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Development of aggregate from bottom ash in environmentally friendly concrete

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Abstract

This research presents a study of bottom ash for using as fine and coarse aggregates in concrete, B-F and B-C, respectively. Results of compressive strength and durability of the concrete containing B-F and B-C aggregates were investigated. Normal fine and coarse aggregates were replaced with the B-F and B-C aggregates at 0, 25, 50, 75 and 100% by weight of the normal aggregates. The results showed that the compressive strengths of the concretes were increased when the B-F and B-C aggregates were used at replacement levels of 25% and 50%. The water absorption and chloride resistances of the concretes were reduced with curing age. Moreover, it was found that the use of B-F and B-C aggregates in concretes effectively improved the compressive strength and the chloride resistances at low replacement levels of 25% and 50%.

1. Introduction

In general, pozzolanic materials can be incorporated in mortar and concrete to enhance a good mortar and concrete property [1-9]. In Thailand, bottom ash (BA) from lignite coal is a waste material. Some works have shown that the bottom ash can be used as pozzolanic materials [10,11]. However, more than 750,000 tons of the BA have been mostly dumped in landfills [12]. The BA in landfills is still the problem of power plants because this waste material is not currently useful for concrete works. In addition, most researchers reported that the use of bottom ash was effectively used in concrete as fine aggregate [12-18] while a few researches have studied the effects of both fine and coarse aggregates on the mechanical property of concrete [19,20] as well as the durability property. Yuksel *et al* [13], Andrade *et al [*14], and Sanjith *et al* [16] studied on 10% to 50% replacement of BA in concrete, and reported that the use of BA as fine aggregate resulted in significantly affected on compressive strength at low replacement levels (10%) at 28 days. The reduction of compressive strength was found at 20% to 50% replacement levels. Furthermore, a high level replacement of 50% had significantly reduced compressive strength. For full replacement level of fine aggregate with 100% of BA researches, Andrade *et al* [14] and Refieizonooz *et al* [17] who found that the compressive strength could be reduced up to 70% in comparison to the control concrete mix. Unfortunately, a few studies about the use of BA to replace fine and coarse aggregates in concrete were reported by Kim and Lee [19]. They utilized the BA as fine and coarse aggregates in high-strength concrete with compressive strength of 60 MPa to 80 MPa. In addition, they indicated that both fine and coarse BA aggregates had an influence on flexural strength than the compressive strength of the concrete.

Therefore, the objective of this research is to investigate the use of bottom ash as both fine and coarse aggregates in concrete. The normal strength concrete was considered to improve the effects of fine bottom ash (B-F) and coarse bottom ash (B-C) aggregates on the durability properties of the concrete. In this investigation, the BA was sieved to have both B-F and B-C aggregates approximately the same particle size as the normal fine and coarse aggregates. The normal fine and coarse aggregates were replaced with the B-F and B-C aggregates at 0, 25, 50, 75, and 100% by weight of the normal aggregate. This research is not only increasing the value of the bottom ash for the concrete industry but also reducing the environmental problems and climate change from consuming less natural aggregate.

2. Methods for preparing materials and testing

2.1 Materials preparing

Portland cement type I (CT), local aggregates (sand and gravel), superplasticizer (SP) type F and bottom ash (BA) from the Mae Moh power plant in the northern part of Thailand were used in this study. River sand with a fineness modulus of 2.95, and natural gravel

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with a fineness modulus of 7.2 was used as normal aggregates. Sieve analysis according to ASTM C33 [20] was used to separate the bottom ash into fine and coarse portions. The fine and coarse bottom ash aggregates were used to replace fine and coarse normal aggregates in the concrete. The particle size distributions of fine bottom ash and coarse bottom ash aggregates were shown in Figures 1 and Figure 2, respectively. The fine portion was assigned as fine bottom ash aggregate (B-F), and the coarse portion was also assigned as coarse bottom ash aggregate (B-C). After sieving to have both approximately the same particle size of normal and bottom ash aggregates, it was seen that the particles size distributions of B-F and B-C aggregates (Figures 1 and Figure 2) were similar to those of normal aggregates, sand and gravel.

Figures 3 and Figure 4 presented the morphology of B-F and B-C aggregates with comparison to the normal aggregates, respectively. The B-F and B-C particles were rough surfaces and angular shaped particles. Furthermore, it had dark grey with brown color. The typical chemical compositions of bottom ash were determined using X-Ray Fluorescence (XRF), and also were tabulated in Table 1. It was found that the main chemical compositions of the bottom ash were 40% of SiO_2, 21% of Al_2O_3, 14% of Fe_2O_3, and 16% of CaO with LOI of 4.4% [21]. Several researches also confirmed that the bottom ash contains mainly SiO_2, Al_2O_3, and Fe_2O_3, and had large particles with low pozzolanic reactivity [11,22].

