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Fiber reinforced lightweight binder with calcined-Sidoarjo mud

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ABSTRACT

Lightweight concrete is widely applied especially at high-rise buildings in order to reduce the risk of earthquake. In general, lightweight concrete is made with less Portland Cement associated with lime and pozzolan material as a binder. In this paper, calcined-Sidoarjo mud was introduced as pozzolan material as cement substitution. The mud contains SiO_2, Al_2O_3 and Fe_2O_3 significantly to be expected as a potential pozzolanic material.

The binder made with a mixture of calcined-Sidoarjo mud, Portland Cement and fiber. The samples were then mixed with a comercial chemical foaming agent to get light weight binder.

The results showed that test of binder specimen using 50% calcined-Sidoarjo mud produced 62 MPa of compressive strength. Based on research result, compressive strength of lightweight binder 40% PC and 1.33% foam agent was 5.20 MPa and weight volume 0.95 gr/cm3.Lightweight fiber binder using 2% fiber produced 5.25 MPa of compressive strength and 0.97 gr/cm^3 of weight volume.

1. INTRODUCTION

Lightweight concrete is widely applied especially at high-rise buildings in order to reduce the risk of earthquake, with using the material as a wall to decrease the weight of building. Recently, lightweight concrete is made from foreign technology with relatively high price, this material has a price range from Rp 800,000 to Rp 1.200.000, - per m^3.Therefore research on lightweight concrete is very useful, especially based on by-product materials. The presence of Sidoarjo mud that interfere people, since 2006, the mud oozing out was estimated at 100,000 m3/day. In December 2006 even

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reached 180,000 m3/day, and tended to decrease to around 75.000 m3/day in July 2009 (Karr MJ 2008). The research idea was using the Sidoarjo-mud compound containing SiO_2, Al_2O_3 and Fe_2O_3 more than 75% of total weight (Bayuaji 2010), and it was activated (calcined) to be pozolanic material. In this research the binder and mortar made with a mixture of calcined-Sidoarjo mud, Cement Portland and kenaf fiber (*(Naturally occurring fibers)*. The samples were then mixed with a comercial chemical foaming agent. The aim of the research is to find the optimum mixing of binder and how it affects when mixed with a foaming agent and kenaf fiber.

2. RESEARCH METHODOLOGY

The flowchart of research methodology is shown in Fig 1.

2.1. Materials

-Cement Portland from PT Semen Gresik. Sidoarjo mud was calcined at 800°C for 2 hours, milled and sieved until passing mess No. 200.
-Foam agent from PT. BASF Indonesia.

2.2.Chemical Analysis

Chemical compound of Calcined-mud was analyzed with XRD.

2.3.Mixing process.

The starting mixture consisted of Portland Cement (PC) , Calcined Sidoarjo-mud and water. Weight of Cement Portland (PC) varied from 5% to 50% by weight of binder and Calcined Sidoarjo-mud varies from 95% to 50% of binder weight, and adjusted the amount of water needs. The specimens were cylindrycal binder with a diameter of 2 cm and a height of 4 cm. The next mixtures were the optimum result of binder mixing before, wich were added with foam agent to form a light weight binder. The last mixture were the result of light weight binder mixed with fiber which its weight varies from 0.1% to 0.3% of weight of binder to form a light weight mortar . Tests performed were found the value of volume weight, compressive strength and porosity.

