INFLUENCE OF CHEMICAL AND MINERAL ADMIXTURES ON SHRINKAGE AND CREEP OF PREPACKED AGGREGATE CONCRETE

HOSSEIN ASLANI

A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Engineering (Civil - Structure)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JUNE 2013

I would like to dedicate this project report
to my beloved family

ACKNOWLEDGEMENT

The author would wish to express his gratitude to Assoc. Prof. Dr. A.S.M. Abdul Awal as the supervisor for his great guidance and cooperation throughout this project. His technical and moral support during this project was admirable. Special thanks to the esteemed staff of the Laboratory of Structures and Materials of Universiti Teknologi Malaysia for their kind cooperation and technical assistance.

Finally, I wish to thank my beloved wife and two lovely daughters for their cooperation and understanding during the course of this project of which would have not been completed on time without them.

ABSTRACT

Prepacked aggregate concrete is a special kind of concrete which is produced by first placing the coarse aggregates inside the molds followed by injection of grout from underneath using pump or gravity method. The grout consists of sand, cement and water plus chemical and mineral admixtures. Two separate stages are included in this study: The first stage consists of manufacturing of grouts with superplastizer as chemical admixture and palm oil fuel ash as mineral admixture. Tests were conducted on grouts to examine bleeding, density, compressive strength, consistency, volume change properties. In the second stage, prepacked aggregate concrete samples were made following grouting by two methods: pump and gravity. Once the specimens were made, shrinkage and creep tests were performed following ASTM C512/C512 M-10. It has been found that the shrinkage and creep of prepacked aggregate concrete was lower than that of normal concrete in both gravity and pump specimens using chemical and mineral admixtures.

ABSTRAK

Agregat konkrit Prepacked adalah sejenis khas konkrit yang dihasilkan dengan terlebih dahulu meletakkan agregat kasar dalam acuan diikuti dengan suntikan grout dari bawah dengan menggunakan pam atau kaedah graviti. Grout ini terdiri daripada pasir, simen dan air serta bahan tambah kimia dan mineral . Dua peringkat yang berasingan termasuk dalam kajian ini : Peringkat pertama terdiri daripada pembuatan grouts dengan superplastizer sebagai campuran bahan kimia dan abu bahan bakar minyak sawit sebagai bahan tambah mineral. Ujian dijalankan ke atas grouts untuk memeriksa pendarahan, ketumpatan, kekuatan mampatan, konsisten , harta perubahan kelantangan. Dalam peringkat kedua, prepacked sampel agregat konkrit telah dibuat berikutan grouting dengan dua kaedah : pam dan graviti. Setelah spesimen yang telah dibuat, pengecutan dan rayapan ujian telah dijalankan berikutan ASTM C512/C512 M- 10. Ia telah mendapati bahawa pengecutan dan rayapan konkrit agregat prepacked lebih rendah berbanding konkrit biasa dalam kedua-dua graviti dan spesimen pam menggunakan bahan tambah kimia dan mineral.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

$S_{(t)}$	Shrinkage after drying time t
S_{00}	final shrinkage according to the cement percentage of the concrete
s	rate of shrinkage which depends on the RH (Relative Humidity) of the lab
ρ	cement paste percentage of the grout
V_1	sample volume at the beginning of the test, mL
V_2	sample volume at intervals taken from the upper surface of the bled water, mL
Vg	grout volume at intervals from the upper surface of the grout, mL
$Sh(t,t_0)$	Shrinkage value
$\varepsilon(t)$	Shrinkage at time t
$\varepsilon(t_0)$	shrinkage at time t0
M	Coefficient of DEMEC gauge
$C(t,t_0)$	Creep value
$\varepsilon_c(t)$	Creep at time t
$\varepsilon_c(t_0)$	creep at time t_0
$C_T(t, t_0)$	Total creep
$\varepsilon_{sh}(t)$	Shrinkage at time t
C_s	Specific creep
σ	Applied stress (MPa)

CHAPTER 1

INTRODUCTION

1.1 Background to the research

Pre-packed aggregate concrete (PAC) is a concrete which is prepared by injecting grout from underneath of a set of clean-placed coarse aggregates inside the formwork. The coarse aggregates are placed densely inside the formwork. PAC is used where common methods of placing concrete is not feasible such as huge reinforcing concrete structural members, underwater concreting, concrete and masonry repair and finally where creep and shrinkage of the member is crucial to be minimum in the design. Moreover, this method is applicable in underwater structures, mass concreting where a smaller amount of heat of hydration and cement content is required. Another application of PAC is in tunnel and sluiceway plugs where high pressure water is present and therefore, low shrinkage is in our interest (King, 1959). PAC is also used in atomic radiation shielding that employs high density concrete, heavy metallic ores and steel as coarse aggregates (Taylor, 1965).