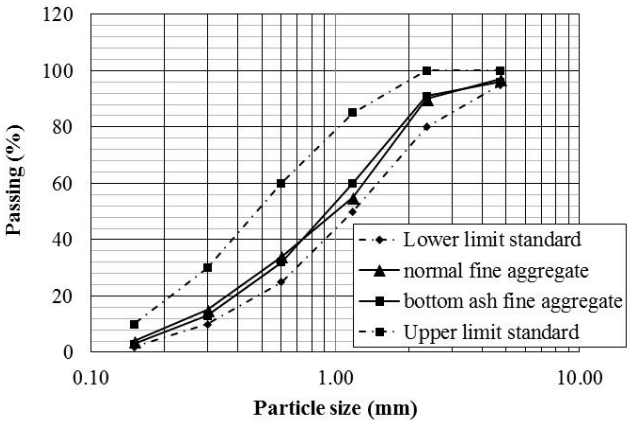

Figure 1. Particle size distribution of fine bottom ash aggregate (B-F) and normal fine aggregate (Sand).

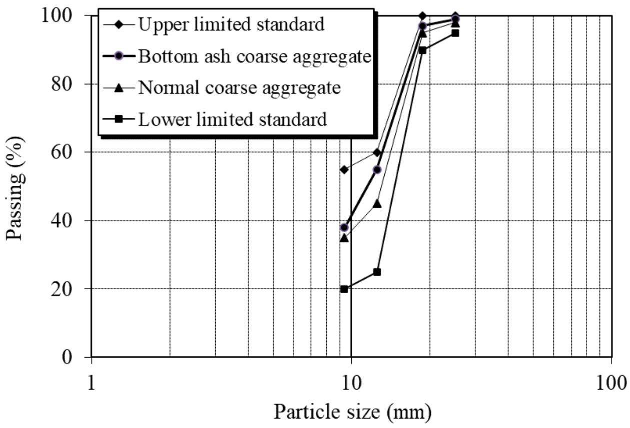

Figure 2. Particle size distribution of coarse bottom ash aggregate (B-C) and and normal coarse aggregate (Gravel).

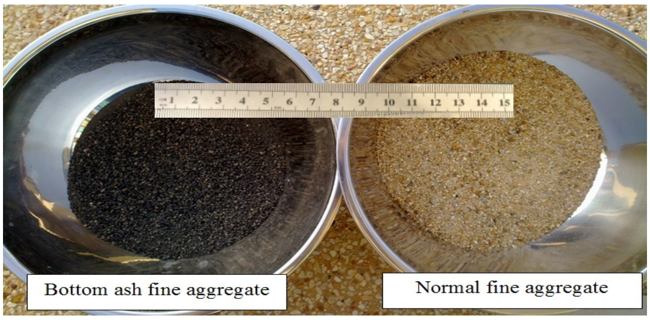

Figure 3. Fine bottom ash aggregate (B-F) and Sand.

Figure 4. Coarse bottom ash aggregate (B-C) and Gravel.

Table 1. Chemical compositions of Portland cement (PC) and bottom ash (BA).

Chemical compositions (%)	Portland cement (PC)	Bottom ash (BA)
SiO_2	39	40
Al_2O_3	17	21
Fe_2O_3	15	14.5
CaO	13	16
Na_2O	4	3
MgO	8	6
K_2O	2	2
SO_3	-	-
LOI	4.5	4.4
SiO_2+ Al_2O_3+ Fe_2O_3	71	74

2.2 Mix design and curing

Normal fine and coarse aggregates were replaced with fine and coarse bottom ashes at the replacement levels of 0, 25, 50, 75 and 100 % by weight of the normal aggregate. The content of Portland cement was used at 520 $kg \cdot m^{-3}$. All concrete mixtures had constant water to cement ratio (W/C) of 0.50 with designed compressive strength of 30 MPa (at the ages of 28 days). A Superplasticizer (SP) type F was used for controlling workability with a slump range from 50 mm to 100 mm. Table 2 shows the mixed proportions of the concrete.

2.3 Compressive strength test

The compressive strength tests were performed at the ages of 7, 28 and 90 days in accordance with ASTM C39 [23]. An average of three concrete specimens was used for all testing dates

Table 2. The concrete mix proportions.

