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Retrofitting Techniques in Conservation Management of a Balinese Historical Builiding

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Abstract: This study presents, the evaluation result of the conservation management of a historical building. The aim of the research is determine the effectiveness of the previous conservation management, as well as knowing the most appropriate system and techniques in the implementation of conservation process of a building which is called Bale Kapal. This research is aimed, at recommending appropriate materials to be used in the implementation of Bale Kapal conservation situated, at a cultural heritage preservation park called Taman Soekasada Ujung (TSU). TSU is a cultural heritage site located in the regency of Karangasem at the province of Bali, Indonesia. It received a conservation treatment in 2001-2003 through the Bali Cultural Heritage Preservation Project under the Project named the Reconstruction and Conservation Project of Taman Ujung Karangasem. Among other buildings, there exists a building called Bale Kapal which did not received the treatment and handling during the reconstruction and left in its existence. The qualitative evaluation method has been used in the research methodology and some comparative study have been conducted. Problems with the quantitative data were solved by experimental method through a series of tests in the laboratory. The study concluded that the conservation which has been made to the Bale Kapal was ineffective. The appropriate conservation system which should be done to Bale Kapal is the reconstruction with reinforcement using grouting techniques. Structural analysis based on laboratory test results showed that with reconstruction, the Bale Kapal building can be returned to its original shape reliably without breaking the rules of conservation. The recommended construction materials are those that have the anticipative properties to the local environmental conditions.

Key words: Building conservation, precast concrete, reinforced concrete, cultural heritage, reconstruction, conservation principles

INTRODUCTION

Conservation of a historical building requires some evaluation of the type of treatment and the most appropriate conservation system to be applied to a particular condition of a building. In this research, researchers present the conservation techniques in the implementation of conservation. This research is also aimed at providing the right recommendation of the appropriate materials to be used to preserve buildings.

The object of the research is a building called Bale Kapal which is situated at a culturally preserved historical park, called Taman Soekasada Ujung (TSU). TSU is a site of cultural heritage in Karangasem regency in the province of Bali, Indonesia. This site is one of the prime attractions for Karangasem regency government in generating the local revenue.

TSU was built in the year 1919 during the reign of King I Gusti Bagus Jelantik (1909-1945) who holds the position, as the Anak Agung Ketut Karangasem Anglurah. The building was inaugurated in the year 1921. This park was used, as a resting place for the king and was intended, as a place to entertain important guests like kings or head sof foreign governments who visited the kingdom of Karangasem (Agung, 1991).

This site received the conservation treatment in the year 2001-2003 through the Cultural Heritage Preservation Project in Bali with the activities of Reconstruction and Conservation Parks of Ujung Karangasem funded by the World Bank (Anonymous, 1999).

This research aims to determine the effectiveness of conservation management that has been done at Taman Soekasada Ujung, especially the conservation of Bale Kapal building. Bale Kapal is one of the existing buildings on this site which did not have the physical handling of the reconstruction and is left in its state of existence (Fig. 1).

This research also identifies the type of treatment and the most appropriate conservation system to be applied

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Fig. 1: The Taman Ujung before the conservation

Fig. 2: Existing condition of the Bale Kapal

to Bale Kapal. Researchers also aimed to learn the conservation techniques in the implementation of conservation and to recommend appropriate materials for use in the implementation of the conservation of the Bale Kapal.

Bale Kapalis was left in its condition while other buildings have been renovated during the Cultural Heritage Conservation Project of Taman Ujung Phase 1 and 2 (Anonymous, 2004).

In the early planning, Bale Kapal was included as one of the buildings which would be renovated. World Bank through its consultant, Kantrika Ebbe of the Social Development Department of the World Bank, recommended to let the element that exist on the Bale Kapal as it is (Fig. 2) (Anonymous, 2003).

MATERIALS AND METHODS

This research is an applied research to solve the problem in conservation efforts and the selection of materials for the conservation. The data gathered are qualitative and quantitative data. Therefore, the research methods used are the evaluation and experimental methods. Explanation of the research is presented in

