Porous Concrete Based on Granite and Limestone Waste: An Innovative Solution for Drainage Channel Base

Oktavia Kurnianingsih[1*], *Delista Putri* Deni[1], *Anandya Rahmad Saddam* Hasyim[1], *Bachtiar Bagus Ary* Wibisana[1], *Namira Aulia* Syahputri[1]

[1]Associate's Degree Program in Civil Engineering, Vocational School, Universitas Sebelas Maret, Indonesia

Abstract. Drainage systems are crucial component of urban infrastructure, but development reduced infiltration areas and lowers drainage channel capacity due to sedimentation, rubbish and channel narrowing. Decreased drainage channel performance causes water to overflow the surface and cause inundation. This research introduces an innovative solution to enhance drainage channel performance by using porous concrete, which allows water to pass through its voids. This research aims to develop porous concrete by utilising granite and limestone waste. Waste granite and waste limestone have no selling value and can damage the environment. The research method uses experimental tests with variations in the mixture of waste as an added material. The mix variation is used to determine the optimal value of porous concrete permeability. Different variations of porous concrete mixtures: normal concrete, C1, C2, C3, C4. The results obtained found that concrete mix B4 with the largest variation of waste mixture. The speed of passing water with the comparison of normal concrete with C1, C2, C3 decreased. Normal concrete with C4 has an increase in speed of 10%. The findings of this study indicate that the larger the voids in the concrete, the greater the ability of water to escape. This paper provides a basis for further studies on flood mitigation in urban areas with reduced infiltration areas.

1 Introduction

Urban drainage is an important infrastructure for managing water [1]. One of the urban drainage problems is the narrowing of channels due to development. Growing urban development leads to reduced infiltration areas [2]. Climate change indirectly impacts urban infrastructure [3]. Increased high rainfall affects the performance of drainage channels [4]. Drainage systems need to be addressed and managed properly. Urban areas where most of the soil is impermeable and water is difficult to seep into the soil layer [5]. One method that can be done in handling drainage problems with an environmentally friendly method with porous concrete

* Corresponding author: oktaviakurnianingsih@staff.uns.ac.id

Porous concrete can reduce rainwater runoff by passing water into the soil [6]. The main components of cement, coarse aggregate, water, additives, and sand will produce effective voids and help infiltrate drainage water [7].Porous concrete mixtures are different from conventional concrete mixtures [8]. The aggregate gradation does not use fine aggregate with material porosity which causes lower compressive and flexural strength than conventional concrete [9]. The strength of porous concrete is affected by porosity, aggregate size, aggregate type, and cement quality [10].

Porous concrete in this study uses waste materials as additives to be environmentally friendly. The waste used in this study industrial waste has been generated and only a few are recycled so that the remaining waste is disposed of and damages the environment [11]. One of these industrial wastes is granite and limestone waste. The use of granite waste in concrete mixtures can increase the compressive strength of concrete [12]. The resulting permeability of the granite waste mixture is better than without using granite waste so that the use of granite waste is more efficiently used in sustainable concrete manufacturing [13]. Granite waste as a substitute for coarse aggregate is easy to use and can reduce production costs in concrete [14]. Waste limestone is easy to process and produces fine grains so that it can be used as cement [15]. Waste limestone as a cement innovation can produce an increase in compressive strength and flexural strength in concrete [16]. This study aims to provide a solution to the problem of decreasing the capacity of drainage channels in flood mitigation with porous concrete. This porous concrete will be used for drainage channel base products in performance improvement. The improved performance of the channel base is expected to overcome the problem of urban inundation.

2 Research methods

The research used in this study uses an experimental method. This research was conducted at the Basic Construction Laboratory, Faculty of Engineering, Sebelas Maret University. This study uses a mix of designs from normal to mixed. The collected materials are then tested to find out the characteristics of each material. Table 1 presents the testing data of the materials to be used in this study and the waste is shown in Figure 1.