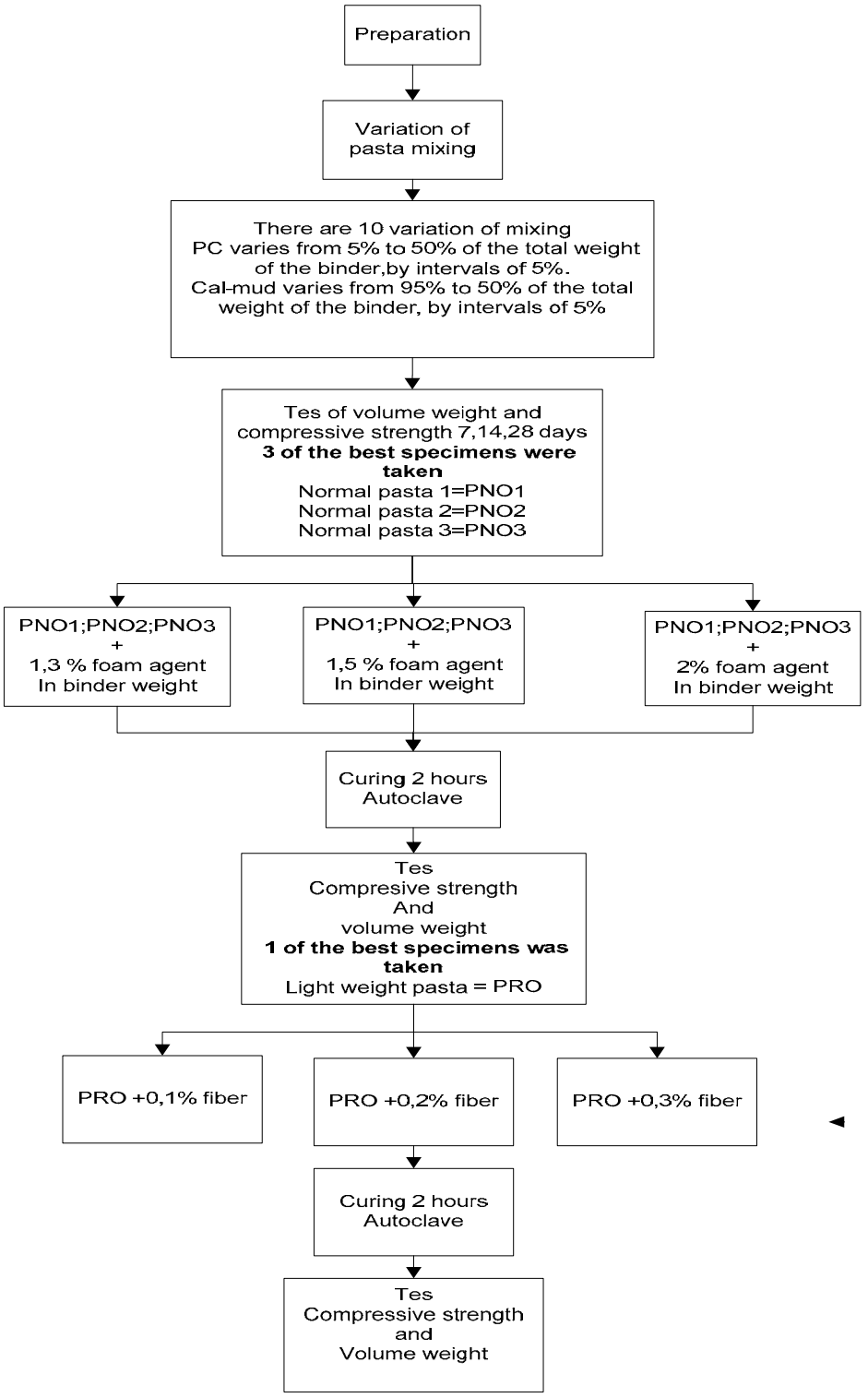

Fig.1 Flow Chart of Research Methodology

3.RESEARCH RESULT

3.1 Material analysis

Sidoarjo Calcined –mud was analyzed by XRD, the result is shown in Fig 2 and Table 1 .

