BACHELOR DEGREE THESIS

COMPRESSIVE STRENGTH OF PERVIOUS CONCRETE MADE OF NICKEL SLAG

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ABSTRACT

Pervious concrete is a special high porosity concrete used for flatwork applications that allows water from precipitation and other sources to pass through, thereby reducing the runoff from a site and recharging groundwater levels. Its void content ranges from 18 to 35% with a compressive strength of 400 to 4000 psi (28 to 281 kg/cm2). Therefore, the use of porous concrete is an environmentally friendly alternative. Its usage is expected to absorb water into the ground. Permeable pavements have different design goals if compared to the conventional pavement, due to the ability to infiltrate the stormwater through the pavement surface. This research aims to get the optimum proportion of porous concrete mixture using a friendly environment binder material. Hence this research used nickel slag from the Nickel mining wastes to replace a certain part of the Portland Cement Composite (PCC). Therefore utilizing, the mining wastes and putting them into good use and at the same time reducing the amount of portland cement is a positive achievement towards environment sustainability and green construction.

Keywords: Pervious Concrete, Sustainability, Green Construction, Environmentally Friendly.

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ABSTRAK

Beton tembus adalah beton porositas tinggi khusus yang digunakan untuk aplikasi pekerjaan datar yang memungkinkan air dari presipitasi dan sumber lain melewatinya, sehingga mengurangi limpasan dari lokasi dan mengisi ulang tingkat air tanah. Kandungan rongganya berkisar antara 18 hingga 35% dengan kuat tekan 400 hingga 4000 psi (28 hingga 281 kg/cm2). Oleh karena itu, penggunaan beton porous merupakan alternatif yang ramah lingkungan. Penggunaannya diharapkan dapat menyerap air ke dalam tanah. Perkerasan permeabel memiliki tujuan desain yang berbeda jika dibandingkan dengan perkerasan konvensional, karena kemampuan meresapkan air hujan melalui permukaan perkerasan. Penelitian ini bertujuan untuk mendapatkan proporsi campuran beton porous yang optimum dengan menggunakan bahan pengikat yang ramah lingkungan. Oleh karena itu penelitian ini menggunakan terak nikel dari limbah tambang Nikel untuk menggantikan bagian tertentu dari Portland Cement Composite (PCC). Oleh karena itu, memanfaatkan, limbah pertambangan dan memanfaatkannya dengan baik dan pada saat yang sama mengurangi jumlah semen portland merupakan pencapaian positif terhadap kelestarian lingkungan dan konstruksi hijau.

Kata kunci: Beton Berpori, Keberlanjutan, Konstruksi Hijau, Ramah Lingkungan.

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NOTATION LIST

(CaO)	= Calcium Oxide
(SiO_2)	= Silica
(Al_2O_3)	= Aluminium Oxide
MgO	= Magnesium Oxide
PCC	= Portland Composite Cement
OPC	= Ordinary Portland cement
($Ca(OH)_2$)	= Calcium Hydroxide
($CaCO_3$)	= Calcium Carbona
ASTM	= American Society for Testing and Materials
MPa	= Megapascal
f'c	= Compressive Strength
P	= Load
A	= Cross-Sectional Area of the Test Object
SNI	= Standard National Indonesia
UCS	= Unicofined Compresseve Strength
UTM	= Universal Testing Machine

CHAPTER 1

INTRODUCTION

A. Background

Concrete is one of the oldest and widely used material in the construction industry. This is due to the fact that concrete have far advantages over other materials. Such as concrete has high compressive strength,long durability, ability to withstand extreme environmental conditions, availability and most significantly it is low cost. The concrete manufacturing process is simple and the raw materials for making concrete are also easily obtain, hence the price is relatively cheap. Furthermore concrete as stated have very good resistance to all environmental conditions. Concrete materials generally consist of cement, aggregate, water and added materials. Planners can develop a selection of materials that are suitable for their composition in order to obtain efficient concrete, meet the boundary strengths indicated by the planner and meet the serviceability requirements which can also be interpreted as reliable service by meeting economic criteria.

However the mass usage of concrete comes at a cost, with the rapid development of the construction industry, the consumption of cement worldwide has surged. At the end of the last century, the global cement consumption exceeded 2.2 billion tons per year. The ordinary portland cement production reached 3.7 billion tons in 2017 which accounting for 3 billion tons of carbon dioxide (CO_2) emissions and for about 7% of the total global emissions making cement production one of the major contributor to the global carbon emission and hence the environmental issues caused by cement production and concrete in the world require urgent attention (Elchalakani et al 2019). In addition the production of concrete used large amount of sand,stone,water and other raw materials and with the large extraction of these raw materials cause severe damage to the land, water resources and air quality, in other words the environmental quality will be greatly affected.

