Repair Methods and Applications to overcomeHoneycomb, Cold Joint and Cracks in Concrete

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ABSTRACT : *In concrete work with structural complexity and large volume of concrete, damage to concrete often occurs such as honeycomb, cold joints and cracks. Damage is caused by internal and external factors and becomes a serious problem, it is not uncommon for demolition of the building to be carried out. Demolition is the last option, for that it is necessary to carry out several stages starting with root cause analysis whose aim is to find out what are the main factors causing damage to the concrete. Then forensic engineering is carried out through visual observation, UPV test, profometer, coredrill with the aim of knowing the quality of the existing concrete and the damage that occurs. The next stage of improvement is through the repair method in the form of grouting, material patching, and injection. Through proper and accurate application, the problem of damage can be solved. Based on the results of the work carried out in the field, it shows good results, so that it can solve the problem of honeycomb, cold joints and cracks that occur. These results prove that the development of concrete technology and concrete materials can solve the damage to concrete. The benefits of this research can be used as a reference to solve the same problem.*

KEYWORDS –*Honeycomb,cold joint, cracks, root cause analysis, forensic engineering*

I. INTRODUCTION

Construction work of power plants, dams and tall buildings, where the volume of concrete is used in large quantities and structures with large diameter reinforcement and very tight spacing between reinforcement, often result in damage to structural elements in the form of honeycombs and cracks. Heterogeneous concrete consists of materials with varying particle sizes and weights, so maintenance is not easy.

Cracks provide easy access for chloride ingress in the concrete and hence crack healing also affects the corrosion of steel in concrete [1,2]. Concrete honeycomb it is rocky zones on the surface or inside of concrete that does not have a fine grain or mortar.Honeycomb occurs whenever mortar fails to effectively fill the voids between the rough aggregate particles.

It is important to know the cause of damage to the concrete, the presence of undesirable defects, including honeycomb, cold joints and cracks on the concrete surface should be evaluated, as these defects will affect the durability and capacity of the structure to be repaired[3,4]. To be able to evaluate and choose a repair method, proper repair will increase the life of the concrete [5] . As the primary object, the mix design needs to be analyzed first for compliance according to codes or specifications. This includes reviewing the materials and mix compositions. Then, a root cause analysis (RCA) is peformed to find the main factors responsible to cause honeycomb, cold joint and cracks.

Then to find out more accurately the honeycomb, cold joint and cracks that occur, it is necessary to test including the ultrasonic pulse pelocity (UPV) test, Profometer and Core drille test [6,7]. it has been proven that non-destructive tests such as ultrasonic pulse pelocity (UPV) and profometer yield good validity, especially for existing structures [8,9].

Repair and rehabilitation of concrete structures is an important aspect of the main maintenance of infrastructure and a major requirement to maintain its current level of safety, functionality and use[10-11].

This research is a process of overcoming damage to concrete in the form of honeycomb, cold joint and cracks starting from testing, repair methods and applications. The benefits of this research, this repair method and application, can be used as a reference to overcome the honeycomb and cracks problems that occur.

II. MATERIALS AND METHODS

First stage : Root Cause Analysis the process of discovering the root causes of problems in order to identify appropriate solutions. RCA is done in 5 steps as follow define the problem. analyze what you see happening, and identify the precise symptoms so that you can form a problem statement, gather data, identify causal factors,determine the root cause, recommend and implement solutions.

The second stage of visual inspection is to get an overview of the building system, structural and non-structural damage that occurs and its effect on the building structure.The results obtained will determine the point / location testing, tools required and visual damage mapping and documentation. Third stage structural audit (Assessment) of concrete structure through 1) concrete surface compressive strength test (Rebound hammer test) 2) Reinforcement configuration test (Rebar scan) 3) Core drill sampling 4) Concrete crack density & depth test (Ultrasonic pulse velocity) 5) Visual inspection regarding the dimensions of structural elements, dimensions of reinforcement, the existing condition of the building in terms of damage (honeycomb, cold joint and cracks).

