Analysis of the Effect of Damdex Addition to Concrete Mixture on Compressive Strength

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Abstract*— This study aims to determine the compressive strength and modulus of elasticity of concrete with the addition of Damdex variables to obtain the best composition. This research method is classified as quantitative research conducted at PT. Fresh Beton Indonesia Batching Plan BSD. In this study, research was conducted using two different concrete mixtures, namely 1 Pc: 2 S: 3 Gr and 1 Pc: 3 S: 2 Gr, each of which was supplemented with Damdex at concentrations of 0.0%, 0.2%, 0.4%, and 0.6%. According to the study's results, the highest compressive strength and modulus of elasticity were achieved in a concrete mixture of 1 Pc: 2 S: 3 Gr, with a variable addition of Damdex at 0.2%, resulting in a compressive strength of Fc 15.11 MPa and a modulus of elasticity of 18975.061 MPa. Meanwhile, the lowest compressive strength and modulus of elasticity results were obtained in the concrete mixture of 1 Pc: 2 S: 3 Gr with the variable addition of Damdex 0.6%, with a compressive strength of Fc 12.90 MPa and a modulus of elasticity of 17049.89 MPa. In the concrete mixture of 1 Pc: 3 S: 2 Gr, the compressive strength and modulus of elasticity were smaller compared to the concrete mixture of 1 Pc: 2 S: 3 Gr, with the highest results in the variable addition of Damdex 0.2%, with a compressive strength of Fc 9.89 MPa and a modulus of elasticity of 13846.477 MPa. Compressive strength and elastic modulus were measured at 28 days in accordance with SNI 1974:1990/2847 procedures. Among the tested mixtures, the 0.20% Damdex addition achieved the highest average compressive strength and elastic modulus. Within the tested conditions, 0.20% Damdex provided the best average performance; however, further work with larger samples and additional durability metrics is needed to confirm this trend.

Keywords— Additives, Compressive Strength, Concrete, Damdex, Elastic Modulus.

I. INTRODUCTION

The development of concrete technology in construction in Indonesia continues to accelerate [1],[2]. The advancement of concrete technology is used to create innovations aimed at improving the quality of concrete. In some cases, concrete mixtures require additions to accelerate hardening, ease processing, increase compressive strength, and so on. According to Matar et al. [3]-[5] Currently, the need for civil construction development requires good-quality concrete that can be produced quickly. With increasingly advanced developments, including concrete technology to meet the needs of concrete in the civil construction sector, this sector is experiencing rapid progress.

According to Waldvogel et al. [6] that admixture is a solution to improve the quality of the concrete mix. The added ingredients listed can enhance the properties of concrete and cement paste so that they can be used for certain jobs, for example, adding admixture into the concrete mix, can delay or speed up the bonding process of the concrete mix, and strengthen the strength of the concrete, and admixture is an additional material that can be in the form of water, aggregate, cement material, fibre reinforcement, etc. which functions as a cement mixture and is added before or during the mixing process to change the properties of the mixture and make mixing easier or produce curing. Admixture is a solution to improve concrete quality. These additional ingredients can affect the concrete properties of cement paste so that it is suitable for work.

According to Amran et al. [7] When mixing large-capacity concrete, the use of ready-mix concrete in the field faces several obstacles related to travel time to the place that is not smooth and the need for acceleration of concrete after pouring [8]-[10]. The problems that exist in the work of casting road concrete in the field require accelerating the hardening of concrete after pouring because the road can be opened as soon as possible for traffic to pass again, so that the road can run properly and not experience congestion [11]. So, to overcome these problems, advances in concrete technology have produced additional materials that can help maintain the quality and workability of concrete. To overcome these problems, advances in concrete technology have introduced additional materials that can help maintain and accelerate the hardening of concrete by using Damdex [12], [13]. This chemical is used to improve several properties of concrete, such as accelerating the hardening process, increasing ease of workability, and increasing compressive strength. However, until now, there has been no specific guideline regarding the dosage of these materials in concrete mixtures. This is very important, especially in

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construction work that demands higher time efficiency [14]-[16]. The addition of chemical admixtures such as Damdex to concrete can affect the quality if it is not compatible with the mixture in an error in the dosage percentage of the addition, which risks changing the strength and properties of the concrete [17], [18]. In addition, admixtures can affect the hardening speed and affect mechanical properties such as compressive strength and durability, so the right mixing technique is needed to produce concrete compressive strength results according to the expected specifications[19]-[20]. Therefore, it is necessary to conduct useful research to test the truth of the two products and what percentage will be used in the concrete mixture.