Table 1. Material testing

Testing	**Gravel**	**Granite**
Sludge content	0.64 %	0.34 %
Unit Weight	1431.82 kg/m^3	1527.27 kg/m^3
Specific Gravity	2.28 gr/cm^3	2.94 gr/cm^3
Specific Gravity (SSD)	2.39	2.95
Infiltration (*Absrobtion*)	4.833 %	0.333 %
Abrasion	56.42	21.74
Gradations	6.826	6.816

The implementation of porous concrete production research is divided into six stages after the preparation stage, as follows: inspection of mix materials with good quality standards, making mix designs with the addition of granite waste and limestone waste, processing stages in concrete, and tests carried out, namely compressive strength and permeability tests.

Fig. 1. Additives to research. a) Granite waste, b) Limestone waste.

The concrete mix design calculation for producing the test specimens refers to ACI Report 522R-10 on Pervious concrete with porous concrete having a slump value close to zero [17] [18]. The quality of concrete used in the mix was K-175. The percentage addition of limestone waste to the weight of cement was 15% and 30%, while the addition of granite waste based on the comparison showed a percentage of 20% and 40% to the coarse aggregate material. The material composition for making specimens with moulds measuring 10 cm x 20 cm is presented in Table 2.

Table 2. Mix design variations.

Materials	**CN**	**C1**	**C2**	**C3**	**C4**	**Unit**
Safety Factor	3					
Cement	3.04	2.58	2.58	2.13	2.13	kg/3 mould
Limestone	-	0.46	0.46	0.91	0.91	kg/3 mould
Gravel	9.38	7.51	5.63	7.50	5.63	kg/3 mould
Granite Stone	-	2.34	4.68	2.34	4.68	kg/3 mould
Water	1.15	1.15	1.15	1.15	1.15	litre
w/c ratio	0.38					

Information:
CN: Normal Concrete
C1: Innovation Concrete (15% Limestone and 20% Granite)
C2: Innovation Concrete (15% Limestone and 40% Granite)
C3: Innovation Concrete (30% Limestone and 20% Granite)
C4: Innovation Concrete (30% Limestone and 40% Granite)

The test objects in this study are cylinders measuring 10 cm x 15 cm. Making test objects as many as 10. Making test objects using existing tools in the laboratory. The next stage is curing so that the concrete remains moist and reaches the targeted quality [8]. Concrete testing in this study includes permeability, compressive strength and water velocity. The compressive strength test was conducted at the age of 7 days, 14 days, and 28 days. According to SNI 03-1974-1990 [19] [20]. concrete compressive strength can be calculated by equation 1 as follows.

$$fc' = P/A \qquad (1)$$

where,
fc' = compressive strength of concrete cylinder (MPa)
P = Maximum compressive load (N)
A = compressive cross-sectional area (mm^2)

Fig. 2. Compressive strength with compressing testing machine.

Permeability testing with test pieces and permeability devices, water and stopwatches. The test procedure is carried out by preparing the test piece that has been cured previously, filling the permeability test device with water to the full, placing the test piece on top of the permeability test device, installing a tank on top of the test piece, preparing 2 liters of water and a stopwatch, and inserting 2 liters of water at the same time calculating the time with the stopwatch until the water does not flow. The permeability value requirement table can be seen in table 3.

Table 3. Permeability of porous concrete (NRMCA, 2011 and ACI 522R - 10).

Value	NRMCA, 2011 (cm/s)	ACI 522R-10 (cm/s)
Minimum	0.2	0.14
Maximum	1.2	1.22

3 Results and discussion

3.1 Concrete compressive strength test

The use of granite and limestone waste in this study in order to obtain an optimal mixture, it is necessary to carry out a compressive strength test. Compressive strength for maximum results with 7-day, 14-day and 28-day test variations. The results of the compressive strength test can be seen in Table 4

Table 4. Compressive strength rating of porous concrete**.**

Variations	Compressive Strength (MPa)		
	7 days	14 days	28 days
CN	5.29	5.93	10.82
C1	5.87	7.52	11.45
C2	3.92	8.53	13.36
C3	4.50	5.35	7.89
C4	2.94	7.38	10.82

