International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 – 6435(Online), Volume 1, Issue 1, Oct 2013)

Repair of Honey-Combed RC Beams Using Cementitious Materials

Samir Shihada[1], Yasser Oida[2]

[1]*Department of Civil Engineering, University of Gaza, Gaza, P.O. Box 108, Gaza Strip, Palestinian Territory*
[2]*Civil Engineering Office - Ministry of Health, Gaza, Gaza Strip, Palestinian Territory*

***Abstract*— This study investigates the use of four cementitious repair materials in terms of restoring the flexural capacities of honey-combed reinforced concrete shallow beams. Fifteen reinforced concrete beams are cast with honeycombs on the tension side, repaired and then tested under four point-loading. The repair materials used include Ultra High Performance Concrete (UHPC), Ultra High Performance Fiber Reinforced Concrete (UHPFRC), Normal Strength Concrete (NSC) and Cement-based Repair Material (CRM). Added to this, three beams with no deteriorations are cast, tested and considered as control beams. The outcome of this study shows that the four repair materials can achieve flexural capacities ranging from 100 % to 130 % of the control beam capacities. In addition, mid-span deflections and crack patterns are also compared.**

***Keywords*— Flexural capacity, honey-combed, shallow beams, stiffness, UHPFRC**.

I. INTRODUCTION

Incompetence of RC elements may be caused by faults in design, use of unsuitable materials, incompetent workmanship, exposure to aggressive environmental conditions and overloading. It is vital to repair deficient concrete members to a satisfactory condition of structural adequacy. The Housing and Building National Research Center in Egypt has operated a statistical study on the causes of deterioration in concrete structures. The study showed that 83% of the causes of damage were referred to bad execution practices. In the same study it was stated that honeycombing presented one of the most serious defects on the behavior of RC beams as it caused a considerable decrease in ductility and flexural stiffness [1].

In the European Union about 84,000 reinforced and prestressed concrete bridges need to be maintained, repaired and strengthened at an annual cost of £215 M, while in the USA, about 27% of highway bridges require repair or replacement [2]. Due to the high cost associated with reconstruction of the damaged elements, repair and strengthening techniques have become a priority in the recent years due to its much lower cost.

Over the last years, serious efforts to improve the behavior of concrete materials by adding fibers have led to the development of Ultra-High Performance Fiber Reinforced Concretes (UHPFRC). These new building materials provide the structural engineer with very high compressive strengths in addition to high tensile strengths [3]. Ultra high performance concretes have been used for improving flexural behavior of damaged concrete beams. Flexural tests showed that these composites can improve the flexural behavior of reinforced concrete beams, including flexural strength and ductility [4-7].

Inadequate compaction, poor mix design, unskilled workmanship and congestion of steel reinforcement can produce honeycombing in concrete elements. Abdel-Rohman [8] carried out an experimental investigation to study the effectiveness of various repair materials applied to honeycombed simply supported RC beams by loading them to failure. The study showed that using a mortar made of fine sand and Portland cement is not very effective in repairing honeycombs as compared with commercial repair materials.

Al-Salloum [9] investigated the performance of some commercial cementitious repair materials when used to repair RC beams. The results showed that the flexural capacities of beams can be retained within 4% using normal strength concrete to repair damaged parts subjected to tension stresses. The results also indicated that there is no sound justification for using highly expensive cementitious repair materials in replacing normal strength concrete for repairing RC beams subjected to tensile flexural stresses.

The objective of this research is to investigate the flexural performance of honey-combed reinforced concrete beams repaired using several cementitious materials, including Ultra High Performance Concrete. The importance of this study stems from the fact that a large number of concrete buildings have been damaged due to the effect of air bombardment caused by outbreak of violence in the Gaza Strip and need to be repaired/strengthened efficiently at low cost.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 – 6435(Online), Volume 1, Issue 1, Oct 2013)

II. EXPERIMENTAL PROGRAM

The main objective of the testing program is to test the flexural capacities of intentionally damaged beams using four several repair materials. In addition, crack patterns and mid-span deflections are to be evaluated.

A. Materials

Concrete

All the beams are cast using normal strength concrete that has a 28-day compressive strength of 25 MPa. Then, the beam specimens, used in the study, are wet cured for a 28-day period.

