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The Impact of Resin as a Substitute for Cement (Polymer) and Ceramic as a Substitution of Fine Aggregate in High-Quality Concrete

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Abstract

Infrastructure is the entire structure and basic facilities needed by the community to support various community activities in daily life. The infrastructure consists of technical facilities, physical, systems, hardware, and software needed to provide services to the community and support the network structure so that the economic and social growth of the community can run well. Concrete is a material that is formed from mining products, therefore concrete has an impact on the environment. The research method used is an experiment using SNI 7656;2012 as a reference. This test was carried out by making 27 concrete samples measuring 15 x 30 cm, 9 samples of polymer concrete with 15% ceramic variation, 9 polymer concrete with 17% ceramic variation, and 9 conventional concrete as comparisons. Polymer concrete has a compressive strength of 31.53 MPa for the 15% ceramic variation and has the highest compressive strength of 32.22 MPa for the 17% variation. The compressive strength of polymer concrete with a variation of 15% is 5.69% stronger than normal concrete, while polymer concrete with a variation 17% is 11.36% higher than normal concrete.

Keywords:
Ceramic Waste, Polymer Concrete, Resin

1. Introduction

Economic growth is a target that is always expected by the government to support the growth and advancement of a country. There are three main pillars in supporting the economic growth of a country: technology, innovation, and infrastructure (Maryaningsih et al., 2014).

Infrastructure is all the basic structures and facilities needed by the community to support various community activities in everyday life (Azizah, 2021). According to N. Gregory Mankiw, the notion of infrastructure is "a form of public capital or public capital which consists of bridges, public roads, sewer systems, and others as one of the investments made by the government". Meanwhile, according to Robert J. Kodoatie infrastructure is "a system that supports the economic and social systems which also mediate the environmental system. Where the system can be used as one of the bases in making policy.

Infrastructure consists of technical, physical, system, hardware and software facilities needed to provide services to the community and support structural networks so that economic and social growth of the community can run well (Ofori-Atta, 2017). Currently the process of infrastructure development is very massive. The construction of toll roads, ports and railways. The most commonly used material for supporting structures is concrete.

Concrete is a composite material consisting of several main materials such as cement, fine aggregate, coarse aggregate, and water in certain proportions (Tjokrodimuljo, 1992). Concrete is often used because it has a more economical value when compared to steel structures. In addition to being more economical than steel, concrete also has several advantages such as being easy to shape according to design, having good compressive strength, easily available raw materials, durable, resistant to fire, not rotting, and can be shaped in the project area (Pane et al., 2015).

Concrete is a material formed from mining materials, therefore concrete has an impact on the environment. Cement water in the process of forming concrete also has a bad impact and pollutes the surrounding environment if it seeps into the ground. In addition, because concrete is a mining material, over time it will run out so that concrete can no longer be made. On this basis, this research was made to be able to replace some of the functions of the concrete constituent materials using resin and ceramic fragments.

Epoxy resins are one of the types of polymers derived from the thermoset group. Epoxy resins are often used for structural materials. In epoxy resin concrete can be used to speed up the concrete drying process due to the heat effect caused (Van Gemert et al., 2005).

Ceramic fragments are waste that is commonly found in the project area. This waste is mostly produced due to residue during the finishing process and due to damage during the installation process. In this study, ceramic waste was used to replace part of the function of sand. In a study conducted by Ahmad Syamsul Huda and Suprapto., M.T from Surabaya State University, it was shown that the replacement of sand with ceramic waste resulted in an increased compressive strength of concrete. Replacement of 6% of sand waste against sand increases the quality of concrete by 9.66% (Huda & Suprapto, 2013).

