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The Effect of the Use of Types Sand on Physical and Mechanical Properties of *Reactive Powder Concrete* (RPC)

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ABSTRACT

Technology in the field of concrete construction continues to develop , this cannot be separated from the demands and needs of the community for increasingly advanced infrastructure facilities, such as bridges, dams that use high quality concrete. To achieve high-strength concrete requires special treatment of concrete. One of the concrete innovations that can be used is concrete with the reactive powder concrete *(RPC) method.* Reactive powder concrete *(RPC) is a concrete innovation that has a high compressive strength of up to 800 N/mm2 or 800 MPa.*

This RPC concrete uses a material with fine particles (powder) which is useful for reactions between all the constituent materials, so that the concrete becomes denser and stronger. In the manufacture of RPC concrete requires materials in the form of cement, sand, water and added materials. Where most of the volume of concrete is filled by fine aggregate, so that the characteristics of the fine aggregate used as a mixture in concrete play an important role in the physical and mechanical properties of the resulting concrete. The fine aggregate used in quartz sand must first be pulverized to be used in RPC concrete mixes.

In this study, the fine aggregates used include quartz sand and river sand. Using five variables, namely 100% quartz sand, 100% river sand and a mixture of river sand and quartz sand with different ratios. From the results of the research that has been done, it turns out that fine aggregate in the form of quartz sand and river sand with various composition variations affects the physical and mechanical properties of the RPC concrete obtained. And it can also be concluded that the best variation is in a 1:1 ratio for the use of quartz sand and river sand in the manufacture of RPC concrete.

KEYWORDS;- *River Sand, Quartz Sand, High Strength Concrete, Reactive Powder Concrete, Physical and Mechanical Properties*

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I. INTRODUCTION

In the early 1990s in France, one of the new breakthroughs in the field of concrete material technology was the introduction of *reactive powder concrete* (RPC), or reactive powder concrete. This material was developed by researchers at the Henningston, Durham and Richardson (HDR) Laboratory at the Bouygues SA company in Paris, France. Then Pierre Claude Aitcin, director of Concrete Science Canada at Sherbrooke University, first applied RPC to a pedestrian and bicycle bridge structure in Sherbrooke, Quebec, Canada. RPC has the characteristics of high compressive strength, ductility and durability. *Properties* that have been produced in the HDR Bouygues laboratory are in the form of compressive strengths reaching 200-800 MPa (Richard, 1996). RPC is still very rarely used, this is because RPC technology is still developing and needs further research.

RPC concrete uses materials with fine particles that are useful for minimizing empty voids, so that the concrete becomes denser and stronger, because the materials that make up RPC concrete are smooth so that they interact with one another. The weight of the RPC produced is lighter than normal concrete because RPC does not use coarse aggregate or stone. Based on RSNI 2847:2018 normal concrete weight ranges from 2,320 to 2,400 kg/m^3, while the results of research conducted by Richard and Cheyrezy (**1994: 6**) RPC concrete has a weight ranging from 1,900 to 2,100 kg/m^3 . Because it is made from aggregates of micro materials, the finished concrete has homogeneity, compactness and high durability. RPC containing micro materials, one of which is silica, is also able to react at higher temperatures in the manufacturing process, thereby accelerating the increase in the compressive strength of concrete. With this series of advantages, RPC can be made with smaller and thinner sections without reinforcement. RPC can also be used for the manufacture of architectural precasts.

This study aims to determine the physical and mechanical properties that can be achieved by using quartz sand and river sand as a mixture of RPC concrete. So that this research can be used as infrastructure development by utilizing quartz sand and river sand in West Kalimantan.

II. METHOD

This research study is divided into 2 (two) parts, namely:

1. Study of literature
2. Experimental Study

Where the study of literature aims to examine the relationship between the variables to be studied, by studying existing theories and how to collect data. Through literature study, research hypotheses will be born which are temporary answers to existing problems.

This experimental study was carried out in the laboratory by making a number of test objects to be tested so that the necessary data were obtained, after the data were analyzed it could be used to test the hypothesis so that a conclusion was obtained.

This study will examine the RPC concrete with a ratio of sand variations, then the best sand variation and in accordance with the final goal of this research is to produce the best RPC concrete and in accordance with the compressive strength plan.