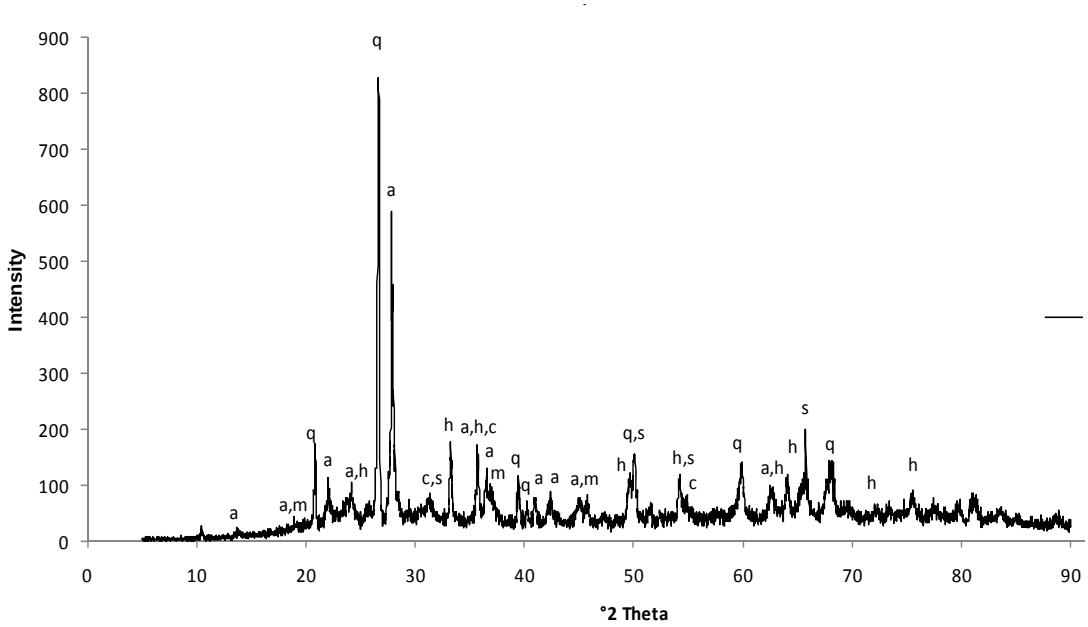

Fig. 2 XRD analysis of calcined-Sidoarjo mud

Table 1 Chemical Compounds of calcined-Sidoarjo mud from XRD analysis

Notation	Minerals	Chemical Formulas
q	Quartz = Silicon Oxide	SiO_2
h	Hematite = Iron Oxide	Fe_2O_3
c	Copper Iron Oxide	$CuFeO_2$
a	Anorthite = Calcium Aluminium Silicate	$CaAl_2Si_2O_8$
m	Manganese Oxide	MnO_2
s	Sillimanite = Aluminium Silicate	Al_2SiO_5

The mud also analyzed by XRF and the result is shown in Table 2.

Table 2 Chemical Composition of calcined- Sidoarjo mud by XRF Analysis

No	Calcined-Sidoarjo Mud	
	Oxides	quantity (%)
1	CaO	7,14
2	SiO_2	32
3	Fe_2O_3	42,22
4	Al_2O_3	5,8

As shown in Table 2, the quantity of (SiO_2 + Fe_2O_3 + Al_2O_3) for calcined-Sidoarjo mud was more than 70% , so the materials are classified as pozolanic material according to ASTM C618-2012.

3.2.Normal Binder

Normal binder mixture ratio is shown in Table 3, the result of compressive strength is shown in Fig. 3, and the result of volume weight is shown in Fig. 4.

Table 3 Mixture Ratio of Normal Binder

Sample code	PC	Cal-mud	water	Age of compression test
	(%) of binder weight	(%) of binder weight	(%) of binder weight	
PN-05	5	95	38	7,14, 28 days
PN-10	10	90	38	7,14, 28 days
PN-15	15	85	36	7,14, 28 days
PN-20	20	80	36	7,14, 28 days
PN-25	25	75	35	7,14, 28 days
PN-30	30	70	35	7,14, 28 days
PN-35	35	65	35	7,14, 28 days
PN-40	40	60	34	7,14, 28 days
PN-45	45	55	34	7,14, 28 days
PN-50	50	50	34	7,14, 28 days

As shown in the Fig. 3 by increasing percentage of Calcined - mud will reduce the value of compressive strength. It is normal since PC volume decreased with increasing Calcined-mud, thus the formation of pure Calcium Silicate Hydrate reduced. At the age of 28 days compressive strength was 62 MPa for 50% PC and 14 MPa for 5% PC.

According to research conducted by Hardjito et all (2012), Strength Activity Index (SAI) of mortar mixture containing 20% of mud was less than 100%.