Information:
CN : Normal Concrete
C1: Innovation Concrete (15% Limestone and 20% Granite)
C2: Innovation Concrete (15% Limestone and 40% Granite)
C3: Innovation Concrete (30% Limestone and 20% Granite)
C4: Innovation Concrete (30% Limestone and 40% Granite)

Table 4 shows the results of concrete compressive strength testing with testing on increasing the age of concrete to obtain the planned compressive strength. Compressive strength values at 7 days of age from CN to C4 indicate different values. The highest compressive strength value at 7 days of age was obtained in the C1 concrete variation with a lower granite mixture of lime. The 14-day age was tested with the addition of compressive strength to the and the highest value was obtained which was 8.53 Mpa with a higher percentage of granite. The 28-day compressive strength test of concrete was carried out, and the results were obtained that among the values of CN, C1, C2, C3 to C4, the highest compressive strength in C2 was Innovation Concrete (15% Limestone and 40% Granite).

The age addition to the compressive strength test provides the compressive strength addition. The longer the life of the concrete, the higher the strength. The C2 value indicates that the addition of the largest granite and the smallest limestone indicates the optimal composition. The lowest percentage of strength is in addition of the largest waste lime and the smallest granite. This result indicates that the addition of the largest granite causes the compressive strength to be greater. The graph of the addition of strength to concrete is shown in Figure 3.

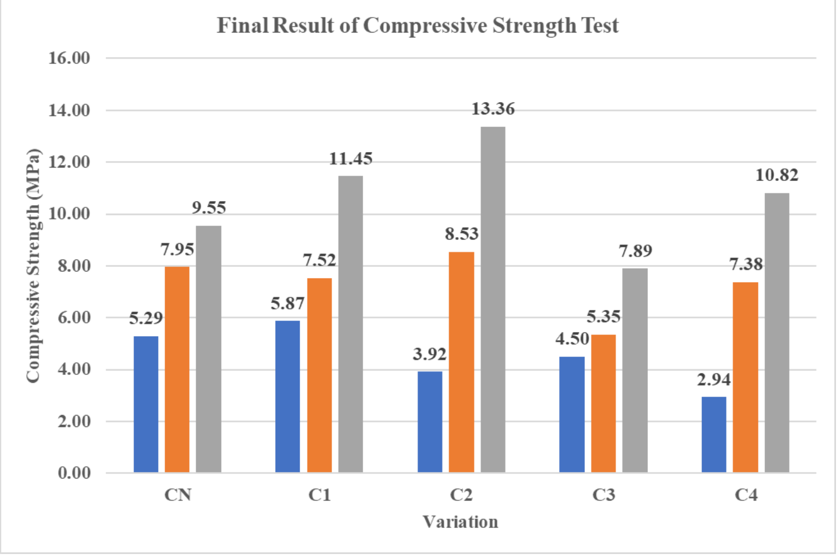

Fig. 3. Overall concrete compressive strength test.

Figure 3 shows the results of the concrete compressive strength test. Blue indicates 7 days of age, orange 14 days and 28 days indicate ash. The graph above can be seen that the use of granite and lime waste as a substitute material affects the compressive strength of porous concrete, there is an increase from normal concrete. The final result of the optimum concrete compressive strength test occurred in the B2 variation (15% Gamping and 40% Granite) which was 13.36 Mpa and the minimum compressive strength occurred in the B4 variation (30% Gamping and 40% Granite) which was 2.94 Mpa.

https://doi.org/10.1051/e3sconf/202457606001

The addition of granite in this study increases compressive strength. Granite has a dense kharateristic and can be used as a substitute for coarse aggregate [8]. Waste utilization in concrete production also provides advantages, namely in terms of cheaper costs, reducing waste that causes environmental damage. The results show that with the addition of a lot of granite waste, the increase in compressive strength is higher. Granite waste that is no longer used causes the environment to be damaged by pollution. The addition of life to 28 days of concrete compressive strength is more optimal.