2.1. Analysis of Materials

The materials to be used in the RPC concrete mix should be analyzed first. This analysis is carried out to determine the properties of these materials, such as water content, specific gravity, volume weight and other materials, which can affect the setting time, because these properties can affect the design calculations *(mix design* of RPC concrete later. The materials used in this research are as follows:

1. The cement used is 4 brands of PCC and 1 brand of PPC.
2. The sand to be used is quartz sand with a size of 1.18
3. The water used is PDAM water with a PH of 6-7.
4. Superplasticizer with the trademark Sikamen LN issued by PT Sika
5. The Sika fume used is the trademark Sikacim from PT Sika
6. The planned compressive strength is 60 MPa.
7. W/C used 0.33
8. The composition of the mixture will be based on the journal.

2.2. Research Place

This research was carried out at the Structure and Materials Laboratory, Faculty of Engineering, Untan

2.3. Population and Sample

The population is all objects to be studied in this study, namely the shape of a cylinder with the following sizes:

1. Cylinder with a diameter of 150 mm, and a height of 300 mm
2. Cylinder with a diameter of 100 mm, and a height of 200 mm

No	SAMPLE	Cylindrical Test Object						
		Compression Streght					Split Tensil	Modulus of Elasticity
		Days					Days	Days
		3	7	14	21	28	28	28
1	V1 (100% Quartz Sand)	5	5	5	5	5	3	3
2	V2 (100% River Sand)	5	5	5	5	5	3	3
3	V3 (Quartz Sand 50% River 50%)	5	5	5	5	5	3	3
4	V4 (Quartz Sand 40% River 60%)	5	5	5	5	5	3	3
5	V5 (Quartz Sand 60% River 40%)	5	5	5	5	5	3	3
TOTAL		125					30	

Table 1 List of Test Object Samples

2.4. Material Inspection

Inspection of materials as follows:

2.4.1. Cement

This inspection is carried out visually on the cement used, namely PCC cement which has met the Indonesian National Standard (SNI 15-7064-2004 and 15-0302-2004).

2.4.2. Fine Aggregate (Quartz Sand)

For sand inspection includes:

1. Examination of Organic Content in Sand Aggregate

2. Checking Sludge Aggregate Levels of sand
3. Sand Aggregate Moisture Check
4. Sand Aggregate Gradation Inspection
5. Specific Gravity and Water Absorption Sand Aggregate

2.4.3. Water

The water used is taken from the PDAM on Perdana street no 257 where RPC is made. However, in this study, the chemical content of water was not investigated.

2.4.4. Superplasticizer

This inspection is carried out visually and by examining the composition of the brochure, which is planned to use the LN type.

2.4.5. Silica Fume

This inspection is carried out visually and by reviewing the composition of the existing brochure. With a composition based on previous research.

3.5. RPC Concrete Testing

Tests carried out for RPC include:

1. Slump Test
2. Compressive Strength Test
3. Split Tensile Strenght Test
4. Elasticity Modulus Test

NO	TESTING TYPE	TESTING TIME (DAYS) AND NUMBER OF TESTING OBJECTS				
		CYLINDER				
		3	7	14	21	28
1	Split Tensile Strength Test					15
2	Compressive Strength Test	25	25	25	25	25
3	Modulus of Elasticity					15

Table 2 Table of Time and Number of Test Objects for 1 Sample Variation

IV. RESULTS AND DISCUSSION

RPC concrete is the final subject of this research. RPC concrete research used a cylindrical specimen with dimensions of 100 x 200 mm and 150 x 300 mm. The material composition plan was obtained from previous research, namely from journal materials using water per binder (w/c) of 0.28. The cylindrical concrete mix design uses different sands, namely quartz sand and river sand. The independent variables used were the volume of quartz sand and river sand used.

4.1 Slump Test

Slump testing is very important to determine the level of workability and the resulting material. Where the slump test is carried out. The data from the research that has been done obtained the following data:

No	Variation	Slump Test (cm)
1	Variation 1	3.0
2	Variation 2	6.0
3	Variation 3	8.0
4	Variation 4	4.0
5	Variation 5	9.0

Table 3 . Slump Test

From the results of the slump, it can be concluded that based on the plan, the slump is 3-6 cm. Thus for variations 3 and 5 do not meet the requirements of the plan. Thus the resulting RPC concrete will not go according to plan. And also the results will be smaller than the original plan.