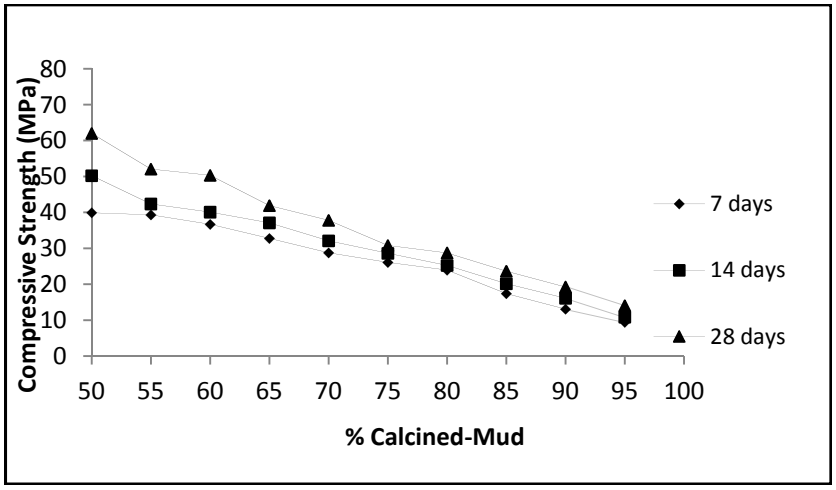

Fig.3 Relationship of Compressive Strength and Percentage of Calcined – Mud

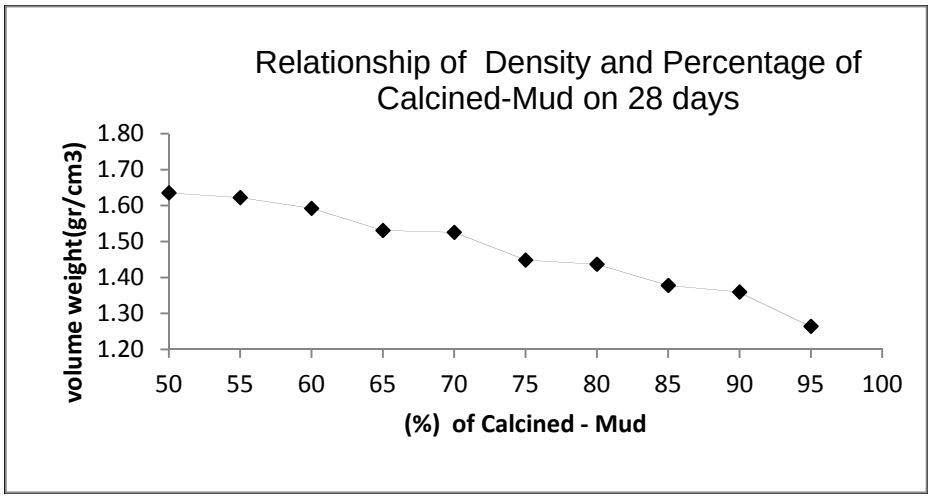

Fig .4 Relationship of density and Percentage of Calcined – Mud on Normal Binder

With increasing percentage of Calcined- mud will decrease the density. It is due to specific gravity of Calcined-mud is lower than PC. The specific gravity of PC is 3.15 gr/cm^3 and the specific gravity of the mud is 2.67 gr/cm^3 .

3.3.Lightweight Binder

From the existing mixture several mixture were choosed which were then added with foam agent to form Lightweight Binder.

The mixing ratio then is shown in Table 4 and the result of Compressive Strength is shown in Fig. 5. The density is shown in Fig. 6.

Table 4 Mixing Ratio of Lightweight Binder

Sample Code	PC	Cal-Mud	Water	Foam	Age of Compression test
	(%) of binder weight	(%) of binder weight	(%) of PC weight	(ml) of binder weight	
PR-10-1,73%	10	90	55	1.73 %	7 days
PR-10-1,53%				1,33%	
PR-10-1,33%				1,53%	
PR-20-1,73%	20	80	55	1.73 %	7 days
PR-20-1,53%				1,33%	
PR-20-1,33%				1,53%	
PR-30-1,73%	30	70	55	1.73 %	7 days
PR-30-1,53%				1,33%	
PR-30-1,33%				1,53%	
PR-40-1,73%	40	60	55	1.73 %	7 days
PR-40-1,53%				1,33%	
PR-40-1,33%				1,53%	
PR-50-1,73%	50	50	55	1.73 %	7 days
PR-50-1,53%				1,33%	
PR-50-1,33%				1,53%	

