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Basic Characteristics of Flowable Fill Materials Containing Demolishing Waste Materials as Cement Replacement

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ABSTRCT

Flowable Fill Materials (FFM) are commonly known as cementitious materials that are low shrinkage, self-compacting and self-leveling. FFM are generally employed to substitute backfill soil and traditional construction fillings. This paper produces the outcomes of experimental study that has intention to examine incorporation demolishing waste materials in production flowable fill materials. the experimental work was separated into two parts, first part investigates the pozzolanic activity for different demolishing waste materials (glass, clay bricks, and Autoclaved Aerated Concrete blocks). Six different mixes of demolishing waste powder were tested by pozzolanic activity index test. The second part used an optimal pozzolanic demolishing waste for producing FFM. Ten mixes of FFM containing the optimal demolishing waste material ranged from 5% to 20% as cement replacement were prepared. Then the basic properties of FFM like flowability , unconfined compressive strength at different age , density were examined. Overall, the outcomes illustrate that demolishing waste materials especially glass powder can effectively utilize as cement replacement in flowable fill application.

الخصائص الاساسية لمادة املاء انسيابية والتي تحتوي على نفايات المواد الانشائية كبديل عن الاسمنت

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الكلمات المفتاحية:
مادة قابلة للتوجيه ذات مقاومة انضغاط واطئة
بديل اسمنتي
مقاومة الانضغاط
ملاط الاسمنت و التربة
فحص الانسياب

الملخص

مادة الاملاء الانسيابية شائعة كمادة اسمنتية تمتلك انكماش قليل ورص وتسوية ذاتيين. تستخدم بصورة عامة كبديل عن إعادة الردم بالتربة ومواد الردم الأخرى. هذا البحث يقدم نتائج دراسة عملية الهدف منها استخدام مواد النفايات الانشائية في انتاج مادة املاء وردم ذات تدفق عالي. الجانب العملي يتكون من جزئيين، الجزء الأول تضمن دراسة الفعالية البوزلانية لبعض النفايات الانشائية مثل (الزجاج، الطابوق الطيني، والكتل الخرسانية الخلوية). ست خلطات مختلفة من مطحون مواد النفايات الانشائية فحصت بفحص الفعالية البوزلانية . الجزء الثاني تضمن استخدام مادة النفايات الانشائية ذات الفعالية البوزلانية الأفضل في انتاج مادة املاء انسيابية. تم تحضير عشرة خلطات مختلفة من مادة الاملاء الانسابية الحاوية على نفايات المواد الانشائية بنسب مختلفة تراوحت من 5 % الى 20% كبديل عن الاسمنت. بعد ذلك تم اجراء الفحوصات الأساسية لمادة الاملاء والتي تضمنت فحص الانسياب وفحص الانضغاط والكثافة بأعمار مختلفة. بصورة عامة، أظهرت النتائج بإمكانية استخدام نفايات المواد الانشائية وخصوصا مطحون الزجاج كبديل اسمنتي في تطبيقات مادة الاملاء الانسيابية.

1. Introduction

The primary target of waste recycling is to minimize the quantity of waste in order to decreases their environmental impacts. Furthermore, the waste recycling proposes a source of replacement materials that contract natural materials diminution rate. Utilization of demolishing waste materials in civil engineering application as replacement materials one of the encouraging methods of recycling materials [1–5]. Flowable Fill Materials (FFM) are a cementitious material, often a mix of cement, sand, fly ash, and water, that does not require compaction, may be self-leveling at time of placement, may harden quickly within a few hours. Which is also recognized by other expressions like controlled low strength materials, unshrinkable fill materials, self-leveling slurry, cement-soil grouts. [6,7]. FFM are

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utilized in numerous civil engineering application involving, backfilling of pipe trenches, filling holes and gaps under roads and buildings without compacting, filling uncontrolled construction under earth and significantly more applications [8–10].