Hence many researchers have been working to develop other alternative to ordinary portland cement concrete, that are more economical and environmentally friendly and sustainable. One of them is porous concrete, it is a type of lightweight concrete that is porous with no fine aggregate in the concrete mix and also known as no-fine concrete, the advantage of pervious concrete are lower density, low cost due to lower cement content, relatively low drying shrinkage, lower thermal conductivity, no capillary movement of water and better insulating characteristics due to the large voids in pervious concrete. Therefore in this research, it investigated pervious concrete by utilizing nickel slag wastes as a raw material for making concrete and the fact that Tin nickel mining are quite abundant in South Sulawesi Province, hence this research aim to innovate and ulitize the nickel slag wastes from the nickel mining. Concrete porosity is the amount of pore content contained in the concrete. Concrete pores are not completely covered by cement paste. These pores are usually filled with air (air voids) or filled with water (water filled space) which are interconnected and are called concrete capillaries. These concrete capillaries will remain even after the water used has evaporated, so these capillaries will reduce the density of the resulting concrete.

Trapped air bubbles and evaporating water are the main sources of cavities / pores in the concrete and concrete that has a small number of pores is waterproof, dense, and strong. Whereas the permeability of concrete is the ease with which a liquid or gas can pass through the concrete (A.M.Neville & J.J Brooks, 1987). Permeability is also defined as the nature of the passability of liquids or gases. Good concrete is a concrete that is relatively impassable by water / gas, or in other words, it has low permeability. According to Murdock (1979), concrete cannot be completely impermeable to water.
Dense and strong concrete is obtained using a minimum amount of water consistent with the degree of workability given to provide maximum density. The degree of density must be considered in relation to the method of compaction and type of construction, in order to avoid the need for excessive work to achieve maximum density. (Murdock, et al 1991).

Engineering porous concrete is mainly produced from cement, coarse aggregate with a special particle size distribution and water, and uses an excellent compaction craft with more than 20% porosity in general. The technology of manufacturing porous concrete is mainly applied to highway pavements differs from the manufacture of ordinary concrete in many aspects, including constituent materials, carried out tests and adjustments, proportional mix, and as well as compaction or molding craft (Zheng Mulian et al. 2006; Yang Jing and Jiang Guoliang 2003. , Hao Jinghua 2007).

In this research, the aggregate used in mixing porous concrete is nickel Slag, as one of the main solid wastes from nickel mining processing process. It is estimated that in the future many countries will experience a water crisis. Even though Indonesia is one of the top 10 water-rich countries, our country is threatened with a water crisis as well as a result of a weak management system for water resources development and the environment in general. This is reflected in the decreasing quality of water, both surface water and ground water, very large fluctuations in river water discharge, inefficiency in water use, and very inadequate regulations. This obstacle then becomes a challenge in itself in the world of civil engineering to be able to make concrete with high quality and durability by using existing constituent materials. Based on this basis it is set that this research and from the descriptions, the author considered it is necessary to carry out further research on the performance of porous concrete using nickel slag with the use of PCC cement as a mixture, therefore the author decided with the title;

"**COMPRESSIVE STRENGTH OF PERVIOUS CONCRETE MADE FROM NICKEL SLAG** ".

B. Problem Formulation

Based on the research background above, the problem formulations in this study are:

1. What are the characteristics of Pervious concrete using Nickel Slag as coarse aggregate?

C. Research Objectives

The objectives of this study are:

1. Analyzing the characteristics of using nickel slag on pervious concrete.
2. Comparing the stress-strain relationship model of pervious concrete using nickel slag and crushed stone.

D. Research Benefit

1. It is hoped that this research will be useful to determine the characteristics of Pervious concrete which are influenced by the use of Nickel Slag.

E. Scope and Limitations of the Study

In this research, the scope boundaries are given so that the research focused more into the explored issues and parameters as follows:

1. The use of nickel slag and crushed stones as a comparison.
2. Use of PPC Cement and Sikament admixture as additives.
3. The nickel deposits used come from the mine of PT. Vale in sorowako
4. The moulds used are a cylinder measuring 10cm x 20 cm.

5. The curing process is by means of water bathing and air.
6. Compressive strength testing is carried out at the age of 3, 7, 28 days.