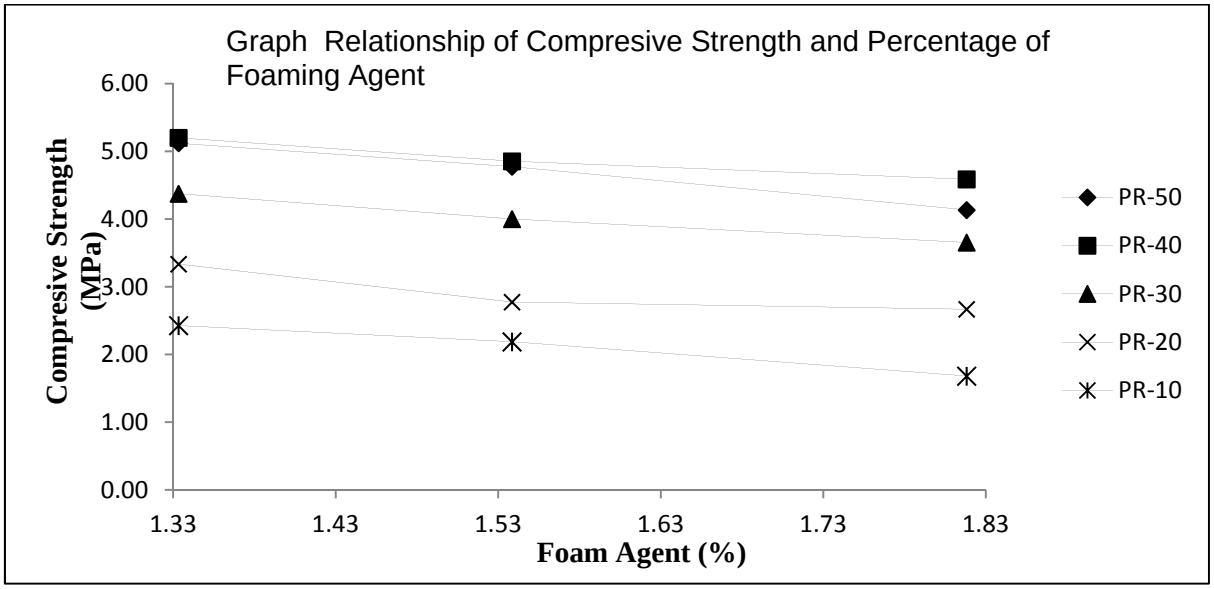

Fig.5 Relationship of Compresive Strength 7 days and Percentage of Foaming Agent

Fig. 5 shown that the increasing volume of foaming agent will decrease the compressive strength, the higher compressive strength value were the PR 50-1,33 and PR 40-1,33 with 1,33 foam agent , the value of compressive strength were about 5,12 MPa for PR 50-1,33 and 5,20 MPa for PR 40-1,33. Compressive strength value of PR 40-1,33 more than PR 50-1,33, since the value of closed porosity of PR 40-1,33 more than the PR 50-1,33. The closed porosity value of PR 40 is 26.73% while the PR50 is 19.66% , the higher the value of closed porosity will increase the compressive strength Triwulan et all.(2011)

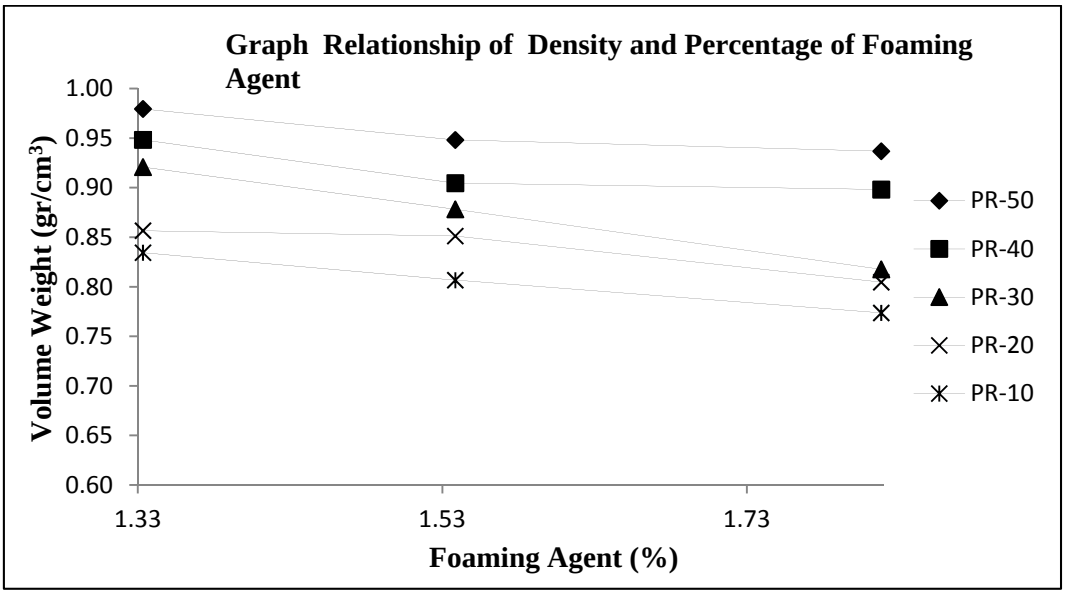

Fig.6 Relationship of density on 7 days and Percentage of Foaming Agent

The lowest volume weight is PR 10 with 1,73 % foam agent and the highest is PR 40 with 1,33 % foam agent, volume weight of PR 10 is 0,73 gr/cm^3 and 0,96 gr/cm^3 for PR 50. It is normal that the increasing of foaming agent will decrease the volume weight.

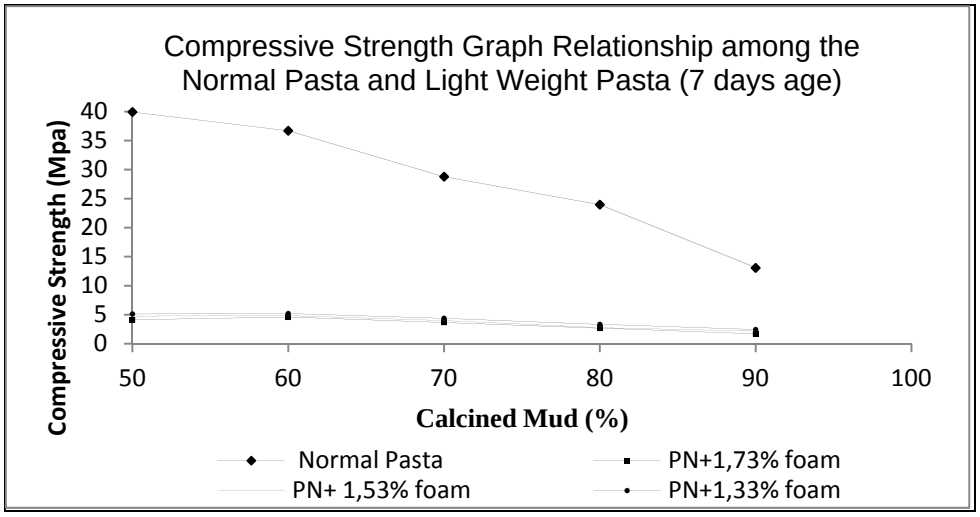

Fig.7 Relationship of Compresssive Strength among the Normal Binder and Lightweight Binder