Repair materials

Beams are repaired using four cementitious materials. Normal strength concrete having a 28-day compressive strength of 25 MPa, Ultra High Performance Concrete having a 28-day compressive strength of 120 MPa and Ultra High Performance Fiber Reinforced Concrete having a 28-day compressive strength of 134 MPa and a tensile splitting strength of 7.82 MPa are used. In addition, a commercial repair material "BETONREP 250" manufactured by YASMO MISR, Egypt having a 7-day compressive strength of 30 MPa is also used. Concrete composition is shown in Table.I.

Table I.
Concrete composition

Components	UHPC	UHPFRC	NSC
		Kg/m^3	
Cement (CEM I52.2 R)	600	600	300
Water	180	180	188
Aggregates	1605	1605	1880
Silicafume	93	93	0
Superplasticizer	18	19.8	18
Steel fibers	0	0.50	0

Steel reinforcement

The yield strengths of the deformed reinforcement used in preparing the test specimens are 420 MPa and 280 MPa, for 12 mm and 8 mm bars, respectively.

B. Test Specimens

Dimensions and reinforcement

Test beams are 150 mm wide, 200 mm deep and 1100 mm long. The actual span is limited to 900 mm. Each of the 15 beams is reinforced on the tension side with 2 bars, 12 mm in diameter and on the compression side with 2 bars, 8mm in diameter. All beams are overdesigned in shear to avoid shear failure using 8 mm stirrups spaced at 50 mm. The beams are designed according to the requirements of ACI 318-11M [10] as tension-controlled. Each of the twelve beams is cast leaving a missing part 50x150x100 mm at mid span on the tension side to resemble honeycombing, Figure.1.

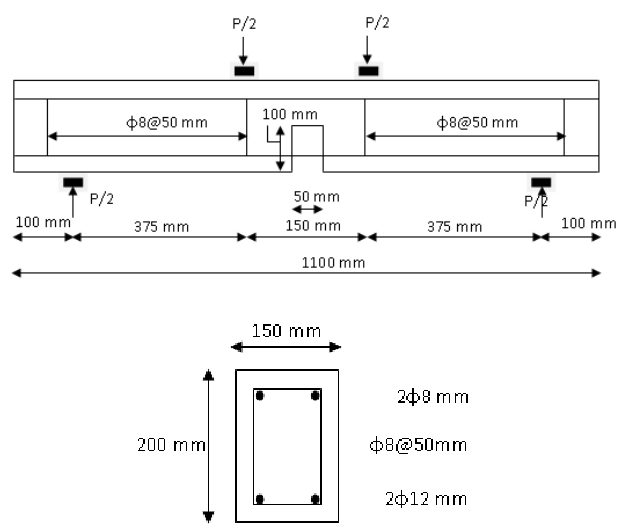


Figure.1. Beam dimensions and reinforcement details

C. Repair Process

The edges of the missing parts are chipped off using a chisel. Then, water is sprinkled on these edges to remove any loose materials, Figure. 2.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 – 6435(Online), Volume 1, Issue 1, Oct 2013)

Figure.2. Honeycomb edges are chipped off

Four beam groups (3 beams each) are then repaired using the four repair materials and wet cured for another 7 days.

D. Flexural testing

Three undamaged beams are tested to failure under four point loading and considered as control specimens. Ultimate loads are recorded, crack patterns are traced and mid-span deflections are measured using dial gauges. In addition, the 12 repaired beams are loaded to failure. Ultimate loads are recorded, crack patterns are traced and mid-span deflections are measured.

III. RESULTS AND DISCUSSION

A. Flexural Capacities

The ultimate loads for beams repaired using NSC are 1.6% more than those for the control beams. Beams repaired using UHPC showed an increase of 19% in flexural capacity. Furthermore, beams repaired using UHPFRC and CRM showed the best results with increases in flexural capacities over the control beams of about 30% and 27%, respectively, Figure. 3.

In general, the four repair materials proved effective in restoring the flexural capacities of the repaired beams, keeping in mind that the repaired beams are tested 7 days only after the repair process.