Variations 1 to 5 have a low or thick level of workability. Thus, a better quality of RPC concrete will be obtained, because a small slump will produce stronger concrete compared to a large slump. Where required in the manufacture of structural concrete (SNI 2002) the ideal slump is 25-100 mm.

4. 2 Volume/Fill Weight Test

The results of the average volume/content weight of RPC concrete bricks that have been tested for a sample size of 150 mm x 300 mm from each variation for each age obtained the following data:

No	Samples	Volume Weight (Kg/m3 / day)				
		3	7	14	21	28
1	Variation 1	2,237.129	2,226.754	2,211.664	2,202.233	2,192.801
2	Variation 2	2,222.982	2,212.607	2,195.631	2,183.37	2,172.052
3	Variation 3	2,189.972	2,173.939	2,161.678	2,134.327	2,132.44
4	Variation 4	2,190.915	2,187.143	2,143.758	2,140.929	2,130.554
5	Variation 5	2,121.123	2,092.829	2,090.942	2,085.283	2,033.411

Table 4 Volume Weight

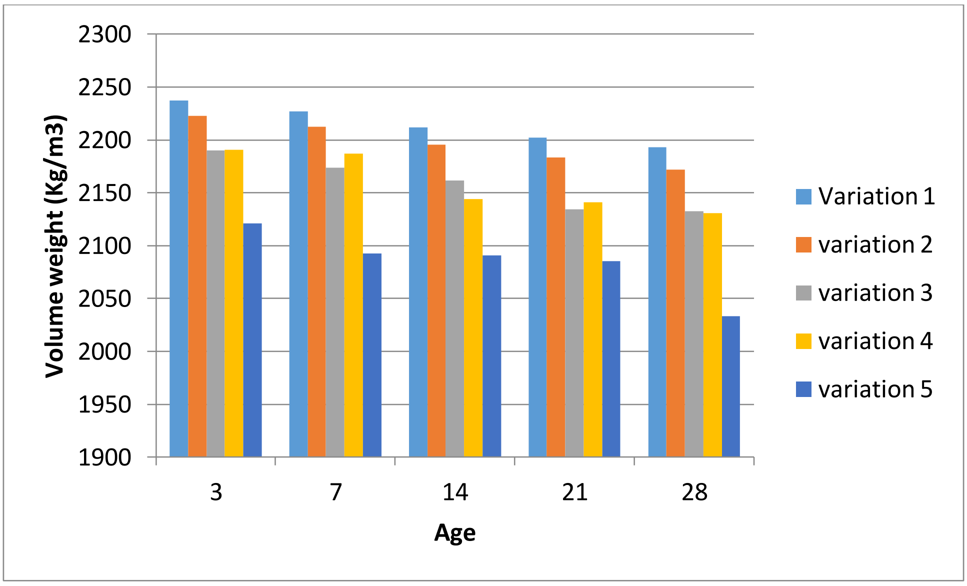

Figure 1 Volume Weight Barchart with Variations

From the table, we can see that the volume weight of RPC concrete at the age of 28 days is 2033,411 – 2192,801 Kg/m3. So that RPC has a volume weight that is smaller than normal concrete of above 2200 kg/m3. Thus, RPC concrete is included in lightweight concrete.
From the barchart, we can see that for all variations in weight the volume will decrease with increasing age of this RPC concrete. This is due to a reaction in the RPC concrete which causes the water contained in the RPC concrete to evaporate due to the hydration process in the RPC concrete.