Damdex is a commercial integral waterproofing admixture containing active silicate compounds that react with $Ca(OH)_2$ in the cement paste to form insoluble crystalline products. These crystals block capillary pores, reduce permeability, and may influence workability and early hydration. The net effect on mechanical properties depends on dosage and curing regime: at appropriate levels, densification of the matrix can increase strength, whereas overdosing may increase micro-voids and reduce bonding. This study, therefore, evaluates four dosages (0.00–0.60%) under controlled curing to identify the range that maximizes performance in normal concrete mixes.

According to Yadav et al.[8]Concrete is a composite material that is easy to make but requires precision in planning, especially related to the water-cement factor (FAS), as well as the mixing and compaction process, so that the concrete is solid. Concrete is a mixture of sand, gravel, or other aggregates with cement paste and water that forms a rock-like mass [21],[22]. Normal concrete uses sand as fine aggregate (≤ 5.0 mm), crushed stone as coarse aggregate (5-40 mm), cement, and water, with a volume weight of 2200-2500 kg/m³ and a compressive strength of 20-40 MPa. [10]. According to Ojha et al. [11]. Concrete is a mixture of hydraulic cement (Portland cement), coarse aggregate, fine aggregate, and water, and can be added with additional materials (admixture or additive) to form a solid mass. Meanwhile, Al-Rashed et al. [12] defines concrete as a construction material consisting of a mixture of cement, sand, coral, water, and additional materials that function to increase ease of work, durability, and hardening time. Concrete has characteristics such as high compressive strength but low tensile strength and will harden like rock. Meng et al. [13] adding that the properties of concrete are influenced by the composition of the mixture, the quality of the material, the casting method, the finishing process, and the curing conditions. Concrete is often chosen because of its advantages, such as high strength, fire resistance, and corrosion resistance. Cement, according to Peters Omale [14], is a hydraulic adhesive material obtained from the refining of clinker, which mainly contains calcium silicates, with the addition of gypsum. This compound reacts with water to form an adhesive substance capable of bonding rocks. In this sense, cement has adhesive and cohesive properties and is usually used as a binder mixed with gravel and sand.

Concrete compressive strength is the ability of concrete to withstand loads per unit area until it collapses when given a certain compressive force, which is tested using a compression machine (SNI 03-1974-1990). Concrete compressive strength reflects the quality of the structure, where the higher the compressive strength value, the better the quality of the concrete [23]-[26]. Li et al.[16]states that the compressive strength value is obtained from testing the axial compressive force per unit area until the concrete is destroyed. According to Ojha et al.[7] Compressive strength is the main property of concrete, which is the main target in the manufacturing process. In concrete technology, the strength produced is influenced by several factors, namely: a) water-to-cement ratio, b) cement-to-aggregate ratio, c) gradation, surface texture, shape, and strength of aggregate particles, and d) maximum aggregate size. Concrete compressive strength testing is carried out to ensure that the concrete strength at the age of 28 days is as planned. The use of Damdex in concrete can also provide environmental benefits. Concrete with better durability will require less maintenance and repair, reducing resource consumption and construction waste [27]-[30]. Thus, the use of Damdex can help in achieving the principle of sustainable development. Although the addition of Damdex to concrete offers various promising benefits, it should be remembered that the use of this additive must be by following per under the applicable guidelines and recommendations. Further research and field testing are needed to fully understand the long-term effects of Damdex use in concrete and ensure the sustainability and safety of the structure. With continued research, the use of Damdex in concrete has the potential to provide innovative solutions to overcome various problems associated with concrete and improve the quality and durability of future building infrastructure [31]-[34].

II. LITERATURE REVIEW

A. General Definition of Concrete

Concrete is one of the construction materials that has been commonly used for buildings, bridges, roads, and others. Concrete is a homogeneous mixture [35]. This concrete is obtained by mixing fine aggregate (sand), coarse aggregate (gravel), or other types of aggregates and water, with Portland cement or other hydraulic cement, sometimes with additional chemical or physical additives in certain proportions, until it becomes a homogeneous mixture. The mixture will harden like a rock [36]. Hardening occurs due to the chemical reaction between cement and water. Concrete is a material made from a mixture of Portland cement, fine aggregate (sand), coarse aggregate (gravel), and water with the addition of air voids.

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B. Materials Constituting Concrete

The following will describe the materials that form concrete, which are also used as concrete materials to be studied in this research. The materials that constitute concrete are as follows:

Portland Cement

Cement is a mixture that is chemically active after encountering waste [37]. In general, the chemical composition of compounds in cement can be seen in Table 1.