Mix	W/C	Materials ($kg·m^{-3}$)					Water	SP	Slump
		PC	Sand	B-F	Gravel	B-C		(%)	(mm)
CT	0.50	520	595	-	1105	-	260	0.6	55
25-F	0.50	520	446.3	148.7	1105	-	260	0.5	58
50-F	0.50	520	297.5	297.5	1105	-	260	0.6	62
75-F	0.50	520	148.7	446.3	1105	-	260	2.5	66
100-F	0.50	520	0	595	1105	-	260	2.6	68
25-C	0.50	520	595	-	828.7	276.3	260	0.3	52
50-C	0.50	520	595	-	552.5	552.5	260	0.5	54
75-C	0.50	520	595	-	276.3	828.7	260	2.1	56
100-C	0.50	520	595	-	0	1105	260	2.6	62

Note: W/C = Water cement to cement ratio (PC = Portland cement), CT = Control concrete, SP = Superplasticizer (by percentage of binder), B-F = Fine bottom ash aggregate, and B-C = Coarse bottom ash aggregate.

2.4 Water absorption test

The water absorption was carried out according to ASTM C642 [24]. The specimens were kept in water until the testing dates of the ages. The values of water absorption are given in Equation (1).

$$C_w = \left(\frac{Q}{A}\right)^2 \times \frac{1}{t} \quad (1)$$

2.5 Rapid chloride penetration test

The rapid chloride penetration tests were performed in accordance with ASTM C1202 [25]. In addition, the RCPT tests were calculated by using Equation (2).

$$\begin{aligned} CP = {} & 900(I_0+2I_{30}+2I_{60}+2I_{90}+2I_{120}+2I_{150}+2I_{180}+2I_{210} \quad (2) \\ & +2I_{240}+2I_{270}+2I_{300}+2I_{330}+I_{360} \end{aligned}$$

Where *C*P is a charge passed (coulomb); *I* is ampere (mA) in time (minute).

Where, C_w is water absorption (m^2/s), *Q* is the quantity of water absorbed in time *t* and *A* is the total surface area of concrete (cm^2).

2.6 Corrosion test

The accelerated corrosion test with impressed voltage was performed according to previous researches, Rukzon and Chindaprasirt [9] and Chindaprasirt and Rukzon [6]. They tested the corrosion of steel in mortar and concrete containing pozzolanic materials. The test result needs a timing record in hours when the concrete starts to crack or to be destroyed due to the electric pressure acceleration. The cylindrical concrete specimens of 100 mm in diameter and 200 mm in height with embedded steel rebar of 12 mm in diameter and 200 mm in length were used for this study. The setup of the accelerated corrosion test is given in Figure 5.

The concrete specimens were tested to the corrosion with power supply and a direct voltage of 12 V DC with constant (the embedded steel rebar acting as the anode). The accelerated corrosion test was monitored visually at intervals of 4 h to observe the initiating time to the first crack of concrete from accelerated chloride (expressed in an hour).

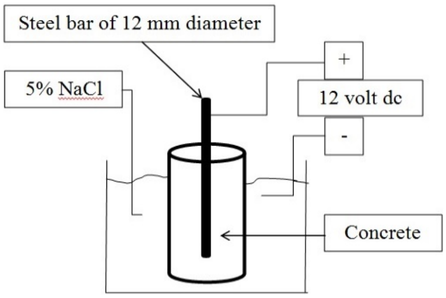

Figure 5. Accelerated corrosion test.

3. Results and discussion

3.1 Requirement of superplasticizer (SP)

From Table 2, it was found that 25-F, 50-F, 75-F, and 100-F concretes required SP of 0.5, 0.6, 2.5, and 2.6% by weight of the binder, respectively while CT concrete required SP of 0.6% by weight of the binder. The high replacement rates of B-F showed the higher SP requirement in the concrete mixtures. Similar results were also found in the replacements of B-C, 25-C, 50-C, 75-C, and 100-C concretes required SP of 0.3, 0.5, 2.1, and 2.6% by weight of the binder, respectively. The results demonstrated that the high replacement of B-F and B-C into natural aggregates needed a high amount of SP to control a slump of mix design between 50 mm to 100 mm. This is due to the bottom ash having a rough surface texture with porous particles as nature [26-28] As a result, the SP amount in the concrete mix is needed to be increased to control the workability. The test results are similar to Remya *et al* [29] and Yogesh and Rafat [30] who reported that the slump values of concrete containing BA have been decreased with an increase in the content of BA. It should be noted that at 25% and 50 % replacement rates of B-F and B-C required the low dosage of SP when compared to the CT concrete.

