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Optimisation of Concrete Casting: Impact of Using Vibrators on the Mechanical Properties and Strength of Concrete Structures

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Abstract – If we look at the properties of hard concrete, which has high compressive strength and is resistant to rusting/rotting due to environmental conditions, concrete can be used as a building construction material with a long-planned life if its implementation is carried out correctly. Mix designers, implementers, and concrete work supervisors need to understand the properties of concrete to avoid mistakes in concrete work. Using vibrators in the building casting process has a crucial role in ensuring the quality and strength of concrete structures. Vibrators are used to remove excess air, ensure even distribution, and increase the density of fresh concrete during the casting process. This research aims to evaluate the impact of using vibrators in building casting on concrete's mechanical properties and strength. The experimental method uses a hammer test by comparing the unconfined compressive strength test of concrete samples released with and without using a vibrator in the same building. The research results show that using vibrators significantly increases the compactness of concrete, reduces the risk of cracking, and increases resistance to pressure. Apart from that, the use of vibrators also has a positive impact on aggregate distribution and reduction of porosity in concrete. These findings emphasise the importance of integrating vibrators as an integral part of the casting process, providing tangible benefits in improving buildings' structural performance and durability. The practical implications of this research include guidance on the optimal use of vibrators in construction projects to achieve better overall results. In construction projects in the field, during and after construction, we often encounter various problems, one of which is damage to the concrete, which can weaken the structure. We can find this damage in concrete structural elements such as columns, beams, plates, and walls. Therefore, it is necessary to prevent this damage by conducting case studies regarding the causes of damage to concrete so that the causes of damage can be identified and minimised.

Keywords: Concrete quality control, Vibrator, Hammer test, Concrete

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1. Introduction

Various types of damage that occur in concrete can be overcome with multiple types of repairs to the concrete. However, in some cases, repairs to poor concrete can also worsen the situation and risk causing other damage to the building. Therefore, to prevent damage to concrete, it is necessary to carry out case studies regarding the causes of damage to concrete so that it can be minimised.

In construction projects, the success of a building depends significantly on the quality and strength of the structure, which functions as a load transmitter from the roof to the foundation. Columns as structural elements play a crucial role in bearing the load of the entire building and distributing it to the ground below. Structural failure of the column can collapse the whole building, per the Indonesian National Construction Standards.[1]

Emphasises ensuring column quality and avoiding defects such as imperfect moulding, size discrepancies, or voids. Defects in columns can significantly impact the strength of the overall structure, making special care and attention to these structural elements a necessity.[2]

A 3-story building construction project is the background for this research, where various column and beam sizes have been used with specific details for each type. However, problems occurred due to delays in the casting schedule and not using vibrators during the casting process. As a result, some columns, beams, and plates experience deformities or lack shape due to extreme pressure and weather effects on the formwork.[3]

The mix design in the laboratory is then used as a guide to produce a Job Mix Formula (JMF) based on data from material sample testing results. Thus, it is clear that the characteristics of the sample material must represent the material that will be used in actual concrete production. A mismatch between the characteristics or quality & condition of the sample material and the solid material during implementation in the field can result in non-fulfilment of the wet quality criteria for fresh concrete mix, even to a significant level of inconsistency between the condition of the sample material. The actual material can be fatal to the quality of the hard concrete produced. Therefore, samples of materials for testing purposes in the laboratory must be taken using the correct sampling technique [4]. In this context, this research aims to avoid using vibrators on the quality of columns, beams and plates in construction projects. This analysis involves evaluating defective structural elements and exploring solutions to minimise the risk of cracks in the concrete and ensure the overall structural integrity of the building. To find out the common causes of damage to concrete, provide precautions to avoid damage to concrete. It is hoped that the benefits of this research will provide assistance and information to practitioners in the field so that they can take precautions before damage to concrete occurs [5]

The vibrator head, which produces vibrations with a frequency of up to 12,000 vibration cycles per minute, has a crucial role in the concrete casting stage. This vibration is channelled into fresh concrete using a needle, producing concrete with an optimal level of density, a flat surface, and without air voids. This technology is critical in achieving lasting results with high-quality standards and ensuring optimal structural strength in each construction element. To achieve optimal results, it is recommended that the compaction duration at each point last between 30 and 120 seconds. However, immediately stop the concrete compaction process if the surface around the vibrator rod looks shiny, air bubbles from the concrete pour are no longer visible, there is a change in the sound frequency of the concrete vibrator machine, or you feel a change in vibration in the vibrator hose.

The reality in the field is that it will be difficult to obtain concrete mixture materials, especially aggregates, that are entirely free from ingredients or substances that negatively influence the quality of the concrete unless they are conditioned. The existence of specifications that determine maximum limit requirements for materials that can damage the quality of concrete, such as aggregate mud content, organic content, etc., are tolerances that are still permitted to obtain concrete that still meets quality requirements from the things that are determined.

