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A STUDY ON THE EFFECTS OF METAKAOLIN FROM TORAGET VILLAGE IN INDONESIA, ON CEMENT CONCRETE PROPERTIES 1STEVE W.M SUPIT, 2RILYA RUMBAYAN, 3ADRIANA TICOALU 1,2,3Manado State Polytechnic-Indonesia, Manado State Polytechnic-Indonesia, Sam Ratulangi University-Indonesia E-mail: 1steve.macq@gmail.com, <mailto:1steve.macq@gmail.com>2rilya.rumbayan@gmail.com, <mailto:2rilya.rumbayan@gmail.com>3adriana31.vi5@gmail.com <mailto:3adriana31.vi5@gmail.com> Abstract- The usage of pozzolanic materials as additive has provided a unique characteristics for the improvement of cement based materials.

In this paper, the effects of Metakaolin from Toraget Village, North Sulawesi in Indonesia, are investigated based on the compressive strength at 3, 7 and 28 days and water absorption of cement concrete at 7 and 28 days. At this experimental works, cement is replaced by 5%, 10%, 15% and 20% Metakaolin (by weight of cement). Results show an improvement on compressive strength and water absorption resistance of metakaolin-blended cement concretes. Concrete with 10% Metakaolin replacement had found to exhibit 50%, 45% and 25% higher compressive strength at 3, 7, and 28 days, respectively, in comparison to that of Portland cement concrete.

On the other hand, based on the summarized sorptivity value, the minimum water sorptivity was 11 and 4 (x10-4 mm/s1/2) at 7 and 28 days, respectively, for concrete containing 10% Metakaolin.The findings are also consistence with volume of permeable voids results. This can be due to the chemical reaction and physical properties of Metakaolin in improving the microstructure and the formation of Calcium Silicate Hydrate (CSH) gel. Index Terms- Cement, Compressive Strength, Metakaolin, Volume of

Permeable Voids, Water Absorption. I.

INTRODUCTION The use of supplementary cementitious materials (SCM) has been frequently discussed due to its contribution to the properties of hardened mortar and concrete through hydraulic or pozzolanic activity. Typical examples of SCM are fly ash, ground granulated blast-furnace slag, silica fume, and Metakaolin which can be used individually with Portland or blended cement or in different combinations. These materials react chemically with calcium hydroxide (CH) that released from the hydration of Portland cement to form cement compounds and make mortar or concrete mixtures more economical, stronger and higher durability resistance.

Among those materials, Metakaolin has been studied widely in recent years. Metakaolin (Al2Si2O7) is a pozzolanic material that thermally activated by firing kaolinite clay within temperature range of 700-800°C[1]. Metakaolin has a particle size range from 0.5 to 2μm, and is a highly reactive pozzolan. Metakaolin can react with lime and produce both C-S-H and hydrated gehlenite [2]: Some works demonstrated that Metakaolin is a very effective pozzolan in enhancing early strength, and some improvement in the long-term strength.

Because of its highly disorganized structure, Metakaolin reacts very rapidly with the Calcium Hydroxide produced during the hydration of Portland cements [3]. The early study on the effect of Metakaolin is reported by Curcio et al.[4]. The results indicated that superplasticized mortars containing 15% Metakaolin as replacement of cement exhibited 15% higher compressive strength than cement mortar at 28 days. In another study, Sayamipuk [5] found that the highest compressive strength of mortar was obtained when 30% Metakaolin was used to replace cement while Batis et al. [6] reported that 10% Metakaolin contributed to the strength development of cement mortar.

This is also supported by Supit [7] who reported that the addition of 10% Metakaolin compensated the loss of compressive strength in normal cement concrete at early and later ages. Similar trend was also found by Rumbayan [8], in high strength concrete. In terms of durability properties such as chloride diffusion, corrosion behavior, and sulphate attack, some researchers also found the best performance obtained when Metakaolin is used as replacement of cement [9]. In this case, the reaction products densified the Interfacial Transition Zone (ITZ), with a decrease in the volume of pores [10,11].

Blended cement pastes containing 10% of Metakaolin was also found to exhibit higher capacities than OPC pastes to reduce the risk of expansive alkali-aggreate reaction in concrete [12]. On the other hand, Courard et al. [10] exhibited the increase in water absorption of concrete mixtures with the increase in Metakaolin content at all curing times. Similar observation were also made by Khatib and Clay [13]. While the Metakaolin improved the mechanical properties of mortar and concrete than that of cement alone, very less results are available on the effect of Metakaolin from Toraget Village, Indonesia, in the development of compressive strength, water sorptivityand volume permeable voids of cement concrete.