3.2 Compressive strength of concrete

The results of compressive strengths of concrete are presented in Figures 6 and Figure 7. At 28 days, it was found that the compressive strengths of bottom ash aggregate concrete ranged from 29 MPa to 43 MPa, and increased to 33 MPa to 48 MPa at 90 days depending on the type and replacement level of the normal and bottom ash aggregates (B-F and B-C) in the concrete mixtures. The compressive strengths of CT concrete are 31, 37, and 42 MPa at 7, 28, and 90 days. In addition, at 25% and 50% replacement levels of B-F and B-C, the concretes gave compressive strengths higher than that of the CT concrete at all ages, although the B-F and B-C concretes were partially substituted by the bottom ash aggregates (B-F and B-C). For example, at 7 days, 25-F, 50-F and 25-C, 50-C concretes had a compressive strength of 36, 35 and 37, 35 MPa, and increased at later ages of 28 days and 90 days. At 28 days and 90 days, the compressive strength of 25-F, 50-F concretes were 42, 47 and 40, 46 MPa, while the 25-C, 50-C concretes were 43, 48 and 42, 46 MPa, respectively. The highest compressive strength was observed in 25% replacement of B-F and B-C, 25-F and 25-C concretes. At 90 days, the compressive strength of concretes was 47 MPa and 48 MPa, about 1.11 times and 1.14 times greater than that of the CT concrete, respectively. The results suggested that the compressive strength development of bottom ash aggregate concrete is rather good, although the B-F and B-C concretes contained less normal aggregates than the CT concrete. As a result, it was concluded that the B-F and B-C aggregates are effective in enhancing the compressive strength of concrete at 25% and 50% of normal aggregate replacement.

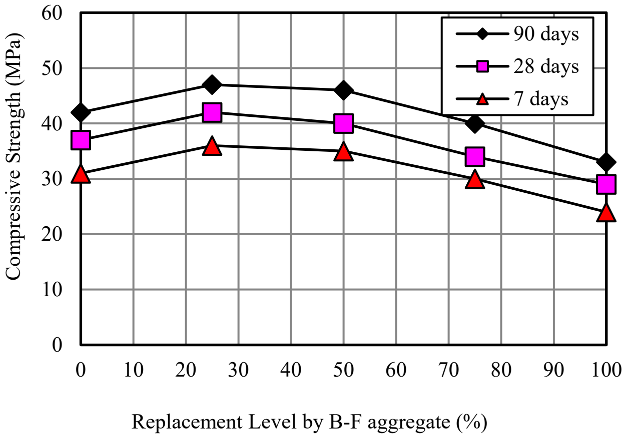

Figure 6. Compressive strength of concrete with fine bottom ash aggregate B-F).

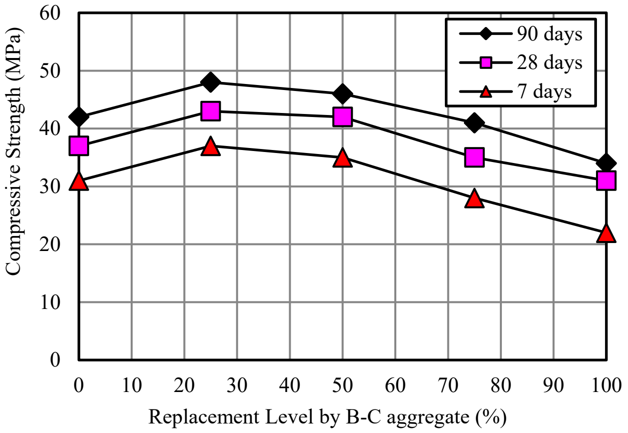

Figure 7. Compressive strength of concrete with coarse bottom ash aggregate (B-C).

At a high replacement level, the results showed that compressive strengths of 75-F and 75-C concretes did not have much difference from that of CT concrete. At 7, 28, and 90 days, the 75-F and 75-C concretes had compressive strengths of 30, 34, 40 and 28, 35, 41 MPa, respectively. Moreover, it was also indicated that the high replacement levels (75% and 100%) of B-F and B-C aggregates had an influence on lower compressive strength than those of low replacement levels (25% and 50%). It can be observed from at full replacement (100%), compressive strengths of 100-F and 100-C were 24, 29, 33 and 22, 31, 34 MPa at 7, 28, and 90 days, respectively. However, it was shown that the 100-F and 100-C concretes had compressive strengths slightly lower than that of the CT concrete at all ages. For all replacement levels, it was found that the compressive strength increased with curing ages as expected because of the hydration reaction of Portland cement. These results indicated that the compressive strength was not significantly affected by the incorporation of fine and coarse bottom ash (B-F and B-C) aggregates in concrete. This result is corresponding to the research of Kim and Lee [19], who reported that the effects of bottom ash aggregates on compressive strength were smaller than those of previous researches because the high proportion of cement paste was higher than those in other researches, Andrade *et al* [14] and Refieizonooz *et al* [17]. Furthermore, Kim and Lee [19] reported that the concrete containing fine and coarse bottom ash aggregates could be created compressive strength as high as 60 Mpa to 70 MPa at 28 days. It was noted that this research used the cement content of 520 kg·m^{-3} to produce B-C and B-F concretes with a design compressive strength of 30 MPa at 28 days.

