VOLUME 3 | NUMBER 1 | JANUARY 2021
Available online at http://proceedings.worldconference.id.
ISSN: 2656-1174 (online)

Concrete Durability by using Ground Granulated Blast Furnace Slag as A Cement Substitution Against Sulfuric Acid and Chloride Penetration

Agung Sumarno, Khoiru Mardiansyah
Department of Civil Engineering, Faculty of Engineering, Universitas Mercu Buana, Indonesia
agung.sumarno@lipi.go.id , 41116310098@student.mercubuana.ac.id

Abstract

It seems that improvements in cement production technology couldn't be expected to suppress carbon dioxide production significantly. Replacement of some parts of cement in the concrete manufacturing process, or in total replacing them with other more environmentally friendly materials becomes a more promising choice. Along with the increasing demand of concrete to serve the needs of construction in Indonesia is growing as well as innovations developed in the manufacture of concrete. One of them is the use of used materials or waste that can be utilized as add material or substitute cement as an alternative ingredient in concrete mixture. The purpose of this research is to find out the durability of concrete with substitution of Ground Granulated Blast Furnace Slag (GGBFS) against the penetration of sulfuric acid (H_2SO_4), the penetration of natrium chloride (NaCl) which also review the results of workability, change in density, into the penetration of sulfuric acid and compressive strength. The more the use of ground granulated blast furnace slag (GGBFS), the stronger it is to withstand the penetration of natrium chloride (NaCl). The average concrete density increased by 0.40%, the biggest change was at TM GGBFS 80% by 0.55%. With or without the use of ground granulated blast furnace slag (GGBFS) in the mixture of reinforced concrete acid sulfate (H_2SO_4) cannot enter into the concrete reviewed from the results of the titration Phenolphthalein is $C_{20}H_{14}O_4$ (pH indicator) the entire concrete surface has been cut in magenta color (base or pH > 8.3). The use of ground granulated blast furnace slag (GGBFS) in the optimum concrete mixture is able to withstand the penetration of sulfuric acid (H_2SO_4) and the penetration of natrium chloride (NaCl) at the age of 14 days with the substitution of 80% GGBFS which is reviewed from the results of compressive strength concrete.

Keywords:
Density, Durability, GGBFS, High quality concrete

1. Introduction

The development of concrete technology in achieving the objectives of environmentally friendly concrete with the improved durability capacity is currently being sought in various kinds of research. Concrete is a mixture of Portland cement or other hydrolic cement, smooth aggregate, coarse aggregate, and water with or without additives or admixture, (Badan Standarisasi Nasional, 2013). The advantages of concrete as a construction material include strong high press, can follow the shape of the building or mold. Another thing that underlies the selection and use of concrete as construction material is the effectiveness factor and efficiency level. Good quality concrete has some advantages including high quality concrete the ability to withstand the environmental conditions of abrasion, weather (hot, cold, sunlight, rain) or the process of the other. Concrete also has some disadvantages, namely weak to strong tensile, inflate and shrink when the temperature changes occur, it is difficult to perfectly waterproof, and is ducking (Tjokrodimuljo, 1996).

Lately, cement and concrete industries are increasingly highlighted, especially by environmental enthusiasts. This is due to carbon dioxide emissions, the largest component of greenhouse gases, resulting from the calcinous process of lime and coal burning. This environmental issue seems to be playing an important role in relation to the issue of sustainable development in the future. In the production of a ton of Portland cement, it will be produced about a ton of carbon dioxide gases released into the atmosphere. From 1995 years of data on cement production in the world recorded at 1.5 billion tonnes, it means the cement industry is releasing 1.5 billion tonnes of carbon dioxide into the wild.

