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Clay Pipe Waste (CPW) as a Partial Cement Replacement

Ali. A. Negm[1], F. Elgabbas[1], A. El-Nemr[2], and Mohamed A. Khalaf[1]

1. Department of Structural Engineering, Ain Shams University, Cairo, Egypt.
2. Department of Civil Engineering, German University in Cairo, Cairo, Egypt.

استخدام مخلفات المواسير الفخارية كبديل جزئي للأسمنت

الملخص العربى:

يهدف هذه البحث إلى دراسة تأثير استخدام مخلفات المواسير الفخارية كبديل جزئي للأسمنت على مقاومة الضغط للخرسانة. وتمثل تلك النقطة أحد الحلول لمشكلة الاحتباس الحراري الناتج عن صناعة الاسمنت بالإضافة الى إعادة تدوير مخلفات المواسير الفخارية، مما يستوجب أعادة تدوير المخلفات الناتجة عن هذه الصناعات. في هذا البحث تم المقارنة بين مقاومة الضغط لعينات خرسانية تم خلطها ومعالجتها بثلاثة نسب مخلفات من مسحوق المواسير الفخارية كبديل جزئي للأسمنت، وبين الخرسانة التي تم خلطها ومعالجتها دون استخدام الفخار فيها. وتم دراسة مقاومة الضغط عند أعمار مختلفة للخرسانة (7، 28، 60 يوم). أوضح البحث بأن الاستبدال جزئي للأسمنت البورتلاندي في الخلطة الخرسانية بمسحوق المواسير الفخارية حتى نسبة 15% من محتوي الاسمنت ليس له تأثير سلبي علي مقاومة الضغط للخرسانة المخلوطة بمسحوق المواسير الفخارية بالأخص في الاعمار المبكرة (7 أيام)، بينما في الاعمار المتأخرة (28 و60 يوم) حصلت الخرسانة المخلوطة بإسمنت فقط على نتائج اعلى وتعتبر قريبة من المخلوطة بمخلفات الفخار.

Abstract:

As cement production, demanding expect to reach double in the up coming recent years with its negative impoact from global warming and carbon dioxide emission. In addition, the clay pipe waste increases the land filling pollution. Therefore, finding applications for recycling the clay pipe waste is very effective in decreasing air and land pollution. This paper aims to experimentally investigate the influence of clay pipe waste powder as a cement replacement on the concrete compressive strength. Moreover, comparisons between the concrete compressive strength for specimens mixed with clay pipe waste powder and the control concrete were implemented at different concrete ages; 7, 28, and 60 days. As a result of the experimental study, it was concluded that using the clay pipe waste powder as a cement replacement slightly increased the compressive strength at an early stage (7 days) at optimum cement replacement of 5%, due to the filling effect. However, using the clay pipe waste powder as a cement replacement at 28 and 60 days slightly reduced the compressive strength compared to the control.

Key Words: Clay pipe waste, metakaolin, concrete, compressive strength.

INTRODUCTION

Cement is considered one of the most used engineering materials due to its high ability to resist compressive strength, and ability to be formed in any shape and heigh durability. Cement is used as a construction material to set, adhere, and harden with other materials to fasten them to one another. However, cement shares from 6.0 to 8.0% of global carbon dioxide emitted emissions, where each one tone of cement production produces one ton of carbon dioxide, in addition to other poisonous gases. On the other hand, lands filling with construction waste material such as ceramic and clay pipe waste have been increased. From this point, recycling of waste material in the concrete industry was the alternativeto save raw materials and energy, as well as to save the environment from pollution whether air or landfilling. The main target of this study is to identify the effects of using pipe waste powder as a cement replacement on the concrete compressive strength.

LITERATURE REVIEW

Clay pipe waste (CPW) is the waste materials produced during the manufacturing process (broken clay pipes). CPW has the same chemical composition as ceramic since both are rich in silica in the range of 57.2% to 61.4% and having alumina in the range of 18% to 24% making them have the same chemical composition with a difference in color addition (iron-oxides or glaze layer), where CPW is not colored. Therefore, CPW can help to investigate the effect of using ceramic waste powder in concrete as a cement replacement after excluding the effect of the painting. On the other hand, Metakaolin (MK) is considered one of the classified materials as a new generation of mineral admixtures that are used as supplementary cementitious materials (SCMs) due to its technical and environmental advantages, in addition to its pozzolanic activity which is gained due to calcination of kaolinite. Kaolin clay is found in Asia, Australia, and China. China has china clay which is one of the purest forms of kaolin clay, which is composed of china clay (15%), mica (10%), and the rest is quartz. MK is used in various industries such as cement, clay pipes, and ceramic. The properties of the fresh and hardened concrete mixture (slump, slump loss, compressive strength, drying shrinkage, etc.) with different content of CPW as a cement replacement has been discussed in this research.