2. Literature Review

2.1. Concrete

Based on SNI 2847:2013, concrete is a mixture of portlannd cement or other hydraulic cement, aggregate (coarse and fine), water, with or without added materials (admixture). The concrete will harden over time, it will reach its planned strength (f'c) at the age of 28 days. Concrete has good compressive strength, therefore it is very often used in the selection of major types of structures such as bridge, building and road structures. Concrete can be distinguished by the weight of its contents, normal concrete and heavy concrete. According to SNI 7656:2012, Normal concrete is a type of concrete that has a content weight of 2200 kg/m^3 to 2500 kg/m^3, while heavy concrete is concrete that has a content weight of more than 2500 kg/m^3. Meanwhile, according to (Mulyono, 2004) there are several types of concrete used in the construction of a building, namely as follows:

1. Normal concrete is concrete that uses normal aggregates.
2. Reinforced concrete is concrete that uses reinforcement with the amount and area of reinforcement without prestress and is planned based on the assumption that the two materials work together in resisting the working force.
3. Precast concrete is concrete whose concrete elements are without or with reinforcement molded in different places from the final position of the element in the structure.
4. Prestressed concrete is concrete where a stress has been applied in the form of reducing the potential tensile stress in the concrete due to the exertion of the working load.
5. Lightweight concrete is concrete that uses a light aggregate or a mixture between light coarse aggregate and natural sand in lieu of light fine ageragat with the provision that it must not exceed the maximum fill weight of concrete 1850 kg/m3 of dry air and must meet the requirements of compressive strength and tensile strength of lightweight concrete for structural purposes.

2.2. Cement

The cement commonly used as a concrete material is Portland cement. Portland cement is cement produced from the hydraulic process produced by boiling clinker consisting of calcium silicate silicate which is hydrolyzed with a cast as an added material.

Cement that exists and can be used in Indonesia can be divided into 7 types. According to the Public Works Office of Housing and Housing Areas of Bantul Regency, the 7 types of cement are as follows:

1. Portland Cement
2. Water proofed cement
3. White cement
4. High aluminum cement
5. Anti-bacterial cement
6. Oil well cement
7. Mixed cement

2.2.1. Portland Cement

Portland cement is a type of hydrolyzed cement produced by grinding Portland cement slag, especially consisting of calcium silicate which is hydrolyzed and ground together with tambhana material in the form of one or more crystals of calcium sulfate compounds and can be added with other additives (SNI 7656: 2012). Portland cement is divided into 4 types

1. Portland cement type 1 : This type of cement is intended for general use that does not require special requirements as in other types.
2. Portland cement type 2 : This type of cement in its use requires high resistance to sulfates or moderate hydration levels.
3. Portland cement type 3 : Cement of this type requires high strength at the initial stage after binding occurs.
4. Portland cement type 4 : This cement is a cement that in its use requires low hydration heat.

2.2.2. Water Proofed Cement

This cement is a homogeneous mixture between Portland cement and "Water proofing agent" in small quantities.

2.2.3. White Cement

White cement is a type of cement whose designation is only for decorative purposes, and is not intended as a constructive material.

2.2.4. High Aluminum Cement

This cement can produce concrete with a fast hardening speed and is resistant to sulfuric, acidic but not resistant to alkali.

2.2.5. Anti-Bacterial Cement

This cement is a mixture of Portland cement with an "anti-bacterical agent". Concrete of this type is resistant to bacterial and fungal attacks.

2.2.6. Oil Well Cement

This cement is a Portland cement mixed with retarder material. This retarder material serves to reduce the hardening speed of cement, so that this cement can be pumped into oil or gas wells.

2.2.7. Mixed Cement

This cement was made because of the need for special properties that Portland cement does not have. These types of cement include:

1. Portland pozzolan cement (SPP)
2. Portland pozzoland cement (PPC)
3. Porltand blast furnance slag cement
4. Cement masonry
5. Mixed Portland Cement (SPC)
6. Portland composite cement (PCC)

2.3. Aggregate

Aggregates are natural minerals that serve as constituent materials in concrete mixtures. The aggregate of its shape is close to spherical with a grain size of 0.063 mm – 150 mm. The aggregate fills approximately 70% to 75%, the selection of a good aggregate will affect the properties of the concrete. therefore Aggregate selection is an important part in concrete making