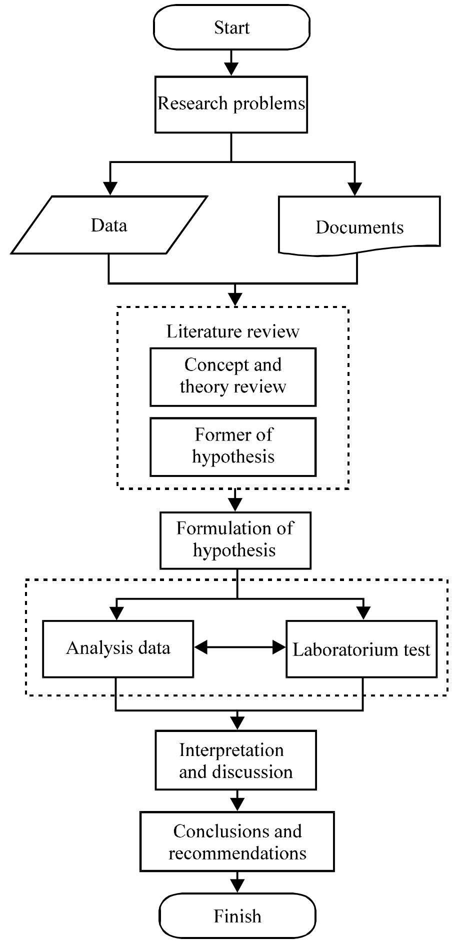

Fig. 3: Research process flowchart

descriptive and comparative manner. The evaluation method to solve the problems is based on qualitative data. Research process flow chart is presented in Fig. 3.

Problems with the quantitative data were solved by experimental method through a series of tests in the laboratory. Qualitative data was quantified into numbers using a particular measurement scale. Meanwhile, quantitative data is processed with a particular statistical method in order to get the output in the form of research results.

The experiment process at the laboratory consists primarily of 2 testing processes. First, the testing of samples and objects was taken from the location of the Bale Kapal at the TSU site. The second process is the testing of samples conducted at the laboratory which include the compressive strength and durability test. The experiment process at the laboratory is shown in the Flowchart depicted in Fig. 4.

Materials tested in this research consists of material that act as a replacement (substitution) and

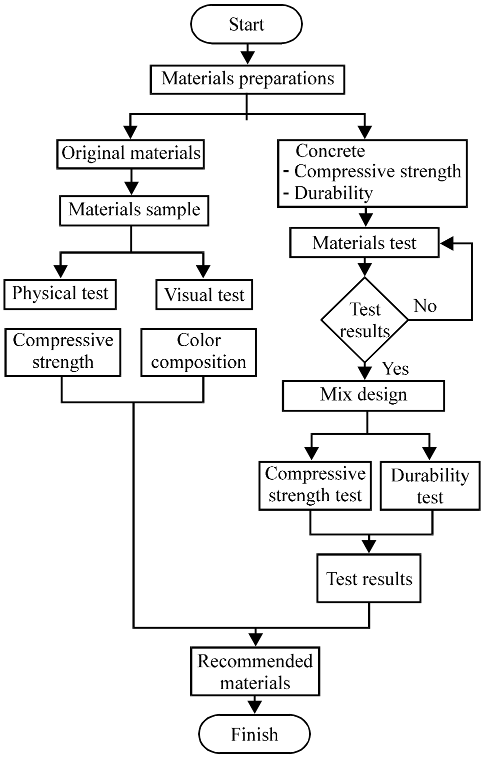

Fig. 4: Process flowchart of the laboratory test

additional ingredients (additives) in addition to material that is commonly used in construction.

Cement is an ingredient that is very familiar in the construction world is selected as one of the tested material. Chrismaningwang (2008), tested 3 variants of the cement paste with different variation of the water cement ratio (w/c), i.e., w/c of 0.3, 0.45 and 0.6. Tests were conducted on the compressive strength of cement paste and vicat with 3 variants.

Compressive strength tests result shows that the highest compressive strength is generated when using cement paste with w/c of 0.45 of 35.876 MPa. Testing vicat generating the most efficient initial setting time of cement paste with w/c 0.45 because not too fast and not too long compared to other variants.

Base on the test results of compressive strength and cement paste vicat showed that w/c 0.45 cement paste variant is the most powerful and efficient material.

Metakaolinis usually regarded, as a substitute for Portland cement with a certain proportion of the weight of cement. If the water in the mixture is controlled, the addition of metakaolin will greatly increase the compressive strength and flexural concrete.

The optimal performance is achieved by replacing 5-20% of cement with metakaolin (Sambowo, 2003). Although, it is possible to use less, the benefit can be fully achieved when at least 10% of the metakaolin is used. Metakaolin used in this research is 15% of the weight of the cement in concrete mixtures.

Various research and studies have been conducted in an effort to support concrete technology with environmentally friendly (sustainable and green concrete) material, the behavior of composite materials in concrete and cementitious, failure analysis, fracture-based structure, the application of concrete structural elements, innovations of aggregate of local materials, local materials of fiber innovation and additive innovation (admixture) of local materials. One of the innovations-added materials (admixture) is to utilize sucrose, sugar cane and the solution (Susilorini and Sambowo, 2010).