There are specifications in the specifications that directly affect the strength of the concrete, the workability of the wet concrete mix, and the cement hydration process, ultimately determining the quality of the production results. Therefore, each mixture material must be studied for its characteristics and influence on the properties of the concrete mixture.

2. Research Methods

2.1. Data collection technique

Data collection techniques consist of

a. direct observation method in all existing activities.
b. Interview method / direct interviews with all parties involved in the project.
c. Documentation in the form of photographs of each project implementation takes place.
d. Retrieve data regarding the project required in the practical work report.
e. Data collection through literature studies provides information on what factors can cause damage to concrete.

2.2. Place and time

Figure 2.1 shows the location of practical work activities carried out from 1 July 2023 to 31 December 2023.

Place of acceptance for practical work PT. Hiqmah Aldina Prima - PT. Natural Light Energy, KSO. This functional work activity was done in Mangkupalas Village, Samarinda Seberang District, Samarinda City.

Figure 2.1 Practical Work Locations

2.3. Photo Proof of not Using Vibrator

As seen in Figure 2.2, the column casting process can be seen that the workers are casting without using a vibrator (manual).

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Figure 2.2 Workers Doing Casting Manually

3. Results and Discussion

3.1. Sifat Mekanis Terhadap Penggunaan Vibrator Beton.

You can see in Figure 3.1 relatively deep and wide holes in the concrete, known as Voids or Honeycomb. Voids are formed when concrete fails to fill areas in the formwork. Usually, voids occur because the concrete is stuck due to the placement of the concrete being too deep or in areas where the reinforcement is too close. Honeycombs form when mortar fails to fill the voids between coarse aggregate particles. The causes of Honeycomb and Voids include concrete slump that is too low, segregation, the distance between reinforcements that are too close, poor compaction implementation, and improper pouring. Almost all Void damage results in structural damage, while Honeycomb damage can be structural or non-structural. Structural depending on the location of the Honeycomb area. It can also be seen in Figure 3.4 that the defects in the columns were caused by manual casting, and can be seen in Figure 3.3 the empty spaces in the beams due to not using a concrete vibrator when casting, which caused spaces/cavities in the casting results of the beams. It can be seen in Figure 3.2 that there are crack width tolerances and structural types and conditions.

Figure 3.1 Image of Voids and Honeycomb

No	Jenis struktur dan kondisi	Toleransi Lebar retak (mm)
1	Struktur dalam ruangan, udara kering, pemberian lapisan kedap air	0,41
2	Struktur luar, kelembaban sedang, tidak ada pengaruh korosi	0,3
3	Struktur luar, kelembaban tinggi, pengaruh kimiawi	0,18
4	Struktur dengan kelembaban tinggi dan dipengaruhi oleh korosi (salju/es, air laut)	0,15
5	Struktur berkaitan dengan air	0,1

Sumber: ***ACI Committee*** **224R (2001)**

Figure 3.2 Crack Width Tolerance Table

Figure 3.3 Documentation of Deformed Beam

Figure 3.4 Documentation of Defect Column

3.2. Strength of Concrete Structure (Hammer Test)

The hammer test is a tool for checking concrete quality without damaging the concrete. This test aims to obtain initial information regarding the quality of the concrete in the structure that has been worked on. Besides that, this method will get quite a lot of data relatively quickly at a low cost. This test method is carried out by applying a load. Impact (impact) on the concrete surface using mass that activated using mass that started using a certain amount of energy; in the hammer test, it is necessary to take several measurements around each measurement location, the results of which are then averaged by the results of the hammer blows. The test is included in the hammer test graph in Figures 3.5 & 3.6 [8]

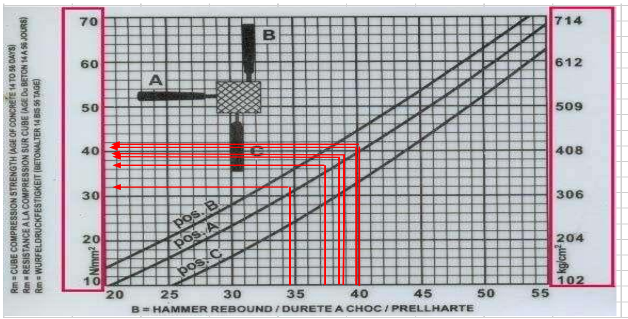

Figure 3.5 Column Hammer Test Graph

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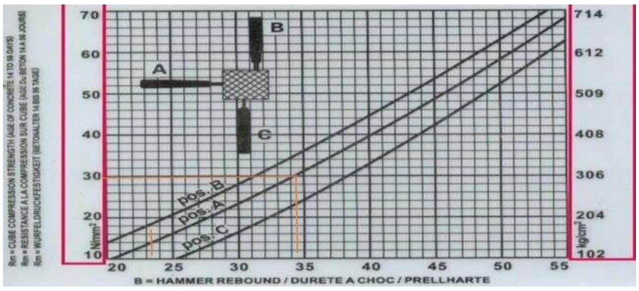