2.3.1. Coarse Aggregates

Coarse aggregates are natural desintegrations of rocks or in the form of crushed stone with a size of 4.76 mm – 150 mm. Based on the weight of the aggregate can be 3, namely:

1. Normal Aggregates : These aggregates are generally derived from ballast, granite, kwarsa and so on. This aggregate has a specific gravity of 2.5-2.7 gr/cm^2.
2. Heavy Aggregates : This aggregate is generally derived from iron powder, barite, and limonite which has a specific gravity of more than 2.8 gr/cm^3. Concrete using this aggregate has a concrete specific gravity of up to 5 gr/cm3. This concrete is used as an X-ray retaining wall.
3. Lightweight Aggregates : This aggregate has a specific gravity of less than 2 gr/cm^3. Usually this aggregate is used in non-structural concrete. This lightweight aggregate has a high absorption rate, so it can accelerate the hardening of the concrete. The advantage of this lightweight aggregate is that it can produce a lightweight structure.

According to SNI-03-2461-2002 there are several parameters of rough aggregate checks.

1. Sludge content
2. Organic matter content
3. Smooth modulus
4. Eternity
5. Absorption
6. Violence
7. Wear
8. Alkali recativeness
9. Flattened aggregate + length

2.3.2. Fine Aggregates

In the manufacture of fine aggregate concrete can be natural sand as a natural desintegration of natural rock rocks, fine aggregates measuring 0.063 mm – 4.76 mm.. According to Tjokrodimuljo (1992) Sand can be cataloged into 3

1. Excavated sand : Sand obtained by digging. This sand is generally sharp, porous, and free of salt content. This sand has a high sludge content, so it must first be washed.
2. River sand : This sand comes from the river. This sand is round in shape, therefore it has a less strong binding power.
3. Sea sand : The sea sand is taken directly from the beach.the grains are smooth and round. This sand is bad for concrete making because it contains salt absorbed from seawater.

2.4. Water

Concrete mortar water is water that can be drunk can be used for concrete mortar water. However, water that can be used for concrete mortar does not mean that it can bemium. For comparison, seawater contains:

1. C1= 3,960 to 20,000
2. S04 = 580 to 2810
3. Na = 2190 to 12200

If you are going to use acid water, alkaline water, household wastewater or industrial waste, seawater, sewer water, sugar water / turbid water / water containing oil, then as long as there is a cleaning process so that the chemical concentration value is below the maximum value, these types of water should be able to be used (Dayaratnam & Sarah, 2017).

2.5. Polymer

Polymers are large molecules (macromolecules) in long chains resulting from the merger of simple molecules (monomers). Polymers are chemical compounds that have a very high molecular mass and are composed of simple reinforcement units that are combined through a polymerization process. Monomers that can form polymers are molecules that have a double bond or that have a certain functional group (Sanjaya, 2017).

Polymer Concrete Polymer Concrete is a composite material that uses polymers as binders to replace whole or part of cement. Polymer concrete was introduced in the late 1950s and became famous in the 1970s which was used for repairing materials, and precast concrete components. The product is known as synthetic resin concrete, or concrete resin, or plastic resin concrete (Blaga & Beaudoin, 1985).

2.6. Resin

According to Boer & Ella, resin is defined as an organic compound or a mixture of various natural polymer compounds called terpetin, solid or semi-solid form that is easily soluble in organic solvents and insoluble in water (Boer & During, 2001).

Meanwhile, resin is defined as a compound that has many carbon chain bonds (polymers) consisting of monomers or short polymmers with epoxide groups at both ends. There are several types of resins that are commonly sold in the market.

2.7. Ceramics

There are several types of ceramics in Indonesia, the following are some types of ceramics that exist:

1. Standard Maritime
2. Terrazzo Ceramics
3. Natural Stone Flooring
4. Mosaic Ceramics

In this study, the ceramics used were powders from the work process and ceramic fragments, with a minimum size of 4.75 mm or equivalent to sand passing filter no.4, because of its function as sand substitution.

3. Methodology

3.1. Research Methodology

In general, research methods are defined as a scientific way to obtain data with a certain purpose and use (Sugiyono, 2013).