3.3 Water absorption

The results of water absorption are given in Figure 8. At the early ages of 7 days, it was indicated that 25-F, 50-F, 25-C, and 50-C concretes had water absorption lower than that of CT concrete, although those concretes contained B-F and B-C aggregates. At 7 days, the water absorption of 25-F, 50-F, 25-C, and 50-C concretes were 3.3 × 10^{-5} m^{2}·sec^{-1}, while the CT concrete was 3.4 × 10^{-5} m^{2}·sec^{-1}. Furthermore, at later ages of 28 days and 90 days, it was also found that the water absorption of the 25-F, 50-F, 25-C, and 50-C concretes were still lower than that of the CT concrete. The 25-F, 50-F, 25-C, and 50-C concretes had of water absorption of 2.8, 2.9, 2.4, 2.1 and 2.4, 2.7, 2.1, and 1.8 × 10^{-5} m^{2}·sec^{-1} (at 28 days and 90 days). At 28 days

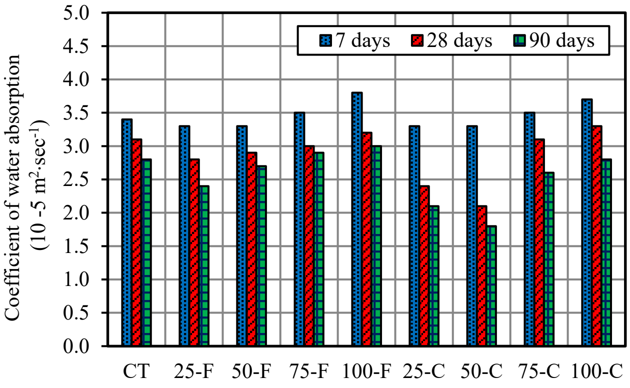

Figure 8. Coefficient of water absorption of concretes.

and 90 days, the CT concrete had water absorption of 3.1 × 10^{-5} $m^2 \cdot sec^{-1}$ and 2.8 × 10^{-5} $m^2 \cdot sec^{-1}$, respectively. As a result, it was indicated that at low replacement levels (25% and 50%) of B-F and B-C aggregates, the water absorption of the concrete was reduced with curing ages. This results because the $Ca(OH)_2$ reaction of Portland cement increases with curing ages; therefore, it creates impermeable, and reduces the porosity of concretes [6,7].

For high replacement levels of B-F and B-C aggregates, 70% and 100% replacements, it was seen that the water absorption was higher than that of CT concrete at the early ages of 7 days. For B-F aggregates, 75-F and 100-F concretes had the water absorption of 3.5 × 10^{-5} $m^2 \cdot sec^{-1}$ and 3.8 × 10^{-5} $m^2 \cdot sec^{-1}$, while 75-C and 100-C concretes had water absorption of 3.5 × 10^{-5} $m^2 \cdot sec^{-1}$ and 3.7 × 10^{-5} $m^2 \cdot sec^{-1}$, respectively. This work found that the water absorption was increased with higher replacement levels of B-F and B-C aggregates. Similar results were also found in those results of fine bottom ash aggregate replacement from Remya *et al* [29] and Cadersa *et al* [31]. However, it seems that the water absorption of 75-F, 100-F, 75-C, and 100-C concretes did not have much difference from the CT concrete at later ages of 28 and 90 days. For example, at 28 days and 90 days, the 75-F and 100-F concretes had water absorption of 3.0, 3.2 and 2.9, 3.0 × 10^{-5} $m^2 \cdot sec^{-1}$, while 75-C and 100-C concretes had a coefficient of water absorption of 3.1, 3.3 and 2.6, 2.8 × 10^{-5} $m^2 \cdot sec^{-1}$, respectively. Moreover, the result of water absorption showed the low effect of using B-F and B-C aggregates at high replacement levels (75% and 100%) in the concrete.