F. Excerpt of the Research Paper

In general, this paper is divided into five chapters, namely Introduction, Literature Review, Research Methodology, Results of Testing and Discussion, and Conclusions and Suggestions. The following is a general breakdown of the contents of the five chapters:

CHAPTER 1 INTRODUCTION

This chapter provides an initial overview of the problems to be discussed through four main points, namely the background, problem formulation, research benefits, and the excerpt of this research.

CHAPTER 2 LITERATURE REVIEW

This chapter contains important theories that are related to the topic of the problem and serve as a basis or reference for the research.

CHAPTER 3 RESEARCH METHODOLOGY

This chapter describes the stages and details of the research implementation, from material preparation to the testing process.

CHAPTER 4 RESULTS AND DISCUSSION

This chapter contains data from the results of research that has been carried out, namely compressive strength, elasticity, and cracking patterns of foam mortar.

CHAPTER 5 CONCLUSION

This chapter discusses conclusions in a nutshell based on the analysis of the results obtained during the research and accompanied by the suggestions suggested.

CHAPER 2

LITERATURE REVIEW

A. Pervious Concrete Materials

1. Portland Cement

Cement is a hydraulic binder, finely ground inorganic material that when mixed with water,forms a paste that set and harden through the hydration reactions and processes and which, after hardening, retains its strength and stability even in water (Standard BS EN 197-1).

Portland cement is a construction material that is most widely used in concrete work. According to SNI 15-2049-2004, portland cement is defined as hydraulic cement produced by grinding portland cement slag mainly consisting of calcium silicate which is hydraulic and ground together with additional materials in the form of one or more crystalline forms of calcium sulfate compounds and may added with other additives.

Portland cement is made from a fine powder of crystalline minerals whose main composition is calcium and aluminum silicate. The addition of water to this mineral produces a smooth paste when drying will have rock like strength.

The weight of the type ranges from 3.12 and 3.16, and the volume weight of one sac of cement is 94 lb $/ft^3$. The raw materials for cement forming are:

1. Lime (CaO) - from limestone,

2. Silica (SiO_2) - from clays,

3. Alumina (Al_2O_3) - from clays (with a slight presentation of magnesia, MgO, and sometimes slightly alkaline). Iron oxide is sometimes added to control the composition.

Figure 1. Portland cement

A. Indonesian Standards

Indonesia has been able to produce Portland cement which consists of 5 types and uses (Portland cement types I, II, III, IV and V). Today, Indonesia has also developed Portland Pozzolan cement and Portland Composite cement using inorganic materials and cement linker (M. Wihardi Tjaronge, 2012).

As for the type and use of portland cement (according to SNI 15-2049-2004) namely:

a. Type I is a general use cement that does not require special requirements as stated in other types.
b. Type II is portland cement which in its use requires resistance to sulfate or moderate hydration.
c. Type III is portland cement which in its use requires high strength at the initial stage after bonding occurs.
d. Type IV is portland cement which in its use requires low hydration heat.

e.Type V is portland cement which in its use requires high resistance to sulfate (SNI 15- 2049-2004).

Portland cement quality requirements (according to SNI 15-2049-2004) are:

B. Cement standards based on ASTM C 150 – 07

Types and uses of Portland cement based on ASTM C 150 - 07 are as follows:

I. Type I, for general use that does not require special requirements as implied in other types.
II. Type IA, Cement Air entraining is used the same as type I, which requires Air entraining.
III. Type II, for its use requires resistance to sulfate or moderate hydration heat.
IV. Type IIA, Cement Air Entraining is used the same as Type II, which requires Air entraining.
V. Type III, for its use requires high strength at the initial stage after bonding has occurred.
VI. VI. Type IIIA, Cement Air entraining is used the same as type III, which requires Air entraining.
VII. Type IV, for its use requires low caloric hydration.
VIII. Type V, for its use requires high resistance to sulfates.

2. Aggregate

a. Nickel Slag Aggregate

Nickel slag is a granular slag formed by natural cooling or water quenching from the melt formed during the smelting process of nickel metal containing FeO, SiO.2, Al2HAI3 and MgO as the main components. Nickel, iron, copper, and other elements in nickel slag can be recovered by an acid leaching process and a selective reduction magnetic separation process. However, along with the improvement of the nickel metallurgy process, the extract-table metal content in nickel slag became very low.