According to the International Energy Authority: World Energy Outlook, the amount of carbon dioxide generated in 1995 is 23.8 billion tonnes. The figure indicates that the production of Portland cement contributes seven percent of the total carbon dioxide produced by various sources. It seems that this proportion will continue to persist or even increase in accordance with the increase of cement production if there is no meaningful change in cement production technology or acquired cement substitute material. In 2010, it was estimated that the total cement production in the world reached 2.2 billion tonnes. The phenomenon causes the emergence of the desire to seek other materials that are not an unforeseen natural resource. It is the case that encourages researchers to find other materials that can be used to replace cement. Such material should have properties such as or at least similar to cement, known as cementitious material. Referring to the amount of cement industry donations to total carbon dioxide emissions, it is necessary to immediately be able to reduce the number of cement production that pollutes this environment. It seems that improvements in cement production technology could not be expected to suppress carbon dioxide production significantly. Replacement of some parts of cement in the concrete manufacturing process, or in total replacing them with other more environmentally friendly materials becomes a more promising choice.

Along with the increasing demand of concrete to serve the needs of construction in Indonesia is growing as well as innovations developed in the manufacture of concrete. One of them is the use of used materials or waste that can be utilized as add material or substitute cement as an alternative ingredient in concrete mixture.

Research on the utilization of waste in the manufacture of concrete has also been done before by some researchers. Some of them use fly ash waste, nickel slag, slag steel and copper slag. From previous research obtained several conclusions including the results of the use of slag on the substitution of concrete mixture K-225 is better in the range of 15% with a strong press reaches 25.34% higher than normal concrete and will decrease its strength when getting a substitution of more than 15% (Zainul, Djamaluddin and Anwar, 2018). The addition of copper slag 60% in lieu of a partially fine aggregate can increase the concrete press strength by 22% of the normal concrete and increase the tensile strength of concrete by 5.76% of the normal concrete (Karimah and Wahyudi, 2016). Compressive strength with substitution ground granulated blast furnace slag (GGBFS) 20% still according to the quality of the plan while the substitution of GGBFS 40% decreased by 7.95%, the substitution of GGBFS 60% decreased by 15.01% and substitution GGBFS 80% decreased by 19.17%. The decline is strong when it gets more than 20% of the subtitution. (Pratama, 2019).

In this case, the author developed the research previously done by Pratama (2019) using the Ground Granulated Blast Furnace Slag (GGBFS) as a material substitution of cement that is expected to produce a better concrete durability against sulfuric acid penetration and chloride penetration.The purpose of this research is to determine the effect of penetration of natrium chloride (NaCl) against changes in concrete density, the depth of sulfuric acid (H_2SO_4) in concrete as well as to determine the effect of the penetration of sulfuric acid (H_2SO_4) and natrium chloride (NaCl) against compressive strength.

2. Literature Review

2.1. Concrete

Concrete is a mixture of Portland cement or other hydraulic cement, smooth aggregate, coarse aggregate, and water, with or without additional mixed materials (admixture), (Badan Standarisasi Nasional, 2013). Concrete is one of the building materials used in the construction world. Because almost all work in the world of civil engineering use concrete as well as dam work, drainage, for rigid pavement and so forth. The higher the quality of concrete, the stronger a building. Factors that affect the quality of concrete are: the quality of materials used, cement type, water cement ratio, coarse aggregate gradation, the process of the implementation of concrete and concrete maintenance process.

2.2. Environmentally friendly Concrete

Almost all concrete basic meterial is a product of environmental damaging results. Need to be sought to minimize the impact of environmental damage caused, before there is concrete technology by replacing all materials used today the experts are developing polymer-based concrete material to replace the most applicative cement is to reduce the use of cement, the use of natural sand and water usage in concrete mixture without changing the quality, workability and durability. It can be said environmentally friendly concrete is concrete with a little cement, a little natural sand and a little water, without lowering the quality, workability, durability and performance (Khrisna P, 2014).

2.3. High quality concrete

Nawy (1985) declares concrete as a set of mechanical and chemical interactions of the constituent material. Neville, A.M. (1987) Give another understanding of concrete is reviewed from the diversity of the constituent material, namely materials made of various types of cement, aggregate and also pozolan materials, fly ash, high density, fiber, utilization of waste, and others. The SNI T-15-1990-03 (1991) defines concrete as a mixture between Portland cement or other hydraulic cement, smooth aggregate, coarse aggregate and water with or without additional mixed materials forming solid mass. Concrete class according to SNI T-15-1990-03 (1991) divided by its quality. According to the development of concrete technology is so rapid, according to Supartono (1998) Apparently high concrete criteria also changed according to the development of the era, concrete is said to be high quality if the strength of power above 50 MPa and above 80 MPa is a very high quality concrete. Because almost all work in the world of civil engineering use concrete as well as dam work, drainage, for rigid pavement and so forth.