RESULTS

Samples tested (samples of existing) is taken from the location of the research object from Taman Soekasada Ujung Heritage Site. Because, it is not possible to take the samples from the column existing on Bale Kapal, the samples were taken from the ruins of buildings within the site. Samples were made in the size 50×50×50 mm.

The compressive strength result of the existing sample mean in 18.67 MPa when converted to be equal with the quality of concrete characteristics (K) according to PBI-71 will get the result of 225 kg cm^{-2}(equivalent to K225).

The tests of concrete compressive strength in this researchis aim to know the ability of grouting material in increasing the compressive strength of ruptured column retrofitted by grouting technique. Moreover that researchers would like to know, the influence of the chosen grouting material on the compressive strength of the existing column through simulating the existing column by modeling the columns in the laboratory.

In column groute testing, there are 3 variants of materialused, i.e., cement paste with w/c 0.45, high strength grouting epoxy and low viscosity grouting epoxy.

The specimens are made from normal concrete with the compressive strength designed at 20 MPa with the size 10×10×38 cm. Each test condition was tested in 3 samples. The test was designed with 5 conditions:

- Columns in the non-damaged condition
- Columns with artificial crack conditions
- The cracked column after grouted with 3 variants of grouted materials

Test results of compressive strength on the column sample without and with grouting aimed to find out the groute material that gives the best effect on improving the compressive strength of cracked columns. The test results are shown in Table 1.

Table 1: Results of the compressive strength test on the sample of column without and with grouting

Variants	Compressive strength kgf	Compressive strength MPa	Avrg. (MPa)	SD
Undamaged column				
1	17.600	17.60	18.73	0.99
2	19.400	19.40		
3	19.200	19.20		
Cracked column				
1	15.800	15.80	14.23	1.55
2	14.200	14.20		
3	12.700	12.70		
Cracked column grouted cement paste w/c 0.45				
1	17.500	17.50	19.20	1.70
2	20.900	20.90		
3	19.200	19.20		
Cracked column grouted high strength grouting epoxy				
1	20.750	20.75	20.25	1.00
2	20.900	20.90		
3	19.100	19.10		
Cracked column grouted low viscosity grouting epoxy				
1	22.300	22.30	17.93	3.80
2	15.400	15.40		
3	16.100	16.10		

Table 2: Tests results of the existing column modeling sample

Sampel No.	Compressive strength kgf	Compressive strength MPa
1	12,500.00	18.14
2	15,800.00	22.94
3	15,000.00	21.77
4	11,900.00	17.27
5	15,600.00	22.64
6	16,400.00	23.81
7	16,200.00	23.52
8	12,400.00	18.00
9	11,800.00	17.13
Average	14,177.78	20.58

To study the behavior of the column after being strengthened with grouting techniques, this research modeling the existing columns with specimen/samples made in the laboratory. For models that resemble the existing column, the sample is made by considering the compressive strength and the slenderness of the column sample in accordance with the existing column.

Existing column has a square cross section with the sides of 27 cm. Net length of the column is 161 cm. Column slenderness rate is 20.66 and is classified as a short column.

The column height of the sample is 50 cm, considering with ease in the compressive strength test. The cross-section corresponding to the slenderness of the existing column is a square with the sides of 8.4 cm long.

If the existing columns using reinforcement with a diameter of 16 mm, based on calculations obtained cross-sectional area of reinforcing bars for the sample column with a diameter of 5 mm. The sample as a model of the existing columns is made of nine pieces. Testing first is the compressive strength. The test results are shown in Table 2.

Table 3: Post grouting compressive strength test results

Sample No.	Compressive strength (f'c): First test (MPa)	Post test kgf	Post test MPa	f'c post test/ f'c first test (%)
1	18.14	9.75681	14.16	78.05
7	23.52	10.19368	14.80	62.92
8	18.00	7.64526	11.10	61.66
9	17.13	11.50430	16.70	97.49
Avrg.	19.20	9.77501	14.19	75.03

Table 4: Composition of a sugar-based additive to cement weight

Parameters	Values (g)
Sucrose	0.10
Granulated sugar	0.30
Cane solution	0.20

For 2 kg of cement = 2000 g cement; Susilorini and Sambowo (2010)

The sample column has a crack pattern similar to the existing columns and given grouting using high strength resin epoxy are shown in sample number 1, 7, 8 and 9. The grouting procedure was carried out in accordance with the relevant material manual. The results of the compressive strength test after the grouting of cracked columns are included in Table 3.