Many researchers studied the properties of Flowable Fill Material (FFM), Duc and Khanh [11] , investigated the hardening and fresh properties of (FFM) including stainless steel slag as a cementitious material. The variable parameters studied, the ratio of cement contained (0%, 10%, 20%, and 30%) and three amounts of binder content (80-, 100-, and 130 kg/m^3). The results showed that the proposed FFM could be employed for eco- friendly trench fills. Saif and Shatha [12] , introduced an experimental program to evaluate the possibility replace flay ash and natural sand by waste glass (fine and coarse powder) to produced flowable fill material. Seven mixes were prepared with used several ratios (10%, 30%, and 50%) of fine and coarse glass. It concluded from this study the compressive strength with fine glass replacement is decreased at 28 days compare with reference mix, but it increases at 90 days. While a mix with coarse waste glass gave the compressive strength higher at 28 and 90 days. Mohd et al [13] , investigated to optimize the plastic properties of FFM by using unprocessed-fly ash and waste cementitious materials . Some results obtained from this study that bleeding, flowability, and SI increase as the ratio of fly ash increase. Shatha [14] , used the ceramic waste and waste hardened mortar to produce the flowable fill material. The results cleared the flowability was decreased with a rise in waste aggregate percentage in the produced mix. Wei-Ting et al [15], utilized waste gypsum as fine aggregate with cementitious materials (cement and fly ash) to produce the FFM. The test results showed that the FFM specimens with a high quantity of waste gypsum had air-hardening properties. Jianbiao et al [16] , used the expansive soils in the production of flowable fill material. Experimental tests were conducted with deferent ratios to evaluate the fresh (flowability, bleeding, and setting time) and hardened (swelling, compressive strength and durability (properties. The results showed The swelling properties are affected by sand-to-soil ratio and cement to-aggregate ratio. FFM does not show rise swelling behavior when cement to-aggregate ratio exceeds 18% and sand-to-soil ratio is at 10%. And flowability drop over time. The flowability loss ratio normally shows a negative exponential correlation with time, ranging from 23%− 33% percent at 90 min. The main objective of this study to investigate the potential employment of the different demolishing waste powder for production sustainable FFM. Firstly, pozzolanic activity for different demolishing waste fine powder were examined by pozzolanic activity index. Then, the optimal pozzolanic materials was incorporated in FFM mixes at differet fractions ranged from 5% to 20% as cement replacement. The basic properties of modified FFM like flowability , unconfined compressive strength , and density were investigated for . Also, effect of water to binder ratios on the properties of FFM was examined.

2. Experimental work

2.1. Materials

The materials used in this research are explained in the following:

Cement, Lafarge ordinary Portland cement type I was utilized in this study. The physical and chemical results showed that the cement conforms to the requirements of ASTM C-150 [17]. Fine aggregate, a standard sand was used in this study, The grading of this sand comply with ASTM C-33 [18]. Chemical Admixture, a third generation super plasticizer for concrete and mortar was used in this study. It is a modified polycarboxylates, which is known commercially as Hyperplast PC175. It was conformed to ASTM C494 [19]. The demolishing waste collected from locally sites under construction involving crashed glass, broken clay bricks, lumps of Autoclaved Aerated Concrete blocks. Water, Potable water is used y for production and curing the specimens.

2.2. Preparation of demolishing waste powder

Three demolishing waste materials (crashed glass, broken clay bricks, lumps of Autoclaved Aerated Concrete blocks) were used to choose the best material that product the Flowable Fill Materials (FFM). To achieve the required fineness for pozzolanoc materials as requisite by ASTM C-618 [20]. Three steps were essential to prepare the powder of each three materials, the first step crushed manually by hammer into small pieces. After that, the crushed practices were grinded by loss angles machine (shown in Figure 1(a)). Then, the powdered materials were milled by high velocity electric grinder for further finesses, as shown in (Figure 1 (b)), to obtain finest particles, and then passed through sieves No. 100 and No. 200, shown in Figure 2.

The activity index for three waste materials was performed according to ASTM C-311 [21] with different proportions mix of glass powder (GP), brick powder (BP), and Autoclaved Aerated Concrete blocks powder (AP), (Control without any pozzolanic materials , GP100, GP50+BP50, GP50+AP50, and GP50+BP25+AP25) as presented in Table 1, to investigate the pozzolanic reaction when replacing 20 % of cement by wastes powder. The pozzolanic activity results donated that the mix contained only glass powder as cement replacement by weight has highest index comparing with other mixes, as shown in Figure 3.

