



Ain Shams University
Faculty of Engineering
Structural Engineering Department

Utilization of Limestone Quarries Powder In Production of Self-Compacting Concrete

A Thesis

Submitted in Partial Fulfillment for Requirements of the Degree of
Master of Science in Structural Engineering

By

Eng. Ahmed Mohammed Hesham Ibrahim Azzam

B.SC. Civil Engineering
Ain Shams University, 2011

Supervisors

Dr. Ahmad Fathy Abd El Aziz

Associate Professor
Structural Engineering Department
Faculty of Engineering, Ain Shams University

Dr. Ahmed Rashad Mohammed

Assistant Professor
Structural Engineering Department
Faculty of Engineering, Ain Shams University

Cairo
2016



AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

APPROVAL SHEET

Researcher Name : Ahmed Mohammed Hesham Ibrahim Azzam
Thesis Title : Utilization of Limestone Quarries Powder In
Production of Self-Compacting Concrete
Thesis : Master of Science in Civil Engineering (Structural)

Examiners Committee:

Signature

Prof. Dr. Tarek Aly El Sayed

.....

Professor of Properties and Strength of Materials
Faculty of Engineering of Mataria - Helwan University

Prof. Dr. El -Sayed Abdel-Raouf Nasr

.....

Professor of Properties and Testing of Materials
Faculty of Engineering - Ain Shams University

Dr. Ahmad Fathy Abd El Aziz

.....

Associate Professor- Structural Engineering Department
Faculty of Engineering - Ain Shams University
(Supervisor)



**AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING**

Researcher Name : Ahmed Mohammed Hesham Ibrahim Azzam
Thesis Title : Utilization of Limestone Quarries Powder In
Production of Self-Compacting Concrete
Thesis : Master of Science in Civil Engineering (Structural)

Supervision Committee:

Signature

Dr. Ahmad Fathy Abd El Aziz

Associate Professor
Structural Engineering Department
Faculty of Engineering
Ain Shams University

.....

Dr. Ahmed Rashad Mohammed

Assistant Professor
Structural Engineering Department
Faculty of Engineering
Ain Shams University

.....

INFORMATION ABOUT THE RESEARCHER

Name : Ahmed Mohammed Hesham Ibrahim Azzam

Date of birth : 28 January 1989

Place of birth : Cairo, Egypt

Last academic degree : Bachelor of Science

Field of
specialization : Structural Engineering

University issued the
degree : Ain Shams

Date of issued degree : August 2011

Current job : Teaching Assistant

STATEMENT

This thesis is submitted to Ain Shams University, Cairo, Egypt, in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering (Structural).

The work included in this thesis was carried out by the author at Properties and Testing of Materials laboratory of the faculty of engineering, Ain Shams University.

No part of this thesis has been submitted for a degree or qualification at any other university or institute.

Date:

Name: Ahmed Mohammed Hesham Ibrahim

Signature:

ACKNOWLEDGMENT

First and foremost, praise and thanks to Almighty Allah, the Most Gracious, the Most Merciful, and peace be upon His Prophet.

I would like to express my deepest gratitude and appreciation to my supervisor, **Dr. Ahmed Fathy Abdel Aziz**, for his valuable guidance and support.

I also greatly appreciate the great help, guidance and support provided by **Dr. Ahmed Rashad Mohammed** throughout all stages of the research, beside his continuous encouragement and valuable advices he gave to me.

The experimental work was carried out at the properties and testing of materials laboratory of structural department at Ain Shams university. The help of the laboratory staff in developing work is greatly appreciated especially Mr. Nabil, Mr. Yehia, Mr. Samir, Mr.Sayed, Mr. Emad, chemist Ashraf and all the labours (Mahmoud, Atef, Hany, Sherif, Islam and M. Asem)

Finally, I would like to express my appreciation to my father, my beloved mother, my great wife, my little son Hesham, my two brothers Seif and Nour and the whole family for lots of support and encouragement.

