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

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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%.

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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

List of Tables

List of Figures

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 to2016, 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 cosequetive 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 365Km2 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), Nikel (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 /m3 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 /m3 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