Fourth stage :determine the repair method according to the type of damage that exists by referring to the standards issued by the american concrete institute [12-13].Fifth stage : material selection for repair of structural concrete fillings. material is selected based on material from several manufacturers such as BASF, SIKA and FOSROC, the basis for selection is mechanical properties, material availability and price. The procedure begins with identifying the cause of the damage and assessing the concrete substrate, and continues withevaluate the mechanical properties and durability of the selected [14-15]. The sixth step: the implementation of repair work in accordance with the methods and materials selected for the type of damage that exists. The seventh step is to control the results of the repair work.To check the success of the work, it is necessary to test the compressive strength of the grouting and patching materials. Additional testing for patching work is carried out with a bond strength test with a pull out test, then on the control concrete injection work in the form of a UPV test before and after the repair is carried out. As shown in Figure 1.

Figure 1. repair work control: before, testing and after work

III. RESULT AND DISCUSSION

Based on the Root Cause Analysis, there are four main factors that cause honeycomb and cold joints and cracks, namely the slump factor (low so that it affects workabiity), low action / lack of management support

in mobilizing skilled workers workers/labor , Lack of supervision and QC inspection during casting, no vibrator with small head/rod available to compact the tight corner basically near the formwork wall. UPV and Coredrille test results, the strength of the existing concrete is fc 35 MPa

There are several type of damages which can be repaired depend on the level of damages. This following repair methods has considered for the use dynamic Foundation.

Type 1. Patching for Honeycomb from 10 mm up to less than 50 mm and concrete cover less than 40 mm(Fig.2)

Repair method and application : preparatory work: The surface that has been checked is sure to meet the requirements of a concrete cover ≥ 50 mm, Clean from dirt or dust. Primer with styrene Butadiene Rubber (SBR)Start the patch job by using a hand trowel Material Master Emaco S 5400 is a cementitious, polymer modified, one component, repair mortar containing reactive microsilica. Technical Properties Compressive Strength 28 days ≥ 70 MPa and adhesion to concrete ≥ 2 MPa

Figure 2. Honeycomb from 10 mm up to 10 mm upto less than 50 mm and concrete cover less than 40 mm

Type 2. Grouting Honeycomb from 50 mm up to 100 mm (Fig.3)

Repair method and application: chipping existing honeycomb, until it passes through reinforcement which is at least 10 mm. Chipping uses Hydraulics, to avoid damage to work. Chipping must be done by repair worker. Chipping is adjusted according to the existing damage zone. Install the shear connector every 250-400mm depending on the surface area to be grouted. Install formwork and attach strong and not leak. After everything is ready, Grouting can be done using a grout pump or pouring system by using for certain positions. Material shear connector is HILTI anchor HUS3-H Type

Material for Grouting: MasterFlow 880 is non-shrink, iron aggregate precision grout with high early and ultimate strength. It is typically placed at a flowable consistency at thickness between 10 mm and 150 mm. Technical properties: Compressive strength :> 90 MPa and Flexural strength > 90 MPa after 28 days.

Figure 3. Honeycomb from 50 mm up to 100 mm

Type 3. Grouting and injection Deepest Honeycomb (Fig.4)

Repair method and application : the injection packers inserted into pre-drilled holes shall be fixed at intervals along the length of each crack. Injection point drill depth is adjusted by ineternal honeycomb or at least 100 mm. The distance between each packer will depend upon the width and depth of the crack. Spacing shall be close enough to ensure that the resin will penetrate along the crack to the next point of injection. This will normally be between 100 mm and 200 mm. Before the grout work is carried out, the formwork installed must be strong, not leaky and use good materials to produce a flat concrete surface that is repaired. Masterflow 880 has good flow properties, so it can fill the deepest honeycomb. Meanwhile, to fill a small void, the injection pipe must be installed/ prepared, the pipe size is longer than the thick grouting. After everything is ready, installation work with Masterflow 880 can be done using a grout pump. then after 1 x 24 hours, injection work with epoxy to fill a small vacuum can be do Material for Grouting: MasterFlow 880 is non-shrink, iron aggregate precision grout with high early and ultimate strength. It is typically placed at a flowable consistency at thickness between 10 mm and 150 mm. Technical properties: Compressive strength :> 90 MPa and Flexural strength > 90 MPa after 28 days.Material for injection :Conbextra EP10TG epoxy is a two part, solvent-less, low viscosity, non-shrink epoxy resin system that forms a permanent bond and seal in cracks in concrete. Crack widths between 0.25 mm - 10 mm can be treated. This epoxy is designed to be injected into cracks using suitable resin injection equipment. The injection pressure should be at least 0.4 N/mm^2 (4 Bar).Technical data : Compressive strength 7 days : 83 N/mm^2 , flexural strength : 63 N/mm^2

