



Cairo University

# **EFFECT OF POLYMERS AND SEAWATER ON THE PERFORMANCE OF RECYCLED AGGREGATE CONCRETE**

By

**Ayed Ahmad Mahmoud Zuhud**

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
in Partial Fulfillment of the  
Requirements for the Degree of  
DOCTOR OF PHILOSOPHY  
in  
Structural Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT  
2017

# **EFFECT OF POLYMERS AND SEAWATER ON THE PERFORMANCE OF RECYCLED AGGREGATE CONCRETE**

By

**Ayed Ahmad Mahmoud Zuhud**

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
in Partial Fulfillment of the  
Requirements for the Degree of  
DOCTOR OF PHILOSOPHY  
in  
Structural Engineering

**Prof. Dr.**

**Ahmed Mahmoud Maher Ragab ,**

.....  
Professor of properties and strength of materials  
Structural Engineering Department,  
Faculty of Engineering  
Cairo University

**Prof. Dr.**

**Mohamed Mohsen El –Attar**

.....  
Professor of properties and strength of materials  
Structural Engineering Department,  
Faculty of Engineering  
Cairo University

**Prof. Dr.**

**Mohamed M.S. Ziara**

.....  
Professor of Civil Engineering Department  
Faculty of Engineering  
Islamic University- Gaza Strip

FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT  
2017

# **EFFECT OF POLYMERS AND SEA WATER ON THE PERFORMANCE OF RECYCLED AGGREGATE CONCRETE**

By  
Ayed Ahmad Mahmoud Zuhud

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
in Partial Fulfillment of the  
Requirements for the Degree of  
DOCTOR OF PHILOSOPHY  
in  
Structural Engineering

## **Approved by the Examining Committee:**

---

Prof. Dr. Ahmed Mahmoud Maher Ragab,                      Thesis Main Supervisor

---

Prof. Dr. Mohamed Mohsen El –Attar                              Member

---

Prof. Dr. Mohamed M.S. Ziara,                                      Member  
Professor of Civil Engineering Department, Faculty of Engineering Islamic  
University- Gaza Strip

---

Prof. Dr. Osama Abd El-Ghafor Hodhod                              Internal Examiner

---

Prof. Dr. Moneer Mohammed Kamal                                      External Examiner  
Professor of properties and strength of materials, Faculty of Engineering  
Menofia University, Egypt

FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT  
Year 2017

**Engineer's Name:** Ayed Ahmad Mahmoud Zuhud  
**Date of Birth:** 11/ 4/ 1965  
**Nationality:** Palestinian  
**E-mail:** eng.zuhud@hotmail.com  
**Phone:** 01010941235  
**Address:** Gaza Strip- Nuseirat  
**Registration Date:** 1/ 3/ 2012  
**Awarding Date:** / /  
**Degree:** Doctor of Philosophy  
**Department:** Structural Engineering



**Supervisors:**

**Prof. Dr. Ahmed Mahmoud Maher Ragab**  
**Prof. Dr. Mohamed Mohsen El –Attar**  
**Prof. Dr. Mohamed M.S. Ziara**

**Examiners:**

**Prof. Dr. Ahmed Mahmoud Maher Ragab**  
**Prof. Dr Mohamed Mohsen El –Attar**  
**Prof. Dr Mohamed M.S. ZiaRA**  
**Prof. Dr. Osama Abd El-Ghafor Hodhod**  
**Prof. Dr. Moneer Mohammed Kamal**

**Title of Thesis:**

**Effect of Polymers and Seawater on the Performance of Recycled Aggregate Concrete**

**Key Words:**

**Construction and demolition wastes; Recycled aggregate; Natural aggregates  
Polypropylene fiber; Siloxane polymer; Structural concrete**