One goal of the research on Bale Kapal is to select the kind of material best suited for retrofitting, as well as other materials that can be used to ensure that the settlement can survive. Bale Kapal should be rebuilt according to its original shape. In addition, alternative material must have the character strength of the same structure as the original material. It must also has a visual character similar to the original material.

Samples are made in the form of a cube with the size of 10 cm in each sides, following the British Standard (BS) 1881. Material variants tested were:

- Normal concrete with planned compressive strength of 20 MPa using PPC
- Concrete with cement substitution as much as 15% using metakaolin produced from the combustion process in the temperature of 750°C
- PPC concrete with substitution of 100% with instant cement
- Concrete with sugar-based additives fit to Table 4

For concrete durability test, the samples were made in the form of a cube with the size of 5 cm in each sides. In one of the central cross-section, reinforced cube is fitted with a diameter of 10 mm.

In this research, the actualization of the influence of environment on concrete durability in protecting the reinforce cement against corrosion was designed by soaking the samples in 2 variants of water, i.e., fresh water (normal water) and sea water. The immersion in sea water is assumed to happen in Bale Kapal environmental conditions near the sea.

Table 5: Results of resistivity measurements on samples immersed in normal water

Varians	Resistivitay (kΩ. cm) onimmersion day-n d+1	d+2	d+3	d+4	d+7	d+14
Normal concrete (20 MPa)						
Avrg.	506.27	200.13	88.78	39.94	25.59	19.05
1	365.20	166.20	26.66	15.45	11.26	24.21
2	871.60	104.20	69.67	81.76	26.02	11.81
3	282.00	330.00	170.00	22.61	39.50	21.13
Concrete with metakaolin content						
Avrg.	440.27	233.57	30.08	33.70	13.96	11.96
1	329.20	164.00	27.92	21.99	8.19	16.64
2	658.00	88.30	39.68	65.65	17.64	9.88
3	333.60	448.40	22.65	13.47	16.06	9.36
Concrete with instant cement						
Avrg.	345.53	227.73	27.18	15.18	16.21	15.35
1	201.00	275.20	28.77	14.22	15.09	18.58
2	600.40	147.40	33.59	15.59	12.18	12.78
3	235.20	260.60	19.19	15.72	21.37	14.70
Concrete with sugar-based additive						
Avrg.	389.87	194.93	189.56	167.70	41.65	21.57
1	209.60	163.40	106.26	269.66	22.10	25.07
2	305.60	153.00	76.41	44.05	81.28	13.13
3	654.40	268.40	386.00	189.39	21.56	26.51

The indicator of the corrosion rate in the reinforced concrete is the concrete resistivity values. The sample's resistivity measurements were performed on immersion day 1, 2, 3, 4, 7 and 14. The test results are shown in Table 5.

DISCUSSION

The reconstruction of Bale Kapal requires the retrofitting of column structures prior to rebuild it to its original shape. However, Bale Kapal status as a heritage building did not allow the application of retrofitting techniques commonly done on other building types.

Retrofitting techniques with jacketing and external reinforcing which will change the look of Bale Kapal building should be avoided. The process should follow conservation rules. Eligible techniques are patching and crack grouting. The selection of retrofitting techniques should refer to the existing condition. During the study, some structural damage of Bale Kapal structures has been identified.

The data of damage in Bale Kapal building consist of the presence of damage to structural elements which formed the existing columns and walls. The damage found consists of cracked and broken material. The pattern of cracks occurs vertically and horizontally. The size of the cracks consists of fine to wide area. The depth of the crack can be classified to shallow and deep penetration to the wall or column section.

In selecting retrofitting techniques, there are some considerations, such as the selection of technical characteristics, durability, useful life (service time) and work ability. Because it is a qualitative nature, the consideration of the alternative retrofitting techniques are measured with a scale interval. The preference values are ranging from not good to excellent as shown in Table 6.

Table 6: Interval scale for measuring the suitability of retrofitting systems

Scale of value	1	2	3	4	5
Preference	Not good	Poor good	Fair good	Good	Very good

The description of the retrofitting technique (Ratay, 2005; Cormact, 2005; Anonymous, 1988; Wang and Salmon, 1985) is based on the assessment the following considerations:

Patching is a strengthening technique that limits the damage occurred on the surface. The filling of cracks in the repair of damage was applied to shallow and deep cracks. In terms of the characteristic of retrofitting techniques, the data results shows that the fillings are pretty good technique (3) and the filling cracks preferences is good (4).