Figure 4. Large Honeycomb

Type 4. Injection with Epoxy to repair cold joint and cracks(Fig. 5)

Repair method and application : injection point nipel is affixed along the crack using epoxy sealing, which must be installed at intervals along the length of each crack. The distance between each packer will depend upon the width and depth of the crack. Spacing shall be close enough to ensure that the resin will penetrate along the crack to the next point of injection. This will normally be between 100 mm and 200mm.

Material for injection: Conbextra EP10TG epoxy is a two part, solvent-less, low viscosity, non-shrink epoxy resin system that forms a permanent bond and seal in cracks in concrete. Crack widths between 0.25 mm - 10 mm can be treated. This epoxy is designed to be injected into cracks using suitable resin injection equipment. The injection pressure should be at least 0.4 N/mm^2 (4 Bar).Technical data : Compressive strength 7 days : 83N/mm^2 , flexural strength : 63 N/mm^2

Epoxy injection work, if carried out with the correct repair method, has been proven to be able to overcome the problem of cold joints and cracks, this is in line with research conducted by several researchers [16].

Figure 5. Repair work cold joint and cracks

The results of the grouting material test that have been applied in the field and the grout standard from the producer show significant results as shown in Figure 6. The standard grout from the producer for 3 days > 60 MPa, 7 days > 75 MPa and 28 days > 90 MPa. Then the results of field tests for 3.7, 28 days were 61.69 MPa, 73.43 MPa and 90.8 MPa. Thus, it can be ascertained that the grout material used is in accordance with the existing quality.

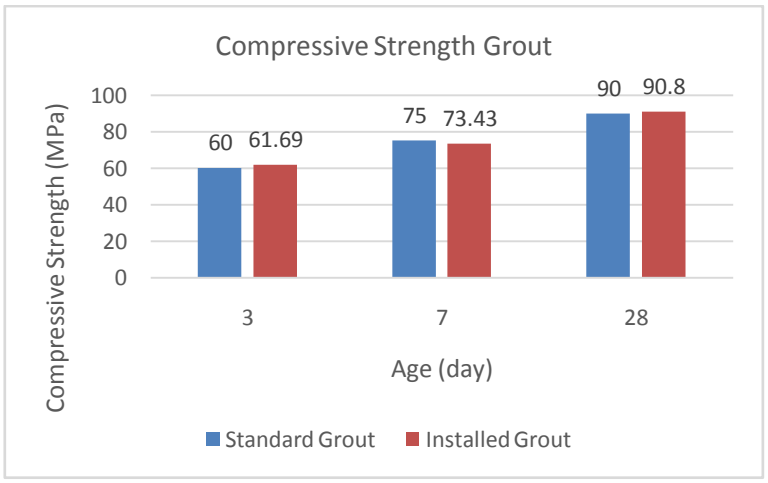

Figure 6. Compressive strength Grout

The results of the patching material test that have been applied in the field and the grout standard from the producer show significant results as shown in Figure 7. The standard patching material from the producer for 3 days > 30 MPa, 7 days > 45 MPa and 28 days > 70 MPa. Then the results of field tests for 3.7, 28 days were 39.12 MPa, 40.59 MPa and 66.8 MPa. These results show the results of the compressive strength in the field reaching 95.4%, this is due to the weather conditions during application repair in the field, but these results are still acceptable

The results of the cold joint and crack work tests through the UPV test showed good results, this can be seen from the test results before and after. If before the repair was carried out the UPV results showed that there were cold joints and cracks, after the work the results showed no cold joints and cracks were seen.