4.3 Compressive Strength Test

The results of the compressive strength test of RPC concrete that have been tested for a sample size of 150 mm x 300 mm from testing 15 samples per each variation for each age obtained the following data:

Samples	Average Compressive Strength (Days) (MPa)				
	3	7	14	21	28
Variation 1	23,682	30.558	35,396	35,965	57,449
Variation 2	22.536	23,682	27,629	34,046	55.768

Variation 3	18.008	25,210	32.503	48,383	50,292
Variation 4	18,335	29.991	30,685	46,473	62,389
Variation 5	14.756	23,810	31.309	40,234	50,802

Table 5 Average Compressive Strength of each variation VS Age

From the table, it can be seen that the RPC concrete of each variation was taken from 15 samples that had been made, which resulted in an average compressive strength of 28 days between 50.292 – 62.389 MPa. From the results obtained, the greatest compressive strength is variation 4 using a mixture of 40% quartz sand and 60% river sand, while the lowest is variation 3 using a 50% river sand and 50% quartz sand mixture. From the table we can also see that the compressive strength of RPC concrete from the age of 3 days to 28 days experienced an increase in strength.

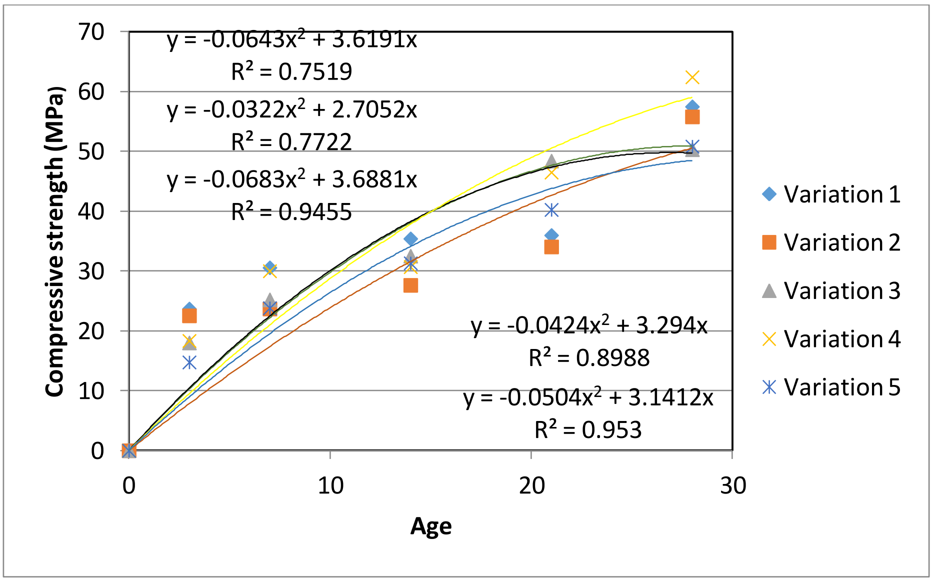

Figure 2. Graph of Compressive Strength Vs Concrete Age

From the graphs and tables above, it can be concluded that with increasing age of concrete, the resulting compressive strength will increase non-linearly. And from the results obtained, it turns out that only variation 4 reaches a design strength of 60 MPa.

4.4. Elasticity Modulus Test

The results of the elastic modulus of RPC concrete that have been tested for a sample size of 150 mm x 300 mm from testing 3 samples per each variation for each age obtained the following data:

No	Samples	Average Modulus of Elasticity (Ec) MPa
1	Variation 1	34,185
2	Variation 2	32,674
3	Variation 3	32,295
4	Variation 4	34,020
5	Variation 5	30,453

Table 6 Modulus of elasticity based on the test

From the table it can be seen that the RPC concrete of each variation was taken from the 3 samples that had been made, which resulted in an average modulus of elasticity of 28 days between 30,453 – 34,185 MPa. From the results obtained, the largest modulus of elasticity is variation 1 using a mixture of 100% quartz sand, while the lowest is variation 5 using a mixture of 60% quartz sand and 40% river sand. From the results obtained, it turns out that the modulus of elasticity of RPC concrete is greater than normal concrete.