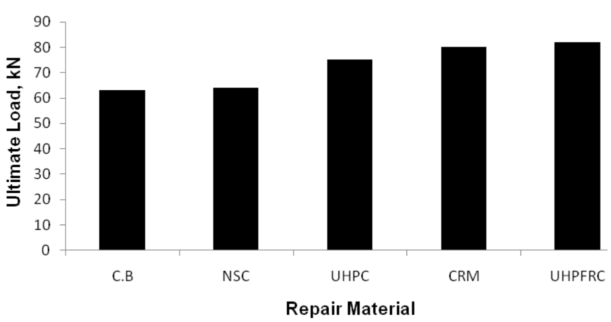


Figure.3. Ultimate loads for control and repaired beams

B. Mid-Span Deflections

The repaired beams, with no exception, show less mid-span deflections than the control beams. This may be attributed to the increase in stiffness of the repaired beams (increase in their moduli of elasticity). The least deflection values are obtained from the beams repaired using CRM and UHPFRC, as shown in Table II and Figure. 4.

Table II.
Mid-span deflections

Load, kN	Mid-span deflections (mm)				
	C.B	UHPC	UHPFRC	NSC	CRM
4.5	1.6	1.35	1.05	1.65	0.95
9	2.4	2.4	1. 5	2.5	1.45
13.5	3.1	2.6	2.0	3.2	1.9
18	3.7	3.2	2.5	3.85	2.25
22.5	4.2	3.6	2.7	4.35	2.55
27	4.7	4.0	3.0	4.85	2.85
31.5	5.1	4.4	3.3	5.3	3.1
36	5.6	4.8	3.6	5.8	3.4
40.5	6	5.2	4.0	6.2	3.65
45	6.5	5.6	4.2	6.7	3.95
49.5	7	6.0	4.6	7.2	4.3
54	7.4	6.4	4.9	7.65	4.5
58.5	7.9	6.8	5.2	8.15	4.8
63	8.6	7.4	6.1	8.9	5.25
67.5	---	7.90	6.7	---	5.55
72	---	---	7.2	---	5.9
75	---	---	7.9	---	6.9
81	---	---	8.4	---	8.3

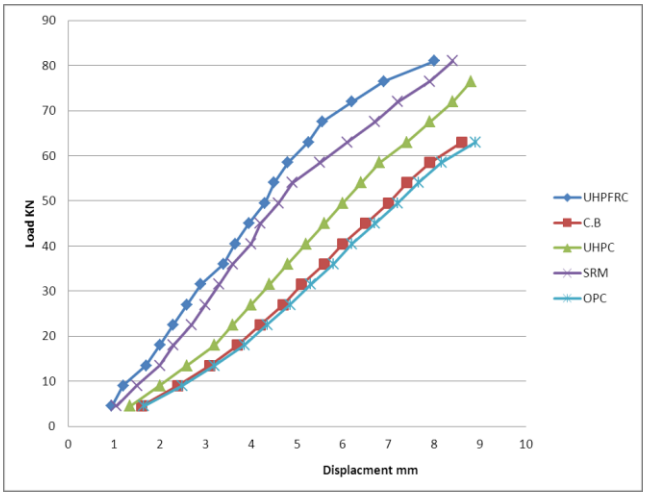
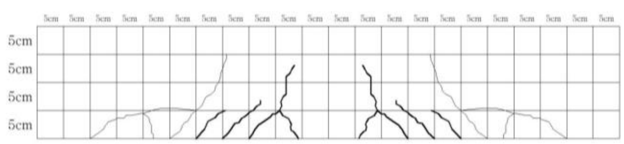


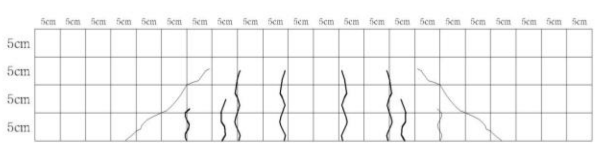
Figure. 4. Load vs. mid-span deflection

C. Crack Patterns

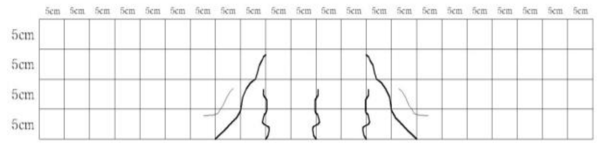
The crack patterns of the repaired beams are flexural cracks outside the repair area. The beams repaired using UHPFRC and CRM showed less crack widths and lengths compared to the beams repaired using UHPC and NSC. Furthermore, web shear cracks are more significant for the repaired beams. This proves the effectiveness of the adopted repair technique in general, Figure. 5.