Limestone is a waste that can be used as a substitute for cement. The results of the study show that with a high limestone preset, the compressive strength decreases. Lime waste has a chelatorytic that can be used as a filler instead of a cement substitute. The use of limestone contributes to the environment. The smooth texture can be used as a filler and results in better mechanical properties.

3.2 Permeability Test Results

Permeability in this study is used to determine the ability of concrete to pass water. Concrete in this study will produce the basic product of the channel. The basis of the channel in this study is an effort to increase the capacity of drainage channels. Soil permeability testing was carried out at the age of 28 days. Permeability testing with water use and time calculation. This test principle is with a falling head meter where the test energy drops. Permeability testing is carried out in the Basic Construction Laboratory. The testing tools in this study still use a simple assembly that is adjusted to laboratory equipment.

Permeability testing on porous concrete with variations of CN, C1, C2, C3 and C4 mixtures. Each variation is tested to see the optimal permeability value that can be used in the product. A table of test results can be seen in Table 5 Figure 4.

Table 5. Permeability test results of porous concrete.

Variations	Permeability (k = cm/s)	ACI 522R – 10 (0.14 – 1.22 cm/s)
CN	0.91	Appropriate
C1	0.88	Appropriate
C2	0.73	Appropriate
C3	0.67	Appropriate
C4	1.02	Appropriate

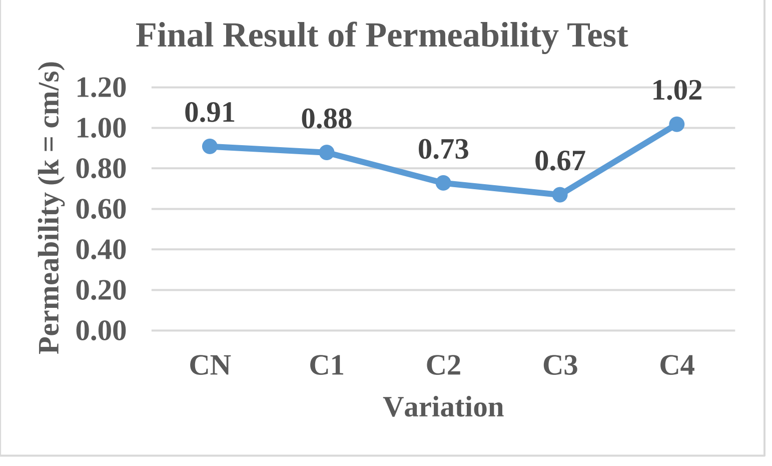

Fig. 4. Permeability test graph

Table 5 and Figure 4 show the permeability test on normal concrete is high, but concrete with a mixture of limestone and granite shows the highest value. The highest score in the C4 permeability test indicates that porous concrete does not use fine aggregate. Fine aggregates make it difficult for water to seep into the concrete. The use of granite and limestone as a mixture makes concrete porous. Porous concrete can be passed by water. Permeability requirements use ACI 522R 10 values of 0.14 – 1.11 cm/s. The CN value results in a permeability of 0.91 cm/s according to the requirements. The value of C1 is 0.88 cm/s, C2 is 0.73 cm/s, C3 is 0.67 % and C4 is 1.2 cm/s. The increase in soil permeability is in accordance with the requirements.

The permeability test in this study will be used as a reference in the manufacture of products. The basic product of the channel requires a high permability value of innovation. C4 with a 40% granite and 30% limestone presentation is used for the next stage. The next stage is product manufacturing.

3.3 Basic Products of Drainage Channels

The research on porous concrete using granite stone waste and limestone powder targets products in the form of channel bottoms. The bottom of the drainage channel was chosen as a solution to urban drainage and flood problems. The use of porous concrete is expected to be able to pass water into the soil so as to reduce the capacity of drainage channels. The application of porous concrete for the base of the drainage channel will be applied in the catchment area around buildings, pedestrians, squares, and city parks. Porous concrete with optimal compressive strength and soil permeability is used for the base products of drainage channels. The use of this product will be used at the bottom of drainage channels with a combination of river rock fragments that are still widely found in many drainage channels. The emphasis is on lower production costs compared to conventional concrete. This product is expected to be able to infiltrate water into the soil to determine its speed can be seen in Figure 5 and the product Figure 6.