Consideration of the resistance is highly dependent on the type of material used in the engineering applications of retrofitting. Patching provides a lower resistance because it is only able to overcome the damage to the surface. The preference level is less well (2). With the crack filling techniques, strengthening resilience will be very good due to the fact that the technique is able to overcome a deep rift. The preference level is very good (5).

The order or time of service is closely associated with the resistance. Retrofitting techniques with good resilience will provide along service life and vice versa. This assessment is in the context of strengthening the use of material with an equivalent resistance in each of retrofitting techniques. Therefore, the retrofitting techniques with cracks grouting have a better preference (4), as compared to patching which get a fairly good preferences (3).

The preferences are based on the consideration of the ease of implementation. The easier implementation technique of strengthening is by increasing the scale value of the preference and vice versa. Patching in its implementation is a relatively easier process because it is only conducted to the surface structure. The preference is good (4). The implementation is more complicated in cracks gouting which demand a higher skills but the preference is quite good (3).

Based on the description of the measurement of alternative retrofitting techniques using an interval scale, results in the form of preference scale values can be arranged in at he matrix shown in Table 7.

Analysis by matrix method concludes that the proper conservation techniques used in the handling

Table 7: Matrix selection analysis of column retrofitting system of Bale Kapal

Retrofitting techniques considerations on retrofitting	Patching	Crack grouting
Characteristic	3	4
Durability	2	5
Service time	3	4
Work ability	4	3
Total	12	16

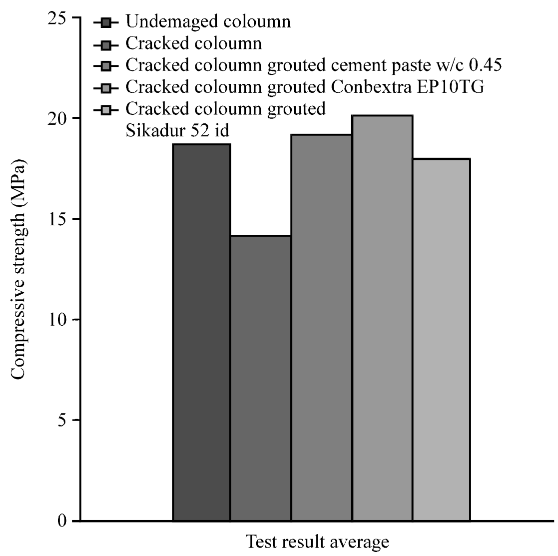

Fig. 5: The compressive strength test result of the grouting material

of Bale Kapal is by strengthening the columns with crack grouting technique. Test results, such as the grouting material evaluation is shown in Table 1. The mean compressive strength of the samples is shown in Fig. 5.

Based on the results of the field tests on samples which have three variants of grouting material, high strength grouting epoxy is a grouting material that gives the effect of compressive strength improvement at both the broken columns.

The result of the press test of a sample of the existing modeling columns are shown in Table 2. The mean compressive strength is 20.58. These results indicate that the compressive strength samples are in accordance with such plan design compressive strength mixtures used.

Modeling the sample columns are conducted after treating the cracks after testing. The columns were selected to those that have crack pattern similar to the crack pattern of the existing columns. In the column damage in the form of cracked and broken part, grouting are conducted with grouting material which gives the influence of compressive strength improvement which research best at breaking the high strength grouting epoxy column.

Table 8: Test result of existing sample taken from reseach object

Sampel No.	Weight (g)	Compressive strength kN	Compressive strength MPa
1	315	50.00	20.00
2	275	40.00	16.00
3	266	50.00	20.00
Avrg.	285	46.67	18.67

Tests results for compressive strength of a returned post-grouting columns is shown in Table 3. The comparison result of the compressive strength after grouting (the final compressive strength) and the compressive strength before the column was damaged (the early compressive strength), shows that the compressive strength is influenced by the reinforcement with grouting high strength grouting epoxy.

The lowest percentage is 61.66% while the average percentage is 75.03%. It can be assumed that by strengthening the existing column by using grouting materials of high strength grouting epoxy will generate the column compressive strength of at least 61.66% of its original compressive strength.

When the initial compressive strength of the existing columns are considered for the test sample at 18.67 MPa, the result is shown in Table 8. The process of strengthening grouting using high strength grouting epoxy will be able to restore the compressive strength of the existing columns into $18.67\times61.66\% = 11.51$ MPa.

