

Handwritten Arabic text in a rectangular box, possibly a library or archival stamp.

AN INVESTIGATION OF THE POTENTIALITY OF GREEK
PORTLAND POZZOLANA CEMENT FOR CONSTRUCTION PURPOSES IN EGYPT

HBRC

Principal Investigator

Prof. Ezzat H. Morsy

Head of SMR & QC Division

Team Leader

Prof. M. Moustafa El-Said

Chairman of GOHBPR

المركز القومي لبحوث الإسكان والبناء
Housing & Building National Research Center
Since 1974

D.
29 B 27

Cairo - Egypt

November, 1979

Applicant for Research :
Association of the Greek Cement Industry,
10 Karitsi Square, Athens - 124, Greece

Handwritten signature or initials in the bottom right corner.

C 77 C 9

4

F O R W A R D

The construction plan in Egypt has been, recently, too ambitious that the total amount of cement produced locally is not sufficient to fulfil the needs. Consequently the importation of cement has become necessary. Portland Pozzolana Cement is among the brands which may be imported. Although this type of cement has been produced and used in different countries, it has not yet been accepted in the building industry in Egypt. Reluctance to its use may be attributed to the fact that it is not locally produced, and when Egypt started to import cement, no attempt was done to provide builders with necessary information about its properties and field of application.

The present study is carried out with a view to provide builders with necessary information about the properties and potentials of Portland Pozzolana Cement for successful utilization in mortars, concrete making and different applications.

HBRC



4/7/1997

المركز القومي لبحوث الإسكان والبناء
Housing & Building National Research Center

C 77 C 9

↓ Since 1954

D.

2 10 12

S Y N O P S I S

The study was carried out under the fulfillment of the protocol of a contract between the Greek Cement Industry Association and the General Organization for Housing, Building and Planning Research, Cairo. The contract was agreed upon on February 8th, 1979.

The scope of the study covers the technological aspects of using Portland Pozzolanic Cement. The phases of the study are separate researches for determining the status of Portland Pozzolana Cement with respect to the requirements of the Egyptian standard specifications for Ordinary Portland Cement, investigating the properties of mortars, properties of concrete and the behaviour of some reinforced concrete elements.

It has been found that Portland Pozzolana Cement containing 10% of pozzolana can be used safely and satisfactorily for different concrete works in replacement to the Ordinary Portland Cement.

All conclusions are only applicable to concrete and mortar mixes made of the same Portland Pozzolana Cement investigated in the present study. Also the mixes have to be made of materials having similar properties and similar proportioning as the corresponding present constituents.

المركز القومي لبحوث الإسكان والبناء
Housing & Building National Research Center

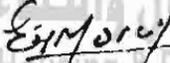
Since 1954

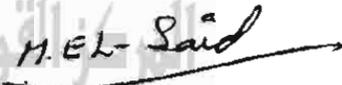
A C K N O W L E D G E M E N T S

The carryout of this programme and the preparation of the reports was a team effort on the part of the staff of both the Strength-of-Materials Research & Quality Control Division and the Central Laboratory, General Organization for Housing, Building and Planning Research, Cairo. The team leader and the principal investigator would like to express their appreciation of the efforts and contribution of the members of the staff to this study.

Acknowledgement is gratefully given to Prof. Moustafa El-Hifnawi, Minister of Housing who initiated the subject by directing the first letter, addressed to him from the Greek Cement Industry Association, to GOHBPR.

Acknowledgement is gratefully expressed for Eng. Hassab Allah El-Kafrawi, Minister of Development and New Communities for his encouragement towards solving problems by scientific research.