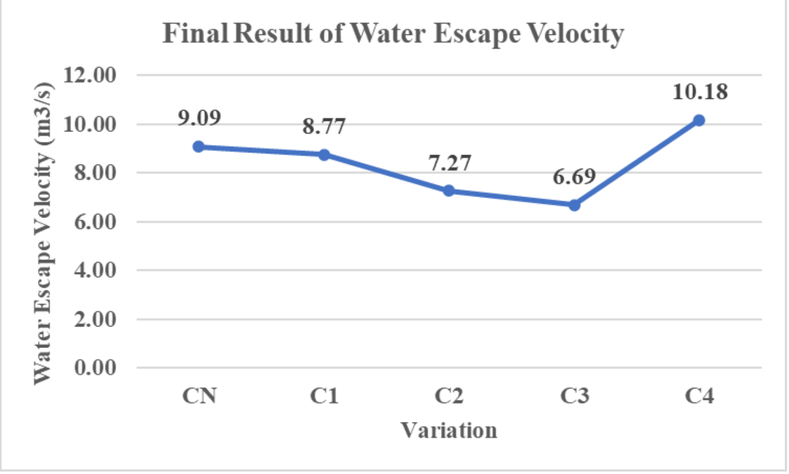

Fig. 5. Drainage channel product speed chart

The velocity results in the drainage channel product for the optimal mix C4 with 10.18 m3/second. Normal concrete 9.09 m3/second with additional speed compared to normal concrete. It is hoped that this product will provide a solution to the problem of drainage channel performance and increase urban development.

Fig. 6. Drainage channel products

Figure 6 is the product of this study. Several urban areas have increased, causing a reduction in areas that have not been built. Areas with infiltration are slightly harmful when high-intensity rain becomes inundation and flooding. Drainage channels are not able to collect rainwater, so this product is used for the bottom of the canal. This product is expected to increase the capacity of drainage channels. Infusing water into the soil in an effort to conserve soil and water.

4 Conclusions

The research on the addition of granite and limestone waste as additives to this research contributes to the environment. The granite innovations used in this study are CN, C1 (15% lime and 20% granite), C2 (15% lime and 40% granite), C3 (30% lime and 20% granite), C4 (30% lime and 40% granite). The compressive strength of concrete is directed at the C2 value with a low percentage of limestone and high granite. The use of granite in concrete mixtures provides optimal compressive strength values. The optimum compressive strength is obtained 13.36 MPa according to the requirements. The requirements in this study used a K value of 175. The increase in age in concrete causes the compressive strength value to increase. The soil permeability value used in this study was 28 days old. The highest peremability value is C4. The use of large granite and large limestone provides a high permeability value. The permeability value of 1.02 cm/s is in accordance with the requirements. High permability value is used for product manufacturing. The basic product of this channel uses a high permeability value. The basic product of this channel is tested to see optimal performance. The results of the study were 10.18 m3/s in velocity in the product. It is hoped that in this study, this product can be used in the bottom of canals, reduce flooding, and increase the capacity of drainage channels. The suggestion in this study is the use of optimal composition so that the compressive strength and permeability are appropriate. The basic products of these channels can be produced and introduced to the construction world. Increasing the capacity of drainage channels is important to overcome urban floods. This product if used can provide groundwater reserves.

Thank you to all parties involved in this research.