The columns on Bale Kapalis considered to have a pure axial load (axial load only) which is column-centric weight-bearing only on cross section (without eccentricity). In this condition, the external forces will be retained by the column cross section which is mathematically formulated in the equation:

$$Pn = 0.85.fc.(Ag - Ast) + Ast.fy \quad (1)$$

Where:

- Pn = Axial load/tap the maximum that can hold (kN)
- f'c = Column concrete strength (MPa)
- Ag = Column cross-sectional area (mm^2)
- Ast = Area bars (mm^2)
- fy = Voltage melting of existing column reinforcement (MPa)

To determine the ability of the columns of Bale Kapal after receiving reinforcement with grouting using high strength grouting epoxy, researchers have calculated the maximum axial load that can be retained by the existing column after reinforcement. The calculation is as follows:

$$fc = 11.51 \text{ MPa}$$

$$Ag = 270\times270 = 72900 \text{ mm}^2$$

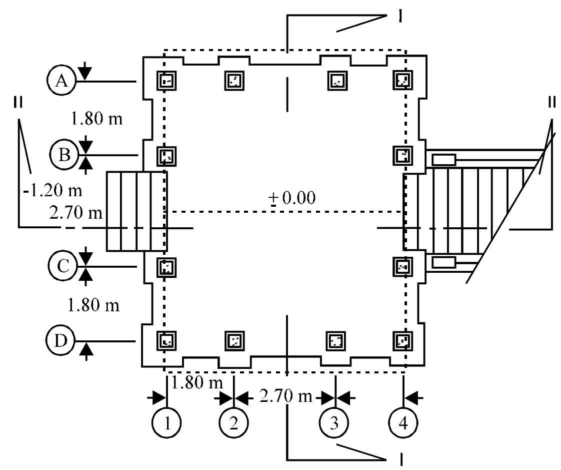

Fig. 6: Bale Kapal floor plan

Table 9: Compressive strength test results of cube with 4 variants of the material

	Compressive strength			
Variants	kN	MPa	Avrg. (MPa)	SD
Normal concrete (20 MPa)				
1	210,00	21.0	24.40	3.40
2	244,00	24.4		
3	278,00	27.8		
Concrete with metakaolin content				
1	195,00		19.67	2.75
2	225,00			
3	170,00			
Concrete with instant cement substution				
1	110,00	11.0	9.83	1.26
2	85,00	8.5		
3	100,00	10.0		
Concrete with sugar-based additive				
1	335,00	33.5	29.33	5.97
2	320,00	32.0		
3	225,00	22.5		

Ast = Diameter of the existing 16 mm

$= 1/4\pi d2 = 201 \text{ mm}^2$

fy = Reinforcing the existing columns are assumed to be wear steel U24 = 240 MPa

By using Eq. 1, axial load/maximal stress (Pn) that can be retained by the columns of Bale Kapal which are:

$$Pn = 0.85\times 11,\ 51\times(72900-201)+ 201\times 240 = 7595 \text{ ton}$$

Based on the calculation, the biggest dead load on Bale Kapal column is 3227.78 kg in columns B1, B4, C1 and C4 (Fig. 6).

The column of Bale Kapal is viewed from the relatively short column slenderness ratio, so there are not enough moments that can support them. Thus, the columns are strong enough to take the weight off when the Bale Kapal is made back to its original form after the first implementation of retrofitting existing column grouting using high strength grouting epoxy.

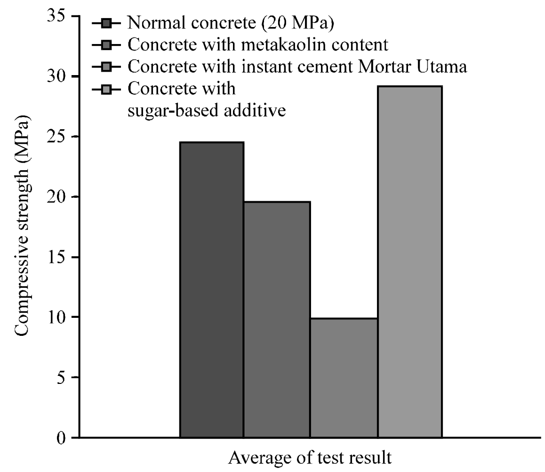

Fig. 7: The compressive strength results of different grouting material

Tabel 10: Dead load of Bale Kapal column

Column code	Death load (kg)
A1, A4, D1, D4	1.69681
A2, A3, D2, D3	1.65161
B1, B4, C1, C4	3.22778

To determine the most appropriate alternative materials to be used in the conservation of Bale Kapal, other than on the basis of compressive strength, researchers also considers the similarity of color and texture to the original material. This is done by conducting visual tests on samples of the original material for all variants of the laboratory test sample.