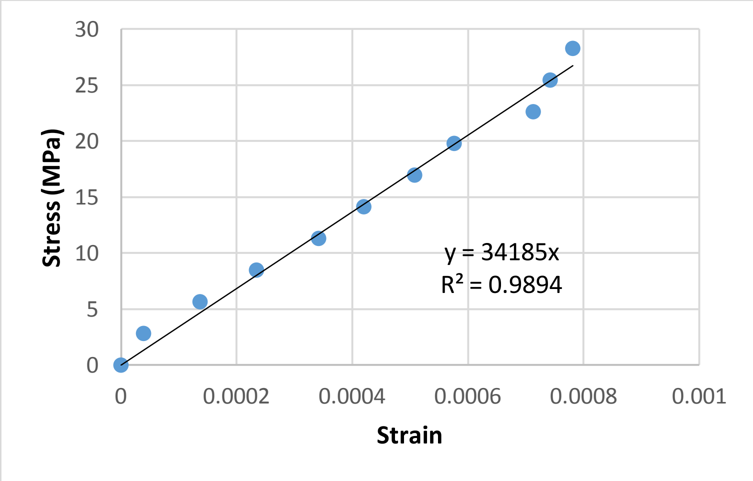

Figure 3 Chart of Stress Vs Strain Variation 1

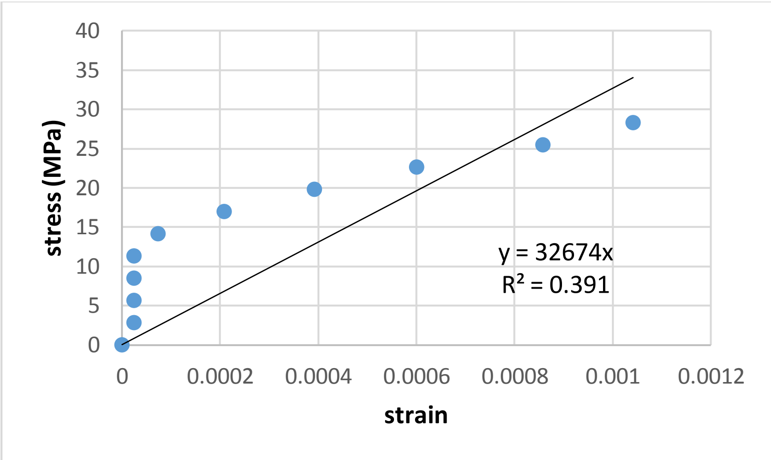

Figure 4 Chart of Stress Vs Strain Variation 2

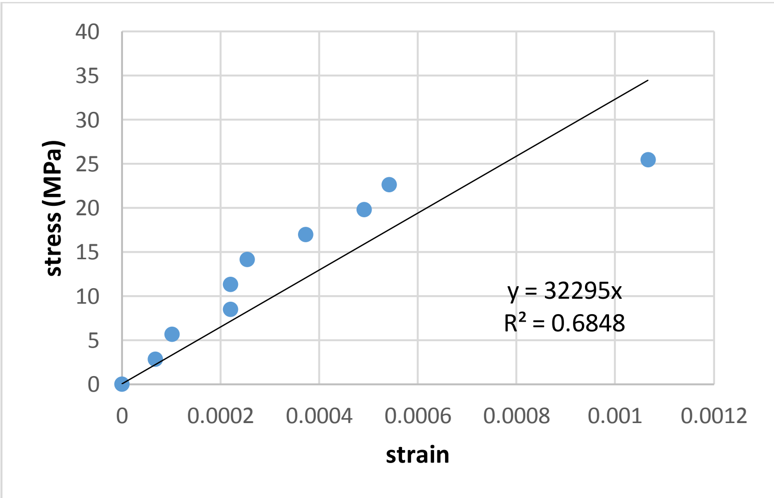

Figure 5 Chart of Stress Vs Strain Variation 3

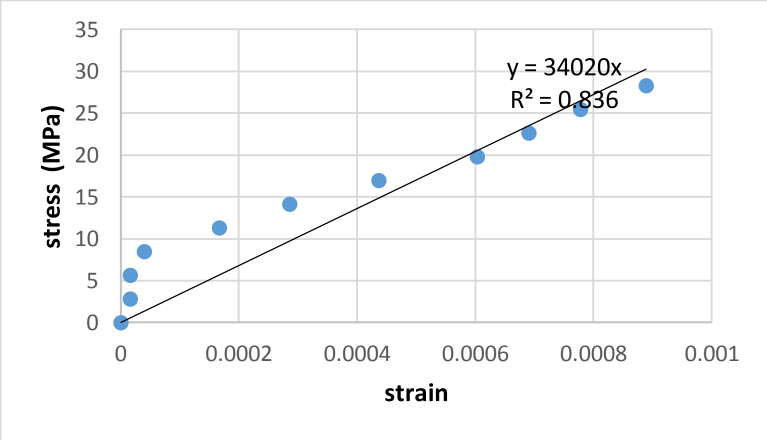

Figure 6 Chart of Stress Vs Strain Variation 4

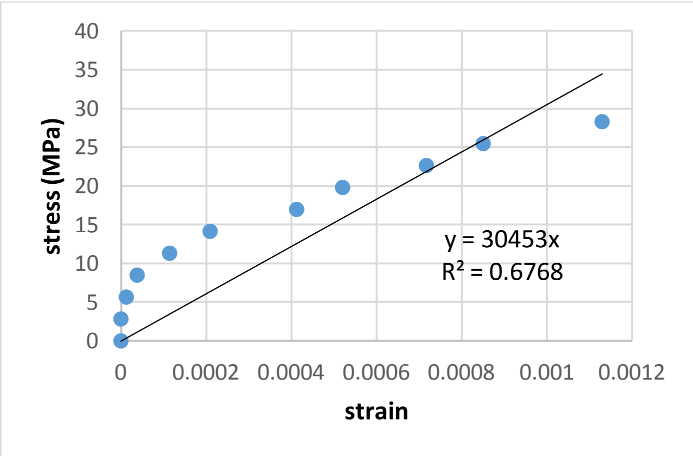

Figure 7 Chart of Stress Vs Strain Variation 5

Meanwhile, if you use the equation issued by S **NI 2847:2018** :

Ec = $Wc^{1.5}$. 0.043 fc′ MPa

Wc = weight of concrete

fc' = Compressive Strength of Concrete

No	Samples	Average Modulus of Elasticity (Ec) MPa
1	Variation 1	34,986.89
2	Variation 2	34,558,70
3	Variation 3	30,437.80
4	Variation 4	35,240,50
5	Variation 5	31,027.21

Table 7 Modulus of elasticity based on SNI

From the table it can be seen that the RPC concrete of each variation produces a modulus of elasticity of 30,558,70 – 35,240,50 MPa. From the results obtained, the largest modulus of elasticity is variation 4 using a mixture of 40% quartz sand and 60% river sand, while the lowest is variation 3 using a mixture of 50% quartz sand and 50% river sand.

4.5 Split Tensile Strength Test

The tensile strength value is obtained by entering the maximum value when the test object is destroyed and split into 2 parts.

NO	Samples	Average Split Tensile Strength (MPa)
1	Variation 1	12.30
2	Variation 2	10.44
3	Variation 3	10.81
4	Variation 4	12.22
5	Variation 5	10.07

Table 8 Data on Split Tensile Strength of RPC Concrete