At the age of seven days, the highest compressive stregnth of Normal Binder from PN 50 was 39,9 MPa and the lowest was PN 10 with the Compressive strength of 13 MPa. Addition of foaming agent will decrease compressive strength value, the highest compressive strength on lightweight binder was PR 40, with 1,33% foaming agent with the compressive strength 5,20 MPa and the lowest is PR 10, with 1,73% foaming agent with the Compressive strength of 1,68 MPa.

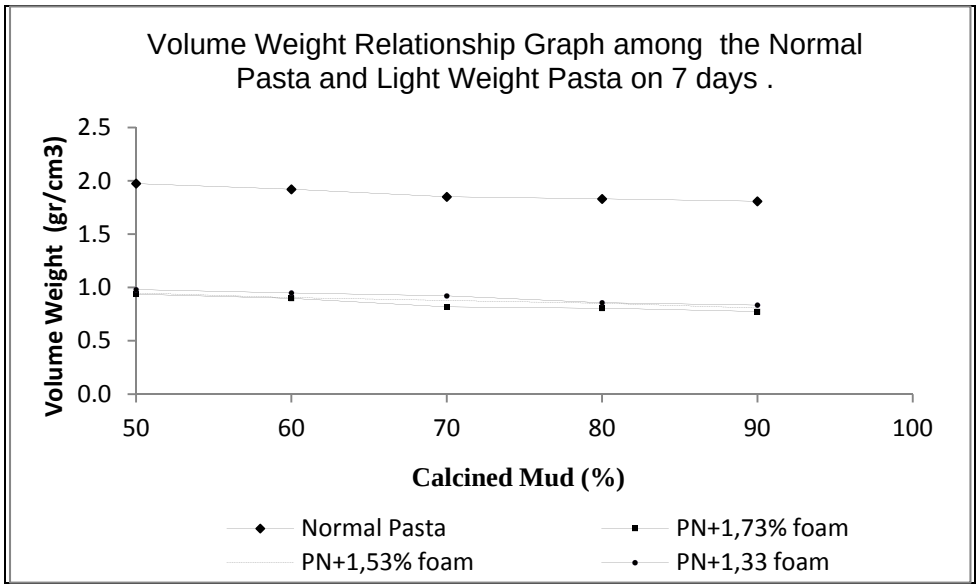

Fig.8 Relationship of volume weight among the Normal and Lightweight Binders

The lowest density of Normal Binder was PN 10 with the density of 1,81 gr/cm^3 and the highest is PN 50 with the density of 1,97 gr/cm^3.The addition of foaming agent will decrease the density , the lowest density of lightweight binder was PR 10, with 1.73% foaming agent with the density of 0,77 gr/cm^3 and the highest is PR 50, with 1,33% foaming agent with the density of 0,98 gr/cm^3.

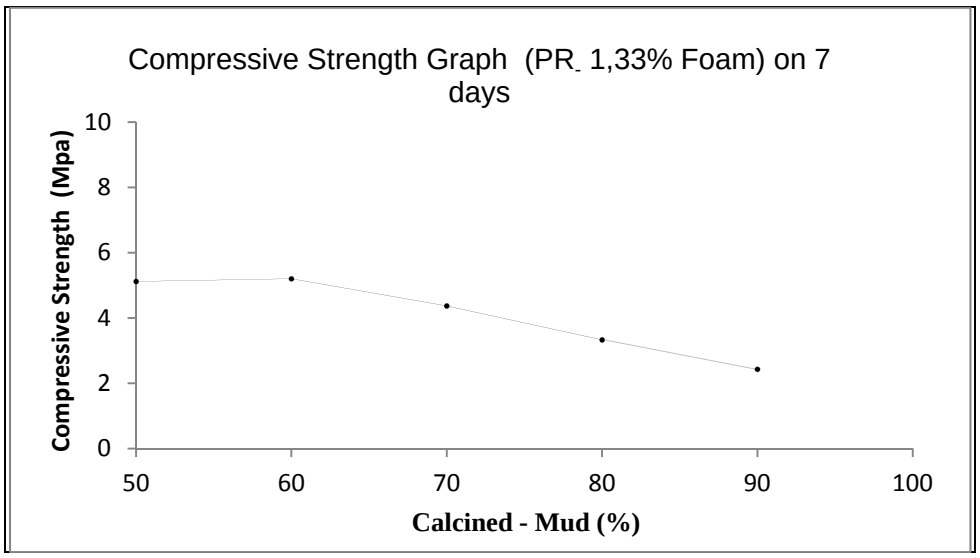

Fig.9 Graph of Lightweight binder with the maximum compressive strength

Fig. 9 shown graph of Lightweight binder with the maximum compressive strength. The maximum of compressive strength is PR 40 (40% PC, 60% Calcined-mud, 1.33% foam) with strength of 5.20 MPa. The compressive strength of PR 40-1,33 was higher than PR 50-1,33, since the closed porosity of PR 40-1,33 was more than the PR 50-1,33.