In this research, researchers tested several variants of the material which can be used as a new material in the reconstruction of Bale Kapal. The test results are shown in Table 9. The mean compressive strength of the samples is shown in Fig. 7. Visual display of the original samples and laboratory samples are shown in Fig. 8.

The character color and texture of the original sample and all samples of alternative materials are visually similar. This means that the consideration of the color and texture do not become the dominant determinant for all alternative materials to produce color and texture characteristics which is similar to concrete (Table 10).

Thus, the compressive strength becomes the primary consideration in determining the choice of alternative materials that can be used as a substitute in the reconstruction of Bale Kapal. Based on the results of the compressive strength testing on the samples, the most

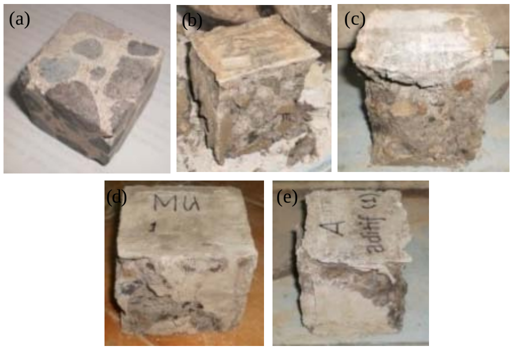

Fig. 8: Visualisation of samples colour and texture: a) Samples column of the existing object; b) Normal concrete with compressive strength 20 MPa; c) Concrete with cement substitution, as much as 15% using metakaolin; d) Concrete with cement instant; e) Concrete with addeding redients (additives) are based on sugar

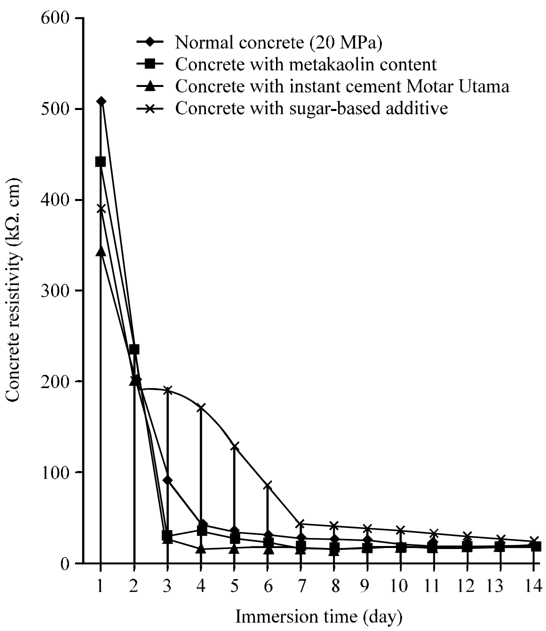

Fig. 9: Concrete resistivity of material soaked in fresh water

recommended material is the normal concrete with sugar-based additives. Normal concrete can also be used for compressive strength test which shows a higher yield than the compressive strength and the compressive strength of the concrete plan of the original.

Tests on the durability of concrete materials in protecting the reinforcement from corrosion is done by testing the ability off the variants of the concrete material being tested in the selection of alternative materials.

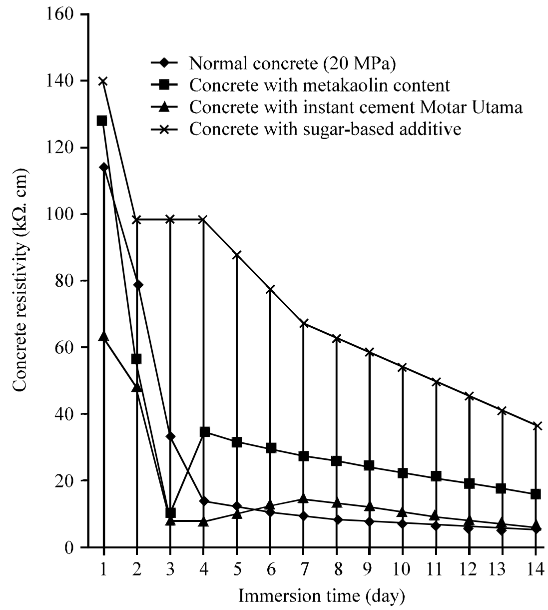

Fig. 10: Concreteresistivitywhen soakedin sea water

Tests/measurements carried out on concrete resistivity which indicates the rate of corrosion that occurs in the backbone. Results of testing by immersion in fresh water samples is shown in Table 5 and immersion in sea water samples is shown in Table 11. The resistivity in both tests are shown in Fig. 9 and 10.

Based on the indicators of the relation between concrete resistivity and corrosion rate of reinforcement is shown in Table 12. The lower the resistivity of the concrete indicates that the level of the reinforcement corrosion in it is higher.