From the table it can be seen that the RPC concrete of each variation was taken from the 3 samples that had been made, which resulted in an average split tensile strength of 30 days between 10.07 – 12.30 MPa. From the results obtained, the largest split tensile strength is variation 1 using a mixture of 100% quartz sand, while the lowest is variation 5 using a mixture of 40% river sand and 60% quartz sand. If we compare the resulting compressive strength, we will get the percentage reduction of the compressive strength which can be seen in the table below:

NO	Samples	Percentage (%) split tensile strength of compressive strength
1	Variation 1	21.4%
2	Variation 2	18.7%
3	Variation 3	21.5%
4	Variation 4	19.6%
5	Variation 5	19.8%

Table 9 Percentage of Split Tensile Strength Vs Compressive Strength

The split tensile strength of concrete is relatively low, about 10%-15% of the compressive strength of concrete, sometimes reaching 20%. This strength is more difficult to measure and the results vary from one experimental material to another than for pressure cylinders (*Ferguson, 1986; 11*). If we see from the results obtained that the value of % RPC concrete already meets the above statement because it is obtained between 19.6% - 21.5%.

4.6 Correlation Factor

From the compressive strength at age 28, we will get the correlation factors for ages 2, 7, 14, 21 and 28 days as follows:

Samples	Correlation Factor				
	3	7	14	21	28
Variation 1	0.41	0.53	0.62	0.63	1
Variation 2	0.40	0.42	0.50	0.61	1
Variation 3	0.36	0.50	0.65	0.96	1
Variation 4	0.29	0.48	0.49	0.74	1
Variation 5	0.29	0.47	0.62	0.79	1

Table 10 Correlation Factors of RPC Concrete

This correlation factor is very necessary if we want to know the compressive strength of concrete at the age of 28 days at the beginning of the RPC concrete age. So that it will make it easier for us to work on and predict the strength of the RPC concrete that we make.