**Summary:**

Gaza Strip doesn't have any source of natural aggregate(NA) to reconstruct the demolished constructions .The mega quantities of highly contaminated construction and demolished wastes with heavy metals have to be reused as recycled aggregate(RA) for structural concrete .Using contaminated RA in concrete mixes will minimize leaching of hazardous materials to surrounded environment. RA is highly water absorbable compared with natural aggregate. The concrete made with RA has low mechanical properties especially tensile strength. To study the effect of RA percentage, Polypropylene fiber (PP) , Siloxane polymer(SP) and seawater in concrete mixes, eight types of concrete mixes were prepared. The results showed large enhancement by 85.0% decrease of water absorption and high concrete resistance to seawater effects by 15% increase in mechanical properties when SP was used. As a reason of using PP fibers, the mechanical properties of RA concrete enhanced so much especially tensile strength by 35.0%.

## **Acknowledgments**

I wish to express my gratitude to my Chief Supervisor Professor Dr. Ahmed Mahmoud Ragab . I am deeply indebted to my Supervisor Professor Dr . Mohamed Mohsen El -Attar for his fundamental role in my doctoral work. Prof. Attar provided me with every bit of guidance, assistance, and expertise that I needed during my first step in Cairo University till this moment; at the same time continuing to contribute valuable feedback, advice, and encouragement . I also want to express my appreciation to my Co-Supervisor Dr Mohamed M.S. Ziara, for his support and encouraging attitude to my work. I owe a great debt of gratitude to the Professors and Doctors committee in the Doctoral program in the Department of Structural Engineering at The Cairo University. I would like to thank Middle East Desalination of Engineering Research center ( MEDRIC ) for their support in completing the chemical and heavy metal tests of recycled aggregate .I would like to appreciate the team who stand beside me in the Materials and Soil Testing Laboratory at the Islamic University of Gaza (IUL). I am deeply thankful to my daughters and sons for their love, support, and sacrifices..

## **Dedication**

This thesis work is dedicated to my beloved wife, S.M, who has been a constant source of support and encouragement during the challenges of life. I am truly thankful to GOD for having you in my life.

# Table of Contents

<b>ACKNOWLEDGMENTS .....</b>	<b>V</b>
<b>DEDICATION.....</b>	<b>V</b>
<b>TABLE OF CONTENTS.....</b>	<b>VII</b>
<b>LIST OF TABLES .....</b>	<b>X</b>
<b>LIST OF FIGURES .....</b>	<b>XII</b>
<b>ABSTRACT .....</b>	<b>XIV</b>
<b>CHAPTER 1 INTRODUCTION .....</b>	<b>1</b>
1.1 BACKGROUND .....	1
1.2 PROBLEM STATEMENT .....	1
1.3 RESEARCH AIM AND OBJECTIVES .....	2
1.3.1 Research Aim.....	2
1.3.2 Research Objectives.....	2
1.4 METHODOLOGY .....	3
1.5 THESIS LAYOUT .....	3
<b>CHAPTER 2 BAD NEEDS FOR RECYCLING OF C&amp;D WASTES IN GAZA STRIP..</b>	<b>5</b>
2.1 BACKGROUND ABOUT GAZA STRIP.....	5
2.2 HOUSING CRISIS AT GAZA STRIP .....	6
2.2.1 Causes of Housing Problem.....	6
2.2.1 Construction Materials Availability in Gaza Strip.....	7
2.3.1 Background.....	7
2.3.2 Historical and Sitting Situation of C&D wastes at Gaza Strip .....	9
2.3.3 Environmental Impact of C&D wastes .....	11
2.4 C&D WASTES RECYCLING .....	12
2.4.1 Recycling of C&D over View.....	12
2.4.2 Production of Recycled Aggregate .....	13
2.4.3 Recycled Aggregate Industry in Gaza Strip.....	17
2.4.3.1Public sector:.....	17
2.4.4 Uses of RAC in Gaza Strip: .....	21
2.5 CONCLUSION: .....	21
<b>CHAPTER 3 LITERATURE REVIEW .....</b>	<b>23</b>
3.2 PROPERTIES OF RECYCLED AGGREGATE .....	23
3.2.1 Chemical Properties .....	24
3.2.3 Durability Properties .....	30
3.2.4 Appropriate Recycled Aggregate.....	31
3.2.5 Properties of Recycled Aggregate Concrete .....	32
3.2.6 Hardened R A Concrete Properties (Mechanical Properties) .....	36