Experimental research methods are included in quantitative research methods. Fraenkel et al. (2009) state that experimentation means trying, searching, and confirming. Patzer (1996) states that causal or causal relationships are at the core of experimental research. A causal relationship is a causal relationship, this means that if an independent variable is changed in value it will change the dependent value. For example, if the incentive rate is lowered, it will change the employee's performance value. The author intends to use the experimental method because the author conducted the research by means of trials based on previous research.

Researchers used SNI 7565:2012 on the procedure for selecting mixtures for normal concrete, heavy concrete, and mass concrete as a reference in conducting this study.

3.2. Research Variables

In this study, researchers will make 27 samples, using a cylinder of 15 x 30 cm. Researchers used resins as a substitute for cement and used ceramics as a substitution for coarse aggregates with grades of 15% and 17%. Researchers will conduct concrete compressive test tests on days 7, 14, and 28 after the treatment process.

4. Research Results

Table 1. Normal Concrete

Normal Concrete				
Day	Sample	Compressive Strength	Average	Unit
	1	19,7		Mpa
7	2	18,9	19,233	Mpa
	3	19,1		Mpa
	1	27,2		Mpa
14	2	26,2	26,366	Mpa
	3	25,7		Mpa
	1	30,7		Mpa
28	2	29,8	29,833	Mpa
	3	29		Mpa

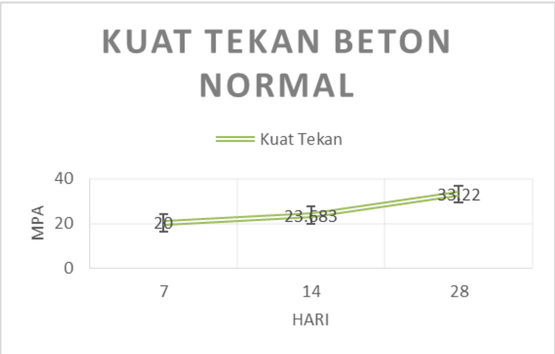

Figure 1. Normal Concrete Compressive Strength

Based on the compressive strength table and the compressive strength chart above, it shows that the compressive strength of normal concrete has increased in accordance with applicable standards. The strength of the normal concrete ekan has also reached the expected compressive strength in accordance with the mix design.

Table 2. Polymere Concrete

Polymer Concrete 15%				
Day	Sample	Compressive Strength	Average	Unit
	1	17,83		Mpa
7	2	16,47	17,963	Mpa
	3	19,59		Mpa
	1	27,2		Mpa
14	2	26,2	26,366	Mpa
	3	25,7		Mpa
	1	40,7		Mpa
28	2	32,4	31,533	Mpa
	3	31,5		Mpa

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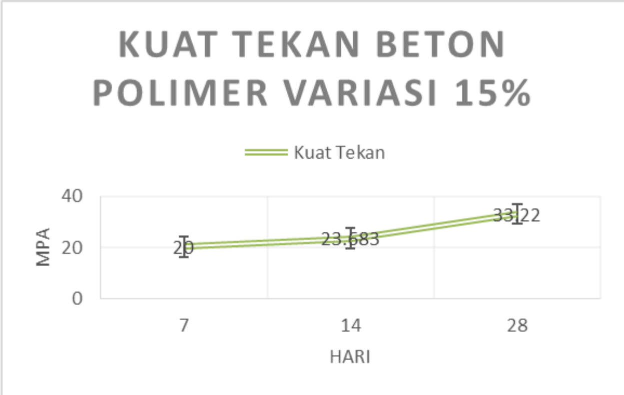

Figure 2. Compressive Strength Of Polymer Concrete Variation 15%

Based on the table and graph above, the compressive strength of polymer concrete has increased and managed to achieve the expected compressive strength on day 28. The compressive strength of concrete has increased significantly at each time of recitation. An increase of 46.78% on the 14th day, and an increase of 19.59% on the 28th day.