Table (1): Mixtures content of pozzolanic activity index.

Mix symbol	Sand, gm	Cement, gm	Glass Powder, gm	Aerated concrete blocks Powder gm	Brick Powder, gm	Water, ml
Control	1375	500	-	-	-	250
GP 100	1375	400	100	-	-	255
GP50+BP50	1375	400	50	-	50	260
GP50+AP50	1375	400	50	50	-	255
GP50+BP25+AP50	1375	400	50	25	25	265


(A)


(B)

Figure (1): The loss angles machine and velocity electric grinder.

Figure (2): Glass and Bricks Powder.

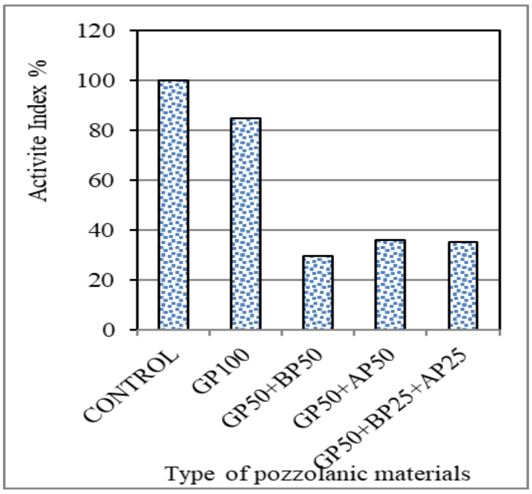

Figure (3): The results of pozzolanic activity for different demolishing waste materials.

2.3. Mix proportion

Depending on the results obtained from the pozzolanic activity test, it was found that replacing cement with glass powder can attain the best compressive strength for the mixtures. Therefore, it was decided to utilize only glass waste powder to replace the cement in developing sustainable FFM. The experimental program consisted of two groups (depended on adding super plasticizer for reducing water to cement ratio), each group included four mixes as well as reference mix. The variable parameter in each mix that proportions of glass powder (0%,5%, 10%, 15%, and 20%) by the cement weight. The proportions for all mixtures show in Table (2).

Table (2): Mixtures proportions (kg/m^3).

Mix representation	Cement	Glass Powder (GP)	Sand	Water	S.P%
GP00SP0	200	0	1200	150	0
GP05SP0	190	10	1200	150	0
GP10SP0	180	20	1200	150	0
GP15SP0	170	30	1200	150	0
GP20SP0	160	40	1200	150	0
GP00SP3	200	0	1200	100	3
GP05SP3	190	10	1200	100	3
GP10SP3	180	20	1200	100	3
GP15SP3	170	30	1200	100	3
GP20SP3	160	40	1200	100	3

2.4. Specimens preparation

After mixing preparation by using different percentages of glass powder, two types of mixes prepared with and without super plasticizer. The mixture was cast into cylinders steel molds with dimension (100×200) mm, each mix needs nine cylinders for compressive strength test at three ages (7,14, and 28) and three cylinders for density test at age 28 days. Next, the specimens were put in water tank to cure.

2.5. Testing Methods

In order to investigate the influence of different percentages of glass powder (0%, 5%, 10%, 15%, and 20%) on the flow ability of fresh mixture and the mechanical properties of hardened material, that compressive strength, density were conducted. The compressive strength test was applicable according to ASTM D4832 [22], in addition to cylinder specimens (100 × 200 mm) are used for density test according to ASTM D6023 [23]. The average of three specimens at each test are taken to obtain the final value of compressive strength and density. To conduct flowability test, a plastic cylindrical tube (of 75 mm diameter, and 150 mm height) was used to measure the spread diameter of the mixture after filling the tube by FFM mixtures then pulling it up to let the mix spread. The flowability test was conducted according to ASTM D6103- 2017 [24]. Figure (4) shows the steps of flowability test.

Figure(4): Steps of flowability test.