ABSTRACT

Since the introduction of Self Consolidated Concrete **SCC** in Japan during the late 1980's, acceptance and usage of this concrete in the construction industry has been steadily gaining momentum. In United States, the use of SCC has been spearheaded by the precast concrete industry. SCC must possess the following key fresh properties: filling ability, passing ability, while being cohesive, i.e. capable to resist segregation. In order to increase segregation resistance, SCC mixes are typically designed with high powder content, and/or contain chemical admixtures such as super plasticizers and viscosity modifying admixtures, which in turn, tend to significantly increase the overall cost of SCC.

In limestone quarries, considerable amounts of limestone powder **LP** are being produced as byproducts from stone crushers. High amounts of powder are being collected; utilization of this byproduct is of big benefit from disposal and environmental pollution aspects. Incorporation of limestone quarry powder in SCC as a filler can reduce the common cost of SCC, beside the improvement of concrete sustainability.

The main objective of this research was to study the effectiveness of using locally available limestone quarries powder, in the production of enhanced SCC mixtures. The influence of carefully chosen powder types resulting from diverse local sources was investigated. An experimental/comparative study of both its fresh and mechanical properties was conducted to decide the best powder source. Then, a profound investigation for the effect of powder content was followed in deep to decide the best performance of the produced SCC, with regard to each of its accomplished properties respectively; fresh, mechanical, and durability. Finally, an examination for the improvement from incorporating a specific content of silica fume with lime powder was followed.

The experimental program was divided into two phases, namely:

Phase one; which designed to evaluate the three different sources of investigated LP, through chemical and physical experimental tests. In addition, the fresh and mechanical properties of three SCC mixes from these powders were conducted.

Phase two; was designed to assess the influence of a variable contents of the best powder source determined from phase one on the fresh, mechanical and durability properties of the developed SCC mixes. A final SCC mix was performed to study the improvement of incorporating the best LP content with silica fumes on the fresh and hardened properties of the concrete.

Experimental test results revealed that Al-Menia quarry powder is the best among other sources, and that 30 to 40% LP replacement of fine aggregate produced a significant improvement for the mechanical and durability properties. Beside LP, employing silica fume was found to have a little improvement on the mechanical and durability properties of concrete.

Keywords: Self-Compacting Concrete, Limestone Powder, Silica Fumes, Fresh Properties, Hardened Properties, Durability.

Table of Contents

	<i>Page</i>
<i>ACKNOWLEDGEMENT.....</i>	<i>i</i>
<i>ABSTRACT.....</i>	<i>ii</i>
<i>TABLE OF CONTENTS.....</i>	<i>iv</i>
<i>LIST OF FIGURES.....</i>	<i>xii</i>
<i>LIST OF TABLES.....</i>	<i>xvi</i>

CHAPTER (1)

1. INTRODUCTION

<i>1.1. Background.....</i>	<i>1</i>
<i>1.2. Definition of the problem</i>	<i>3</i>
<i>1.3. Objectives of The Research Work:</i>	<i>4</i>
<i>1.4. Thesis Organization</i>	<i>5</i>

CHAPTER (2)

2. LITERATURE REVIEW

<i>2.1. Introduction</i>	<i>7</i>
<i>2.2. Development History of SCC</i>	<i>9</i>
<i>2.3. Advantages and Disadvantages of SCC.....</i>	<i>11</i>
<i>2.4. Applications of SCC</i>	<i>12</i>
<i>2.4.1. Using SCC in Burj Dubai.....</i>	<i>13</i>
<i>2.4.2. SCC in Arlanda Airport Control Tower in Sweden</i>	<i>15</i>
<i>2.4.3. National Museum of 21st Century Arts in Rome</i>	<i>16</i>
<i>2.5. Fresh Properties of SCC</i>	<i>17</i>
<i>2.5.1. Rheology.....</i>	<i>18</i>