Batis [1] studied the effect of using metakaolin as a partial cement or sand replacement on the steel bar corrosion resistance. The specimens were placed in a corrosive environment (NaCl solution) and the corrosion rate of steel bars were measured. Two types of metakaolin were used a commercial one (MKC) of high purity and a normal (MK), where the normal MK is richer in silica than the MKC. The results showed that both MK and MKC have the same improvements concerning the compressive strength. While for corrosion resistance as the MK % increase the concrete loses its steel bar corrosion resistance.

Gruber [2] used High Reactive Metakaolin (HRM) to investigate the durability properties of concrete by replacing cement with 0%, 8%, 12%. HRM was obtained from height-purified kaolin clay. HRM has an average particle size of 2 µm. The usage of HRM decreased the chloride ion diffusion by 50% and 60% for replacement levels 8% and 12% respectively, compared to the control mix. As the exposure time of the specimen to chloride increases the bulk diffusion value decreases due to the usage of HRM.

Ding [3] investigated the physical and mechanical properties of concrete containing MK and slag as a cement replacement. Slag was used to improve the properties of MK concrete. Four mixes were designed with replacement values, as shown in **Table 1**. The MK mixture (M1) had the least fluidity making the control mixture having a higher fluidity. By increasing the amount of slag, the fluidity of the mix was improved, since slag reduced the water requirement of the mix. This shows that the addition of slag helps in improving the fluidity of MK concrete. For compressive strength, specimens S3and S2 had lower strength than M1 and PC at 3 days, while at 7 and 28 days S2 and S3 have higher strength than the other mixes, this could be attributed to the development effect of slag and MK which improved the microstructure of the concrete.

Table 1: Concrete Mixture Design

Mixture No.	PC Content (%)	MK Content (%)	Slag Content (%)
PO	100	0	0
M1	90	10	0
S2	70	10	20
S3	60	10	30

Sanchez et al. [4] used ceramic waste from the sanitary ware industry as a coarse aggregate for concrete manufacturing. The recycled waste used replaced the coarse aggregate with 15, 20, and 25 % replacement values. This study carried out mechanical tests as well as X-ray Diffraction (XRD) test to study the microstructure and interfacial transition zone (ITZ) that advises the cement past and the coarse aggregate. The slump was reduced as the waste aggregate percentage increased since the recycled ceramic aggregate was of high porosity. The mechanical properties of the concrete improved as the ceramic aggregate percentage increased; this could be due to the ITZ thickness decreased, as well as the coarse aggregate make the concrete more compact and with fewer pours.

Higashiyama et al. [5] used ceramic waste (CW) produced from the electrical insulators as a cement replacement and a fine aggregate. The mixture containing ceramic powder showed higher compressive and fewer pore values than the control mixture. The usage of 30% CW as a cement replacement was the optimum value for compressive strength.

MATERIAL AND PROCEDURE

The materials used in the study are the constituents of a traditional concrete mix which includes water, cement, coarse aggregate, fine aggregate, except for the usage of recycled vitrified clay, which is used as a partial cement replacement with 0, 5, 10, and 15 to produce 25 MPa compressive strength concrete.

The Clay pipe waste is produced from the Sweillem clay pipe factory. The Vitrified clay was manufactured through the heating process of the China clay at 1200°C forming the Metakaolin (MK). The vitrified clay pipe waste was crushed using the ginder machine to form powder of a maximum nominal size of 10µm. The produced MK was rich in silica and alumina. The fine aggregate was natural sand of specific gravity 2.63 and finesse modules 2.5. The used coarse aggregate of maximum nominal size of 20 mm.

Table 1: Sieve Analysis Test Results for Fine Aggregate

Sieve Size	**Passing (%)**
4.75 mm	100
2.36 mm	96.2
1.18 mm	79.2
600 µm	64.2
300 µm	6.2

Table 2: Sieve Analysis Test Results for Coarse Aggregate

Sieve Size	**Passing (%)**
37.5 mm	100
31.5 mm	86
28 mm	25.3
20 mm	13
10 mm	0.4

Twelve concrete cubes of dimensions 150×150×150 mm were cast from each patch to determine the concetere compressive strength after 7, 28, and 60 days of curing.