Ezzat H. Morsy


M. Moustafa El-Said

30.11.1979 30.11.1979

T A B
M E M B E R S O F T E A M

Team Leader

Prof. M. Moustafa El-Said, Dr. Eng. Chairman of GOHBPR

Principal Investigator

Prof. Ezzat H. Morsy, Dr. Eng., Head of SMR & QC Division,
GOHBPR

Working Group

Dr. Eng. A.S. Girgis

Dr. Eng. F.E. El-Refai

Dr. Chem. M.A. Shater

Eng., M.Sc. M.M. Kamal

Eng., M.Sc. H. Bahnasawy

Eng. A.M. Gendy

Eng. G. Hegab

Eng. H.Y. Abd El-Fattah

Chem. M. Taher

Eng. N. Nofal

Eng. S. Kotb

Chem. S. Tantawi



T A B L E O F C O N T E N T S

	<u>Page</u>
Front Page	i
Forward	ii
Synopsis	iii
Acknowledgements	iv
Members of Team	v
Table of Contents	vii
List of Tables	viii
List of Illustrations	xiv
Notation	xiv

Section ONE

Summary and Conclusions

1.1	Synopsis	1.2
1.2	Historical	1.3
1.3	Definitions	1.4
1.4	Portland Pozzolana cement in comparison with the standard requirements of Ordinary Portland Cement.	1.6
1.5	Mortar with Portland Pozzolana Cement	1.7
1.6	Concrete with Portland Pozzolana Cement	1.8
1.7	Reinforced Concrete with Portland Pozzolana Cement	1.10
1.8	Concluding remarks	1.11

Section TWO

An Experimental Investigation of Portland Pozzolana Cement in Comparison with the Standard Specifications for Ordinary Portland Cement

2.1	Synopsis	2.2
2.2	Materials	2.3
2.3	Main tests considered by specifications	2.3
2.4	Test series	2.3
2.5	Test results	2.4
2.6	Comments on test results	2.4

Section THREE

An Experimental Investigation of Mortar with Portland Pozzolana Cement

3.1	Synopsis	3.1
3.2	Materials	3.3
3.3	Test series	3.3
3.4	Presentation of test results	3.6
3.5	Discussion of test results	3.6

Section FOUR

An Experimental Investigation of Plain Concrete with Portland Pozzolana Cement

4.1	Synopsis	4.2
4.2	Materials	4.3
4.3	Test series	4.5
4.4	Presentation of test results	4.7
4.5	Discussion of test results	4.7

Section FIVE

Structural Behaviour of Reinforced Concrete Elements with Portland Pozzolana Cement

5.1	Synopsis	5.2
5.2	Materials, Mixes and Reinforced Elements	5.3
5.3	Casting and Curing of Elements	5.7
5.4	Testing of Elements	5.7
5.5	Control Specimens Test Results	5.8
5.6	Test Results and Comments of Column	5.9
5.7	Test Results and Comments of Beams	5.11

References

Appendices

المركز القومي لبحوث الإسكان والبناء
Housing & Building National Research Center

Since 1954

LIST OF TABLES

Section ONE: No tables

Section TWO

- Table 2.1.a Chemical analysis of clinker and pozzolana
Table 2.1.b Chemical analysis of Portland Pozzolana Cement
Table 2.2 Physical properties of Portland Pozzolana Cement
Table 2.3 Compressive strength of standard mortar made from Portland Pozzolana Cement
Table 2.4 Tensile strength of standard mortar made from Portland Pozzolana Cement

Section THREE

- Table 3.1 Properties of siliceous sand
Table 3.2 Investigated mixes

Section FOUR

- Table 4.1 Properties of aggregates
Table 4.2 Investigated mixes

Section FIVE

- Table 5.1 Properties of steel reinforcements
Table 5.2 Concrete mixes used in reinforced concrete columns and beams
Table 5.3 Reinforced concrete elements
Table 5.4 Performance Efficiency for PPC. in Comparison with OPC. in Reinforced Elements

HBRC
المركز القومي لبحوث الإسكان والبناء
Housing & Building National Research Center
Since 1954

Section ONE

- Figure 1.1 Properties guide for mortar mixes using Portland Pozzolana Cement and siliceous sand (1:3) based on curing by immersion in water
- Figure 1.2 Design chart for concrete mixes using Portland Pozzolana Cement and siliceous aggregates, based on curing by immersion in water
- Figure 1.3 Coefficients for prediction of 28-days compressive strength from strengths at earlier ages for concrete with PPC.
- Figure 1.4 Tensile strength as a percentage of the compressive strength of concrete with PPC.
- Figure 1.5 Bond strength with steel reinforcement as a percentage of compressive strength of concrete with PPC.