The manufacture of crystal glass, the main component of nickel slag, such as calcium, silicon, magnesium, aluminum and other oxides, is also an important component of glass. However, only a small amount of nickel slag is used in the manufacture of glass-ceramics and will easily cause secondary pollution.

Cement and concrete production: as additives in the manufacture of Portland cement or substitutes for aggregates Production of building materials: as raw materials for building blocks, autoclaved products, unburned bricks and geopolymers. Preparation of mine fillers: nickel slag quenched with flash furnace water is used as a filler aggregate to meet the tensile strength and pressure requirements of the mine filling process (Qisheng Wu, 2013)

Figure 2. Nickel Slag (5-10**)**

Figure 3. Nickel Slag (10-20)

b. Freshwater

Water is vital necessity in the manufacture of concrete to allow chemical reactions with cement to wet the aggregate and to lubricate the mixture for easy processing. In general, drinking water can be used for concrete mixing.

Water containing dangerous compounds, contaminated with salt, sugar oil, or other chemicals, when used for concrete mixtures will greatly reduce its strength and can also change the properties of the cement. In addition, such water can reduce the affinity between the aggregate and the cement paste and may also affect the ease of working, since the character of cement paste is the result of a chemical reaction between cement and water, it is not the ratio of the amount of water to the total (cement + fine aggregate + coarse aggregate) of the material that determines, but only the ratio between water and cement in the mixture that determines. Excessive water will cause a lot of water bubbles after the hydration process is complete, while too little water will cause the hydration process to not completely finish. As a result, the resulting concrete will lack strength (Nawy, E. G. 1998).

3. Superplasticizer

According to SNI 03-2495-1991, additional material is a material in the form of slurry or liquid, which is added to the concrete mixture during stirring in a certain amount to change some of its properties. Admixture or can be called Additive is a natural or artificial additional material in the form of liquid or powder mixed into the concrete mix, processed before or during the concrete mixing process to modify the characteristics of the concrete.

The terms and conditions for the quality of chemical additives are in accordance with ASTM C 494-81 "Standard Specification for Chemical Admixture for Concrete". The definition of the types and types of chemical additives can be explained as follows:

a. Type A: Water Reducing Admixture, is an additional material that reduces the amount of water mixing concrete to produce concrete with a certain consistency.

b. Type B: Retarding Admixture, is an additional material that acts to inhibit the binding of concrete.

c. Type C: Accelerating Admixture, is an additional material that functions to accelerate the binding and development of the initial strength of concrete.

d. Type D: Water Reducing and Retarding Admixture, is an additional material that doubles to reduce the amount of mixing water required to produce concrete with a certain consistency and inhibits concrete bonding.

e. Type E: Water Reducing and Accelerating Admixture, is a dual function additive to reduce the amount of mixing water required to produce concrete with a certain consistency and speed up the bonding of the concrete.

f. Type F: Water Reducing and High Range Admixture, is an additional material that functions to reduce the amount of mixing water required to produce concrete with a certain consistency by 12%.

g. Type G: Water Reducing, High Range and Retarding Admixture, is an additional material that functions to reduce the amount of mixing water required to produce concrete with a certain consistency by 12% or more and also inhibits the binding of the concrete.

Figure 4. Additive

B. Effect of nickel slag as a concrete mixer

Using nickel slag as raw material for producing Portland road cement. The effect of nickel slag content, desulphurisation gypsum content and calcination temperature on the performance of raw materials, clinker and cement paste, is very suitable for use in the mixture of highway Portland cement with nickel slag as raw material. The addition of nickel slag in the right amount reduces the f-CaO content in the clinker and promotes the growth of dense and uniform granules in the clinker. When desulphurisation gypsum is used as a raw material for calcium to mix with clinker, the f-CaO content in clinker increases, so it is not conducive for the manufacture of clinker. The optimal process for making road portland cement with nickel slag is: the content of nickel slag, limestone, fly ash, steel slag, desulfurized gypsum, and calcium fluoride (weight percentage) were 14%, 74%, 4%, 7%, 0.6% and 0.4%, respectively; The calcination temperature was 1350LC and the heat preservation time was 60 minutes. The f-CaO content in the clinker prepared by this process is 0.22%. The compressive and bending strength for 3 days of the prepared cement paste were 21.9 MPa and 6.9 MPa, respectively. The 28-day values were 52.4 MPa and 14.5 MPa, respectively. The strength level reaches the level of 42.5MPa. The amount of wear and tear at the age of 28 days of hydration is 2.1 kg / m2. Magnesium in nickel slag is mainly present in the form (Mg, Fe)2SiO4, MgSiO3, and Ca2Mg (SiO7) . After calcination, it is present in clinker in the form of $CaMgSi_2HAl_6$, $Mg_2Si_5Al_4HAl_{18}$ and MgO, as well as $Mg(OH)_2$ after hydration.(Qisheng Wu et al 2018)