3.4 Chloride penetration

Figures 9 and Figure 10 show the results of the rapid chloride penetration test (RCPT) of the concretes containing B-F and B-C aggregates, respectively. According to ASTM C1202, the resistances to chloride penetration of CT concrete were found to be "moderate" at the ages of 7 days and 28 days, with total charge passed of 2,650 coulombs and 2,150 coulombs, respectively. After that at 90 days, chloride penetrability of the CT concrete was found to be "low" with a total charge passed of 1,655 coulombs. For B-F concretes, it was found that at lower replacement levels, 25-F and 50-F concretes had total charge passed lower than that of the CT concrete at all ages. At the early ages of 7 days, the chloride penetrability of 25-F and 50-F concretes was found to be "moderate" with total charge passed of 2,200 coulombs and 2,420 coulombs, respectively. The chloride penetrability of 25-F and 50-F concretes decreased with curing ages and has been found to be "low" according to ASTM C1202 at 28 days and 90 days. It can be observed from, at 28 and 90 days, the total charge passed of the 25-F and 50-F concretes were 1,600, 1,850 and 1,150, 1,320 coulombs, respectively. Similar results were also found from those results of fine aggregate replacement with fine bottom ash, which was reported by Singh *et al* [32], and the chloride penetrability of concretes containing other pozzolans, as expected [3,5,9].

For high replacement levels at 75% and 100% of B-F aggregate, it was found that the 75-F and 100-F concretes had total charge passed slightly higher than that of the CT concrete at all ages, and was found to be "moderate" at the ages of 7 days and 28 days. At 7 days and 28 days, the 75-F and 100-F concretes had total charge passed of 2,650, 2,750 and 2,250, 2,200 coulombs, respectively. At 90 days, the chloride penetrability of 75-F and 100-F concretes were decreased, and had been found to be "low" with total charge passed of 1,850 coulombs and 1,850 coulombs, respectively. It was noted that at 90 days, the 75-F and 100-F concretes had chloride penetrability similar to the CT concrete, although the B-F concretes contained high replacement levels of B-F at 75% and 100%. Therefore, it was suggested that the incorporation of B-F aggregate at 25%, 50%, 75%, and 100% replacement levels is effective for producing concrete that has a good performance for chloride penetration resistance.

Similar results were also established from the use of B-C aggregate in concretes. At low replacement levels, 25-C and 50-C concretes had chloride penetrability lower than that of the CT concrete at all ages. At the early ages of 7 days, the 25-C and 50-C concretes had total charge passed of 2,100 coulombs and 2,320 coulombs, respectively. At 28 days and 90 days, the total charge passed of the 25-C and 50-C concretes were decreased to be 1,600, 1,750 and 1,250, 1,350 coulombs, respectively. It was also shown that the chloride penetrability of the 25-C and 50-C concretes reduced with curing ages. As a result, the chloride penetrability of 25-F and 50-F concretes was found to be "moderate" at 7 days, and to be "low" at 28 days and 90 days according to ASTM C1202. For 75-C and 100-C concretes, chloride penetrability was found to be "moderate" at 7 days and 28 days, and to be "low" at 90 days. At 7 days and 28 days, the total charge passed of 75-C and 100-C concretes were 2,660, 2,580 and 2,150, 2,100 coulombs,

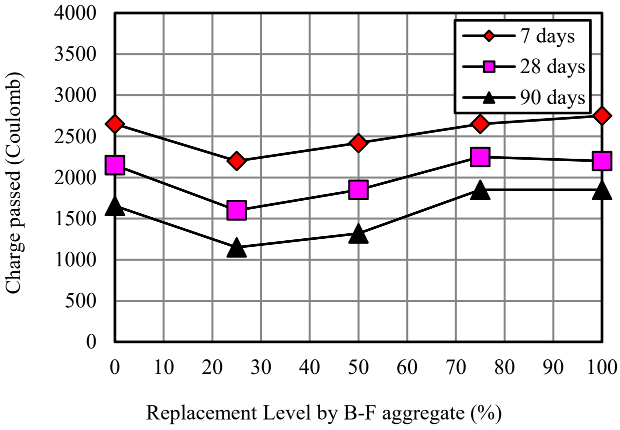

Figure 9. Chloride penetration of concrete with fine bottom ash aggregate (B-F).

