | 10.011 | 1.502 | 15 | 0.34 | 3,40 |
| | | | | | | | | |
| II | EM 0% | 4.36 | 10.382 | 10.382 | - | - | 0.073 | 0,70 |
| | EM 5% | 4.256 | 10.134 | 10.134 | 0.507 | 5 | 0.162 | 1,59 |
| | EM 10% | 4.157 | 9.898 | 9.898 | 0.99 | 10 | 0.247 | 2,49 |
| | EM 15% | 4.063 | 9.673 | 9.673 | 1.451 | 15 | 0.329 | 3,40 |
| | | | | | | | | |
| III | TEM 0% | 4.624 | 10.275 | 10.275 | - | - | 0.072 | 0,70 |
| | TEM 5% | 4.515 | 10.034 | 10.034 | 0.502 | 5 | 0.161 | 1,59 |
| | TEM 10% | 4.411 | 9.803 | 9.803 | 0.98 | 10 | 0.245 | 2,49 |
| | TEM 15% | 4.312 | 9.583 | 9.583 | 1.437 | 15 | 0.326 | 3,40 |

**ECC Mortar Fresh Mortar Making**

All related ingredients begin by weighing according to the specified *Mix Proportion*. Next, it is mixed in a dry container, stirring well until the expected consistency of mortar is achieved. The mixing process usually takes about 12 minutes and the manufacture of fresh mortar ECC mortar is done for all specimen codes. Then a fresh mortar of ECC mortar is put into the *Abrams* cone and removed slowly. Next, the *flowability time* (T500) and the average diameter of the distribution of fresh mortar ECC mortar were measured. The procedure for carrying out the *workability* test can be seen in Figure 1.

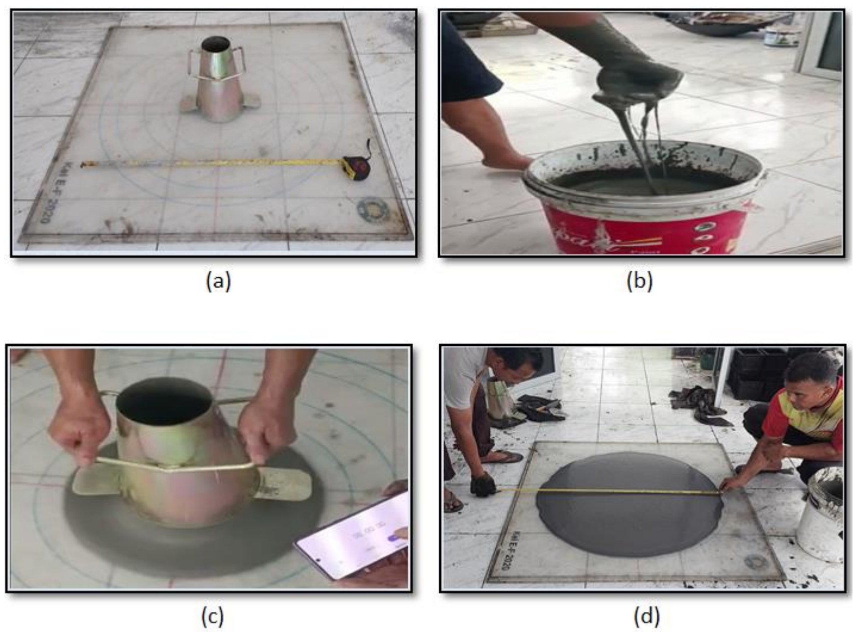


**Figure 1**
**Implementation of workability tests on fresh mortar ECC mortar.**

## 3. Result and Discussion

Based on the results of *workability testing* on fresh mortar ECC mortar against the addition of palm kernel shell ash and *superplasticizer* to 3 types of mortar, namely Type-I specimen code AME, Type-II with specimen code EM and Type-III specimen code TEM, the *flowability* value of T500 and the average slumpflow diameter as shown in Figure 2-3 were obtained.