Figure 3.6 Hammer Test Chart for Beams and Plates

3.2.1 Quality Control

By the scope of observations, the discussion that will be discussed in this chapter does not cover all project implementation activities from start to finish: beam and plate. There was a delay in the column casting work schedule, which did not match the schedule in the schedule, and the method of casting the column did not use a vibrator. This causes the column formwork to rot, which can cause damage to the formwork during casting, such as making the column form deformed or imperfect, and can even reduce the quality of the concrete from what was planned and the presence of voids which makes the casting result not as solid as it should be. The methods used in project quality control are inspection and review of plan drawings, quality planning, checking whether the equipment is functioning correctly, and carrying out sample testing.

In implementing this project, sample testing was carried out using the hammer test method.

3.2.2 Check The Fromwork Before Casting

Formwork is very important to maintain the quality of concrete

To remain according to plan, the formwork must be tight prevent mortar loss from concrete, inspect formwork and immediately remove damaged material before concrete is placed to maintain required elevation tolerances and camber (curvature) of formwork to compensate for deflections in the formwork anticipated during concrete casting. If the formwork is curved, set the screed to the same camber to maintain the specified concrete thickness. Set the formwork and create a screed in the centre of the slab accurately to provide the fixed elevation and finished surface contour before dismantling the formwork. Make sure that the shape of the edges and lines of the screed are strong enough to withstand vibrations of the roller pipe coating or screed if finishing using this equipment is required.

Continuously observe the formwork during concrete casting. Stop casting if deviations in required elevation, alignment, verticality, or camber (curvature) are found and the formwork shows improper settlement or distortion. Repair the affected formwork and continue casting. [7]

Figure 3.7 Column Hammer Test Point

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Hammer Test Plate: O Hammer Test Beam: O

Figure 3.8 Hammer Test Points for Beams and Plates

3.2.3 Quality Control

From the slump test, an error may occur if the fresh concrete mix is accepted or rejected, namely the homogeneity of the mixture and the consistency of the concrete mix, which ensures that it has not yet been set.

Things that need to be paid attention to when testing Slump: The shape and size of the mould are not precise, The sample of the mix used is not representative, The method of making the test object does not comply with standards, There is interference with the test object before it reaches a stable condition, especially during the bonding process. If conditions like that occur, then the results of the concrete quality evaluation do not reflect the actual results.

The slump test results are obtained from the average values.

An average of 7 cm, as seen in Figure 3.9, where the slump value meets the planned slump value. From visual observation, it can be seen that fresh concrete has good adhesive properties between paste or mortar and aggregate so that segregation and bleeding do not occur. [7]

Figure 3.9 Slump Test

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Figure 4.0 Self-Documentation of Hammer Test Plates in the Field

Figure 4.1 Column Hammer Test Self-Documentation in the Field

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No	Angka Pantul R										Rata-rata	Faktor koreksi	R koreksi	Kuat Tekan	
Lokasi	1	2	3	4	5	6	7	8	9	10				N/mm2	kg/cm
1	35	36	42	34	34	39	41	35	35	35	36.6				
1	35	36		34	34	39	41	35	35	35	36.0	1.03	37.08	41	494
2	36	34	35	35	35	37	35	35	34	35	35.1	1.03	36.15	39	470
3	35	49	38	39	38	34	36	44	34	34	38.1				
3	35		38	39	38	34	36	44	34	34	36.9	1.03	38.00	41.9	505
4	33	33	35	35	33	32	34	34	38	41	34.8				
4	33	33	35	35	33	32	34	34	38		34.1	1.03	35.13	47	566
5	35	33	32	34	38	38	36	36	35	38	35.5	1.03	36.57	39.9	481
6	32	29	31	31	33	30	33	31	31	33	31.4	1.03	32.34	32	386
7	25	23	23	25	25	21	22	22	21	21	22.8	1.03	23.48	14	169
8	21	26	25	25	28	23	23	27	23	27	24.8	1.03	25.54	17	205

Table 4.2 Column Hammer Test Results Data

No	Angka Pantul R								Rata-rata	Faktor koreksi	R koreksi	Kuat Tekan	
Lokasi	1	2	3	4	5	6	7	8				N/mm2	kg/cm
B1	32	33	43	39	34	36	35	35					
B1	32	33		39	34	36	35	35	34.9	1.03	35.90	30	306
B2	35	33	34	32	33	36	39	45					
B2	35	33	34	32	33	36	39		34.6	1.03	35.61		
P1	25	26	22	22	23	21	20	20	22.375	1.03	23.05		
P2	23	24	23	20	23	22	21	23	22.4	1.03	23.05		

Table 4.3 Hammer Test Results Data for Beams and Plates

It can be seen in Figures 4.0 & 4.1. This Hammer Test was carried out directly at the Advanced Development Project of SMA Negeri 17 Samarinda, taking 8 column samples with 10 points in one

The column sample is 327.47kg/cm2, and two samples do not meet the planned compressive strength of 300 kg/cm2, namely samples 7 and 8, which are 169 kg/cm2 and 205 kg/cm2, respectively.