RESULTS AND DISCUSSION

Compressive strength of concrete is assessed by applying axial compressive load to the cubic concrete specimens at a specified rate until failure. The compressive strength of the specimen is obtained by dividing the maximum load by the cross-sectional area of the specimen. This procedure was carried out as specified in ASTM C39/C39M [6].

Table 3: Average Compressive Strength for Concrete in MPa

ID	7 Days	28 Days	60 Days
M_{25-0}	21.10	30.12	34.22
M_{25-5}	23.90	28.63	30.90
M_{25-10}	15.46	26.81	29.07
M_{25-15}	20.57	28.26	29.47

خطأ! لم يتم العثور على مصدر المرجع. shows the strength development of concrete speciments with time, where the control achived at age of 7 days 70% of the compressive strength compared to age of 28 days, and the concrete kept gaining strength up to the age of 60 days with an improvement of 14% higher than age of 28 days. For the 5 % cement replacmnet, the specimen achived at age of 7 days about 83% of the compressive strength compared to age of 28 days, while for 60 days the concrete compressive strength improved by 8%. For the specimens of 10% replacmnet of cement by CPW, the compressive strength at 7 days achived about 58% of the compressive strength at 28 days, and about 8% at 60 days. For the specimens of 15% replacmnet of cement by CPW, the compressive strength at 7 days developed about 73% and 4% of the compressive strength after 28 and 60 days, respectively.

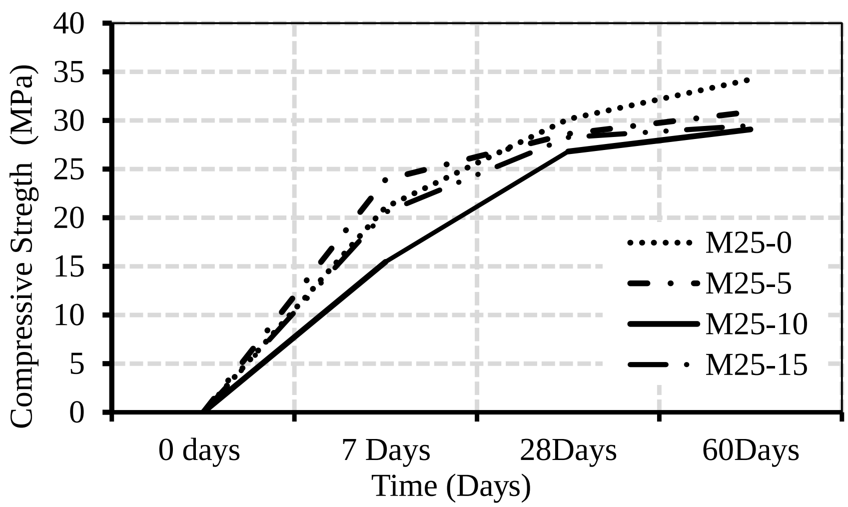

Figure 1: Compressive strength values for various mixtures with cement replacement by; 0, 5, 10, and 15% MK at 7, 28, and 60 days age

As shown in **Figure 2** and **Table 3**, the chart represents the 7 days compressive strength, where the specimen of 5% cement replacmnet showed an improvmrnt in the strength with 13% more than the control sprecimen. While for the 10% and 15% showed a decreas in the compressive strength compared to control specimens by 27% and 3%, respectively.

Figure 3 represents the compressive strength values at 28 day. The 5% and 15% of cement replacmnet achived about 95% and 94% of the compressive strength of the control specimen, respectively, as well as a slight decrease in the compressive strength comprared to the 10% replacmnet which achived only 89% of th control specimen.

At the age of 60 days, as shown in **Figure 4,** the 5% cement replacmnet specimen achived the nearst compressive strength value to the control specimen with a slight decrease in the strength with 10% compared to 15% and 14% decrease in compressive strength for the 10% and 15% cement replacmnet, respectively.