2.4. Aggregate

Aggregates are natural mineral granules that serve as filler materials in concrete mixtures. Aggregates can come from nature or from artificial aggregates. The use of aggregates in concrete can save the use of portland cement, produce great strength on concrete, reduce concrete hardening and control the workability of concrete mixing. Aggregate selection is an important part of concrete making (Tjokrodimuljo., 1986).

2.5. Water

In the manufacture of concrete, water is one important factor, since water can react with cement, which will be an aggregate binding paste. Water in the concrete mixture is required to react with cement, as well as a lubricant material between aggregate grains for easy concrete to be worked on and compacted. Another advantage of water is that it will together with a minute move to the surface of a fresh concrete stir that has just been sheathed (bleeding) into a mold that then becomes froth and is a thin layer called laitance. Thin membranes reduce the attachment between layers of concrete and are weak connecting fields (Tjokrodimuljo., 1986).

2.6. Ground Granulated Blast Furnace Slag (GGBFS)

GBFS/GBS Granulated Blast Furnace Slag/Granulated Blast Furnace Slag is a high furnace combustion residue is a non-metal product that is a granular material. The GBFS element consists mostly of lime, silica and alumina contained in iron when inserted into the furnace. The separation reaction between iron/steel and other elements occurs after being heated to a temperature of 1,600oC in the blast furnace that will convert it into liquid. When this liquid is cooled by dipping it in water then there will be a crystal called GGBFS. These Crystal granules can be used as aggregate substitutes. Finely ground GBFS is referred to as GGBFS/GGBS Ground Granulated Blast Furnace Slag/Ground Granulated Blastfurnace Slag. Currently the use of GGBFS as a portland cement substitution material with various advantages that it has is well known in the world even GBFS and GGBFS are freely traded. In Indonesia the use of this material has not been socialized well. In particular GBFS/GBS is still categorized as Waste B3 (Hazardous and Toxic Materials) where producers, containers, carriers and users /processing are limited by very strict regulations and licensing. Materials that include B3 waste when it has one or more explosive features, flammable, reactive, toxic, infectious, corrosive, etc.

GGBFS/GGBS or Semen Slag mainly contains calcium, aluminum and silica which have a chemical composition no different from natural ingredients including hydration materials such as Portland Cement. It is often used as a mixture of Portland Cement in the manufacture of concrete, mortar and others. This product mixture is referred to as cement blended. The variation of the GGBFS/GGBS mixture on Portland Cement makes it possible to optimize the special properties of concrete and mortar. GGBFS/GGBS exhibits the same adhesive quality as Portland Cement. It can therefore replace the Portland Cement function at a wide range with a specific mass comparison ratio. Various levels of GGBFS/GGBS replacement start from 10% to more than 70%. Some research results are generally used between 30%-50%. (Krakatau Semen Indonesia).

2.7. Chemical Admixture

Admixture is a material in the form of powder or liquid, which is added to the concrete mix during stirring, with the aim of changing the properties of the stir or concrete (Specifications of Additional Materials for Concrete, (SNI T-15-1990-03, 1991). Based on ACI (American Concrete Institute), the added materials are materials other than water, aggregate and hydraulic cement mixed in concrete or mortar added before or during stirring. The addition of added materials in a concrete or mortar mixture does not change the large composition of other materials, as the use of this added material tends to be a substitute or susbtitusi from within the concrete mixture itself. Because the goal is to improve or change the specific properties and characteristics of the concrete or mortar to be produced, the tendency of composition changes in weight-volume is not felt directly compared to the initial composition of concrete without added materials. The use of added materials in a concrete mixture should pay attention to applicable standards such as SNI (Indonesian National Standard), ASTM (American Society for Testing and Materials) or ACI (American Concrete Institute) and most importantly pay attention to the instructions in the trade product manual. In general, the added materials used in concrete can be distinguished into two, namely chemical admixture and additives.