TABLE I. COMPOSITION OF PORTLAND CEMENT ELEMENTS [14]

No.	Composition	Percentage (%)
1.	Lime (CaO)	60 – 65
2.	Silica (SiO2)	17 – 25
3.	Alumina (Al2O3)	3 – 8
4.	Iron (Fe2O3)	0.5 – 6.0
5.	Magnesia (MgO)	0.5 – 4.0
6.	Alkali (K2O + Na2O)	0.5 – 1.0
7.	Sulphur (SO3)	1-2

The Portland cement used must meet the requirements (SII 0013-81) and is divided into 5 types as follows [13].

- Type I, Portland cement, does not require special requirements in its use like other types.
- Type II, Portland cement requires resistance to sulphate and moderate heat of hydration in its application.
- Type III, Portland cement requires high early strength in the initial phase after setting occurs.
- Type IV, Portland cement requires low heat of hydration in its application.
- Type V, Portland cement requires higher resistance to sulphate.

Portland cement used for structures must have certain quality standards that have been established to function effectively.

Aggregate

According to SNI 03-2847-2002, aggregate is defined as granular material, such as sand, gravel, crushed stone, and blast furnace slag, which is used together with a binding medium to form concrete or hydraulic cement mortar [38]. From its source, aggregates can be classified into two categories: natural aggregates and artificial aggregates.

The purposes of using aggregates in concrete mixtures are as follows:

- Saving the use of Portland cement
- Producing great strength in concrete
- Reducing shrinkage during the hardening of concrete
- Achieving a dense concrete mix with good gradation will result in concrete that is easy to work with.
- The workability of concrete can be tested with a well-graded mix.

Based on their size, aggregates are classified into two categories: fine aggregate and coarse aggregate (SNI 03-2847-2002):

- Fine aggregate. According to SNI 03-2847-2002, fine aggregate is natural sand resulting from natural disintegration or sand produced by the stone crushing industry, with a maximum particle size of 5.0 mm.
- Coarse aggregate. According to SNI 03-2847-2002, coarse aggregate is gravel resulting from the natural disintegration of stone or crushed stone obtained from the stone crushing industry, with a particle size ranging from 5 mm to 40 mm.

Properties and Strength of Concrete in General

Table 2 presents the gradation limits of fine aggregate based on sieve analysis, classified into four zones (Zone I to Zone IV). All zones show 100% passing at the 10 mm sieve, indicating uniform maximum particle size. As the sieve size decreases, the percentage passing varies across zones, reflecting differences in fineness. Zone I represents coarser sand with lower percentages passing finer sieves, while Zone IV indicates the finest sand with higher percentages passing smaller sieves. Zones II and III fall between these extremes. This classification is essential for determining suitable aggregate gradation to achieve desired concrete strength and workability.

TABLE II. PROPERTIES AND STRENGTH OF CONCRETE

Hole Sieve (mm)	Percentage Through the Grain That Passes Through the Sieve			
	Zone I	Zone II	Zone III	Zone IV
10	100	100	100	100
4.8	90 – 100	90 – 100	90 - 100	95 – 100
2.4	60 – 95	75 – 100	85 – 100	95 – 100
1.2	30 – 70	55 – 90	75 – 100	90 – 100
0.6	15 – 34	35 – 59	60 – 79	80 – 100
0.3	15 – 20	8 – 30	12 – 40	15 – 50
0.15	0 – 10	0 – 10	0 – 10	0– 15

C. Chemicals in Concrete

A retarder is a chemical additive used to slow down the setting time so that the mixture remains workable for a longer period. Temperatures as high as 30 – 32 °C or more often cause faster hardening, which makes pouring and finishing difficult. Retarders are generally sugar-based materials. The mechanism of how retarders work is by coating the cement particles with OH-, thus slowing down the initial reaction of hydration.

Types of Retarders:

- Type A (Water-Reducing Admixtures)

  Water-reducing admixtures (reducing water content) are additives that reduce the amount of mixing water needed to produce concrete with a certain consistency. The aim is to make the concrete easier to work with without adding water.
- Type B (Retarding Admixtures)

  Retarding Admixtures are materials that function to delay the setting time of concrete. The purpose is to postpone the setting time of concrete, for example, due to hot weather, or to extend the finishing time, to avoid cold joints, and to prevent the impact of slump during fresh concrete or the pouring process.
- Type C (Accelerating Admixtures)

  Accelerating Admixtures, also known as calcium chloride, are materials that function to accelerate the setting

and early strength development of concrete. The purpose is to speed up the hydration process.