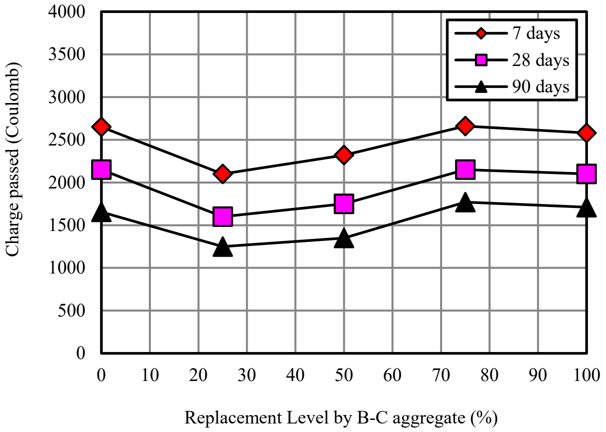

Figure 10. Chloride penetration of concrete with coarse bottom ash aggregate (B-C).

respectively. After that, at 90 days, the total charge passed of the 75-C and 100-C concretes was decreased to be 1,770 coulombs and 1,170 coulombs, respectively. The results indicated that at high replacement levels (75% and 100%), the 75-C and 100-C concretes showed good chloride penetration resistance at later ages of 90 days when compared to the CT concrete.

The results of chloride penetrability of concrete containing B-F and B-C aggregates, it was suggested that the bottom ash aggregates (including B-F and B-C) are effective for producing concrete at 25% and 50% replacement levels of normal aggregate at 28 days. For high replacement levels of B-F and B-C aggregates, it was also suggested that the B-F and B-C concretes at 75% and 100% replacement levels had a good chloride penetration resistance at later ages of 90 days. In addition, the result of the chloride penetrability of concrete containing B-F and B-C aggregates corresponds with that result of the coefficient of the water absorption test. This is due to the presence of the porosity of the B-F and B-C aggregates, and similar to the result of recycled aggregate in concrete, which was reported by Tuyan *et al* [33]. The use of recycled aggregate in concrete enhanced chloride penetrability at a higher replacement level because of the relatively higher porosity of the concrete due to the presence of the porous nature of the recycled aggregate in comparison to crushed natural aggregates. These pores are an easy route for the diffusion of chloride ions into concrete.

The relationship between compressive strength and charge passed of concretes is given in Figure 11. It was indicated that the reduction in total charge passed of the B-F and B-C concretes was related to their compressive strengths, the total charge passed decreased with the higher compressive strength. It was the same trend of those results in concrete containing pozzolans, which was reported by Rukzon and Chindapraseirt [3], Chindaprasirt *et al* [5], and Rukzon and Chindaprasirt [7]. Therefore, the compressive strengths of B-F and B-C concretes were probably used as an indicator to affect the chloride penetrability of the B-F and B-C concretes.

3.5 Resistance to corrosion

The test results of time to the first crack of corrosion are presented in Figures 12 and Figure 13. The time to the first crack is used as a measurement of the specimen's relative resistance against chloride attack and reinforcement corrosion [6,9]. The results found that the times to the first crack at 7, 28, and 90 days of CT were 85, 90, and 105 h, respectively, and increased with the incorporation of B-F and B-C aggregates. For the incorporation of B-F aggregate, at early ages of 7 days, the times to the first crack 25-F and 50-F concretes increased to 118 h and 110 h compared with that of the CT concrete, respectively. In addition, it was found that the times to the first crack increased with curing ages. At later ages of 28 days and 90 days, the times to the first crack increased further to 122, 113 and 131, 120 h, respectively. Moreover, it was found that the times to the first crack slightly reduced when the high replacement levels of B-F aggregate were incorporated. At 75% and 100% replacement levels, 75-F and 100-F concretes showed the times to the first crack at early ages of 7 days of 96 h and 91 h, and increased further at later ages of 28 days and 90 days to 110, 95 and 115, 108 h, respectively. The highest replacement of 100%, 100-F concrete showed the times to the first crack higher than that of the CT concrete, although the 100-F concrete did not have normal fine aggregate. The results clearly showed that the incorporation of 25% and 50% of the B-F aggregates effectively increased the resistance to chloride attack as indicated by the increasing time to the first crack. This means that the concrete mixed with 25% and 50% of B-F aggregates has good resistance to the steel corrosion because of they had a longer time of the first crack.

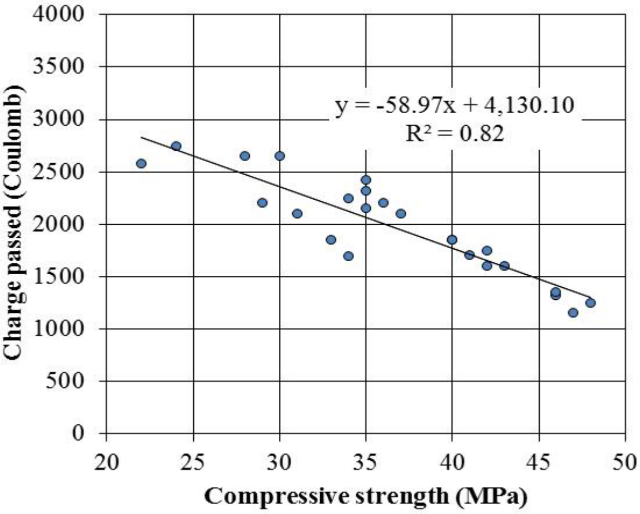

Figure 11. Relationship between compressive strength and charge passed of concretes.