This is important since the hydration products that responsible for the strength and durability performance of concrete depend upon the level of reactivity of Metakaolin, which in turn depends upon the processing conditions and purify of feed clay [3]. The main line of this study was to investigate the possibility for using Metakaolin from Toraget Village as efficient mineral admixture in the cement and concrete industry in Indonesia. II. EXPERIMENTAL PROGRAM A. Materials Ordinary Portland Cement Type I (PC), Metakaolin (MK), sand,and water are used in all mixes. Metakaolin is obtained from Toraget Village, Minahasa District, North Sulawesi Province, Indonesia.

The chemical analysis of PC Type I and Metakaolin are listed in Table 1. TABLE 1. CHEMICAL COMPOSITION OF MATERIALS B. Mixture Proportions The experimental work is divided into two parts. The first part investigated the effects of 5%, 10%, 15% and 20% Metakaolin as partial replacement of cement based on the 3, 7 and 28 days compressive strength of cement concrete. The workability of Metakaolin concretes is also investigated in this part. The second part evaluated the effect of Metakaolin on water absorption and volume or permeable voids of cement concretes at 7 and 28 days. The mix proportions of concretes are shown in Table 2. TABLE 2.

MIXTURE PROPORTIONS OFMETAKAOLIN CONCRETES (kg/m2) C. Methods All concretes were mixed in a pan mixer using water/binder ratio of 0.46. The concrete sample of size 100x200 mm cylinder were cast and demoulded after 24hour. The concrete specimens were cured in water at room temperature for 3, 7 and 28 days. Compressive strength of concrete specimens were tested according to ASTM C39 [14]. In addition, the rate of water absorption of concretes was determined using 50 mm thick disk after curing at 7 and 28 days, based on ASTM C1585 [15].

The principle of the method is that a specimen has one surface in free contact with water (no more than 5 mm above the base of the specimen) while the other sides are sealed. The test of concretes on volume of permeable voids (VPV) was conducted to estimate the percentage of voids present in concrete specimens at 7 and 28 days, based on ASTM C642 [16] standard. VPV is determined by boiling 50 mm cut concrete specimens for at least 5 hours in a water tank at 105°C, weighing the samples in water, then measuring the percentage of boiled specimen with dried mass and mass in the water.

The workability of concretes is measured in terms of slump values according to ASTM C143 [17]. Since the Metakaolin has a higher specific surface than cement, a naphthalene sulphonate superplasticizer (SP) was used to maintain the workability of concretes containing Metakaolin. III. RESULTS AND DISCUSSIONS A. Water Demand or Workability Fig. 1 shows the slump value of concretes.

It can be seen that the addition of Metakaolin up to 20% of replacement by weight of cement decreased the slump value from 100 mm (PC) to 55 (MK-20) mm indicating the effect of Metakaolin in providing water-tightness at water to binder ratio of 0.46 due to smaller particle size and higher surface area of Metakaolin. Similar observation was also found by Ramlochan et al. [18], where Metakaolin increased the cohesiveness of concrete thus required the addition of plasticizer to achieve desired workability. The reason for higher water demand in the use of Metakaolin is that this pozzolan material has high reactivity and consumes water very early. Figure. 1. Workability of concretes containing Metakaolin B.

Compressive Strength The effect of different Metakaolin contents on 3, 7 and 28 days compressive strength of cement concrete is shown in Fig. 2. We noticed that the compressive strength of concretes containing Metakaolin increases with increase in Metakaolin content up to 10%. We observed that the highest improvement is in concrete containing 10% (by wt.). Results show that the addition of 10% Metakaolin improved the compressive strength of cement concrete, where 50%, 45% and 25% improvement in compressive strength is observed at 3, 7, and 28 days, respectively.

However, the compressive strength is gradually decrease with further increase in Metakaolin content up to 20%, but still maintained the improvement of compressive strength between 16% and 38% when compared to PC concrete. The slightly lower compressive strength of concrete with 15% and 20% Metakaolin (by wt.) can be attributed to the smaller particles sizes of Metakaolin that requires higher water/binder ratio, while in this experiment water/binder ratio was kept constant at 0.46.

This clearly indicates that a properly-proportioned affected the compressive strength of Metakaolin concrete. We also observed in this study that the improvement of compressive strength is more significant at early age (3 days) than the later ages. This can be due to the faster pozzolanic reaction on Metakaolin with calcium hydroxide (CH) in the hydration reaction of cement and formed additional CSH gel that responsible for the compressive strength improvement. The results from Zhang and Malhotra [19] also showed that the compressive strength of blended Metakaolin-cement concrete exhibited 30% and 10% higher compressive strength at 7 and 28 days, respectively, than Portland cement concrete.