- Type F (Water Reducing, High Range Admixtures)

  Water Reducing, High Range Admixtures are additives that function to reduce the amount of mixing water required to produce concrete with a consistency higher by 12% or more than that of plain concrete.

- Type G (Water Reducing, High Range Retarding Admixtures)

  Water Reducing, High Range Retarding Admixtures are additives that function to reduce the amount of mixing water required to produce concrete with a consistency greater than 12% or more and to delay the setting time of the concrete. This type of material is a combination of a superplasticizer with a setting time retarder [39]. It is usually used in constrained work conditions because it requires less labor.

III. Materials and Methods

This study uses a quantitative method with an experimental approach conducted at the location: PT. Fresh Beton Indonesia Batching Plan BSD.

The concrete mix design follows the SNI-7656-2012 method concerning the procedure for making normal concrete using Damdex additives with variations of 0.00%, 0.20%, 0.40%, and 0.60%. Concrete cube 150 x 150 x 150 mm were cast and water-cured at 27 ± 2 °C for 28 days prior to testing. The water-cement ratio (w/c) = 0.56 for all batches unless noted. A target slump of 8 ± 2 cm was maintained for all mixtures by adjusting mixing water within the w/c tolerance. Each data point represents three replicate specimens (n=3). The independent variable in this study is the variation of the Damdex mixture, while the dependent variable is the compressive strength of the concrete [40].

Testing standards. Compressive strength at 28 days followed SNI 03-1974-1990 (equivalent to cube compression procedures), and the elastic modulus was evaluated as a secant modulus from the load–deformation response using dial gauges mounted on the cube faces. Aggregate characterization followed SNI 03-1968-1990 (sieve analysis) and SNI 03-4804-1996/1998 (unit weight). The material tests carried out include: (1) Aggregate sieve analysis, (2) Mud content testing, (3) Examination of specific gravity and aggregate absorption, (4) Aggregate unit weight testing. The materials used in the study, The Effect of Adding Chemical Admixtures (Chemical Admixture) Damdex on Concrete Compressive Strength, are as follows: Portland cement to be used in the study. The following Fig. 1 is the research flow that will be carried out.

In this study, the quality concrete test material was made with a percentage variation of 0.00%, 0.20%, 0.40%, and 0.60%. Analysis of the Addition of Chemical Admixture Damdex to Concrete Compressive Strength, where concrete samples will be made as many as test materials for each mixture variation, and later the total sample will be 12 pieces.

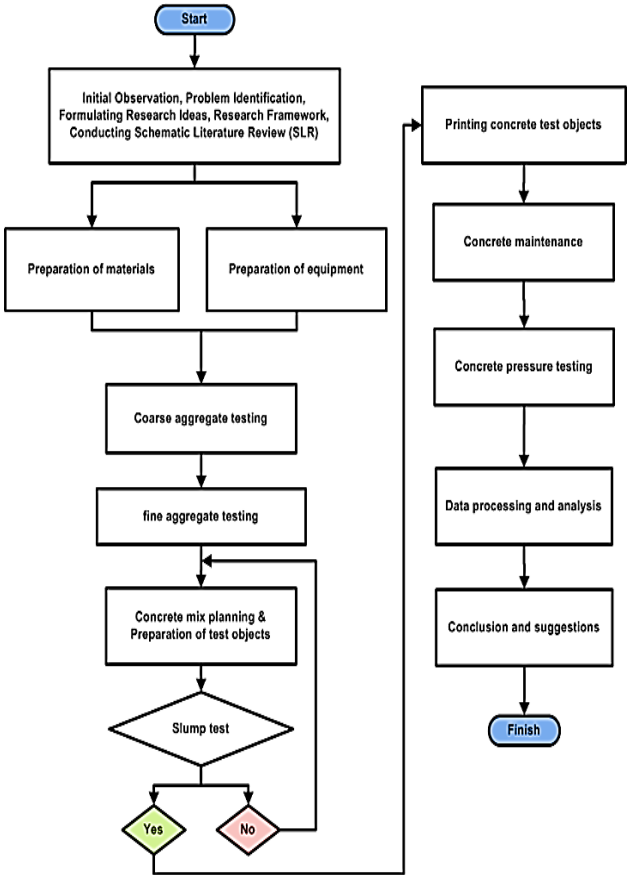


Fig. 1. Research Design

The sample will be tested for compressive strength at the age of 28 days with variations in the addition of Damdex 0.00%, 0.20%, 0.40%, and 0.60%. The number of samples in this study is as follows:

Table III. Number and Variation of Concrete Mix Samples

No	Concrete Mix Variations	Number of Samples
1	+ 0.00% Normal Concrete	3
2	+ 0.20% Damdex increase	3
3	+ 0.40% additional Damdex	3
4	+ 0.60% additional Damdex	3
	Total Concrete Sample	12

Concrete design in this study is targeted to achieve concrete quality. The concrete mix design process is carried out based on normal concrete guidelines by following the SNI DT-91-0008-2007 method concerning the Procedure for Calculating Unit Prices for Concrete Works issued by the Department of Public Works. Axial strain was measured using dial gauges with a gauge length of 200 mm and a resolution of 0.002 mm, mounted on opposite faces of the cube specimens. The mixture consists of the following types of materials:

Table IV. Concrete Mix Composition

No	Material	Index	Volume
1	Cement	384 Kg	7.6 sacks
2	Coarse Aggregate	629 Kg	0.49 m^3
3	Fine Aggregate	1039 Kg	0.78 m^3
4	Water	215 L	215 L

Source: *SNI 7394:2008*

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The material requirements for the test object mixture are as Table 5

TABLE 5. CONCRETE COMPOSITION (DAMDEX)

Variatio Mixture	Weight of materials for the 3 concrete cube test objects				
	Sand (Kg)	Cement (Kg)	Damdex (L)	Water (L)	Split (Kg)
0.00%	7.30	4.884	-	2.490	13.552
0.20%	7.30	4.884	0.062	2.490	13.552
0.40%	7.30	4.884	0.124	2.490	13.552
0.60%	7.30	4.884	0.186	2.490	13.552

Source: Research Data

IV. RESULTS

A. Fine Aggregate Test Results

The fine aggregate used in this study is sand that has met the Indonesian National Standard (SNI). Testing of fine aggregates is carried out to determine the gradation zone and fineness modulus.

TABLE VI. FINE AGGREGATE SIEVE TEST RESULTS (SNI.03 - 1968 – 1990)

Filter	Check the result
No. 4	3 g
No. 8	12.5 g
No. 16	55.7 g
No. 30	131.6 g
No. 50	119.2 g
No. 100	151.4 g
No. 200	13.9 g

Source: Test Results

Based on the table above, the research results from the Materials Laboratory show that the fine aggregate gradation of sand is mostly retained on the 100-sized sieve, with a weight reaching 151.4 grams.

TABLE VII. LOOSE FINE AGGREGATE UNIT WEIGHT TEST RESULTS (SNI.03 – 4804 – 1996)

Loose	Sample I	Sample II
A. Weight of place + test object (kg/m³)	5.838	5.940
B. Weight of the place (kg/m³)	1.887	1.887
C. Weight of test object (kg/m³)	3.951	4.053
D. Contents (kg/m³)	2.722	2.722
E. Weight of the test object (kg/m³)	1451	1488
Average test specimen volume (kg/m³)	1470	

Source: Test Results

TABLE VIII. RESULTS OF SOLID FINE AGGREGATE UNIT WEIGHT TEST (SNI.03 – 4804 – 1996)

Congested	Sample I	Sample II
A. Weight of place+test object(kg/ m³)	6.135	5.940
B. Weight of the place (kg/m³)	1.887	1.887
C. Weight of test object (kg/m³)	4.248	4.313
D. Contents (kg/m³)	2.722	2.722
E. Weight of the test object (kg/m³)	1560	1584
Average test specimen volume (kg/m³)	1572	

Source: Test Results

B. Coarse Aggregate Test Results

The coarse aggregate used in this research is peacock split stone, which is used in the presentation of this research because the quality of peacock split stone is generally used in building materials.

TABLE IX. COARSE AGGREGATE SIEVE TEST RESULTS (SNI.03 - 1968 – 1990)

Filter	Check the result
1	181 g
¾	3025 g
½	5931 g
3/8	3476 g
4	1887 g

Source: Test Results

From the test results in the table above, the results of the research on the coarse aggregate sieve of peacock split stone were mostly retained on the sieve (1/2"), namely 5931 grams.

TABLE X. COARSE AGGREGATE UNIT WEIGHT TEST RESULTS (SNI.03 – 4804 – 1998)

Loose	Sample I	Sample II
A. Weight of the container + test object (kg/m³)	24.784	25.020
B. Weight of place (kg/m³)	5.790	5.790
C. Weight of test object (kg/m³)	18.999	19.230
D. Fill in the space (kg/m³)	14.080	14.080
E. Weight of test object (kg/m³)	1349	1365
Average weight of test specimens (kg/m³)	1357	

Source: Test Results

All aggregate unit-weight values were recalculated from raw measurements, and unit conversions were applied explicitly to avoid arithmetic inconsistencies.

