

# ASSESSMENT OF DOME BUILDING DAMAGE AND REPAIR METHOD

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# ASSESSMENT OF DOME BUILDING DAMAGE AND REPAIR METHOD

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**Abstract.** The paper deals with the assessment of the damage of a concrete dome type of structure and the method of repairment. Due to own weight of the dome, the concrete portion of the dome near bottom rim is in tension and the steel reinforcement was not sufficiently provided, causing cracks at bottom and leakage at top of dome. UPV tests, profometer tests and core drilling were carried out to observe the condition of existing dome. Testing results were used as bases for constructing repairment method, epoxy grout, epoxy mortar and the use of carbon fibre reinforced plastic (CFRP).

## 1. Introduction

The dome type of structural system was widely applied since the early 80s, when concrete material was made by using conventional methods and ready-mix was yet not present. After some years, damages occurred on several structures, in crack and leakage occurrences. These occurred due to nonuniformity and high permeability of the concrete and insufficient reinforcement. Similar problems occurred in a dome structural system at Halim Perdanakusumah, Jakarta which constructed at that time. The dome is of spherical type, with 44 meters in diameter and 25.7 meters in height. The dome is functioned as coverage of national radar system. The dome is made of concrete, 0.08 meter thick at dome tip and varied to 0.5 meter at the bottom. Several damages occurred; i.e., leakage at upper portion of the dome, and cracks at lower portion of the dome. Prompt action to remedy the damages was required to save important national radar system. The paper deals with several test carried out to find the factors that caused the damages, and based on tests finding, to establish the method of repair. The tests included non-destructive test (NDT), and destructive test. Non-destructive test consists of Ultrasonic Pulse Velocity (UPV) and Profometer test. Destructive test consists of core drill test and chipping. Based on test finding, method of structural repairment was established. The results of non-destructive and destructive tests may be compared [1]. The estimate of concrete compression strength obtained by means of combined method is better than that obtained by single method [2]. The waves velocity decreases by 1-3% with degree of substitution and the overall waves velocity increases with material age [3]. While In SCC, the core drilling direction relative to the casting direction had no significant on compressive strength value [4].

## 2. Field Survey and Testing.

Some field surveys and laboratory testings were carried out, classified in non-destructive test (NDT) and destructive test. The NDT test consists of ultrasonic pulse velocity (UPV) test and profometer test.



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The destructive test consists of core drill and concrete chipping. The field investigation to verify the accuracy of previously obtained information with condition survey to assess the physical condition.

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### 2.1 Ultrasonic Pulse Velocity Test

Ultrasonic pulse velocity (UPV) test is intended for observing the uniformity of existing concrete and existency of cracks. Indirect method was applied (Fig. 1) The UPV test were carried out at five location to observe dome concrete crack region.



Figure 1: UPV test

### 2.2 Core Drill Test

Core drilling (Fig.2.) is intended for obtaining specimen out of existing concrete was before test in laboratory to find compression strength of concrete. The size of specimen cylinder is 200 mm height and 100 mm diameter. Coring is performed along the dome around 8 points with a height variation of 50 mm and 100 mm from the dome base.



Figure 2: Core Drilling

### 2.3 Profometer Test

Profometer test is intended for inspecting the existing 14 mensions and spacing of the reinforcing bars. The testing was carried out at eight locations ranging from a height of 500 mm from the bottom to the top of the dome. See Fig. 3 as explanation. The results are Meridian reinforcing 2 D13 with 10 cm distance and 10 mm diameter longitudinal reinforcement with 30 cm distance.



Figure 3: Profometer Testing

#### 2.4 Destructive Test

Destructive test carried out was chipping of concrete so as to be able to inspect the size and spacing of reinforcing bars (Fig.4). The results were then compared to the ones obtained out of profometer test, which turned out to be the same result with the test results of the profometer.

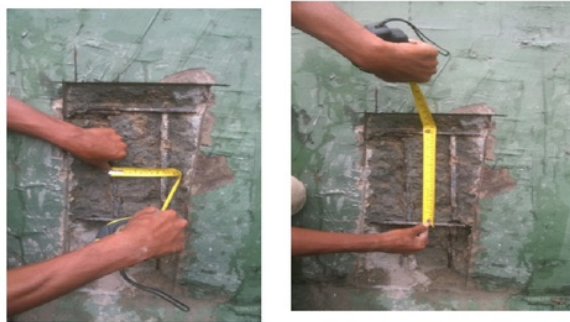


Figure 4: Destructive Test

### 3. Result and Discussions

#### 3.1 Non Destructive and Destructive Test

The UPV test results show that the crack depth in the dome building is 65-100 mm. The crack depth of 65-100 mm occurred larger than the concrete cover is 50 mm. This indicates the cracks a structural crack. So it needs repair by injection with epoxy material. Based on 4 samples of coring tested press obtained concrete strength  $f'_c$  20 MPa

The Destructive test results show that the meridian reinforcement is 13 mm in diameter while the longitudinal reinforcement diameter is 10 mm

#### 3.2 Structural Analysis

Two kinds of analysis were carried out on dome structure. The first was the problem concerning leakage. The second related to the cracks problem.