2.8. Mix Design

There are several methods in the design of concrete mix design, including:

1. ACI Method (American Concreat Institute) Method, requires a mixture of concrete design taking into account the economic side by taking into account the availability of materials in the field, ease of work, as well as durability and strength of concrete work. The way ACI sees that with a certain aggregate size, the amount of percussic water will determine the consistency level of the concrete mixture that will ultimately affect workability.
2. Road Note Method No.4, this method of design is emphasized on the effect of aggregate gradation on ease of workmanship.
3. SK method. (SNI T-15-1990-03, 1991) / Current British Method (DoE), compiled by the British Departement of Environment in 1975 to replace the Road Note.4 in the UK. For conditions in Indonesia there has been an adjustment to the size of the strong variation of concrete press.
4. Trial and error mix method, trial and error method developed based on car methods ACI, Road Note No.4 and (SNI T-15-1990-03, 1991), after implementation and evaluation. This way of trying to get minimum pores or maximum concrete density means that the need for maximum fine aggregate to get minimum cement needs.

3. Method

The methods applied in this study are experimental methods. The free variable in this study is to reduce the use of cement in concrete mixture with substitution using GGBFS variation use GGBFS 0%, 60%, 70% and 80% which will be tested in the slump (workability), density changes due to the penetration of natrium chloride (NaCl), depth of sulfuric acid penetration (H_2SO_4) All the processes and procedures in conducting this research refer to SNI (Indonesian national Standards), ASTM (American Society for Testing and Material), as well as previous research journals. Before the implementation of concrete making, the preparation of materials will be used, further testing of materials to determine the quality and specifications of the material, as for the testing conducted for the aggregate physical testing is the moisture test (coloid content test), grading test (sieve analysis test), the specific gravity, absorption of (absorption), the test of clay lump test, the organic content of fine aggregate (organic impurities for fine aggregates) , the fill weight (density), the rough aggregate abrasion test (abration test) then carried out the mixture planning (mix design), after mixed composition obtained then a trial mix concrete with the test slump flow, the manufacture of test objects in the form of cylinders (diameter 10 cm, height 20 cm). In this chapter will be explained about the steps of testing, the manufacture of cylinder test objects, workability, the testing of the initial ikat (setting time), strong press (compressive strength), the penetration of sulfuric acid (H_2SO_4) and natrium chloride (NaCl) (durability).

4. Experimental Program

While the material used for Trial Mix include:

1. The fine aggregate is sourced from the quarry Ex. Jambi and Ex. Leles West Java.
2. The coarse aggregate size of 5-10 mm is sourced from the quarry Ex. Rumpin.
3. Semen OPC of type I of cement Gresik product.
4. Superplasticizer type F using P200 New product of PT. KKI Consol.
5. GGBFS from PT. Krakatau Semen Indonesia.
6. Sea water (NaCl).
7. Sulfuric acid (H_2SO_4).
8. Phenolftalein $C_{20}H_{14}O_4$ (pH indicator).

The mix design calculation is divided into 4 combinations:

JOURNAL OF WORLD CONFERENCE
VOLUME 3 | NUMBER 1 | JANUARY 2021
Available online at http://proceedings.worldconference.id.
ISSN: 2656-1174 (online)

Table 1. TM 0%, TM 60%, TM 70%, TM 80%

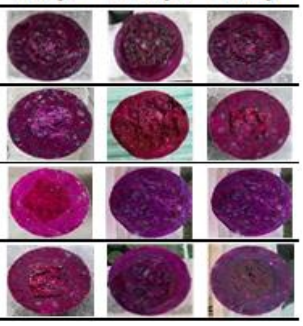
Description	Unit	TM 0%	TM 60%	TM 70%	TM 80%
Target of Strength (f'c)	Mpa	50	50	50	50
Target of Slump	Cm	50-60	50-60	50-60	50-60
Water Cement Ratio (w/c)		0,293	0,293	0,293	0,293
Cement OPC Tipe I Gresik	Kgs/m³	460	184	138	92
GGBFS Ex. PT.KSI	Kgs/m³	0	276	322	368
Fine Aggregate Ex. Jambi	Kgs/m³	472	462	460	458
Fine Aggregate Ex. Leles	Kgs/m³	468	458	456	454
Coarse Aggregate Ex. Rumpin	Kgs/m³	844	850	851	852
Additive Type F	Ltr/m³	4,73	4,73	4,73	4,73
Water	Ltr/m³	135	135	135	135