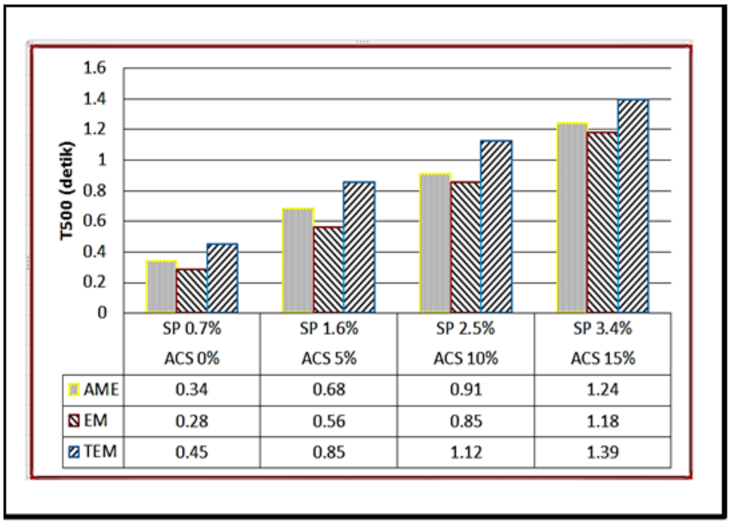


**Figure 2 Flowablity T500 on ECC mortar fresh mortar**

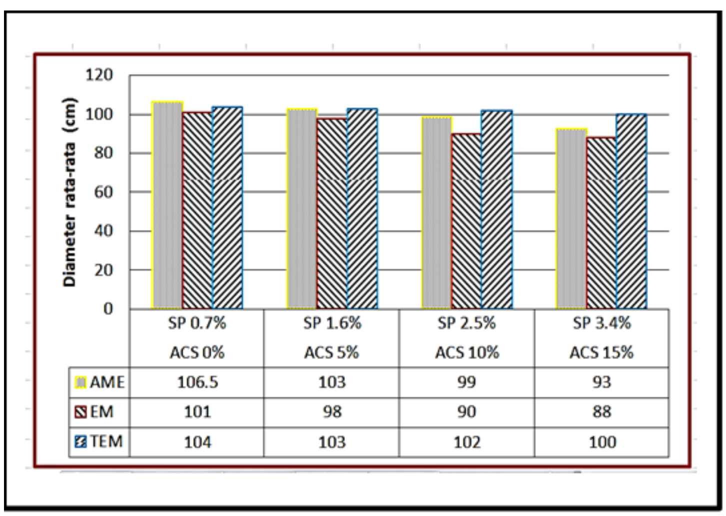


Figure 3 **Average diameter of flowability in ECC mortar fresh mortar**

Based on the test results, it can be seen that the *flowability* (T500) in Type-I specimen codes AME 0%, AME 5%, AME 10% and AME 15% has a greater T500 value along with the addition of the percentage of palm kernel shell ash and *superplasticizers*. This is because *superplasticizers* that work on fresh mortar ECC mortar can reduce the surface tension between cement particles and aggregates so as to increase ductility and flow. Likewise for EM and TEM specimen codes. Then for testing the average diameter on fresh mortar ECC mortar, the average diameter for Type-I was obtained with the AME specimen code 0% greater than the AME specimen code 5% and AME 10% and the average diameter of the AME specimen code 15% was the smallest. The same thing in Type-II with EM specimen code and Type-III with TEM specimen code obtained EM 0% has an average diameter greater than EM 5%, 10% and 15%. The 0% TEM specimen code has a larger diameter than the 5%, 10% and 15% TEM specimens. This result shows that the amount of palm kernel shell ash that is increasing in the fresh mortar of ECC mortar will absorb water and make the average diameter that occurs decrease.

## 4. Conclusion

Based on the results of research that has been conducted, it can be concluded that the role of superplasticizers on the workability of fresh mortar ECC mortar due to an increase in the percentage of palm kernel shell ash is very influential. This is seen by using the same cement water factor but the amount of addition of palm kernel shell ash (ACS) up to 15% and superplasticizer (SP) is only 3.40%, but the workability that occurs is still good. The largest flowability value (T500) for the 15% TEM specimen code was 1.39 seconds and the lowest value for the 0% EM specimen code was 0.28 seconds. The largest average diameter for 0% AME specimens is 106.5 cm and the lowest for 15% EM specimens is 88 cm.

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