##### 3.2.1 Leakage Problem

The cracks occurred at the top portion of the dome. It is understood that at the time the dome was built, the concrete ready-mix or mix design were not present. Therefore, the concrete pouring was carried out by conventional method. As consequence, the concrete honeycomb exists at some location and permeability of the concrete was relatively high.

### 3.2.2 Cracks Problem

The crack occurrence can be described by conducting an analysis with respect to dome dead load as follows [5]. The dimension of the Dome: height of 25.7 m, circumference of 134.8 m, thickness varies from 80.0 mm at dome tip to 500.0 mm on the bottom of the dome. Therefore, a conclusion is drawn, the dome is half sphere shaped with the radius of 25.0 m.

The next dome was analysed with a computer program of SAP (Structural Analysis Program). The dome is represented by a discrete model by using finite element. By taking forces into account including self-weight and plus live load of 10.0 kN/m<sup>2</sup>. Ultimate moment distribution is given in Table 1.

Table 1: Moment Capacity and Reinforcement

Level	Investigation data	Slab thickness	Average spacing		f <sup>'</sup> c=20MPa fy=400 & 240 Capacity M22(kN.m)
			2D13 Vertical	D10 Horizontal	
Level 6 m	Level 2.2m t=300	300	172.5	230	123.641
Level 8 m	Level 7.2m t=180	180	152.5	310	71.51
Level 10 m	assumed	160	162.5	260	59.89
Level 12 m	assumed	140	202.5	225	41.229
Level 14 m	assumed	120	27	222.5	25.778
Level 16 m	assumed	100	16	282.5	16.484
Level 18 m	assumed	80	17	207.5	11.072
Level 22 m	Level 24,23,22 t=80	80	220	240	8.95

Meridian membrane force = -220 kN/m and  
Longitudinal memberan force = 220 kN/m

From above analysis it is shown that the hoop reinforcement of the dome is inadequate at bottom portion until the height of 3.8 meters. This inadequacy should be strengthened.

Based on the results of non-destructive test, destructive and structural analysis, then the next must be considered all repair materials have limitations, and the material specifier and user should select the materials [19]. The selection of Retrofitting materials uses CFRP because it has a low weight, high stiffness, corrosion resistance, lower maintenance cost and faster installation time [7]. Then based on the results of previous research that CRFP can increase shear resistant and confinement in members subjected to high and deformation reversals [8,9,10]. CFRP laminate have been recognized as effective method for their repair and retrofitting [11,12].

## 4. Method of Repairment

There are two kinds of problem experienced by the dome; i.e., leakage problem and crack problem. The repairment methods of the two problems are described in the following.

### 4.1 Repairment of Leakage

The leakage causes problem since the dome function is to cover delicate radar system equipments. The leakage had to be overcome as soon as possible. The repairment was indeed simple; i.e., to fill the porous region of existing concrete with epoxy grout and further screeding with epoxy mortar.

#### 4.2 Repairment of Cracks

To overcome cracks that occur the first step of Injection with epoxy material using a special tool pressurized. the epoxy point distance is 250 mm. injection performed from bottom to top

Since inadequate reinforcing bars are embedded in the concrete, then it was not possible to insert additional reinforcing bars in the concrete. Another way to strengthening the hoop reinforcing bars was adopted. The method of repairment was to use carbon fibre reinforced plastic (CFRP). The need for CFRP material was computed as follows. The demand of CFRP usage on the lower area with height of  $0.629 \times 22\text{m} = 13.838\text{ m}$  is done as shown below. The total tension force is 1522.18 kN. the CFRP was needed is  $304\text{ mm}^2$  and reinforcement width required is 2.53 m.

Based on the safety factor, therefore, 3.8m was attached. The installment of the repairment is shown in Figure 5.



Figure 5: Instalment of CFRP to Strengthening Dome

#### 5. Conclusions

The dome experienced damages as leakage and cracks due to rather poor construction method and inadequate hoop reinforcement at bottom of the dome. Since the dome was intended for housing delicate national radar system equipments, prompt action to overcome problems was necessary.

The handling of the problem was executed in several steps. First, several field surveys and sampling were carried out. The testing was carried out in non-destructive and destructive kinds of testing. The testing results that the leakage was due to high permeability of the existing concrete. The cracks were due to inadequacy of hoop reinforcing bars at bottom region of the dome.

The repairment was carried out in two steps. First, the leakage problem was overcome by epoxy grout and epoxy mortar at problematic region of the dome. Secondly, the cracks at bottom portion of the dome was overcome by Injection with epoxy, then covering internal and external surfaces of bottom portion of the dome by carbon fibre reinforced plastic (CFRP). The region covered was from support until 3.8 meter height.

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