5. Results And Discussion

Test results and analysis of concrete endurance research using Ground Granulated Blast Furnace Slag (GGBFS) as a cement substitution material against sulfuric acid penetration (H2SO4) and natrium chloride (NaCl). The results of material testing and analysis carried out include fine aggregate testing, crude aggregate testing, slump (workability) testing, initial set time testing, changes in concrete density due to the penetration of natrium chloride (NaCl), testing of C20H14O4 Phenolftalein titration (pH indicator) after penetrating sulfuric acid (H2SO4), a compressive strength test due to penetration of sulfuric acid (H2SO4) and natrium chloride (NaCl).

Table 2. Titration Test Results

No.	Code	Visual & Age Penetration Sample		
		7 Days	14 Days	28 Days
1.	TM GGBFS 0%			
2.	TM GGBFS 60%			
3.	TM GGBFS 70%			
4.	TM GGBFS 80%			



According to table 2, after the cut is done titration Phenolphthalein is C20H14O4 (pH indicator) It can be concluded that sulfuric acid (H2SO4) cannot enter into concrete is reviewed from the titration results of the entire magenta-coloured concrete surface (base or pH > 8.3).

Table 3. Concrete Density testing Results (NaCl penetration)

No.	Code	Early Density (kgs/m³)	Final Density (kgs/m³)	Density change (%)
1.	TM GGBFS 0%	2300	2308	0,35%
2.	TM GGBFS 60%	2229	2233	0,18%
3.	TM GGBFS 70%	2205	2216	0,53%
4.	TM GGBFS 80%	2325	2338	0,55%

VOLUME 3 | NUMBER 1 | JANUARY 2021
Available online at http://proceedings.worldconference.id.
ISSN: 2656-1174 (online)

According to table 3, The average change in concrete density increased by 0.40%, the biggest change is in TM GGBFS 80% by 0.55%. This suggests that with the increasing number of substitutions of GGBFS, the stronger it is to withstand the penetration of natrium chloride (NaCl).