Creep and shrinkage are time dependent phenomena which occur in concrete structural members. Viscoelastic materials undergo a time dependent deformation in excess of initial elastic strain as a result of sustained applied stresses. On the contrary, shrinkage is the deformation of a structural member over time in absence of applied stresses. Hence, the total strain of a concrete specimen is determined through the summation of initial elastic strain, creep strain and shrinkage strain.

In order to reduce the shrinkage and creep of concrete, several solutions are offered by scientists. One method is to increase the aggregate/cement ratio (a/c). Another way is to reduce the water-cement (w/c) ratio by means of superplasticizer (SP). Hence, the water and cement content of the specimen will decrease. As it turns out, the reduced volume of cement is responsible for shrinkage and creep of concrete specimens. This reduction in cement content of the grout will be made up by means of higher proportion of aggregates to lower the speed of shrinkage and creep of concrete (Borsoi,2009).

The recent interest in incorporating mineral admixtures has persuaded officials to study the effect and structure of mineral admixtures on concrete. There are two major reasons for such an act: first, better economy results from the use of mineral admixtures since they are abundant in nature. Second, these admixtures are not environmentally friendly and their disposal will pose environmental pollutions. When they are used in concrete technology, the cement consumption will decrease and hence, the carbon dioxide of the atmosphere will decrease as well (Ferraris,2001).

The consumption of pozzolanic materials has long been in use. Pozzolans are either natural or artificial. One such artificial pozzolan is fly ash. Fly ash is a widely recognized pozzolanic material which has become so popular around the world. Incorporating fly ash in concrete will produce highly workable concretes. In addition to fly ash, there are other pozolanic materials which belong to this family. One such pozzolanic material is palm oil fuel ash (POFA), which is obtained from burning palm oil husk and palm kernel shell as fuel in palm oil mill boilers. POFA has a great extent of silica in its micro structure which makes it a great pozzolanic material (Awal and Hussin, 2009).

According to ASTM C618- 94a (1994), POFA may be classified between class C and class F.

1.2 Problem Statement

A higher amount of coarse aggregates will lead to lower shrinkage and creep of PAC. Since the aggregates are in close contact, they directly bear the load and affect the shrinkage and creep of the concrete which is lower than normal concrete. PAC has long been in use for dam projects, piers, retrofitting structures, underwater concreting and so on. However, over this long period, lots of issues have been addressed as problems regarding the creep and shrinkage of PAC. Questions like: how to increase the fluidity of the grout without having extreme shrinkage and creep? What sort of grading can be used to improve the creep and shrinkage behavior of PAC? What sort of admixtures can be used to improve creep and shrinkage properties of PAC? What proportion of water-cement and cement-sand can be used to improve the fluidity of the grout?

1.3 Objectives of Study

The objectives of this research are listed as below:

1. To manufacture grouts with high fluidity and proper water-cement and cement-sand ratios incorporating suitable amounts of mineral and chemical admixtures.

2. To conduct tests on the grouts in terms of bleeding, density, compressive strength, consistency and volume change properties.

3. To make PAC cylinders and test their creep and shrinkage according to the relevant standards and compare them with control cylinders.

1.4 Scope of Study

The scope of this research can be summarized as follows:

1. Manufacture of several suitable grouts using chemical and mineral admixtures to promote their workability and consequently, the strength of PAC. Also, time of efflux of the cement grout is derived through the use of a standardized flow cone which is used for PAC in accordance with ASTM C939-10.

2. Making PAC and normal concrete specimens according to the following mix proportion:

   PAC: coarse aggregate 1321 kg, fine aggregate 548 kg, cement 378 kg, water 197 kg.

   Normal concrete: coarse aggregate 1095 kg, fine aggregate 774 kg, cement 378 kg, water 197 kg.

3. Replacement of cement by trial amounts of POFA and super plasticizers.

4. Keeping the cylinders intact for 20 to 48 hours before demolding. Then, the specimens will be cured in a moist condition for 7 days.

5. The creep and shrinkage tests will be performed following the specifications of ASTM C512/C512M-10 and ACI Committee 209.

1.5 Significance of Study

One of the benefits of using PAC is the reduced costs to almost 25% - 40% comparing to normal concrete. This lower cost results from the reduction of cement by 30% compared to normal concrete. However, this reduced amount of cement does not impose any changes on mechanical properties of PAC. What's more, improved flow characteristics and better economy result from the use of mineral admixtures in PAC. Also, drying shrinkage is reduced by the use of chemical admixtures. For example, reduced number of cracks and reduced-width cracks in retrofitting structural members is a function of applying chemical admixtures.

Creep and shrinkage are two properties of concrete which need great care. These two properties are time-dependent and based on the amount of coarse aggregates and amount of water in cement paste. In PAC, since the amount of coarse aggregates is more than conventional concrete, creep and shrinkage will be decreased significantly. Also, by applying chemical admixtures like superplasticizer, the water content will decrease and therefore, creep and shrinkage will decrease as well. Hence, incorporation of PAC will help solve the problem of creep and shrinkage to a great extent.