TABLE XI. RESULTS OF COARSE AGGREGATE CONTENT WEIGHT TEST (SNI.03 – 4804 – 1998)

Congested	Sample I	Sample II
A. Weight of the container + test object (kg/m³)	26.46	26.25
B. Weight of place (kg/m³)	5.790	5.790
C. Weight of test object (kg/m³)	20.67	20.46
D. Fill in the space (kg/m³)	14.080	14.080
E. Weight of test object (kg/m³)	1468	1453
Average weight of test specimens (kg/m³)	1461	

Source: Test Results

From the results of the examination above, it can be concluded that, based on the research results, the average coarse aggregate density value is 1357, and the average solid value is 1461.

A one-way ANOVA indicated a statistically significant effect of Damdex dosage on compressive strength ($p < 0.05$), with the 0.20% mixture showing the highest mean value.

V. DISCUSSION

A. Slump Test Results

The test conducted before the process of making research materials is the Slump Test. The purpose of this slump research is to determine the standard degree of fresh concrete casting facilities and obtain the ideal concrete slump by using the Abrams cone equipment, namely, equipment that is coloured with a truncated chimney (Cone). According to SNI, the ideal slump feasibility should not be more than 12 cm and less than 8 cm. In this examination, the ideal slump obtained is 8 cm for each research material, and it is declared feasible. The same target slump (8 ± 2 cm) was maintained for all mixtures to ensure comparable workability during casting. Fresh density and air content were not directly measured and are acknowledged as a limitation of the present study.

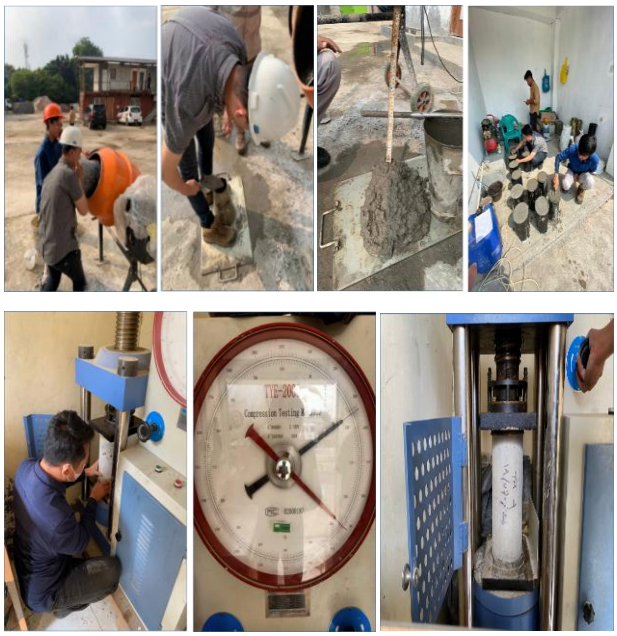


Fig. 2. Slump Abrams Test Measurement

B. Testing and Calculation of Specific Gravity, Compressive Strength, and Modulus of Elasticity of Concrete

Concrete Specific Gravity Testing uses the formula:

$$\text{Volume weight, } V = \frac{weight}{volume} \quad \dots (1)$$

This compressive strength test aims to determine the compressive strength of concrete at the age of 28 days. After the test object is 28 days old, the test object is weighed, and its compressive strength is tested. And calculated using the formula:

Concrete Compressive Strength, $\sigma = P/A$

σ = Compressive strength of test concrete (Mpa) … (2)

Where, P = Durability of test concrete (N)

A = Surface area of pressure (m2)

The purpose of this Elastic Modulus Test is to determine the modulus of elasticity of concrete at the age of 28 days.

After the test, the object is 28 days old, then the modulus of elasticity test object. The test object is placed in a place that has been provided on the press machine, and a dial gauge is also installed on the test object. The data obtained from the dial gauge reading is then used to calculate stress and strain.

Elastic modulus (secant) was obtained from the load–deformation response at 28 days as:

$E_c = \frac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1}$ with $\sigma_1 = 0.3 f_c'$ and $\sigma_2 = 0.8 f_c'$.

Strain was measured using dial gauges with a gauge length of 200 mm and a resolution of 0.002 mm. For comparison, the empirical expression

$$E_c \approx 4700\sqrt{f_c'}(\text{MPa}) \quad \dots (3)$$

Normal-weight concrete was also used to cross-check the order of magnitude.