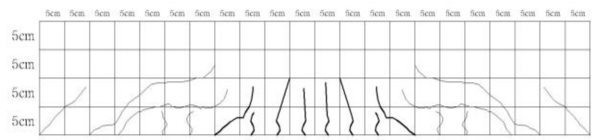
Crack pattern of control beams



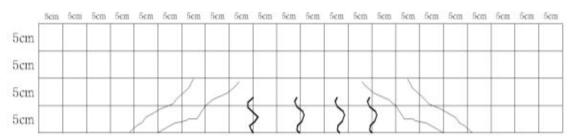
Crack pattern of UHPC beams



Crack pattern of UHPFRC beams



Crack pattern of NSC beams



Crack pattern of SRM beams

Figure. 5. Crack patterns of all of the tested beams

IV. CONCLUSION

Based on the results of the executed experimental program, the following may be drawn out

- It is recommended to use UHPFRC or CRM "BETONREP-250" for repair of beams damaged in the form of honeycombing, if extra flexural strength is required.
- Smaller mid-span deflections are recorded when CRM and UHPFRC repair materials are used.
- The crack patterns of the beams repaired using UHPFRC and CRM show less flexural cracks compared with the rest of the beams.

- NSC as a repair material can restore the flexural capacity of the honeycombed beams (similar to that of the undamaged beams).

Acknowledgements

The authors would like to extend their gratitude to the Deanery of Scientific Research at IUG-Gaza for funding this research. Furthermore, the undiminished help and support provided by the director and staff of the Material and Soil Laboratories at IUG-Gaza is also appreciated.

REFERENCES

[1] Elrakib, T. and Arafa, A. 2012. Experimental Evaluation of the Common Defects in the Execution of Reinforced Concrete Beams under Flexural Loading.j.hbrcj, Vol.(8), pp:47-57.

[2] Pacheco-Torgal F, Abdollahnejad Z, Miraldo S, Karahan S, Baklouti S, Ding Y. 2012. An Overview on the Potential of Geopolymers for Concrete Infrastructure Rehabilitation. J.conbuildmat. Vol.(36), No.6, pp:1053-1058.

[3] Bruhwiler, E. 2012. Rehabilitation and Strengthening of Concrete Structures using Ultra-High Performance Fibre Reinforced Concrete. Concrete Repair, Rehabilitation and Retrofitting III – Alexander et al. (eds), Taylor& Francis, London, ISBN 978-0-415-89952-9.

[4] Wang N, Xu SL. 2011. Flexural Response of Reinforced Concrete Beams Strengthened with Post-Poured Ultra High Toughness Cementitious Composites Layer. J of Central South University of Technology. Vol(18), No.3,pp:932-939.

[5] Kim SW, Yun HD. 2011. Crack-Damage Mitigation and Flexural Behavior of Flexure-Dominant Reinforced Concrete Beams Repaired with Strain-Hardening Cement-based Composite. J.compositesb.Vo. (42), no.4, pp:545-656.

[6] Diab Y. 1998. Strengthening of RC Beams by using Sprayed Concrete: Experimental Approach. Engineering Structures. Vol.(20), No.7, pp:631-643.

[7] Shihada, S. and Oida, Y. 2013. Repair of Pre-cracked RC Beams using Cementitious Materials. Journal of Scientific Research and Reports. Vol.(2), No. 2, pp:655-664.

[8] Abdel-Rohman, M. 2005. Efftiveness of Patch Repair in Reinforced Concrete Beams with Exposed Honeycombs. Kuwait J. Sci.Eng., Vol. (32), pp:187-208.

[9] Al-Salloum, Y. 2007. Flexural Performance of RC Beams Repaired with Commercial Repair Materials. J. King Saud University, Vol.(19), Eng. Sci. (2), pp:153-173.

[10] ACI Committee 318. 2011. Building code requirements for structural concrete (ACI 318M-11) and commentary, Farmington Hills.503 pp.