3.2.7 Effect of Sea water on R A Concrete Properties.....	43
3.2.8 TREATMENT OF R A TO IMPROVE R A CONCRETE PROPERTIES .....	45
3.3 FIBER RECYCLED AGGREGATE CONCRETE (FRCA) .....	47
3.3.1 Fibers Overview .....	47
3.3.2 Fiber Types and Properties .....	47
3.4 CONCLUSION .....	55
<b>CHAPTER 4 MATERIALS AND EXPERIMENTAL PROGRAM.....</b>	<b>57</b>
4.1 INTRODUCTION .....	57
4.2 CHARACTERISTICS OF USED MATERIALS .....	57
4.2.1 Aggregate .....	57
4.2.2 Cement .....	59
4.2.5 Siloxane Polymer (SP) Silicon Based Polymer .....	60
4.2.6 Polypropylene (PP) Fiber.....	61
4.2.7 Reinforcing Steel .....	63
4.2.8 Admixtures.....	63
4.2.9 Storage of Materials .....	63
4.3 Treatment of RA with SP.....	63
4.4 PREPARATION OF SAMPLES .....	63
4.4.1 Concrete Mix Design and Batches.....	63
4.4.2 Test program .....	64
4.4.3 Concrete Mixing .....	66
4.4.4 Sampling .....	66
4.4.5 Curing .....	68
4.4.6 Testing of concrete.....	68
4.4.6 Reinforcement Steel Test.....	74
<b>CHAPTER 5 TEST RESULTS AND DISCUSSION.....</b>	<b>75</b>
5.1 INTRODUCTION .....	75
5.2 DISCUSSION OF MATERIALS TEST .....	75
5.2.1 Aggregate .....	75
5.2.2 Cement Test .....	81
5.2.3 Chemical constituents of Mediterranean seawater .....	81
5.3 DISCUSSION OF EXPERIMENTAL RESULTS.....	81
5.3.1 The Optimum PP fiber percent .....	82
5.3.2 Properties of concrete .....	84
<b>CHAPTER 6 COST EFFECTIVENESS OF USING RECYCLED AGGREGATE IN CONCRETE CONSTRUCTIONS .....</b>	<b>102</b>
6.1 INTRODUCTION .....	102
6.2 C&D RECYCLING ECONOMIC ASPECTS.....	102
6.2.1 Global Economic Concerns of Recycling of C&D.....	103
6.3 FEASIBILITY OF USING RA CONCRETE MIXED WITH PP FIBERS AND SP IN CONCRETE STRUCTURES .....	106

6.3.1 Cost of RA Produced For Concrete Constructions .....	106
6.3.2 Cost of RA with PP Fibers and SP.....	107
6.3.3 Cost of Dumping C&D Wastes in the Landfill.....	107
6.4 CONCLUSION .....	108
<b>CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS .....</b>	<b>109</b>
7.1 CONCLUSIONS.....	109
7.1.1 Conclusions Concerning the Chemical, Physical and Mechanical Properties of RA .....	109
7.1.2 Conclusions concerning effect of RA percentage on fresh and hardened properties of concrete.....	109
7.1.3 Conclusions concerning effect of PP Fibers on fresh and hardened properties of RA concrete .....	110
7.1.4. Conclusions concerning the effect of SP on fresh and hardened properties of RA concrete .....	111
7.2 GENERAL CONCLUSIONS .....	112
7.3 RECOMMENDATIONS FOR FUTURE .....	112
<b>REFERENCES.....</b>	<b>114</b>
<b>APPENDIX .....</b>	<b>129</b>
Appendix A .....	130
Appendix B .....	137
Appendix C .....	144
Appendix D .....	150