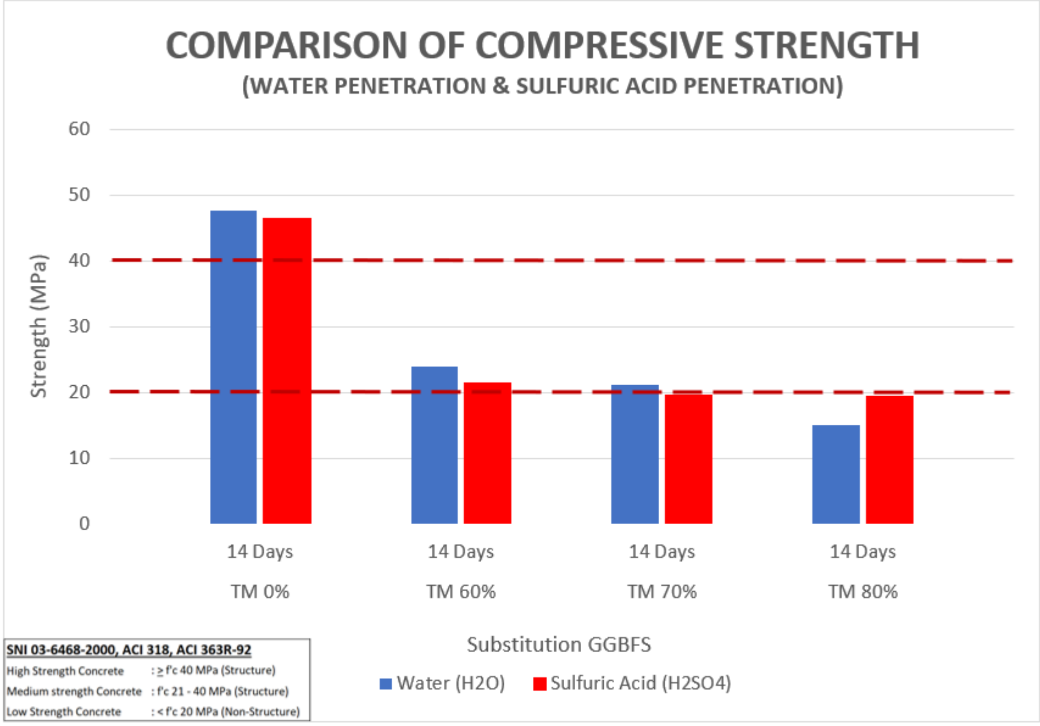


Figure 1. Comparison of Compressive Strength
(Water Penetration & Sulfuric Acid Penetration)

Based on Figure 1, it can be concluded that the use of 80% GGBFS substitution in a concrete mix of age 14 days is able to withstand the penetration of sulfuric acid (H_2SO_4) better than normal concrete (without substitution).

Table 4. Compressive Strength Concrete Result age 14 days

No.	Code	Age	(H_2O)	(H_2SO_4)
1	TM GGBFS 0%	14D	47,75	46,48
2	TM GGBFS 60%	14D	23,94	21,56
3	TM GGBFS 70%	14D	21,23	19,66
4	TM GGBFS 80%	14D	15,18	19,50

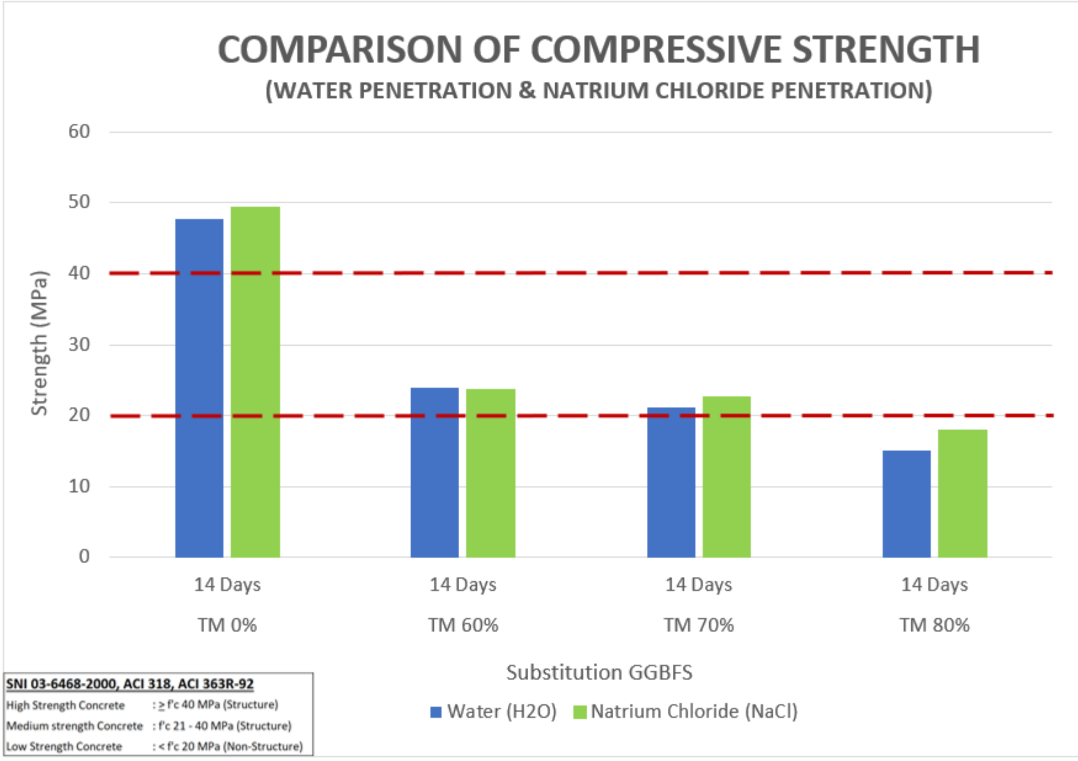


Figure 2. Comparison of Compressive Strength
(Water Penetration & Natrium Chloride Penetration)

Based on Figure 2, it can be concluded that the use of substitution GGBFS 70% and 80% in the concrete mixture of age 14 days is able to withstand the penetration of natrium chloride (NaCl) is better by 6.50% and 18.45% than normal concrete (without substitution).