3. Results and Discussion

3.1. Fresh Stage

Flowability is a significant fresh state characteristic that specifies FFM as a special filler material and assists the mixture for self-compacting, cavities-filling, and self-leveling. Established on ACI 229 [25] , the FFM flowability at fresh state ranged from 200 to 300 mm without segregation . Figure (5) display the outcomes of the flow spreading for all mixes. It observed that flow values for all mixes (with and without super plasticizer) are within the required limits (200-300 mm). as showed in Figure (5), the values of flowablity increased as the percentage of glass powder increased up to 15 % cement replacemen compared with control mix (without glass powder). While the 20 % the flowability values slightly decreased when compared with control mix. The increasing percent of the fowability for without super plasticizer are about 2%, 8% , 15% for mixes with glass powder replacement 5 % , 10 % , and 15 % correspondingly when compared with control mix . while the decreasing percent of 20% glass powder replacement is 4% when compared with control mix. Furthermore, the fowability values for mixes with super plasticizer higher than the corresponding mixes with comparable fraction of glass powder replacement.

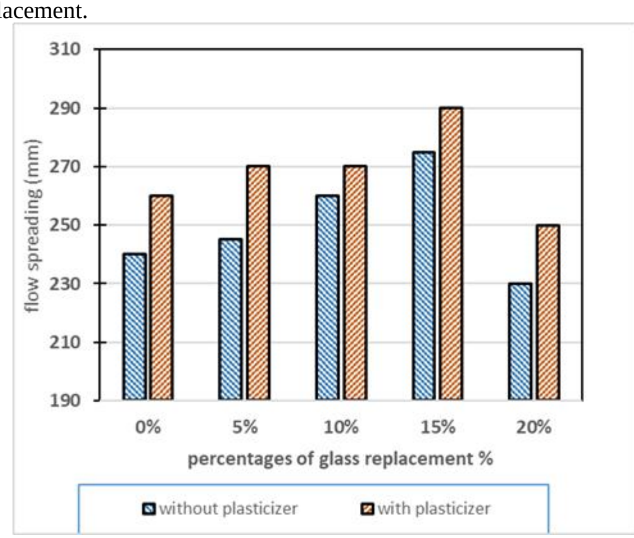

Figure (5): Flowability with different glass replacement.

3.2. Hardened Stage

3.2.1. Unconfined Compressive Strength

FFM is generally utilized instead of the conventional compacted soils, and it must have self-compacting, self-filling, and low shrinkage. As identified in ACI 229 [25] , the uniaxial unconfined compressive strength of FFM ranged between 4 MPa to 8 MPa. Figures (6) and (7) demonstrate the results of unconfined compressive strength of FFM at 7, 14, 28 days. The results revealed that the unconfined compressive strength improved as the glass powder replacement percent increased. The increment of unconfined compressive strength for mixes without super plasticizer at 28 days' age are about 2.5 %, 4.5%, 15%, and 26% for 5, 10, 15 and 20 glass powder replacement respectively when compared to control mix. Furthermore, the increment of unconfined compressive strength for mixes with super plasticizer at 28 days' age are about 1 %, 4 %, 11%, and 18 % for 5, 10, 15 and 20 glass powder replacement respectively when compared to control mix. This attributed to pozzolanic activity for fine glass powder. This trend is similar to that abstained by [26] . The outcomes indicate that the mixes with super plasticizer higher than corresponding mixes without super plasticizer at all test ages. This attributed to different of water to binder ratio, the mixes without super plasticizer have higher water content than mixes with super plasticizer.

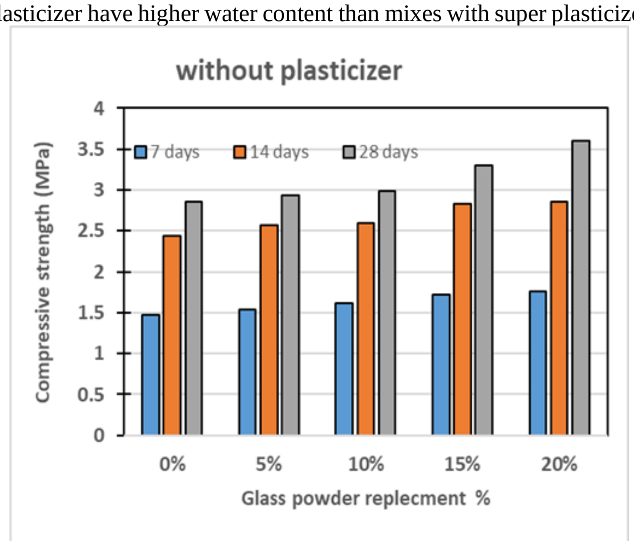

Figure (6): Uniaxial unconfined compressive strength at different ages for without super plasticizer mixes.