## List of Tables

table (2.1): Quantities Of C&D Wastes For The Countries In The Eu(D. Matias,2013) .....	8
Table ( 2.2):Percent Of Variant Building Materials, Concrete Occupies The Biggest Percent (W. Li. ,2002).....	9
Table (2.3): Number Of Destroyed Houses In Districts Of Gaza Strip Year 2000 To 2005(Unrwa Field Office, 2005).....	9
. Table (2.4): Distribution Of Concrete Rubble War 2008 In Gaza Strip (Undp,2008).....	10
Table(3.1):Recycled Aggregate Groups , Constituents And Description (B R E) Digest 433	32
Table(3.2): Maximum Recommended Levels Of Impurity By Weight .....	32
Table (3.3): Typical Properties Of Fibers Used For Reinforcing Cementitious Materials(Nemkumar Banthia Et Al.,2012).....	49
Table (4.1): Chemical Composition Of Ordinary Portland Cement (Mindess Et Al. (2002); Taylor (1997)). .....	60
Table (4.2): Index And Parameters Of PP Fibers (Sika Egypt.Com,2014 ) .....	62
Table(4.3):The Quantities Required For A Targeted Strength $F'_c = 25$ Mpa.....	63
Table(4.4):The Three Major Mixes N,NR And R.....	64
Table(4.5):The Other Five Batches Used In The Test Program .....	64
Table (4.6): Mixing Procedure According To Astm C 192. ....	66
Table ( 5.1) : The Chloride ,Calcium And Sulfate Content Of All The Granular Constituents Of Concrete (Environmental & Rural Research Centerat The Islamic University Gaza,2015). .....	76
Table ( 5.2 ) :Heavy Metals In Ra( Institute Of Water & Environment At Al-Azhar University-Gaza,2015).....	77
Table(5.3):Physical Properties Of Aggregates Used In The Test Program .....	77
Table (5.4):Mechanical Properties Of NA And RA.....	79
Table(5.5):Mechanical Properties Of Cement .....	81
Table(5.6):Mediterranean Seawater Chemical Analysis-( Institute Of Water & Environment At Al-Azhar University-Gaza,2015).....	81
Table(5.8):Comparison Between Actual And Calculated According Aci209r-92 7 Day Age Compressive Strength .....	88
Table(5.9):Comparison Between 300 Days Age Curing In Potable Water And Sea Water And The Percent Increase Or Loss .....	89

Table(5.10): Actual Es Of Concrete Specimens From Stress-Strain Curve And Calculated Upon Aci Correlation.....	91
Table(5.10): Peak Strain Correspond To Ultimate Compressive Strength .....	92
Table (5.11):Splitting Tensile Strength Correlation With Compressive Strength .....	97
Table(5.12):Correlation Of Flexural Strength With Corresponding Compressive Strength ...	98
Table 6.1: Comparison Of Cost Elements In The Processing And Handling Of Natural Aggregates And Recycled Aggregates [Dfl = Dutch Guilders], (Hansen, 1992) .....	104
Table 6.2: Cost Comparison Between Concretes Made With Na, Ra, Brick Rubble, And Mixed Concrete And Brick Rubble Aggregate In The Netherlands (1982), (Hansen, 1992).....	104
Table 6.3: Comparisons Of Economic Impacts Of RA Versus NA In Highway Construction,(Donalson Et Al,2011) . .....	105
Table 6.4: Cost Recovery Of Post-War Rubble Removal And Crushing In Gaza Strip El Kharouby,(2010).....	106