References

1. Zhi G, Liao Z, Tian W, Wang X and Chen J, A 3D dynamic visualization method coupled with an urban drainage model *J. Hydrol.* **577** 123988 (2019)
2. Samouei S and Özger M, Evaluating the performance of low impact development practices in urban runoff mitigation through distributed and combined implementation *J. Hydroinformatics* **22** 1506–20 (2020)
3. Szabó Z, Szijártó M, Tóth Á and Mádl-Szőnyi J, The Significance of Groundwater Table Inclination for Nature-Based Replenishment of Groundwater-Dependent Ecosystems by Managed Aquifer Recharge *Water (Switzerland)* **15** (2023)
4. Patel M P, Gami B, Patel A, Patel P and Patel B, Climatic and anthropogenic impact on groundwater quality of agriculture dominated areas of southern and central Gujarat, India *Groundw. Sustain. Dev.* **10** 100306 (2020
5. Locatelli L, Mark O, Mikkelsen P S, Arnbjerg-Nielsen K, Deletic A, Roldin M and Binning P J, Hydrologic impact of urbanization with extensive stormwater infiltration *J. Hydrol.* **544** 524–37 (2017)
6. Zhu Q, Dong X, Hu J, Yang J, Zhang X, Ding Y and Dong S, High strength aligned SiC nanowire reinforced SiC porous ceramics fabricated by 3D printing and chemical vapor infiltration *Ceram. Int.* **46** 6978–83 (2020)
7. Sánchez-Mendieta C, Galán J J and Martinez-Lage I, Physical and hydraulic properties of porous concrete *Sustain.* **13** (2021)
8. Kurnianingsih O, Abid M, Putra Firdaus H and Tri Ashari H, Waste and Marble Waste Variations on the Compressive Strength and Permeability of Porous Concrete *IOP Conf. Ser. Earth Environ. Sci.* **1317** (2024)
9. Moretti L, Di Mascio P and Fusco C, Porous concrete for pedestrian pavements *Water (Switzerland)* **11** (2019)
10. Zhang Y, Li H, Abdelhady A, Yang J and Wang H, Effects of specimen shape and size on the permeability and mechanical properties of porous concrete *Constr. Build. Mater.* **266** 121074 (2021)
11. Kurnianingsih O, Canggih Gilang Pradana H S, Rahmi A T, Pratiwi K H and Legowo S J, Utilization of plastic bottles and fiber mask in eco-friendly concrete mixtures *IOP Conf. Ser. Earth Environ. Sci.* **1180** (2023)
12. Jain K L, Sancheti G and Gupta L K, Durability performance of waste granite and glass powder added concrete *Constr. Build. Mater.* **252** 119075 (2020)
13. Jain A, Gupta R and Chaudhary S, Performance of self-compacting concrete comprising granite cutting waste as fine aggregate *Constr. Build. Mater.* **221** 539–52 (2019)
14. Rina Aswanti, Penggunaan Silika Fume Untuk Reduksi Semen dengan Limbah Granit Sebagai Pengganti Agregat Kasar terhadap Kuat Tarik Beton, Undergraduate Thesis, Universitas Bosowa Makassar, Indonesia (2023)
15. Krindho, Togi H. Nainggolan M E, PENGARUH LIMBAH BATU MARMER SEBAGAI PENGGANTI AGREGAT KASAR 10/10 PADA LAPISAN ATB (ASPHALT TREATED BASE) TERHADAP NILAI KARAKTERISTIK *J. Penelit. Progam Stud. Tek. Sipil S-1 FTSP, ITN Malang* 19–26 (2020)
16. Topcu I B and Baylavli H, Use of concrete wastes as limestone replacement in limestone blended cement production *kuwait J. Sci.* **46** (2019)
17. ACI Committee, ACI 522R-10. Report On Berpori Concrete (2010)
18. Aulia A N, *Karakteristik Beton Pori (Pervious Concrete) dengan Penambahan*

Admixture terhadap Laju Alir, Kuat Tekan dan Kuat Tarik Belah (UNIVERSITAS JEMBER) (2018)

19. Badan Standardisasi Nasional, Persyaratan Beton Struktural untuk Bangunan Gedung *Sni 2847-2019* 720 (2019)
20. Tyas Y W, Nurtanto D and Krisnamurti, Pengaruh Variasi Prosentase Superplasticizer terhadap Sifat Mekanik dan Porositas Beton Berpori *Media Tek. Sipil* **18** 33–41 (2020)