Table of Contents

2.5.2. Yield stress.....	20
2.5.3. Workability.....	20
2.5.3.1. Filling ability.....	20
2.5.3.2. Passing Ability	23
2.5.3.3. Resistance to segregation	25
2.5.4. Testing of Fresh Properties of SCC	26
2.5.4.1. Slump Flow and T_{50} Test.....	27
2.5.4.2. J-Ring Test	29
2.5.4.3. V-Funnel Test T_0 and T_5 minutes.....	31
2.5.4.4. L-Box Test	33
2.5.4.5. GTM Screen Stability Test	35
2.5.5. Mortar testing.....	37
2.5.6. Parameters Influencing Fresh Characteristics of SCC	38
2.6. Hardened Properties of SCC.....	40
2.6.1. Mechanical Properties	41
2.6.1.1. Compressive Strength	41
a. Introduction.....	41
b. Strength Ratio	42
i. Cement Strength Class.....	43
ii. Addition Type.....	43
iii. Air Content	45
iv. Strength Model.....	45

Table of Contents

<i>2.6.1.2. Tensile Strength</i>	<i>48</i>
<i>2.6.1.2.1. Indirect Tensile Strength</i>	<i>48</i>
<i>2.6.1.2.2. Flexural Tensile Strength</i>	<i>50</i>
<i>2.6.1.3. Modulus of Elasticity</i>	<i>51</i>
<i>2.6.1.4. Bond Strength to Reinforcement</i>	<i>52</i>
<i>2.6.2. SCC Shrinkage</i>	<i>52</i>
<i>2.6.2.1. Autogenous Shrinkage</i>	<i>52</i>
<i>2.6.2.2. Drying Shrinkage</i>	<i>53</i>
<i>2.6.2.3. Plastic Shrinkage</i>	<i>54</i>
<i>2.6.3. Long-Term Durability</i>	<i>54</i>
<i>2.6.3.1. Paste Microstructure</i>	<i>54</i>
<i>2.6.3.2. Resistance to freezing and thawing and deicer salt scaling</i>	<i>55</i>
<i>2.6.3.3. Resistance to Carbonation</i>	<i>56</i>
<i>2.7. Mix Proportioning for SCC</i>	<i>56</i>
<i>2.7.1. Mixture Proportion Methodology</i>	<i>57</i>
<i>2.7.1.1. Powder Type SCC</i>	<i>57</i>
<i>2.7.1.2. Viscosity Agent Type SCC</i>	<i>58</i>
<i>2.7.1.3. SCC Combination Type</i>	<i>59</i>
<i>2.7.2. Performance Requirements of SCC</i>	<i>60</i>
<i>2.7.3. Constituent Materials Requirements</i>	<i>61</i>
<i>2.7.4. Mixture Proportioning Procedure</i>	<i>61</i>
<i>2.7.4.1. Provisions of ACI for SCC Proportioning</i>	<i>62</i>

Table of Contents

<i>A. Establishing coarse aggregate content</i>	<i>63</i>
<i>i. Coarse aggregate content for Category (I).....</i>	<i>64</i>
<i>ii. Coarse aggregate content for Category (II).....</i>	<i>64</i>
<i>B. Powder and water content.....</i>	<i>65</i>
<i>C. Paste and mortar volume</i>	<i>65</i>
<i>2.7.4.2. European Guidelines of SCC (EFNARC)</i>	<i>66</i>
<i>A. Initial mix composition.....</i>	<i>66</i>
<i>B. Adjustment of the mix</i>	<i>67</i>
<i>2.7.4.3. Japan Society of Civil Engineers method</i>	<i>68</i>
<i>2.8. Sustainability of Concrete</i>	<i>68</i>
<i>2.8.1. Harmful Emissions from Cement Industry.....</i>	<i>69</i>
<i>2.8.2. Limestone Powder Disposal.....</i>	<i>70</i>
<i>2.8.3. Different Uses of Limestone (Ground calcium carbonate)..</i>	<i>71</i>
<i>A. Coarse/Medium ground.....</i>	<i>71</i>
<i>B. Fine/ultrafine ground</i>	<i>72</i>
<i>C. Crushed stone (Aggregates).....</i>	<i>72</i>
<i>2.8.4. Limestone Powder in Cement and Concrete.....</i>	<i>72</i>
<i>2.8.4.1. Limestone powder as a cement filler</i>	<i>73</i>
<i>2.8.4.2. Limestone Powder as a Filler in Concrete</i>	<i>74</i>
<i>2.8.5. Environment friendly SCC using limestone powder</i>	<i>75</i>
<i>2.9. Research Related to the Use of By-products in SCC</i>	<i>76</i>
<i>2.10. Need for this research</i>	<i>78</i>