The immersion in water up to the normal day to 4 has not shown a significant level of corrosion. It is negligible in all variants of the material because the resistivity is still above 20 kΩ cm. Until the 14th day of immersion, the corrosion rate is still low and does not mean that the differences are not significant numbers of resistivity.

The test result shows that the influence of fresh water immersion from day 1-14 against all variants of the material is not significant in increasing the corrosion rates. With the assumption that the fresh water immersion test conditions is similar to the condition of the open building in a normal environment, the durability of concrete component material variants in protecting the reinforcement against corrosion is equal.

The immersion in sea water up to the day 4 in samples of normal concrete and the main mortar shows a low corrosion rate (resistivity 10-20) while the sample of concrete with metakaolin and sugar-based additives does

Table 11: Results of resistivity measurements on samples immersed in sea water

Varians	Resistivitay (kΩ. cm) on immersion day-n d+1	d+2	d+3	d+4	d+7	d+14
Normal concrete (20 MPa)						
Avrg.	114.01	78.41	33.30	14.00	9.52	6.06
1	170.20	98.00	26.83	15.93	8.59	9.21
2	82.83	74.47	53.77	16.31	5.83	8.96
3	88.99	62.77	19.30	9.77	14.15	0.00
Concrete with metakaolin content						
Avrg.	127.44	56.55	9.78	33.96	27.76	15.73
1	74.00	46.10	13.01	18.42	25.54	28.77
2	164.00	48.10	8.11	75.03	26.62	6.88
3	144.33	75.46	8.21	8.44	31.12	11.54
Concrete with instant cement Mortar Utama						
Avrg.	63.72	49.02	9.04	8.09	14.66	6.25
1	60.37	45.94	6.09	4.65	24.76	6.05
2	68.36	52.65	9.35	13.06	7.13	6.97
3	62.44	48.47	11.69	6.55	12.09	5.74
Concrete with sugar-based additive						
Avrg.	139.20	98.68	98.40	98.12	66.68	35.98
1	137.00	131.97	134.06	136.15	131.96	13.31
2	95.00	104.94	93.03	81.13	18.41	8.78
3	185.60	59.14	68.11	77.09	49.67	85.84

Table 12: The relationship between the resistivity and the corrosion rates

Resistivity (kΩ. cm)	Corrosion rate
<3	Very high
5-10	High
10-20	Low
>20	Negligible

not affect the corrosion rate due to the greater resistivity of 20. At the age of 7 day, the immersion still shows the same indication with soaking at the age of 4 days.

At the age of 14 days of immersion, samples of normal concrete and the main mortar shows higher corrosion rates compared to the samples of concrete with metakaolin having a lowc orrosion. Meanwhile, the concrete samples with sugar-based additives shows that the corrosion is insignificant (resistivity>20).

CONCLUSION

Based to the condition when the research of Bale Kapal is conducted, the appropriate conservation techniques to be applied is to strengthen the structure of the column with the grouting technique. In the application of this technique, grouting material which gives the effect of an increase in compressive strength at both the column is the high-strength epoxy resin. The study shows the results of sample testing of the existing field modeling and calculation of the dead load on Bale Kapal. After getting the retrofitting columns with high strength grouting epoxy resin, the column was strenghtenedso that reconstruction can be done to restore the Bale Kapal to its original condition.

Based on the results of compressive strength test, the best concrete materials to use in the conservation of Bale Kapalis concrete with a sugar-based additives. Normal concrete with compressive strength of 20 MPa mix design is recommended for compressive strength test results which are higher than the original concrete compressive strength. Visual evaluation of color and texture of normal concrete and concrete with additives of sugar-based shows that they are almost the same as the original concrete, so that both can be used in conservation. The best concrete materials to protect the reinforcement against durability of corrosion can be implemented in the conservation of Bale Kapal is the concrete with a sugar-based additives.

Some lesson learned from the research is if the column retrofitting technique using high strength epoxy resin grouting will be implemented to Bale Kapal, further research on the real corrosion level should be conducted before doing the grouting process. In the application of grouting techniques in the site researchers need to assess the Bale Kapal working techniques/operation, so that proper implementation of the research can be managed effectively.

Testing of durability of concrete in protecting the reinforcement against corrosion on the location of the object of research needs to be done by putting the speciment on the location of Bale Kapal to obtain a more accurate test results in accordance with local climate conditions. Other materials that will be used in reconstruction should follow the principle of conservation, as much as possible so that it will be similar to the original material. The selection must follow the rigorous research process.

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