Fig. 10 shown that the best value of total porosity is PR 40, 1.33% foam agent, with the value of total porosity is 57,25%. As well for closed porosity values, the higher value of closed porosity is PR 40, 1.33% foam agent, with the value of closed porosity is 26.73%, while the PR50 is 19.66%.

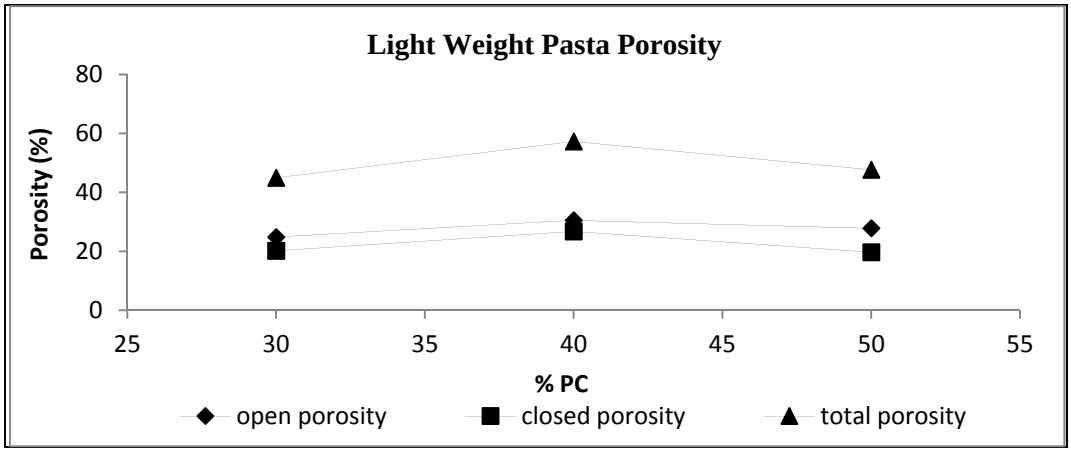

Fig.10 Porosity value of Lightweight Binder.

3.4.Fiber Lightweight binder

All the composition of lightweight binder were given fiber with the weight varying from 0.1% to 0.3% by weight of binder. Ratio of composition are shown in Table 5. Compressive strength result are given in Fig. 11 while the volume weight result are shown in Fig. 12.

Table 5 Ratio the Composition of fiber Lightweight binder

Sample Code	PC	Cal-Mud	Water	Foam	Kenaf Fiber	Age of Compression test
	(%) of binder weight	(%) of binder weight	(%) of PC weight	(%) of binder weight (ml)	(%) of binder weight	
MR-$10_{0.1}$	10	90	55	1.33	0,10	7 days
MR-$20_{0.1}$	20	80	55	1.33	0,10	
MR-$30_{0.1}$	30	70	55	1.33	0,10	
MR-$40_{0.1}$	40	60	55	1.33	0,10	
MR-$50_{0.1}$	50	50	55	1.33	0,10	
MR-$10_{0.2}$	10	90	55	1.33	0,20	7 days
MR-$20_{0.2}$	20	80	55	1.33	0,20	
MR-$30_{0.2}$	30	70	55	1.33	0,20	
MR-$40_{0.2}$	40	60	55	1.33	0,20	
MR-$50_{0.2}$	50	50	55	1.33	0,20	
MR-$10_{0.3}$	10	90	55	1.33	0,30	7 days
MR-$20_{0.3}$	20	80	55	1.33	0,30	
MR-$30_{0.3}$	30	70	55	1.33	0,30	
MR-$40_{0.3}$	40	60	55	1.33	0,30	
MR-$50_{0.3}$	50	50	55	1.33	0,30	

From the Fig. 11 it is shown that the maximum compressive strength present in mixture by 2% fiber, the higher strength is the MR 40 (40% PC, 60% Calcined-mud, 1.33% foam and 0,2% fiber) with the value 5.25 MPa. Similar with a mixture of normal binder, the highest compressive strength values achieved for mixtures by 2% fiber Fadyah et all (2012). Kim et all (2010) reported that the addition of fiber by 1-4% in the mixture caused reduce in compressive strength about 25%.