If the results of the correlation factor above are compared with the correlation factor for normal concrete based on PBI 71 as follows:

Samples	Correlation Factor				
	3	7	14	21	28
Portland cement with high initial strength	0.55	0.75	0.90	0.95	1

Table 11 . Normal Concrete Correlation Factor

Where the approach is for Variation 3, while for the other variations it is not close. Maybe because RPC is a high-strength concrete, the possibility for 28 days of strength is still increasing with age. So there is still a need for research until it is 365 days old according to PBI 71.

V. CONCLUSION

Based on the analysis of the research results, several conclusions can be drawn as follows:

1. Gradation of fine aggregate in the form of quartz sand obtained fineness modulus for quartz sand including zone IV and fine quartz sand 1.744. The quartz sand gradation falls into the upper and lower intervals for zone IV with a max size of 1.18 mm. The specific gravity of the quartz sand used is between 2,576 Kg/m3. The absorption of quartz sand used is between 0.361%. The average volume weight of the quartz sand is 1,543 kg/m ^{3} and the organic content contained in the quartz sand does not exceed the tolerance (standard color No. 3). The silt content contained in the quartz sand is less than 5%, the water content of the quartz sand for the RPC concrete mix is 5.99%. So it can be concluded that quartz sand aggregate can be used as a mixture in the manufacture of RPC concrete because its physical properties have met the standard as fine aggregate.
2. Gradation of fine aggregate in the form of river sand obtained fineness modulus for quartz sand including zone III and fine quartz sand 2.240. The quartz sand gradation falls into the upper and lower intervals for zone IV with a max size of 2,380 mm. The specific gravity of the quartz sand used is between 2,615 Kg/m3. The absorption of quartz sand used is between 0.361%. The average volume weight of the quartz sand is 1,660 kg/m ^{3} and the organic content in the quartz sand does not exceed the tolerance (standard color No. 3). The silt content contained in the quartz sand is less than 5%, the water content of the quartz sand for the RPC concrete mix is 5.99%. So it can be concluded that quartz sand aggregate can be used as a mixture in the manufacture of RPC concrete because its physical properties have met the standard as fine aggregate.
3.
4. The results of the sand analysis can be seen in the table below:

No	Testing	Quartz sand	River Sand
1	Absorption (absorption) %	0.361	0.422
2	Apparent Density kg/m ^{3}	2,600	2,633
3	Volume weight kg/m ^{3}	1,543.33	1.5800
4	Water content %	5.99	5.99
5	Fine Modulus of Grain (MHB)	1,744	2,240
6	Organic Substance Content	3	5
7	Mud Content %	1.351	1.515
8	Gradation of details	Fine Sand	Medium sand

Table 12 Fine Aggregate (Sand) Inspection Results

In PCC cement, the largest elements are calcium oxide (CaO) or lime, silicon dioxide (SiO_2), aluminum oxide (Al_2O_3) and ferric oxide (Fe_2O_3). The cement used includes cement II, which has a high-early-strength-Portland-cement. This type gains great strength in a short time, so it can be used for the manufacture of RPC concrete.

4. The water used is PDAM water with a PH of 6 -7 and clean conditions because the water can be used for drinking water, thus the water has met the standards and can be used for mixing in the manufacture of RPC concrete.
5. In this study, Sikamen LN was used as a chemical admixture to reduce the use of water, formulated for the precast concrete element industry, to increase the initial strength of the concrete so that the formwork can be released quickly and can be used as much as possible so that the time used can be used faster. Where Sikamen LN is a type F chemical admixture with high initial strength and water reduction, making it suitable for the manufacture of RPC concrete. Its specific gravity is 1.22 ± 0.01 kg/L at 2+20 °C. The usage varies for each variation, for variation 1 as much as 7.16 kg, variation 2 as much as 6.78 kg, variation 3 as much as 6.03 kg, variation 4 as much as 4.90 kg, and variation 5 as much as 3.77 kg.

