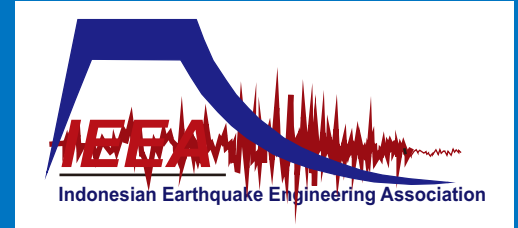




ITS
Institut
Teknologi
Sepuluh Nopember



ICEEDM

**The 2nd International Conference
on Earthquake Engineering
and Disaster Mitigation (ICEEDM-II 2011)**

**“Seismic Risk Reduction and Damage Mitigation
for Advancing Earthquake Safety of Structures”**

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FRACTURE MECHANICS APPROACH IN DETERMINING PRESSURE AND INJECTION TIME TO REPAIR CONCRETE CRACKS

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ABSTRACT

For the existing buildings and bridges, during the service period it is commonly found the problem of cracks in the beam, girder and slab. Crack that could appear due to the load of work during the service period of construction, faults of the design and recently earthquakes. These cracks have an impact on anxiety owner or agency that responsible for building the bridge of the dangers that will occur as collapse and structural failure. Considering that the building is already standing and still in use, there should be conducted some checkings and repairing that should not disturb the on going activity of the buildings or bridges.

Checking with UPV Test (Ultrasonic Pulse Velocity Test) is one of a non-destructive methods which not damage the existing building structure. Result obtained from UPV test include crack depth and strength of the concrete.

After obtained the data of crack depth and strength of the concrete, the critical question is how to repair the crack. Injection with epoxy material is a solution that can be done to repair the cracks and finally retrofit the strength of the structure.

The approach of this study is to determine the injection pressure and time for injection based on the depth of the crack. This appropriate with the results obtained from UPV test whereas based on the previous studies, crack injection was based on crack width.

Based on this study obtained a calculation of injection pressure and time needed for injection so that the crack depth can be fully filled through a fracture mechanics approach.

Keywords : UPV test, crack, injection, fracture mechanics

1. INTRODUCTION

In buildings and bridges that exist, as long as the service commonly found problems such as occurrence of cracks on the beam, girder and slab, rift that could arise due to the work load during the service construction, design faults and earthquakes are common lately. These cracks have an impact on anxiety owner or agency responsible for building the bridge of the dangers that will occur as collapse and structural failure. Considering the building is already standing and still in pemakaian it is necessary inspections and repairs that do not disrupt operations or bridge building.

Generally, a wise step taken was the examination conducted by UPT (Ultrasonic Pulse Velocity) one non-destructive method which is a method that does not damage the building structure ada. Hasil obtained from UPT test include crack depth and strength of concrete.

After the data depth of cracks that occur, the critical question is how to make improvements such cracks. Injection with epoxy material is a solution that can be done to repair the rift that ultimately can restore the strength of the structure to its original state.

But in fact this work during the epoxy injection done by specialist contractors (*applicator*) is not based on a calculation that can be accounted for, but just based on feeling and routine habits. This can be seen from the absence of data about how much pressure should be given and how long it takes epoxy injection?, so that the cracks that occur, completely filled by the liquid epoxy.

This is important given the high cost of epoxy materials and repairs by epoxy injection, it needs special attention for the job is not in vain or repair just a formality.

2. PROBLEM FORMULATION

The approach in this study to determine the pressure injection of epoxy and epoxy injection timing based on the depth of the crack. This is accordance with results obtained from UPT test. Literature so far as fundamental rift is the width of crack injection.

For that we need a calculation based on fracture mechanics approach, before making cracks about how much pressure injection should be given and the time required for the crack depth, in order to obtain optimal results.

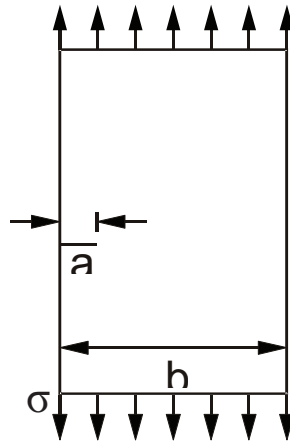
3. PAST STUDIES

Epoxy resin is injected into concrete cracks, the velocity depends on the viscosity, injection pressure and crack width (K. Kamimura and Kitsutaka 1990). Epoxy injection can be easily and effectively to repair cracks in concrete, not only until the wrong use of material and injection method (Miyles A. Murra). Injection using a resin with a mechanical application of pressure or manually into the concrete structure is highly dependent on the viscosity of the resin material. (T. Nireki et al .1990). To get the injection well to note the distance the point of injection. (Y. Hayashi et al 1989), as in table 1.