## List of Figures

figure (2.1): Gaza Strip Map .....	5
Figure( 2.2): Homeless Families In Gaza Strip After Subsequent Wars(Amnesty,2010) .....	6
Figure (2.3) : The Horrible Destroying Of Gaza Strip During War 2014.....	10
Figure (2.4): Number Of Damaged Level To Houses War 2014 (Undp, 2014) .....	11
Figure(2.5): Random And Uncontrolled Demolishing Waste Disposal In Gaza Strip .....	12
Figure (2.6): Load Into Primary Crusher .....	14
Figure (2.7): Electromagnetic Separation Process Figure (2.8): Picking Shed.....	15
Figure (2.8): Wet Separation Process.....	15
Figure (2.10): Screening Plant	16
Figure (2.11):Washing Plant.....	16
Figure (2.12): Construction Of The New High School In Sorumsand, Oslo, Norway .....	17
Figure (2.13): Rafah Municipality Stationary Recycling Plant .....	18
Figure (2.14): Unpp Mobile Recycling Plant.....	19
Figure (2. 15): Screening Plant Of Ministry Of National Economy .....	19
Figure( 2.16): Crushing The Massive Blocks Of Concrete Rubbles By Mpwh .....	20
Figure (2.17):Hollow Block Factory Using Crushing Machine For Recycling Aggregate In Gaza Strip.....	20
Figure (2.18):Stationary Recycling Plant.....	21
Figure (3.1): Schematic Diagram Of Old And New Itz In Rac.....	35
Figure (3.2): Photos Of Various Types Of Fibers Used In Cementitious Materials .....	48
Figure (3.4.A): (Gfrc) Pipeline Trench	51
Figure (3.4.B): (Gfrc) Sewer Lining.....	51
Figure (3.4.C): (Gfrc) Stanford Graduate School Of Business .....	51
Figure (3.4.D): Steel Fiber-Reinforced Concrete Segmental Tunnel Lining.....	51
Figure (3.4.E): (Gfrc) Permanent Formwork For Beams In Puerto Rico .....	52
Figure (3.4.F): Precast Fiber Sewer Pipes Concrete .....	52
Figure (4.1):Immersing Of Concrete Samples In Sea Water For 300 Days .....	60
Figure (4.2): 12mm Length Monofilament PP Fibers.....	62
Figure(4.3):Adding Pp Fiber To The Concrete Mix .....	66
Figure(4.4):The Mold Used For Reinforced Concrete Flexural Test.....	68
Figure (4.5):Slump Test Apparatus .....	69
Figure (4:6): Compressive Strength And Strain Test Machine.....	70
Figure(4.7):The Splitting Tensile Strength Machine .....	71

Figure(4.8):Diagram Of Loading And Arrangement Of Splitting Tensile Strength.....	71
Figure (4.9) : The Machine Used For Flexural Test .....	72
Figure (4.10) : The Location Of Supports And The Location Of The Concentrated Load In Flexural Strength(Mr) Test Machine .....	72
Figure (4.11): Flexural Beam Test Dimensions .....	73
Figure (4.12): Flexural Beam Test Machine .....	73
Figure (2.13):The Optical Set Used For Reading The Crack Width.....	74
Figure (4.14): Reinforcement Steel Test Machine .....	74
Figure(5.1):Sample Of RA Used In This Experimental Program.....	75
Figure(5.2) : Samples Of Treated RA With Sp Prepared For Water Absorption Test. ....	78
Figure (5.3):Sieve Grading Of Coarse Na.....	79
Figure (5.4): Sieve Grading Of Coarse Ra .....	80
Figure (5.5): Sieve Grading Of Natural Fine Aggregate.....	80
Figure(5.6):Slump Test Of R Concret Against Percent Of Pp Fiber By Volume.....	82
Figure(5.7): Compressive Strength Of R Concrete Against Percent Of Pp Fiber By Volume ....	83
Figure(5.8):Compressive Strength Of R Concrete Against Percent Of Pp Fiber By Volume .....	83
Figure (5.9):Slump Test Of Samples.....	85
Figure(5.10):Density Of Concrete Specimens .....	85
Figure (5.11): Compressive Strength Of Concrete Samples At 28 Day Curing In Potable Water.....	86
Figure(5.12):Machine Used For Compressive And Digital Strain Reading .....	87
Figure(5.13):The Compressive Strength For All Samples At Age 7&28 Days.....	88
Figure(5.15):Stress –Strain Diagram Of All Concrete Samples 28 Day Curing .....	91
Figure(5.16):Stress-Strain Diagram Of Samples Cured For 300 Days In Potable Water.....	93
Figure (5.17):Stress-Strain Diagram Of Samples Cured For 300 Days In Seawater.....	94
Figure(5.18):Failure Pattern Of R Concrete Specimens After Curing 300 Days In Seawater.....	95
Figure(5.19):Splitting Tensile Strength.....	96
Figure (5.20);Pattern Of Splitting Tensile Failure .....	97
Table(5.21): Flexural Strength Of Concrete Specimens .....	98
Figure(5.22):Load Deflection Curves Of Plain Concrete .....	99
Figure (5.23):Load Deflection Curve For Reinforced Concrete Beams .....	100
Figure (5.24):Load Crack Width Curve For Reinforced Concrete Beam.....	101