They concluded that the properties of concrete incorporating Metakaolin are comparable and sometimes better than Silica Fume concrete. Overall, Metakaolin has substantial contents of silica and alumina oxide showing its capability to produce Calcium Silicate Hydrate and Calcium Alumina Hydrate which has bonding characteristics in the concrete. Figure 2. Compressive strength development of concretes containing Metakaolin at 3, 7 and 28 days C. Water Sorptivity Fig. 3 and Fig. 4 present the effect of Metakaolin on water absorption of cement concrete at 7 and 28 days.

The best-fit lines in the figures as based on coefficient of determination (R) values greater than 0.98 for all mixes. It can be seen that the cumulative volume of water absorbed in the concrete increased with the square root of time. On the other hand, the slope of the obtained line defines the sorptivity of different concretes during the initial 6 hour of testing, as seen in Fig. 5. Based on the summarized sorptivity value, the minimum water sorptivity was 11 and 4 (x10-4 mm/s1/2) at 7 and 28 days, respectively, for concrete containing 10% Metakaolin.

In comparison with PC concrete, the sorptivity value of MK-10 concrete scored 56% and 81% lower at 7 and 28 days of curing ages. The sorptivity value increased as the increase of Metakaolin replacement (by wt.) up to 20%. The reduction in water soprtivity can be explained as the rapid reaction of Metakaolin in consuming Calcium Hydroxide (CH) thus accelerate the hydration products and then improving the bonding effect between cement paste and aggregate. This result confirms the investigation from Duan et al.

[20] who found that Metakaolin has positive effect on pore structure and Interfacial Transition Zone enhancement of concrete higher than Silica Fume (SF) and Ground Granulated Blast Furnace Slag (GGBFS). Figure 3. Water absorption of Metakaolin concretes at 7 days Figure 4. Water absorption of Metakaolin concretes at 28 days Figure 5. Sorptivity value of Metakaolin concretes at 7 and 28 days D. Volume of Permeable Voids The effect of Metakaolin on the volume permeable voids of cement concretes is presented in Fig. 6. As expected, the VPV of cement concrete containing Metakaolin shows a decreasing trend with increase in curing time.

The concrete with 10% Metakaolin had a very low percentage of voids (at about 50% and 80% lower),than that of the corresponding PC concrete.As seen in Fig. 6, the VPV of concrete mixture using 10% Metakaolin was 11% and 5%,at 7 and 28 days, respectively. This results is consistence with sorptivity value and compressive strength results, where the 10% Metakaolin concrete performed better than PC concrete, presumably due to packing effect and pozzolanic contribution of the Metakaolin. However, the volume of permeable voids of Metakaolin concretes was increased as the increase of Metakaolin content up to 20% at the same level of water/binder ratio.

The results indicate that the influence of Metakaolin on VPV depends not only on the content of Metakaolin, but also on the water/binder ratio of concrete. Figure 6. Volume of Permeable Voids of Metakaolin concretes at 7 and 28 days CONCLUSIONS This study allows drawingof the following conclusions: 1. The use of Metakaolin as a local product from Toraget Village, can be utilized as a pozzolanic material replacing a significant portion of the Portland cement in concrete.

However, further studies on its performance based on other durability tests such as chloride diffusion, sulfate attack, corrosion and also the microstructure analysis and phases identification are still needed to validate the findings. 2. Metakaolin increased the cohesiveness of concrete thus required the addition of plasticizer to achieve desired workability. The reason for higher water demand in the use of Metakaolin is that this pozzolan material has high reactivity and consumes water very early. 3.

The blending by Metakaolin in cement concrete affects the compressive strength development at 3, 7, and 28 days. Metakaolin could achieve optimum improvements as to the 28-days compressive strength at about 10% partial replacement of PC. The contribution of Metakaolin to the compressive strength improvement in concrete was higher at early age than later age.This can be due to the faster pozzolanic reaction on Metakaolin with calcium hydroxide (CH) in the hydration reaction of cement and formed additional CSH gel that responsible for the compressive strength improvement. 4.

The 7 and 28-days water sorptivity resistance was improved by partial replacement of PC by Metakaolin. The optimum percentage replacement was found effective at 10% where the sorptivity value decreased at about 56% and 81% at 7 and 28-days of curing ages. 5. The concrete with 10% Metakaolin had a very low percentage of volume permeable voids at 7 and 28 days of curing ages, (at about 50% and 80% lower), when compared to PC concrete. The investigated results indicate that the influence level of Metakaolin on VPV not only depends on the replacement level but also the water/binder ratio of concrete mixture.

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