Section TWO No illustrations

Section THREE

- Figure 3.1 Sand grading
- Figure 3.2 Tests for strength properties
- Figure 3.3 Water-cement ratios for different degrees of flow
- Figure 3.4 Effect of workability on the compressive strength of mortar immersed in water
- Figure 3.5 Effect of workability on the compressive strength of mortar cured by sprinkling water in laboratory
- Figure 3.6 Effect of workability on the compressive strength of mortar cured by sprinkling water outdoors (sun and air)
- Figure 3.7 Effect of age on the compressive strength of mortar immersed in water
- Figure 3.8 Effect of age on the compressive strength of mortar cured by sprinkling water in laboratory

- Figure 3.9 Effect of age on the compressive strength of mortar cured by sprinkling water outdoors (sun and air)
- Figure 3.10 Compressive strengths at earlier ages as functions of 28-days strength
- Figure 3.11 Compressive strengths as functions of the strength of mortar cured in water
- Figure 3.12 Effect of workability on the tensile strength of mortar immersed in water
- Figure 3.13 Effect of workability on the tensile strength of mortar cured by sprinkling water in laboratory
- Figure 3.14 Effect of workability on the tensile strength of mortar cured by sprinkling water outdoors (sun and air)
- Figure 3.15 Effect of age on the tensile strength of mortar immersed in water
- Figure 3.16 Effect of age on the tensile strength of mortar cured by sprinkling water in laboratory
- Figure 3.17 Effect of age on the tensile strength of mortar cured by sprinkling water outdoors (sun and air)
- Figure 3.18 Tensile strengths as functions of the strength of mortar cured in water
- Figure 3.19 Effect of workability on the abrasion resistance of mortar immersed in water
- Figure 3.20 Effect of workability on the abrasion resistance of mortar cured by sprinkling water in laboratory
- Figure 3.21 Effect of workability on the abrasion resistance of mortar cured by sprinkling water outdoors (sun and air)
- Figure 3.22 Effect of age on the abrasion resistance of mortar immersed in water
- Figure 3.23 Effect of age on the abrasion resistance of mortar cured by sprinkling water in laboratory

- Figure 3.24 Effect of age on the abrasion resistance of mortar cured by sprinkling water outdoors (sun and air)
- Figure 3.25 Abrasion resistances as functions of the abrasion resistance of mortar cured in water
- Figure 3.26 Mortar tensile strength as a function of the compressive strength.

Section FOUR

- Figure 4.1 Testing of bond between Concrete and Reinforced Steel
- Figure 4.2 Effect of water-cement ratio on the consistency of fresh concrete
- Figure 4.3 Effect of consistency on the compressive strength of 200-kg/m³ - concrete cured in water
- Figure 4.4 Effect of consistency on the compressive strength of 300-kg/m³ - concrete cured in water
- Figure 4.5 Effect of consistency on the compressive strength of 350-kg/m³ - concrete cured in water
- Figure 4.6 Effect of age on the compressive strength of concrete of dry consistency
- Figure 4.7 Effect of age on the compressive strength of concrete of medium consistency
- Figure 4.8 Effect of age on the compressive strength of concrete of wet consistency
- Figure 4.9 Compressive strength at earlier ages as function of 28-days strength for dry concrete mixes
- Figure 4.10 Compressive strength at earlier ages as function of 28-days strength for medium concrete mixes
- Figure 4.11 Compressive strength at earlier ages as function of 28-days strength for wet concrete mixes
- Figure 4.12 Effect of cement content on the compressive strength of concrete of dry consistency