3.2.2. Density

As specified in ACI [25] , the density of FFM higher than conventional soil backfilling, the density of FFM ranged between 1840 to 2230 kg /m^3. Figure (8) displays the density of all mixes (with and without super plasticizer). The results demonstrate that the density slightly increased when increasing the glass powder increased. Also, the density values within the require limits for FFM, the density ranged between 2018 to 2150 kg/m^3.

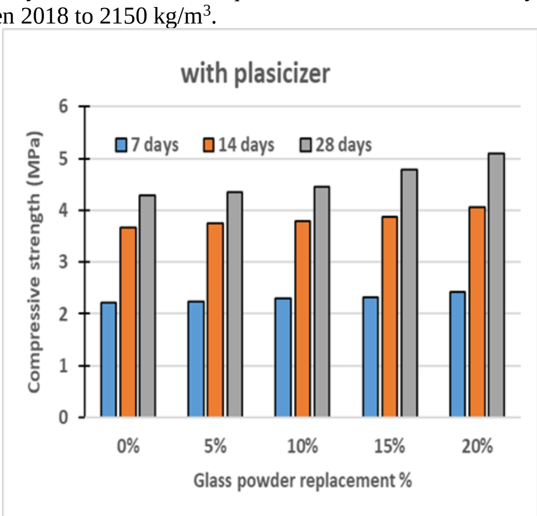

Figure (7): Uniaxial unconfined compressive strength at different ages for with super plasticizer mixes.

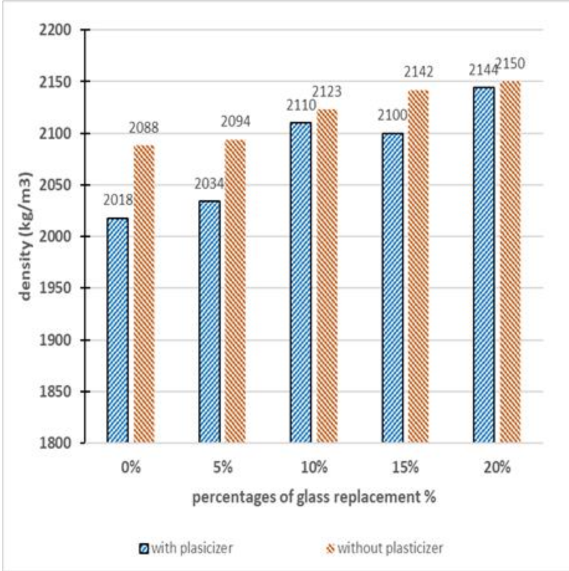

Figure (8): Density of all mixes at 28 day ages.

4. Conclusions

In this study, ten FFM mixes with different fine glass powder as cement replacement were prepared for flowability, unconfined compressive strength, and density tests. the following conclusions are drawn:

1- The pozzolanic activity of the fine glass powder higher than cellular concrete blocks and clay bricks powder.

2- The flowabilty of FFM for increased as fine glass powder as cement replacement increased up to 15 %. While, the flowability of 20 % replacement lower than control mix.

3- The unconfined compressive strength of FFM increased as fine glass powder cement replacement increased. The increment in unconfined compressive strength ranged between 2 % to 26 %.

4- The inserting of the fine glass powder in FFM as cement replacement up to 20 % slightly effect on the density.

5- Utilizing of the super plasticizer in FFM assist for decreasing water-cement ratio without effect in flowability.

6- Based on the flowability and unconfined compressive strength results, the optimal replacement of fine glass powder as cement replacement is 20 % with using super plasticizer.

5. Abbreviations

Abbreviation	Meaning
ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
AP	Autoclaved aerated concrete blocks Powder
BP	Brick Powder
GP	Glass Powder
FFM	Flowable Fill Materials
S.P.	Super Plasticizer

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