Table 1: Spacing of injector according to the width of crack

Width of crack (mm)	Spacing of injector (mm)
0.05 - 0.20	200 - 250
0.20- 3.00	300- 350

Uniaxial Tensile Plate with Single-edge Crack



$$K_I = \sigma \sqrt{\pi a} g_1 \left(\frac{a}{b} \right)$$

$$g_1 \left(\frac{a}{b} \right) = 1.12 - 0.231 \frac{a}{b} + 10.55 \left(\frac{a}{b} \right)^2 - 21.72 \left(\frac{a}{b} \right)^3 + 30.39 \left(\frac{a}{b} \right)^4 \quad (1)$$

Where a : crack depth

b : height of girder

John and Shah proposed to determine

$$K_{Ic} = 0.06 (f_c')^{0.75}$$

in units of $\text{MPa}\sqrt{\text{m}}$ (2)

Calculating the equation of time to use your injection

$$Sv = A / t \quad (3)$$

$$Sv = \pi a^2 / 2t$$

$$tcr = \pi a^2 / 2Sv$$

where a : crack depth

As for calculating the Area Velocity = Sv

$$Sv = ah^2P / \mu \quad (4)$$

Where S_v : area (cm^2 / s)
 a : characteristic value according to kamimura et.al the value of $a = 120.1$
 h : crack width (mm)
 P : Injection Pressure (MPa)
 μ : viscosity of injection solution (MPa.s)

4.Eksperimental : Materials and Methods

Type Epoxy Araldite Gy 250 and HY 2964 ex Ciba-Geigy by viscosity = 1200 MPa.s . Injection Equipment: Type-Polyplan RFQ-Werkzeuge GmbH

Technical work done after the injection of crack depth data obtained, it is done with the epoxy injection procedures: the first stage to mounting point injection with a distance of 25 cm, the second stage to sealing cracks on the side that is not installed, the third stage: injection performed at the specified injection point . Fourth stage: injection point was moved after the indication of the release of epoxy on the next point. Fifth stage : after one day of the injection point cut and clean.

This research was done on the Bridge pier that are developing cracks, before injection work, then do the work UPV test. Test Data can be seen in Figure 1.

Table 2: Calculation of pressure and injection time

Crack Depth mm	KI ($\sqrt{\text{m}}$)	KIC ($\text{MPa}\sqrt{\text{m}}$)	P (MPa)	S_v (cm^2/s)	tc (s)
65	1.608 P	0.863	0.54	2.28	29
70	1.671 P	0.863	0.52	2.55	30
45	1.333 P	0.863	0.65	1.32	24
45	1.333 P	0.863	0.65	1.32	24
45	1.333 P	0.863	0.65	1.32	24

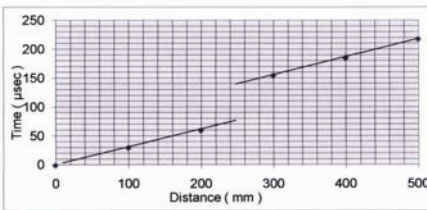
5.RESULT

From the table that there are visible cracks depth there was a rift depth relationships with a wide crack that occurred. Crack depth of 65 mm requires injection pressure of 0.54 MPa, crack depth 70mm requires injectin pressure of 0.52 MPa, and for the crack depth of 45 mm requires injection pressure of 0.65 MPa. This means that the deeper the crack that happens then the mean crack width is greater, so that given enough injection pressure 0.31 MPa. To clear the depth of injection time is long crack injection takes longer, compared with a smaller crack depth, To a crack depth of 65 mm needed time 29 s, while for 45 mm depth crack need 24 s. After the injection of epoxy under pressure and time have beencalculated, then the job evaluation of injection.

The evaluation was done by testing the UPV test as shown in Figure 2 (after injection)

(1). Structure : Pilar - Titik 1 Before Repair

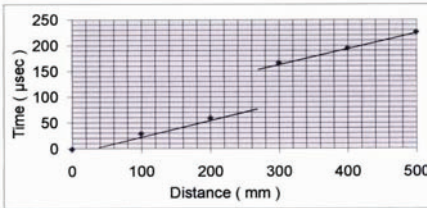
Distance (mm)	Time (μsec)
0	0
100	30
200	60
300	155
400	185
500	218