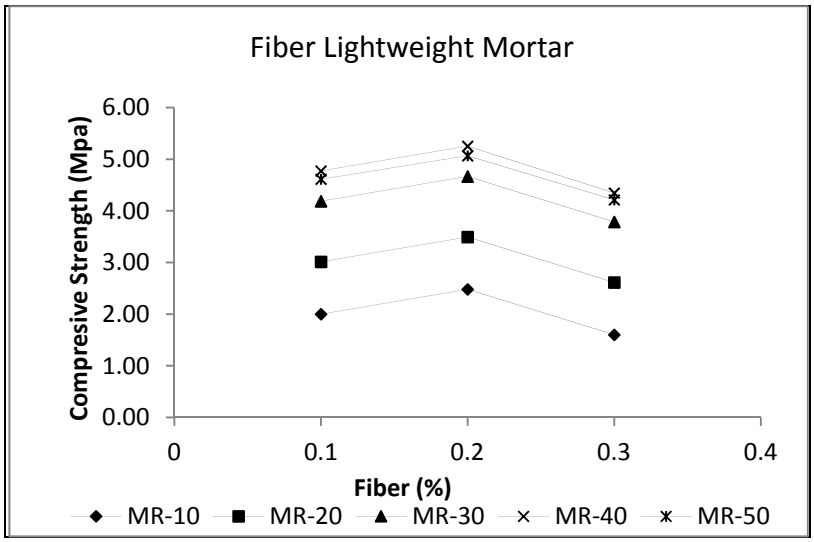

Fig.11. Relationship of Compressive Strength and Percentage of Fiber

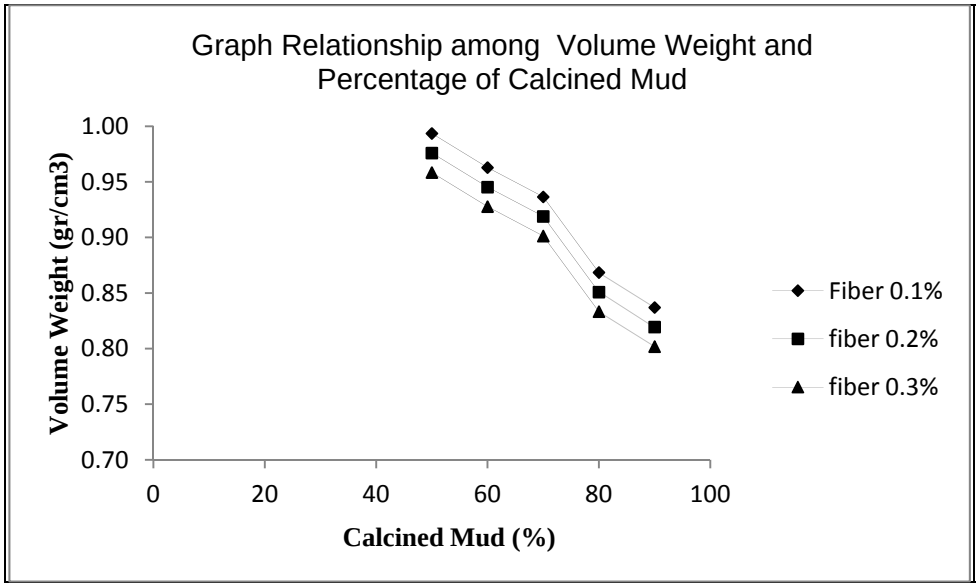

Fig.12 Relationship of Volume Weight and Percentage of Calcined-mud

The lowest volume weight value is MR 10 with 03% fiber (10% PC, 90% Calcined-mud, 1.33% foam and 0,3% fiber) with the value of volume weight is 0.8 gr/cm^3. But in this mixtures the value of compressive strength is very low 1.6 MPa lower than 2 MPa. The volume weight of MR 40 (40% PC, 60% Calcined-mud, 1.33% foam and 0,2% fiber) is 0.97 gr/cm^3.

4.CONCLUSIONS

1. The quantity of ($SiO_2 + Fe_2O_3 + Al_2O_3$) for calcined-Sidoarjo mud more than 70%, so the materials are classified as pozolanic material.
2. The normal binder mixtures, 7 days optimum compressive strength obtained at PN 50 (50% PC and 50% Calcined mud) by value of 39,9 MPa, but on lightweight binder mixtures, 7 days optimum compressive strength obtained at PR $40_{1,33}$ (40% PC, 60% Calcined mud and 1.33% foam) by the compressive strength of 5.2 MPa, and volume weight 0,95 gr/cm^3.
3. On the lightweight fiber binder mixtures, 7 days optimum compressive strength obtained at MR $40_{0.2}$ (40% PC,60% Calcined mud, 1.33% foam and 0,2% fiber) by the compressive strength of 5.25 MPa, and volume weight 0,947 gr/cm^3

5.REFERENCES

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