REFERENCE

Abdelgader, H. S. (1996). Effect of the quantity of sand on the compressive strength of two-stage concrete. *Magazine of concrete research. 48 (177): 353-360.*

Abdelgader, H. S. (1999). How to design concrete produced by a two-stage concreting method. *Cement and concrete research. 29 (3): 331-337.*

Abdelgader, H. S. and Elgalhud, A. A. (2008). Effect of grout proportions on strength of two-stage concrete. *Structural Concrete. 9 (3): 163-170.*

Abdelgader, H. S. and Najjar, M. F. (2009). Advances in Concrreting Methods.

Awal, A.S.M.A. (1984). *Manufacture and Properties of Pre packed Aggregate Concrete. Master of Engineering Science ,University of Melbourne.*

Awal, A.S.M.A.(1988). Failure mechanism of prepacked concrete, *Journal of Structural Engineering*, ASCE, Vol.114, No.3, pp.727-732.

Awal, A.S.M.A.(1992). Creep recovery of prepacked aggregate concrete, *Journal of Materials in Civil Engineering*, ASCE, Vol.4, No.3, pp.320-325..

Awal, A.S.M.A. (2002). A study on shrinkage and creep of prepacked aggregate concrete. *(Advances in Mechanics of Structures and Materials: Proceedings of the 17th by Y. C. Loo, Sanaul H. Chowdhury, Sam Fragomeni).*

Awal, A.S.M.A.(2002). A study on shrinkage and creep of prepacked aggregate concrete,*Proceedings of the 17th Australasian Conference on the Mechanics of Structures and Materials*, Gold Coast, Australia, pp.261-264.

Awal, A.S.M.A.(2009). Influence of chemical admixture in the development of strength of prepacked concrete. *Proceedings of the 7th Asia Pacific Structural Engineering and Construction Conference & 2nd European Asian Civil Engineering Forum (APSEC & EACEF 2009)*, Langkawi, Malaysia, pp.752-757.

Awal, A.S.M.A. and Hussin, M. W. (2009). Strength modulus of elasticity and shrinkage behaviour of POFA concrete. *Malaysian Journal of Civil Engineering. 21 (2): 125-134.*

Awal, A.S.M.A. and Hussin, M. W. (2011). Effect of Palm Oil Fuel Ash in Controlling Heat of Hydration of Concrete. *Procedia Engineering. 14 2650-2657.*

Awal, A.S.M.A. and Nguong, S. K. (2010). A Short-Term Investigation on High Volume Palm Oil Fuel Ash (POFA) Concrete. *Proceedings of the 35th Conferenece on our World in Concrete and Structure. 185-192.*

ACI Committee 209. *Prediction of Creep, Shrinkage, and Temperature Effects in Concrete Structures.* ACI Publication SP-27, pp. 1-42

ACI Committe 304. *Guide for the Use of Preplaced Aggregate Concrete for Structural and Mass Concrete Applications.* ACI Journal.

Acker, P. and Ulm, F. J. (2001). Creep and shrinkage of concrete: physical origins and practical measurements. *Nuclear Engineering and Design. 203 (2): 143-158.*

Ahmad, M., et al. (2008). Compressive strength of palm oil fuel ash concrete. *Proc. of the International Conference on Construction and Building Technology, Kuala Lumpur, Malaysia.* 297-306.

Akroyd, T. N. W. (1962). *Concrete: properties and manufacture.* Pergamon Press Oxford.

Altwair, N. M., et al. (2012). Flexural performance of green engineered cementitious composites containing high volume of palm oil fuel ash. *Construction and Building Materials. 37 518-525.*

ASTM C31/C31M – 12. *Standard Practice for Making and Curing Concrete Test Specimens in the Field.* American Society For Testing and Materials.

ASTM C136. *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.*American Society For Testing and Materials.

ASTM C192/C192M − 12. *Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory.* American Society For Testing and Materials.

ASTM C512/C512M − 10. *Standard Test Method for Creep of Concrete in Compression.* American Society For Testing and Materials.

ASTM C618 − 12. *Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.* American Society For Testing and Materials.

ASTM C937 − 10. *Standard Specification for Grout Fluidifier for Preplaced-Aggregate Concrete.* American Society For Testing and Materials.

ASTM C938 − 10. *Standard Practice for Proportioning Grout Mixtures for Preplaced-Aggregate Concrete.* American Society For Testing and Materials.

ASTM C939 − 10. *Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method).* American Society For Testing and Materials.

ASTM C940 − 10a. *Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory.* American Society For Testing and Materials.