## Abstract

Concrete is considered a thermometer for measuring development in countries, the second most consumed material on Earth after water, in 2006 the world consumed about 21 to 31 billion tons per year of concrete. As any part of the world, Gaza Strip consumption was about 80 million cubic meter of concrete in the eRA 2002 to 2016, where concrete is the only available substance that can be offered and the cheapest building material compared to other materials, steel, wood and others. As a reason of consecutive wars against Gaza Strip, hundred thousands of house holders are homeless as their building has been destroyed during wars. Two main problems have to be solved as fast as, the housing needs and the environmental problems. The environmental problem is immense due to the mega quantities of construction and demolition (C&D) wastes related to scarcity of land required for dumping in Gaza Strip. The most hazardous environmental problem is with very high contamination of recycled aggregate with heavy metals. Gaza Strip is one of the most populated area all over the world where more than two million persons lives in an area not exceeding 365Km<sup>2</sup> with no any kind of natural resources can be used as building material except sand. In addition to the housing and C&D problems, siege and blockade of borders by Israelis exacerbated the problem, where the building materials are prohibited especially huge volumes like aggregates. Recycling of C&D waste to produce new aggregates may be a creative and practical for solving the problems of aggregates shortages, needed for new houses building, and need of landfilled for dumping. But the most serious problem that can be solved by recycling is the environmental pollution caused by random dumping without following the standards and health regulations. Recycled aggregate in the Gaza strip may differ than any other recycled aggregate, where it's parent was exposed to explosives with very high elevated temperatures and toxic materials during wars. The test program proved this differences of recycled aggregate produced in Gaza Strip, where the heavy metal contamination reached very high levels compared with the guide value in drinking water according to the World Health Organizations. For example, the content of heavy metals was 52.8, 386.3, 10.8, 338.6, 24372.2, 101.5, 18022.2, 10136.6, 20487.7, 14.6 and 10.6 ppm for Chromium (Cr), Strontium (Sr), Lithium (Li), Copper (Cu), Iron (Fe), Nickel (Ni), Lead (Pb), Zinc (Zn), Aluminum (AL), Cadmium (Cd) and Cobalt (Co) respectively. According to many researchers the optimum solution to avoid leaching of heavy metals is cementitious materials to cover the surface are of recycled aggregate.

The experimental program of this thesis was conducted to find out the effect of polymers (Polypropylene (PP) fibers as fulfillments, with 12 mm in length and 18 micro in diameter mixed with coarse recycled aggregate (RA) and silicon based polymer called Siloxane polymer (SP) for surface treatment RA) and sea water on the performance of recycled aggregate concrete. Coarse recycled aggregate (RA) was used, where the fine aggregate were excluded due to its negative influence in concrete mixes according to many researchers' investigations. The fine aggregates used in this program were a mix of sand (available in abundance in the Strip) and fine natural aggregate.