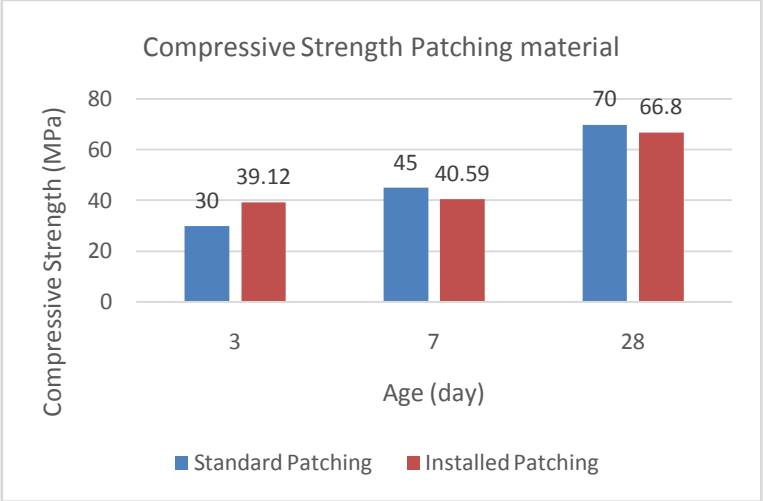

Figure 7. Compressive strength patching material

IV. CONCLUSION

The correct repair method is the key to success in repairing honeycombs, cold joint and cracks, it is proven that the damage that occurs to the structural elements can be repaired with good results. The application process requires experienced experts in the selection of materials to be used and application in the field. The materials used must have product quality that is tested in the laboratory and test results in the field.

REFERENCES

[1] In-Deok Han and Dongyeop Han, Introducing a New Quantitative Evaluation method for Segregation of Normal Concrete, International Journal of ConceteStrucyures and materials 15:21, 2021. .https://doi.org/10.1186/s40069-021-00458-9

[2] Faiz Uddin Ahmed Shaikh, Effect of Cracking on Cprrosion of Steel in Concrete, Journal of ConceteStrucyures and materials, Januari 2018. DOI 10.1186/s40069-018-0234-y

[3] WaelZatar, Hai Nguyen, Hien Nghiem, NondustructiveEvaluastion of reinforced Concrete Slabs Rehabilitated with Glass Siber Reinforced Polymers, symposium paper Volume 356 pp 224-237,January 2022.

[4] Leonel Lipa, Laura M. Navarro, and Enrique N.Pasquel, Influence of Steel Bars in Detection of voids in Concrete using ultrasonic pulse-Echo Method,materials Journal Volume 116, Januari 2019.

[5] ACI 546R-04 , Concrete Repair Guide, Reported by ACI Committee 546, Farmington Hills. Michigan. December 2004.

[6] Shankar S, Hikmat RJ. Comparison of concrete properties determined by destructive and nondestructive *t*ests, *Journal of the Institute of engineering* **10** (2014)130-139.

[7] Benyahia KA, Ghrici MS, Kenai, Breysse D and ZM Sbartai. Analysys of the relationship between nondestructive and destructive testing of low concrete strength in new structure , *Asian Journal of Civil Engineering*, **18** (2017) 191-205

[8] Rucka M., Wilde K. :Ultrasound monitoring for evaluation of damage in reinforced concrete. *Bull. Pol. Acad. Sci. TechvSci.* ;63:65–75 (2015)

[9] Breysse, D. and Balayssac, J.P. Non-destructive testing and assessment of reinforced concrete and masonry structures. Construction and Building Materials, 182, 1-9 (2018)

[10] S.Sajedi, Q. Huang, A.H. Gandomi, B. Kiani, Reliability-based multiobjective design optimization of reinforced concrete bridges considering corrosion effect, ASCE-ASME J. Risk Uncertain. Eng. Syst. Part A: Civil Eng. (2016) 04016015.

[11] Concrete repair guide, ACI, American Concrete Institute, Farmington Hills, MI, 2004

[12] Guide foe Evakuation of concrete structures before rehabilitation, ACI363.IR-07. Farming Hills, MI, 2007.

[13] Code requirements for assessment , repair and rehabilitation of existing concrete structures, ACI 562-19, Farming Hills, MI, 2019.

[14] M. Dyanati, Q. Huang, D. Roke, Cost-benefit evaluation of self-centering concentrically braced frames considering uncertainties, Struct. Infrastruct. Eng. 13 (5) (2017) 537–553

[15] Behnamkiani, Robert Y. Liang , Jacob Gross, material selection for repair of structural concrete using Vikor Method. Case studies in Construction materials 8 (2018) 489-497.

[16] A. Issa and P. Debs, "Experimental study of epoxyrepairing of cracks in concrete", Construction and BuildingMaterials, vol. 21, pp. 157-163, 2007

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