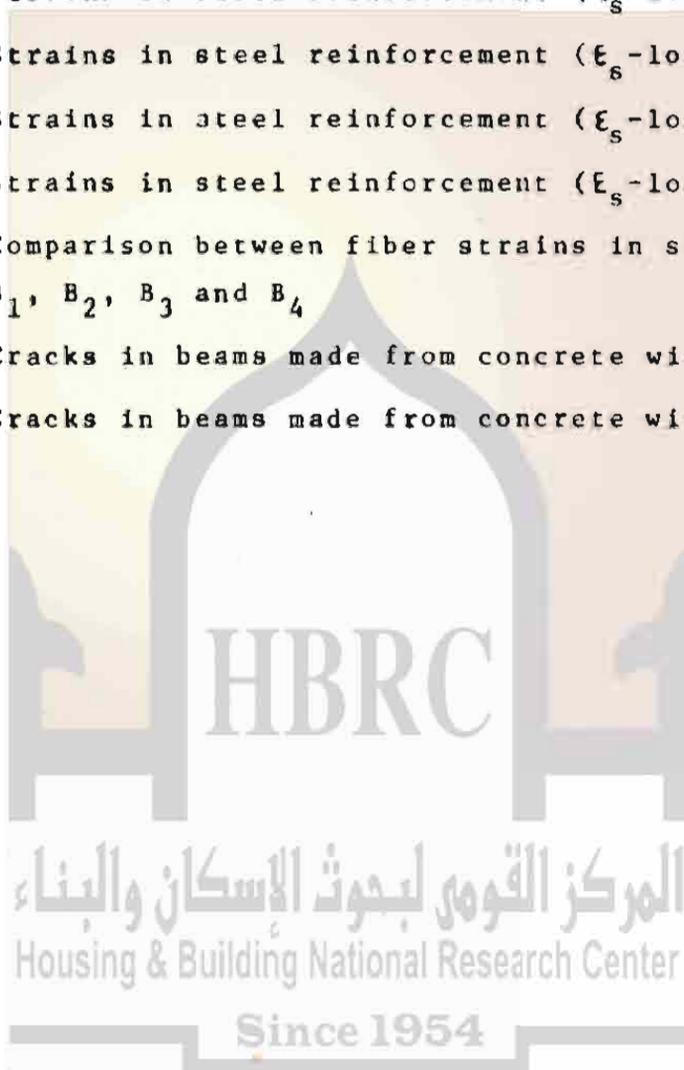
- Figure 4.13 Effect of cement content on the compressive strength of concrete of medium consistency
- Figure 4.14 Effect of cement content on the compressive strength of concrete of wet consistency
- Figure 4.15 Effect of curing conditions on compressive strength of concrete of 200 kg/m³ cement content and dry consistency
- Figure 4.16 Effect of curing conditions on compressive strength of concrete of 300 kg/m³ cement content and dry consistency
- Figure 4.17 Effect of curing conditions on compressive strength of concrete of 350 kg/m³ cement content and dry consistency
- Figure 4.18 Effect of curing conditions on compressive strength of concrete of 200 kg/m³ cement content and medium consistency
- Figure 4.19 Effect of curing conditions on compressive strength of concrete of 300 kg/m³ cement content and medium consistency
- Figure 4.20 Effect of curing conditions on compressive strength of concrete of 350 kg/m³ cement content and medium consistency
- Figure 4.21 Effect of curing conditions on compressive strength of concrete of 200 kg/m³ cement content and wet consistency
- Figure 4.22 Effect of curing conditions on compressive strength of concrete of 300 kg/m³ cement content and wet consistency
- Figure 4.23 Effect of curing conditions on compressive strength of concrete of 350 kg/m³ cement content and wet consistency
- Figure 4.24 Indirect tensile strength of concrete mix of dry consistency