Remarks : Depth of crack = 65mm

(2). Structure : Pilar - Titik 2 Before Repair

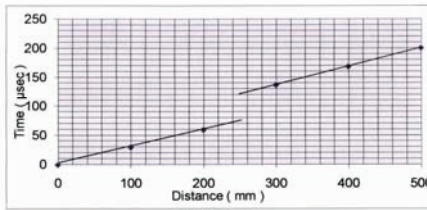
Distance (mm)	Time (μsec)
0	0
100	30
200	60
300	167
400	196
500	227



Remarks : Depth of crack = 70mm

(3). Structure : Pilar - Titik 3 Before Repair

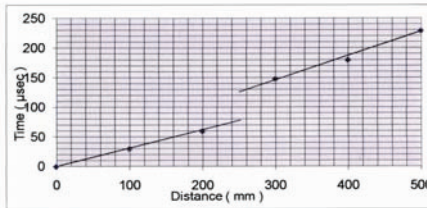
Distance (mm)	Time (μsec)
0	0
100	30
200	60
300	137
400	169
500	201



Remarks : Depth of crack = 45mm

(4). Structure : Pilar - Titik 4 Before Repair

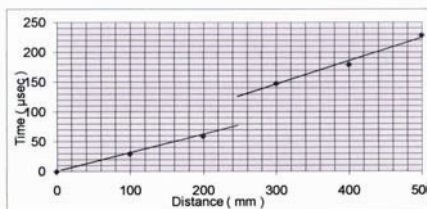
Distance (mm)	Time (μsec)
0	0
100	30
200	60
300	148
400	180
500	229



Remarks : Depth of crack = 45mm

(5). Structure : Pilar - Titik 5 Before Repair

Distance (mm)	Time (μsec)
0	0
100	30
200	60
300	150
400	179
500	228

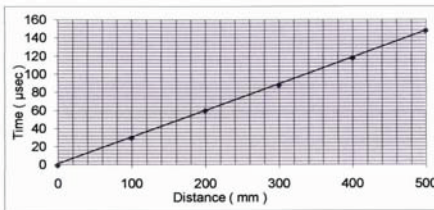


Remarks : Depth of crack = 45mm

Figure 1 : UPV Test before injection

(1). Structure : Pilar - Titik 1 After Repair

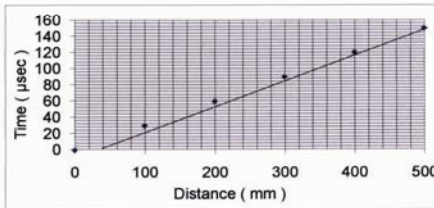
Distance (mm)	Time (μsec)
0	0
100	30
200	60
300	88
400	118
500	148



Remarks : No crack detected

(2). Structure : Pilar - Titik 2 After Repair

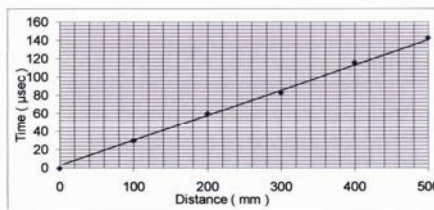
Distance (mm)	Time (μsec)
0	0
100	30
200	60
300	90
400	120
500	150



Remarks : No crack detected

(3). Structure : Pilar - Titik 3 After Repair

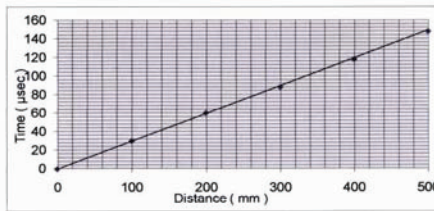
Distance (mm)	Time (μsec)
0	0
100	30
200	60
300	83
400	116
500	143



Remarks : No crack detected

(4). Structure : Pilar - Titik 4 After Repair

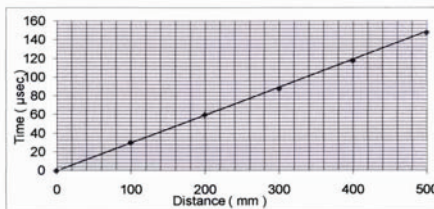
Distance (mm)	Time (μsec)
0	0
100	30
200	60
300	88
400	118
500	148



Remarks : No crack detected

(5). Structure : Pilar - Titik 5 After Repair

Distance (mm)	Time (μsec)
0	0
100	30
200	60
300	90
400	120
500	147



Remarks : No crack detected

Figure 2 : UPV Test after injection

6.CONCLUSION

Based on these results can be concluded to make a rift so deep crack injection will determine the pressure and time of the epoxy injection.

Fracture mechanic approach combined with the existing injection methods can be used to determine the epoxy injection pressure and injection time, so that repair cracks became more optimal injection

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