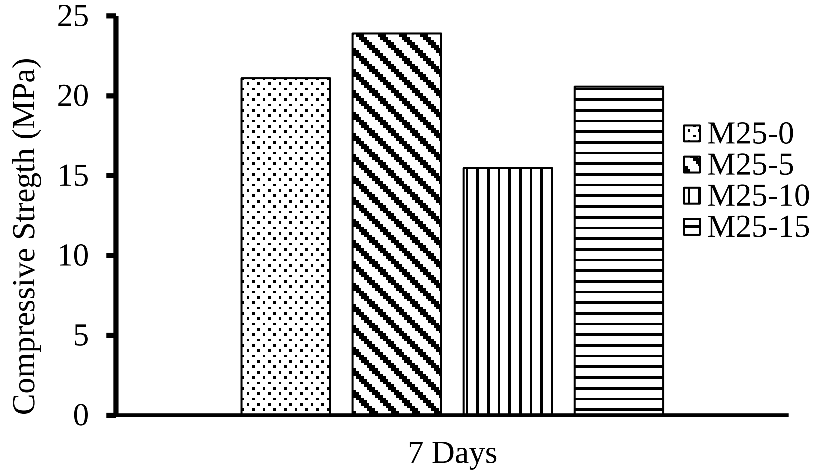

Figure 2: Compressive strength values for various mixtures with cement replacement by; 0, 5, 10, and 15% MK at 7 days age

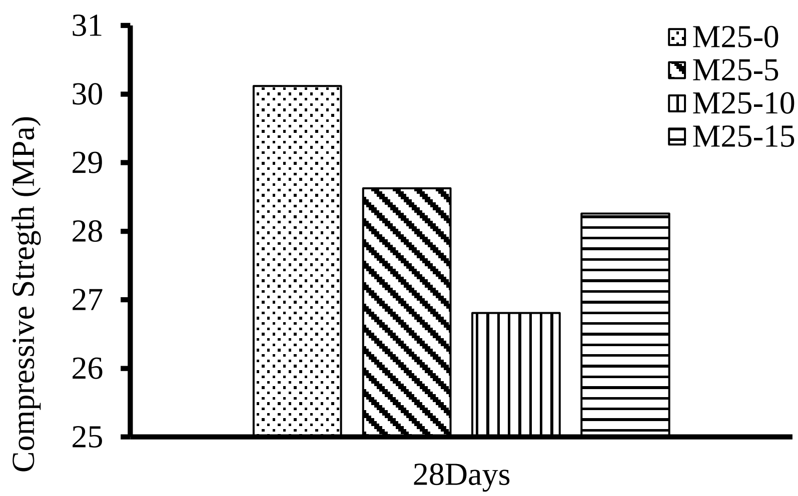

Figure 3: Compressive strength values for various mixtures with cement replacement by; 0, 5, 10, and 15% MK at 28 days age

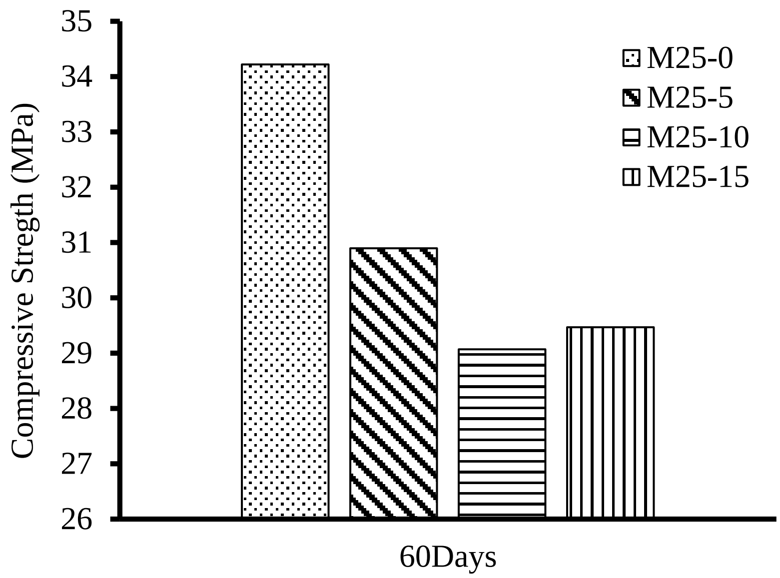

Figure 4: Compressive strength values for various mixtures with cement replacement by; 0, 5, 10, and 15% MK at 60 days age

CONCLUSIONS

This study investigate the effect of using clay pipe waste as cement replacement on concrete compressive strength. Based on the findings from the ecxuted experimental study, it was concluded the following:

1. Compressive strength of concrete whether control or with clay pipe waste as a cement replacement shows nearly same values at 28 days, with a slight difference in case of 5 and 15% replacement.
2. Compressive strength of concrete whether control or with clay pipe waste as a cement replacement shows a development in the control specimens than the other specimens at age of 60 days.
3. The optimum ratio for cement replacement with clay pipe waste as fine material is 5%, as it has nearly the same strength development for the control specimen.
4. Concrete containing clay pipe waste as a cement replacement must be tested before use for various properties, as properties of the clay pipe waste varies from one factory to another depending on the temperature used for burning kaolinite.

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