Symbols:

f_c'= compressive strength (MPa);

σ= stress (MPa);

ε= strain (–).

Unless stated otherwise, values in Tables XII and XIII are mean ± standard deviation (n = 3).

A non-monotonic response was observed: performance increased up to 0.20% Damdex but declined at 0.40–0.60%. A plausible mechanism is that overdosing promotes excessive crystalline precipitation within capillaries, increasing micro-voids and hindering hydration continuity, which offsets any pore-blocking benefit. Similar behaviour for waterproofing admixtures has been reported in the literature and is typically dosage-sensitive. Under- or over-dosage, therefore, directly affects strength development.

The experimental elastic modulus values align with the empirical relation $E_c \approx 4700\sqrt{f_c'}$ for normal-weight concrete, giving expected ranges around 18–19 GPa for $f_c' \approx$ 15MPa. This agreement supports the validity of the measured stiffness values.

TABLE XII. MEAN ± SD OF COMPRESSIVE STRENGTH AND ELASTIC MODULUS (N = 3)

No	Concrete mix 1 pc 2 Sand 3 Gravel			
	Variable Damdex	Volume Weight Kg/m³	Strong Press (MPa)	Modulus Elasticity
1	0.00%	2295.21 ± 10.3	10.28 ± 0.34	16037.398 ± 480
2	0.20%	2298.98 ± 9.8	15.11 ± 0.42	18975.061 ± 510
3	0.40%	2287.66 ± 11.2	13.02 ± 0.38	17616.134 ± 470
4	0.60%	2283.88 ± 12.0	12.90 ± 0.36	16681.279 ± 450

Note: values are mean ± standard deviation (n = 3); density in kg/m³, strength in MPa.

TABLE XIII. MEAN ± SD OF COMPRESSIVE STRENGTH AND ELASTIC MODULUS (N = 3)

No	Concrete mix 1 pc 3 Sand 2 Gravel			
	Variable Damdex	Volume Weight Kg/m³	Strong Press (MPa)	Modulus Elasticity
1	0.00%	2283.88 ± 11.0	8.35 ± 0.31	13657.779 ± 420
2	0.20%	2242.36 ± 12.5	9.89 ± 0.35	14254.842 ± 460
3	0.40%	2298.98 ± 10.8	7.56 ± 0.29	13023.101 ± 410
4	0.60%	2212.16 ± 13.2	6.25 ± 0.27	11672.573 ± 390

Note: values are mean ± standard deviation (n = 3); density in kg/m³, strength in MPa.

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From the calculation results in Table XII and XIII, the following data are obtained for the specific gravity, compressive strength, and average modulus of elasticity.

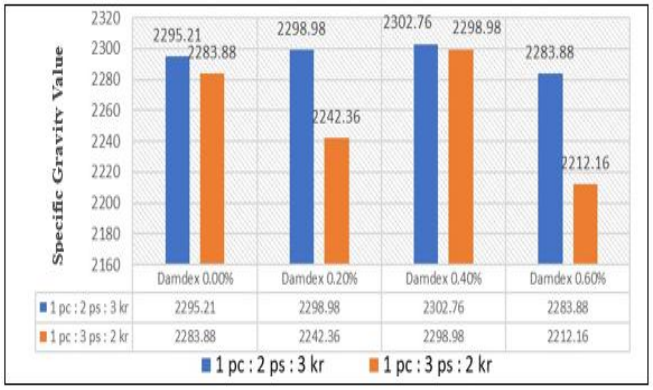


Fig. 3. Average Specific Gravity Results Graph

Based on Fig. 3 above, the average concrete density is obtained at the highest concrete density value at the Damdex variable of 0.00% with a concrete mixture of 1 Pc: 2 Sand: 3 Gravel of 2336.73 Kg/m3, and the lowest concrete density value at the Damdex variable of 0.60% with a concrete mixture of 1 Pc: 3 Sand: 2 Gravel of 2212.16 Kg/m3.