6. In this study, Selica Fume was used as a mineral admixture to provide excellent internal cohesion and water retention in fresh concrete. The concrete becomes highly pliable and the pump ability is substantially improved. In hardened concrete, the later reactive silica fume forms chemical bonds with free lime (CaOH2). The hydration product formation additive resulted in a significantly denser cement matrix . Where Sika Fume is a type F admixture mineral with the following properties:
   - High stability
   - eco-friendly concrete
   - Greatly increased endurance
   - Salt Resistant
   - Ultimate power increase
   - Improved abrasion resistance
   - Improved water abrasion resistance
   - Increased viscosity of gas
   - Reduces chloride penetration
   - SikaFume does not contain chlorides or other corrosion-inducing agents for steel, and therefore can be used without limitation for the construction of prestressed concrete

7. The specific gravity is 0.65 kg/l and the chloride ion is < 0.3 M%. . The use is 28.64 kg, so it is 11.40% by weight of cement. It turned out to exceed the existing brochure 5-10% of the weight of cement. Because this is based on previous research where the basis is in making high-strength concrete that is used is between 15-25% of the weight of cement.

8. All variations for the slump test were obtained on average above 30-90 mm, this means that the mixture of variations 1 to 5 has a low or viscous level of workability. Thus, a better quality of RPC concrete will be obtained, because a small slump will produce stronger concrete compared to a large slump. Where required in the manufacture of structural concrete (SNI 2002) the ideal slump is 25-100 mm.

9. The average volume weight/content of RPC concrete is between 2033,411 – 2192,801 kg/cm [3.] The volume weight of RPC concrete in general will be lighter with increasing age of the concrete. This is due to a reaction in the RPC concrete which causes the water contained in the RPC concrete to evaporate due to the hydration process in the RPC concrete.

10. The average compressive strength for the age of 28 days is between 50.292 – 62.389 MPa. From the results obtained the greatest compressive strength is variation 4 using a mixture of 40% quartz sand and 60% river sand while the lowest is variation 3 using a mixture of 50% river sand and 50% quartz sand. The compressive strength of RPC concrete from the age of 3 days to 28 days experienced an increase in its compressive strength along with the age of the RPC concrete. And from the results obtained, it turns out that only variation 4 reaches a design strength of 60 MPa.

11. RPC concrete produces an average modulus of elasticity of 28 days between 30,453 – 34,185 MPa. From the results obtained, the largest modulus of elasticity is variation 1 using a mixture of 100% quartz sand, while the lowest is variation 5 using a mixture of 60% quartz sand and 40% river sand. From the results obtained, it turns out that the modulus of elasticity of RPC concrete is greater than normal concrete, where Ec for normal concrete is 21000 MPa.

12. RPC concrete produces an average split tensile strength of 28 days between 10.07 – 12.30. From the results obtained, the largest split tensile strength is variation 1 using a mixture of 100% quartz sand, while the lowest is variation 5 using a mixture of 60% quartz sand and 40% river sand. From the results obtained, it turns out that the split tensile strength of RPC concrete is greater than normal concrete, namely from 19.6%-21.5% of its compressive strength, while normal concrete is 10%-15% of normal concrete compressive strength.

13. From the conclusions above, the H1B hypothesis which states that there is an effect of variations in the use of quartz sand and river sand on the physical and mechanical properties of RPC concrete is evident from the conclusions above. This can be seen from the physical and mechanical properties of the resulting concrete.

14. Judging from the results obtained, the best variation (optimum) is variation 4 (40% quartz sand and 60% river sand) in terms of its physical and mechanical properties.

15. The following table summarizes the results of the RPC concrete test using a mixture of sand types with several percentages:

Testing	Variations				
	1	2	3	4	5
Slumps (mm)	30	60	80	40	90
Volume Weight (Kg/m3)	2,192.801	2,172.052	2,132.44	2,130.554	2,033.411
Compressive Strength (Mpa)	57.449	55.768	50.292	62.389	50.802

Modulus of Elasticity (Mpa)	34.185	32.674	32.295	34.020	30.453
Split Tensile (Mpa)	12.30	10.44	10.81	12.22	10.07

Table 13 . Recapitulation of RPC Concrete Test Results

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