C. CONSTRUCTION THAT HAS BEEN USING PERVIOUS CONCRETE

The use of non-sand concrete as a pavement material is very limited and has only recently been developed for certain applications. However, non-sand concrete has been widely used as a structural building material in Europe, Australia and the Middle East for more than 70 years (Macintosh et al, 1965, in Harber, 2005). The earliest use of non-sand concrete occurred in England in 1852 with the construction of two houses and sea groves 61 m long and 2.15 m wide (Francis, 1965, in Harber, 2005). The use of non-gritty concrete became much more widespread during the shortage of materials after World War II, for load-bearing walls molded in place for multilevel buildings. The initial use of non-sand concrete, especially for two-story structures, was then developed for five-story buildings in 1950 and continues to grow. In recent years non-sand concrete has been used as a load-bearing material in tall buildings up to ten floors. The most remarkable use of non-sand concrete was carried out in Stuttgart, Germany where tall buildings were constructed using conventional concrete for the lower six floors and non-sand concrete for the remaining thirteen floors (Malhotra 1976, in Harber, 2005).

D. Strength of Pervious concrete and the relationship between each property.

1. Compressive strength and modulus of elasticity

ACI standard lightweight concrete was used for comparison, since porous concrete is also categorized as lightweight concrete [18]. It can be seen that the increase in compressive strength is proportional to that in the modulus of elasticity. One of the ACI diagrams used here is the ACI for lightweight concrete with a mixture of light weight and normal aggregate (ACI 213R-03), as a study also used a combination of normal aggregate and volcanic pumice (light aggregate). The graph shows that the modulus of elasticity of porous concrete obtained is significantly lower than the ACI standard for lightweight concrete. The decrease in elastic modulus of porous concrete indicates that the strain under compression loading in porous concrete increases faster than normal concrete and lightweight concrete. The development of porous concrete strains can be accelerated because it removes fine aggregates in porous concrete. Therefore, concrete creeps rapidly when the bond between the aggregate and the cement paste has reached the maximum stress. Based on the results, it can be assumed that porous concrete has high deformability, so it has the potential to be used as an energy absorbing impact. (Source Hiroki Damai Dkk 2015)

The modulus of elasticity is the ratio of the normal tensile or compressive stress to strain. The modulus of elasticity depends on the age of the concrete, the properties of the aggregate and cement, the loading speed, the type and size of the specimen. From the 15/30 concrete cylinder press test, the modulus of elasticity of concrete is calculated using the formula ASTM C 469-02 as follows:

$$Ec = \frac{\sigma 2 - \sigma 1}{\varepsilon 2 - \varepsilon 1} \longleftrightarrow \text{Equation 1}$$

Where:
E_c = modulus of elasticity of concrete [kg/m^3]
σ_2 = stress at 40% firm collapses [kg]
σ_1 = stress at the value of the strain curve $\varepsilon_1[m^3]$
E_c = modulus of elasticity of concrete [kg/m^3]
ε_2 = the value of the strain curve that occurs at the moment $\sigma_2[m_3]$
ε_1 = strain equal to 0.00005 $[m_3]$

The compressive strength of the concrete is the amount of load per unit area, which causes the concrete test object to fail when loaded with a certain compressive force, which is generated by a compression machine (SNI 03-1974-1990)

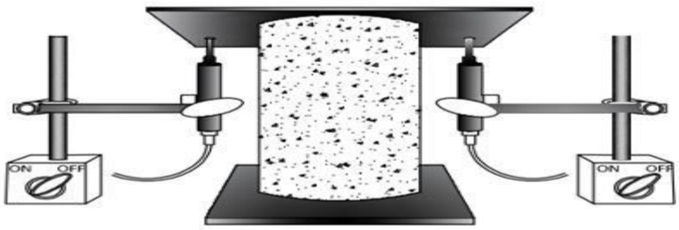

FIGURE 5. Compressive Strength Testing

The formula for getting compressive strength:

$$f_c = \frac{P}{A} \longleftrightarrow \text{Equation 2}$$

Where:
f_c = Compressive Strength [MPa]
P = Maximum Load (kN)
A = Cross-sectional area (mm^2)