- Figure 4.25 Indirect tensile strength of concrete mix of medium consistency
- Figure 4.26 Indirect tensile strength of concrete mix of wet consistency
- Figure 4.27 Relation between cube compressive strength and indirect tensile strength
- Figure 4.28 Bond strength of concrete with steel reinforcement for dry consistency mixes
- Figure 4.29 Bond strength of concrete with steel reinforcement for medium consistency mixes
- Figure 4.30 Bond strength of concrete with steel reinforcement for wet consistency mixes

Section FIVE

- Figure 5.1 Stress-strain curves for concrete in compression
- Figure 5.2 Steel reinforcements for columns
- Figure 5.3 Steel reinforcements for beams
- Figure 5.4 Arrangements of plugs on columns and beams
- Figure 5.5 Strains (in steel and concrete) in columns made from concrete with cement content 300 kg/m^3
- Figure 5.6 Strains (in steel and concrete) in columns made from concrete with cement content 350 kg/m^3
- Figure 5.7 Strain distribution over middle section and deflection line curve for Beam B_1
- Figure 5.8 Strain distribution over middle section and deflection line curve for Beam B_2
- Figure 5.9 Strain distribution over middle section and deflection line curve for Beam B_3
- Figure 5.10 Strain distribution over middle section and deflection line curve for Beam B_4
- Figure 5.11 Maximum deflection-load curves for beams B_1 and B_2

- Figure 5.12 Maximum deflection - load curves for beams B_3 and B_4
- Figure 5.13 Fiber strains in concrete (ϵ_c -load curve) for B_1
- Figure 5.14 Fiber strains in concrete (ϵ_c -load curve) for B_2
- Figure 5.15 Fiber strains in concrete (ϵ_c -load curve) for B_3
- Figure 5.16 Fiber strains in concrete (ϵ_c -load curve) for B_4
- Figure 5.17 Comparison between fiber strains in concrete for Beams B_1 , B_2 , B_3 and B_4 .
- Figure 5.18 Strains in steel reinforcement (ϵ_s -load curve) for B_1
- Figure 5.19 Strains in steel reinforcement (ϵ_s -load curve) for B_2
- Figure 5.20 Strains in steel reinforcement (ϵ_s -load curve) for B_3
- Figure 5.21 Strains in steel reinforcement (ϵ_s -load curve) for B_4
- Figure 5.22 Comparison between fiber strains in steel for Beams B_1 , B_2 , B_3 and B_4
- Figure 5.23 Cracks in beams made from concrete with 300 kg/m^3
- Figure 5.24 Cracks in beams made from concrete with 350 kg/m^3



N O T A T I O N

GOHBPR	General Organization for Housing, Building and Planning Research
AGCI	Association of the Greek Cement Industry
SMR & QCD	Strength-of-Materials Research & Quality Control Division
PPC	Portland Pozzolana Cement
OPC	Ordinary Portland Cement
f	Stress
ϵ	Strain
f_c	Concrete stress in compression
f_{cu}	Concrete ultimate strength in compression
f_{ccu}	Concrete ultimate cube strength in compression
f_{clu}	Concrete ultimate cylinder strength in compression
$f_{ccu3,7,14,28}$	Ultimate concrete cube strength at the ages of 3,7, 14 and 28 days respectively
f_t	Concrete stress in tension
f_{tu}	Concrete ultimate tensile strength
f_{tfu}	Concrete ultimate splitting tensile strength
f_{bu}	Concrete ultimate bond strength between concrete and steel reinforcement
E_c	Modulus of elasticity of concrete in compression
E_s	Modulus of elasticity of steel
P_u	Ultimate failure load in compression
M	Bending moment
M_r	Cracking bending moment

M_u

Ultimate bending moment

ϵ_c

Strain in concrete

ϵ_s

Strain in steel