Table 3. Polymere Concrete 17%

Polymer Concrete 17%				
Day	Sample	Compressive Strength	Average	Unit
	1	18,9		Mpa
7	2	20,41	20,37	Mpa
	3	21,8		Mpa
	1	21,95		Mpa
14	2	23,27	23,683	Mpa
	3	25,81		Mpa
	1	32,12		Mpa
28	2	32,32	33,22	Mpa
	3	35,21		Mpa

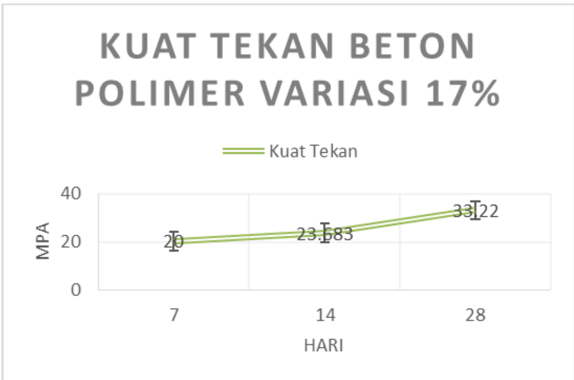

Figure 3. Compressive Strength Of Polymer Concrete Variation 17%

Based on the tables and graphs on the polymer concrete compressive strength test variation of 17% ceramics there was an increase in the compressive strength of concrete in each test. On day 14 testing, there was only a slight increase from day 7 testing of only 16.26%, while day 28 testing experienced an increase of 40.27%.

Table 4. Conventional Concrete

Material	Heavy	Unit	Price/Unit	Total Price
Cemen	357	Kg	IDR 1,050.00	IDR 374,850.00
Fine Aggregate	0.293	M^3	IDR 250,000.00	IDR 73,250.00
Coarse Aggregates	0.386	M^3	IDR 340,000.00	IDR 131,240.00
Total Concrete Cost Per M^3				IDR 579,340.00

Table 5. Compressive Strength Of Polymer Concrete Variation 17%

Material	Heavy	Unit	Price/Unit	Total Price
Resin	357	Kg	IDR 40,000.00	IDR 14,000.00
Fine Aggregate	0.293	M^3	IDR 250,000.00	IDR 54,750.00
Coarse Aggregates	0.386	M^3	IDR 340,000.00	IDR 131,240.00
Ceramic Waste	0.0448	M^3	IDR 100,000.00	IDR 4,480.00
Total Concrete Cost Per M^3				IDR 14,190,470.00

Table 6. Compressive Strength Of Polymer Concrete Variation 15%

Material	Heavy	Unit	Price/Unit	Total Price
Resin	0.35	Kg	IDR 40,000.00	IDR 14,000,000.00
Fine Aggregate	0.224	M^3	IDR 250,000.00	IDR 56,000.00
Coarse Aggregates	0.386	M^3	IDR 340,000.00	IDR 131,240.00
Ceramic Waste	0.0396	M^3	IDR 100,000.00	IDR 3,960.00
Total Concrete Cost Per M^3				IDR 14,191,200.00

5. Conclusion

1. Ceramics can be used as a substitution material in place of fine aggregates.
2. The influence of the use of resins as well as ceramics in the manufacture of polymer concrete has almost the same result, even greater than that of normal concrete.
3. Polymer concrete has a compressive strength yield of 31.53 Mpa for a variation of 15% ceramics, and has the largest compressive strength of 32.22 Mpa for a variation of 17%. The compressive strength of variation polymer concrete15% stronger is 5.69% than normal concrete, while variation polymer concrete17% higher by 11.36% than normal concrete.
4. Polymer concrete has a higher cost when compared with conventional concrete, therefore polymer concrete can be used only in special situations.the greatest compressive strength of 32.22 Mpa for a variation of 17%. The compressive strength of variation polymer concrete15% stronger is 5.69% than normal concrete, while variation polymer concrete17% higher by 11.36% than normal concrete.
5. Polymer concrete has a higher cost when compared with conventional concrete, therefore polymer concrete can be used only in special situations

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