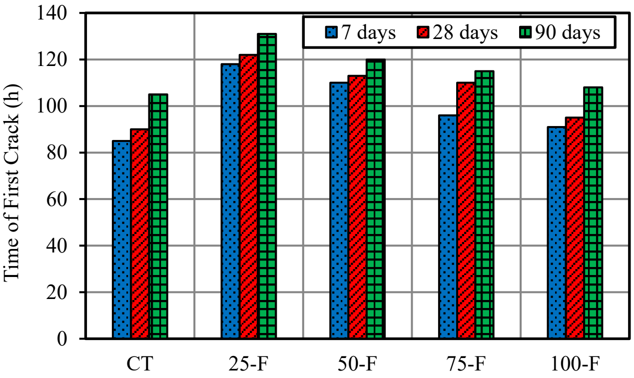

Figure 12. Corrosion resistance of concrete with fine bottom ash aggregate (B-F).

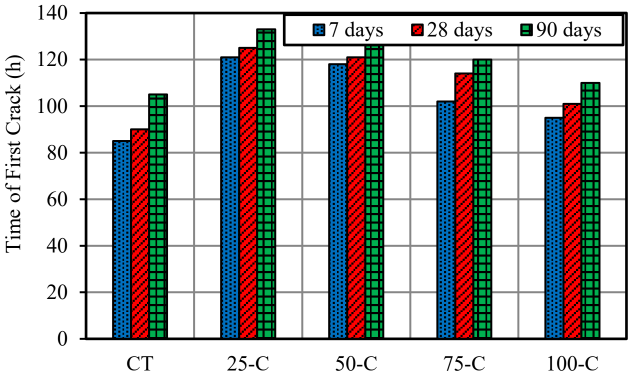

Figure 13. Corrosion resistance of concrete with coarse bottom ash aggregate (B-C).

For B-C concretes, the results of times to the first crack were similar to those results of the B-F concretes but increased slightly when compared to the B-F concretes. At the early ages of 7 days, 25-C, 50-C, 75-C, and 100-C concretes had times to the first crack of 121, 118, 102, and 95 h, respectively. The times to the first crack of the B-C concretes also increased with an increase curing ages. At 28 days and 90 days, the times to the first crack of 25-C and 50-C concretes were 125, 121 and 133, 128 h, and 75-C and 100-C were 114, 101 and 120, 110 h, respectively. The results also showed that the times to the first crack of the B-C concretes decreased with the higher replacement level of coarse bottom ash aggregate. However, the time to the first crack of 100-C concrete is high when compare with CT concretes. It was indicated that the good performance of resistance to the steel corrosion was 25-C and 50-C concretes with the times to the first crack of 125 h and 121 h at 28 days, respectively.

4. Conclusions

Based on the experimental results, it can be concluded that at 25% and 50 % replacement rates of B-F and B-C required the low dosage of SP when compared to the CT concrete. The SP dosage in the B-F and B-C mix proportions is needed to be increased to control the workability or slump. The compressive strengths of B-F and B-C concretes ranged from 29 MPa to 43 MPa at 28 days and increased to 33 MPa to 48 MPa at 90 days depending on the type and replacement level of aggregates. The highest compressive strength was observed at a low replacement level (25%) of 25-F and 25-C concretes. The coefficients of water absorption of the concrete were reduced with curing ages. At 25 and 50% replacements, 25-F, 50-F, 25-C, and 50-C concretes had a coefficient of water absorption lower than that of CT concrete at all ages. The durability properties of B-F and B-C concretes showed good performance at 25% and 50% replacement levels of B-F and B-C aggregates in concretes. For the resistance to reinforcement corrosion, B-F and B-C concretes with higher strength concrete have the higher time to the first crack. With regards to the results of chloride penetrability, the incorporations of 25% and 50% of B-F and B-C aggregates resulted in a less permeable concretes. Consequently, the use of bottom ashes as fine and coarse aggregates improves the resistance to chloride corrosion as well as the durability properties of the B-F and B-C concretes.

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