CHAPTER (3)

3. EXPERIMENTAL WORK

3.1. Introduction	80
3.2. Objective of Research Plan	80
3.3. Experimental Program	81
3.4. Mix Proportions	84
3.5. Specimen Preparation	85
3.5.1. Mixing.....	85
3.5.2. Casting.....	86
3.5.3. Curing.....	86
3.6. Testing Procedure	88
3.6.1. Fresh Concrete Tests.....	88
3.6.1.1. Slump Flow and T50 Test	88
3.6.1.2. J-Ring Test	89
3.6.1.3. L-Box Test	90
3.6.1.4. V-Funnel Test.....	92
3.6.1.5. GTM Screen Stability Test	93
3.6.2. Hardened Concrete	95
3.6.2.1. Compressive Strength Test.....	95
3.6.2.2. Tensile Splitting Strength Test	95
3.6.2.3. Flexural Strength Test.....	96
3.6.2.4. Bond Strength Test (Pull out Test).....	97

Table of Contents

<i>3.6.2.5. Modulus of Elasticity</i>	<i>99</i>
<i>3.6.2.6. Drying Shrinkage</i>	<i>101</i>
<i>3.6.3. Durability Tests</i>	<i>102</i>
<i>3.6.3.1. Water Penetration Depth Test</i>	<i>102</i>
<i>3.6.3.2. Rapid Chloride Penetration Test</i>	<i>104</i>
<i>3.6.3.3. Sorptivity Test</i>	<i>109</i>
<i>3.6.3.4. Sulphuric Acid Attack Test.....</i>	<i>110</i>
<i>3.6.3.5. Abrasion Resistance Test</i>	<i>111</i>

CHAPTER (4)

4. MATERIAL CHARACTERIZATION

<i>4.1. Introduction</i>	<i>113</i>
<i>4.2. Characteristics of the Used Materials</i>	<i>113</i>
<i>4.2.1. Cement.....</i>	<i>113</i>
<i>4.2.2. Fine Aggregate.....</i>	<i>114</i>
<i>4.2.3. Coarse Aggregate.....</i>	<i>115</i>
<i>4.2.4. Limestone Powder.....</i>	<i>117</i>
<i>4.2.5. Superplasticizer.....</i>	<i>120</i>
<i>4.2.6. Water</i>	<i>121</i>

CHAPTER (5)

5. RESULTS & DISCUSSIONS

5.1. Introduction.....	122
5.2. Phase (I)	123
5.2.1. Fresh Properties Test Results	123
5.2.1.1. Slump Flow Test.....	123
5.2.1.2. J-Ring Test	124
5.2.1.3. L-Box Test	125
5.2.1.4. GTM Screen Stability Test	127
5.2.1.5. V-Funnel Test.....	129
5.2.2. Hardened Properties.....	131
5.2.2.1. Compressive strength.....	132
5.2.2.2. Splitting Tensile Strength.....	133
5.2.2.3. Modulus of Elasticity Test.....	134
5.3. Stage (2).....	136
5.3.1. Fresh Properties Test Results	136
5.3.1.1. Slump Flow and T50 Test	136
5.3.1.2. J-Ring Test	138
5.3.1.3. L-Box Test	139
5.3.1.4. GTM Screen Stability Test	140
5.3.1.5. V-Funnel Test.....	141
5.3.2. Hardened Properties.....	143