Table 5. Compressive Strength Concrete Result age 14 days

No.	Code	Age	(H2O)	(NaCl)
1	TM GGBFS 0%	14D	47,75	49,39
2	TM GGBFS 60%	14D	23,94	23,62
3	TM GGBFS 70%	14D	21,23	22,61
4	TM GGBFS 80%	14D	15,18	17,98

6. Conclusion

The growing number of substitutions of Ground Granulated Blast Furnace Slag (GGBFS), the stronger the penetration of natrium chloride (NaCl). The average concrete density increased by 0.40%, the biggest change was at TM GGBFS 80% by 0.55%. With or without the use of substitution Ground granulated Blast Furnace slag (GGBFS) on the mixture of concrete acid sulphate (H_2SO_4) can not enter into the concrete is reviewed from the results of the titration Phenolphthalein is $C_{20}H_{14}O_4$ (pH indicator) all surfaces that have been cut in magenta color (base or pH > 8.3). Use of substitution Ground Granulated Blast Furnace Slag (GGBFS) in the optimum concrete mixture is able to withstand the penetration of sulfuric acid (H_2SO_4) and the penetration of natrium chloride (NaCl) at the age of 14 days with a substitution of 80% GGBFS which is reviewed from the results of compressive strength.

7. Acknowledgment

This research was supported supported by Agung Sumarno. We thank our colleagues from Department of Civil Engineering, Faculty of Engineering, Universitas Mercu Buana who provided insight and expertise that greatly assisted the research, although they may not agree with all of the conclusions of this paper.

VOLUME 3 | NUMBER 1 | JANUARY 2021
Available online at http://proceedings.worldconference.id.
ISSN: 2656-1174 (online)

References

Badan Standarisasi Nasional (2013) *Persyaratan beton struktural untuk bangunan gedung, SNI 2847:2013*, *Jakarta: BSN*.

Karimah, R. and Wahyudi, Y. (2016) 'KAJIAN PENGGUNAAN COPPER SLAG SEBAGAI AGREGAT HALUS BETON', *Media Teknik Sipil*, 14(2). Available at: https://media.neliti.com/media/publications/152436-ID-kajian-penggunaan-copper-slag-sebagai-ag.pdf.

Khrisna P, D. (2014) *Aplikasi Beton Ramah Lingkungan Beton Ramah Lingkungan*.

Nawy, E. G. (1985) *Beton Bertulang. Suatu Pendekatan Dasar*. Prentice Hall.

Neville, A.M., dan J. J. B. (1987) *Concrete Technology*. New York: Longman Scientific and Technical.

Pratama, F. F. H. (2019) *NALISIS KUAT TEKAN BETON MENGGUNAKAN BATU KARANG SEBAGAI PENGGANTI AGREGAT HALUS*. Bachelor thesis.

SNI T-15-1990-03 (1991) *Tata Cara Rencana Pembuatan Campuran Beton Normal, Departemen Pekerjaan Umum*. Bandung: Yayasan Lembaga Penyelidikan Masalah Bangunan.

Supartono (1998) *Beton Berkinerja Tinggi, Keunggulan dan Permasalahannya*. Jakarta: Seminar HAKI.

Tjokrodimuljo., K. (1986) *Penulangan Buhul Pada Konstruksi Beton Bertulang Tahan Gempa.*

Tjokrodimuljo, K. (1996) *Teknologi Beton*. Yogyakarta: Nafiri.

Zainul, Djamaluddin and Anwar, H. (2018) 'ANALISIS PERBANDINGAN SUBSTITUSI SLAG PADA SEMEN DAN PASIR PADA CAMPURAN BETON MUTU K-225 PADA PT IMIP KABUPATEN MOROWALI PROVINSI SULAWESI TENGAH', *Jurnal Geomine*, 6(2). Available at: https://media.neliti.com/media/publications/274108-analisis-perbandingan-substitusi-slag-pa-2aeff176.pdf.