Eight types of concrete mixes were made to achieve the objectives of this study: (1) N- 0.0% RA (100% coarse natural aggregate (NA)); (2) NR-50.0% RA; (3) R-100.0 % RA; (4) NRF - 50.0% R mixed with PP fiber; (5) RF-100.0% RA mixed with PP Fibers; (6) NRS-50.0% of treated RA with SP; (7) RS-100.0% of treated RA with SP and (8) RSF-100.0% of treated RA with SP mixed with PP Fibers. Same number of molds were casted from every type of mixes to be tested for finding out the compressive strength, splitting tensile strength, flexural tensile strengths, deflections of plain concrete beams and deflections and crack width of steel

reinforced concrete beams(RC) beams. The casted concrete was cured in potable water for 28 days. Number of cylindrical samples casted for compressive strength test from all types other than 28 day curing, were immersed in in potable water for 7 days and for 300 days in potable and sea water.

The results showed higher chemical contents (chloride and sulphate ) ,low density , high water absorption of RA and high loss of weight according to abrasion and soundness tests of RA compared with NA. In spite of low quality of RA with respect NA ,standards and researcher declared, the chemical content and mass loss of RA are within the accepted range. Water absorption test showed ,treatment RA with SP reduced the water absorption capacity of RA by more than 80.0% where it was 4.6 and 0.8% before and after treatment respectively. The optimum percent of PP Fibers mixed with R samples that achieved maximum compressive and splitting tensile strengths was 0.17% per volume .

The compressive strengths of early age, 7 days curing in potable water were about 0.71 ,0.7 ,0.61, 0.75,.71,0.58,0.52and 0.6 as a fraction of its 28 day compressive strength for N, NR, R, NRF ,RF, NRS ,RS and RSF respectively .The 7 day result showed, as the percent of RA increases the earlier gained strength is smaller compared with 7day N samples. On the other hand PP fiber concrete gained earlier compressive strength faster than any samples . In contrast to PP fiber concrete, the SP treated aggregate concrete was late in gaining strength where it was in average 0.55 of its 28 day compressive strength. The ACI 209R-92 equation for predicting the compressive strength according to time isn't applicable for concretes other than natural concrete(N samples) according to the results in this program.

28 day concrete densities were 2395,2310,2250,2285,2196,2356,2289 and 2246 Kg /m<sup>3</sup> for N, NR, R, NRF ,RF, NRS ,RS and RSF respectively. Increasing the percent of RA leads to less dense concrete where the density decreased by 6.0% compared with N density .The PP fiber has decreased the density compared with its origin weather NR or R where it was 2250 and 2196 Kg /m<sup>3</sup> for R and RF respectively but samples of SP treated aggregate achieved dense concrete where ,the density of RS increased by about 2.0% compared with R(RA concrete without SP treatment).

28 day compressive strength showed some contradictions ,where dense SP concrete compared with PP fiber concrete achieved a compressive strength 21.65 Mpa for RS while RF gained 26.56 Mpa. The compressive strength of NRF and RF specimens was 29.62 and 26.56 with an increment of about 7.0% in relation to NR and R respectively. RSF samples showed unnoticeable increase with respect to RS .50.0% RA concrete has a satisfactory compressive strength compared to 100% RA.

The compressive strength of concret after 300 days immersing in seawater showed the advantage of treating RA with SP where the highest percentage of increment 7.5% was achieved by NRS and RS when compared with 28 day curing for the same samples, while PP fiber concrete lost about 4.5% of its compressive strength in relation to its 28 day compressive strength. There was no loss of compressive strength with RA concrete after immersing 300 days in seawater. In general there is considerable increase of compressive strength for all specimens after curing 300 days in potable water. As the percent of RA increases the percent of achievement of compressive strength decreases, where it was 15.7 and 7% for NR and R samples. The PP fiber concrete has the lowest increase percent among the all the types ,since it was about 6.5%.The SP concrete has a considerable increase which was about 13%.

The stress-strain curves conducted for all the specimens at 28 day curing in potable water and300days curing in potable and sea water showed:(1) the strain of RA concrete increases with the increase of RA percent where it was .0021 and .0025 for NR and R samples while it was .0019 for N;(2) using PP Fibers enhanced the rigidity where it was 0.00185 and 0.0020 for NRF and RF (3) and the strain of treated samples with SP was about .0028 and for RSF samples was .0025. The investigated toughness ,showed the toughness for NRF and RF