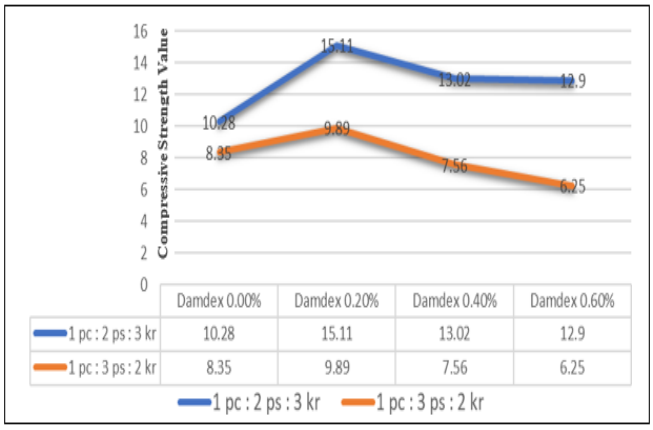


Fig. 4. Average Compressive Strength Result Diagram

Based on Fig. 4 above, the average concrete compressive strength obtained the highest compressive strength value in the Damdex 0.20% variable with a mixture of 1 Pc: 2 Sand: 3 Gravel of fc 15.11 Mpa, and the lowest compressive strength value in the Damdex 0.40% variable with a mixture of 1 Pc: 3 Sand: 2 Gravel of fc 6.25 Mpa.

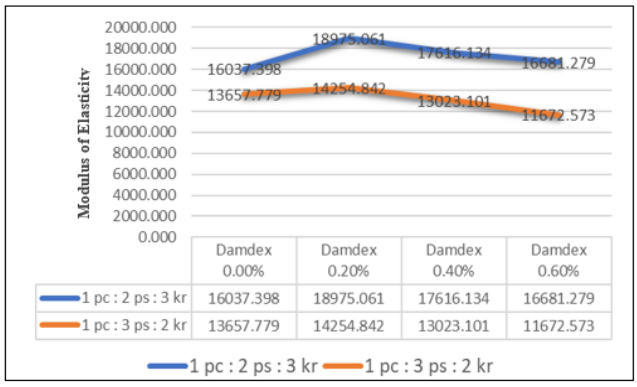


Fig. 5. Average Elastic Modulus Results Diagram

Based on Fig. 5, the average elastic modulus obtained the highest value in the Damdex 0.20% variable with a mixture of 1 pc: 2 Sand: 3 Gravel of 18975.061 MPa, and the lowest value in the mixture of 1 pc: 3 sand: 2 gravel Damdex 0.60% variable of 11672.573 MPa.

VI. Conclusion

In the research results using a concrete mix of 1 Pc: 3 Sand: 2 Gravel with variations of damdex additions of 0%, 0.2%, 0.4%, and 0.6%, the highest compressive strength was achieved with the damdex addition of 0.2%, yielding a compressive strength value of fc 9.89 MPa, an increase of 15.40% compared to the normal concrete mix / without using damdex (damdex 0%). For the modulus of elasticity, the highest value was obtained with the damdex addition of 0.2%, amounting to 14254.842 MPa, an increase of 13.21% compared to the normal concrete mix / without using damdex (damdex 0%). It can be concluded that the addition of damdex can affect the compressive strength and modulus of elasticity of concrete. For the research results using a concrete mix of 1 Pc: 2 Sand: 3 Gravel with variations of damdex additions of 0%, 0.2%, 0.4%, and 0.6% produces, the highest compressive strength is produced in the variant with 0.2% Damdex addition, with a compressive strength value of fc 15.11 MPa, an increase of 48.30% compared to the normal concrete mix without using Damdex (Damdex 0%). Within the tested mix proportions and curing conditions, the 0.20% Damdex addition yielded the highest average compressive strength (1 Pc : 2 S : 3 Gr) and elastic modulus. However, given the limited sample size and the absence of durability metrics, these results should be considered indicative; further work with larger n and additional tests (permeability, sorptivity, chloride penetrability) is recommended.

For the modulus of elasticity, the highest value was obtained in the variant with 0.2% Damdex addition, which is 18975.061 MPa, an increase of 47.18% compared to the normal concrete mix without using Damdex (0%). It can be concluded that the addition of Damdex can affect the compressive strength and modulus of elasticity of concrete. Thus, the maximum compressive strength of concrete is achieved with the additional variable of 0.2% Damdex in a concrete mix of 1 Pc: 2 Sand: 3 Gravel, resulting in fc 15.11 MPa. Higher by 52.20% of the concrete mix 1 Pc: 3 Sand: 2 Gravel and the maximum elastic modulus value of concrete with the additional variable damdex 0.2% with the concrete mix 1 Pc: 2 Ps: 3 Kr is 18975.061 MPa, which is 65.11% higher than the concrete mix 1 Pc: 3 Sand: 2 Gravel.

Limitations and Future Work

This study used n = 3 specimens per dosage, two nominal mix proportions, and did not include durability indices (permeability, sorptivity, chloride penetrability) or microstructural observations. Future work should

- expand the dosage range with finer increments around 0.20%,

- include durability and microstructural tests to relate pore structure to strength, and
- evaluate different curing regimes to assess robustness.

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