It can be seen in Table 4.3 that the results of the hummer-free compressive strength test on beams and plates show that the results for the beams themselves meet the standards. As for the plates themselves, the average calculation results in the table show that they do not meet the standards for the compressive strength of the concrete itself.

This may be caused by the casting being done manually without using a vibrator, which causes a large number of air cavities which affect the Rebound reading on the Hammer Test. The beam can meet the compressive strength itself, and the plate has problems that cannot meet the requirements due to the large number of air cavities—caused by not using the Vibrator.

From the percentage results above, you can get a result of 10156%. According to PBI 1971 article 4.8 paragraph (1), "If from these experiments a characteristic concrete compressive strength value is obtained which is at least equivalent to 80% of the concrete compressive strength value."

From the percentage results above, you can get a result of 10156%. According to PBI 1971 article 4.8, paragraph (1) "If from these experiments a characteristic concrete compressive strength value is obtained which is at least equivalent to 80% of the concrete compressive strength value" and paragraph (2) "If from this experiment a strength value is obtained "The minimum characteristic compressive strength of concrete is equivalent to 75% of the required characteristic concrete compressive strength value" and in SNI 2847:2019 in article R26.12.4 "about test investigations with low compressive strength results it is explained that it is used.

Destructive and non-destructive testing in 2 concrete tests is considered sufficient if:

1. The average of the test object is equal to or at least 85% of the fc' value
2. There is not a single test object whose value is less than 75% of the fc' value

   From the statement above, the compressive strength test can be said to be sufficient or meet the requirements because the percentage result obtained is 101.56%.

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4. Conclusions and recommendations

4.1. Conclusions

1. The compressive strength value can be said to be sufficient or meets the requirements because the percentage result is 101.56%. From the results above, two samples do not meet the planned compressive strength of 300 kg/cm2, namely samples 7 and 8 with 169 kg/cm2 and 205 kg/cm2, possibly caused by the casting being done manually without a vibrator, which causes a large number of air cavities which affect the Rebound reading on the Hammer. The highest value for the compressive strength of concrete obtained using the Hammer Test is in column 4, with a sample of 566 kg/cm2, and the smallest value is in column 7, namely 169 kg/cm2. The compressive strength value for an individual beam can be said to be met with the data and graphs listed. As for the plate itself, the compressive strength is not met, and as shown in the data and graphs, the plate is unsuitable due to casting due to not using a vibrator. Based on the research that has been carried out, it is stated that the hammer test is not an alternative method for testing concrete compressive strength.
2. Causes that have the potential to cause concrete damage during the construction phase are Problems with casting height, ironing errors, and vibrator implementation errors. Design failures and formwork installation errors. The most common cause of damage during the construction phase is problems with compaction using vibrators. Prevention that can be taken is that before removing the plate formwork, you must first obtain approval from the contractor by looking at the compressive strength test results. The compressive strength test results must be by the planned design so that the structure can accept its load and load when the formwork is opened. Worker. If concrete casting is carried out in hot weather, the problem that will arise is the rapid slump loss (Slump Loss) caused by the rapid rate of water evaporation. Conditions like this usually encourage implementers to add water to the mixture so that the concrete remains easy to work with without considering the consequences of hard concrete quality. Implementers must understand the factors that influence the rate of water evaporation in the concrete mix.

4.2. Suggestion

1. When casting manually, you must use a vibrator so the concrete castings can fill the entire column volume evenly.
2. When shooting the hammer at the column, beam and plate samples, you must be more careful because the shooting position can affect the rebound value.
3. Prevention of Vibrator errors is done by maximising the compensation with the Vibrator. Construction workers must follow the procedures For correct use of vibrators in SNI 03-3976 (1995).
4. The best way to use a vibrator is in a vertical position to prevent segregation. On the other hand, a vibrator with a slanted condition will result in segregation. The thickness of the concrete mixture must be by the capacity of the vibrator used so that if the casting is done in more than one layer, it will be easier to obtain unity between the cast layers
5. Curing is a process for maintaining ideal humidity levels and temperature to prevent excessive hydration and ensure that hydration occurs continuously. Curing is generally understood as concrete maintenance, which aims to ensure that the concrete does not lose water too quickly or as an action to maintain the humidity and temperature of the concrete immediately after the concrete finishing process is complete and the total setting time is reached.

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