ASTM C943 − 10. *Standard Practice for Making Test Cylinders and Prisms for Determining Strength and Density of Preplaced-Aggregate Concrete in the Laboratory.* American Society For Testing and Materials.

ASTM C39/C39M − 12a. *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.* American Society For Testing and Materials.

Barnforth. P (1980). The effect of temprature variation on the creep of concrete, *UEG Tech*. Note UTN 19. p. 44.

Baumann, P. (1948). Use of Prepacked Aggregate Concrete in Major Dam Construction. *ACI Journal Proceedings.* ACI,

Bazant, Z.P. and Wittmann, F.H. (1982). *Creep and Shrinkage in Concrete Structures*. John Willey & Sons Ltd.

Bazant, Z.P. (1988). *Mathematical Modelling of Creep and Shrinkage of Concrete*. John Willey & Sons Ltd.

Bazant, Z.P. and Baweja, S. (1995). *Creep and Shrinkage Prediction Model for Analysis and Design of Concrete Structures-Model B3*. RILEM Recommendation, Materials and Structures, v.28, pp.357-365.

Bazant, Z.P and Baweja, S. (2000). *Creep and Shrinkage Prediction Model for Analysis and Design of Concrete Structures:Model B3*. American Concrete Institute, Farmington Hills, Michigan.

Borsoi, A., et al. (2009). Influence of chemical admixtures on the drying shrinkage of concrete. *this Symposium.*

Champion, S. and Davis, L. T. (1958). *Grouted Concrete Construction', Journal, Reinforced Concrete Review, pp. 569-608 (March).*

Chefdeville, M. J. (1963). *'Prepacked Aggregate Concrete and Activated Mortar', D.S.I.R., Building Research Station, Library Communication LC1190 (May).*

Cook, D. J. (1987). "A discussion of the paper " reaction product of lime and silica from rice husk ash " by J. James and M. Subba Rao." *Cement and Concrete Research* 17(4): 685-686.

Davis, R. E., et al. (1948). Restoration of Barker Dam. *ACI Journal Proceedings.* Proc., Vol.44, pp. 633-667 (April).

Dhir, R. K. (1986). "Pulverized-fuel ash." Cement Replacement Materials (Ed. RN Swamy), Survey University Pres, London

Ferraris, C. F., et al. (2001). The influence of mineral admixtures on the rheology of cement paste and concrete. *Cement and concrete research. 31 (2): 245-255.*

Gamble, B. and Parrott, L. (1978). Creep of concrete in compression during drying and wetting. *Magazine of concrete research. 30 (104): 129-138.*

Gebler, S. H. and P. Klieger (1986). "Effect of fly ash on physical properties of concrete." *ACI Special Publication* 91.

Hauggaard, A. B., et al. (1999). Transitional thermal creep of early age concrete. *Journal of engineering mechanics. 125 (4): 458-465.*

Hussin, M.W. and Awal, A.S.M.A.(2009). A short-term investigation on the deformation behaviour of concrete containing palm oil fuel ash, *Proceedings of the 7th Asia Pacific Structural Engineering and Construction Conference 2009 & 2nd European Asian Civil Engineering Forum (APSEC & EACEF 2009)*, Langkawi, Malaysia, pp.584-588.

Huo, X.S., Al-Omaishi, N. and Tadros, M.K. (2001). *Creep, Shrinkage, Modulus of Elasticity of High Performance Concrete.* ACI Materials Journal, v.98, n.6, November-December.

Joshi, R. C. and R. P. Lohtia (1997). Fly Ash in Concrete: Production, *Properties & Uses,* CRC PressI Llc.

King, J. C. (1959). Concrete by intrusion grouting. *Handbook of Heavy Construction.*

Smadi, Mohammad M., Salte, Floyd O., Nilson and Athur H. (1987). *Shrinkage and creep of High, Medium and Low Strength Concretes, Including Overloads.* ACI Materials Journal, vol.84. May-June.

Smerda, Zdenek and Kristek, Vladimir (1988). *Creep and Shrinkage of Concrete Elements and Structures*. New York: Elsevier Science Publishing Company.

Swamy, R. (1990). "Fly ash concrete-potential without misuse." *Materials and structures* 23(6): 397-411.

Swamy, R. N. and H. B. Mahmud (1989). "Shrinkage and creep behaviour of high fly ash content concrete." *ACI Special Publication* 114.

Lamond, J. F. (2006). *Significance of tests and properties of concrete and concrete-making materials.* ASTM International.

Lyse, I. (1959). The shrinkage and creep of concrete. *Magazine of concrete research. 11 (33): 143-150.*

MacGregor, James G. (1997). *Reinforced Concrete: Mechanics and Design*. 3rd ed. Prentice Hall.

Mindess, Sidney and Young, J. Francis. (1981). *Concrete*. Englewood Cliffs, N.J.: Prentice-Hall

Mokarem, D.W. (2002). *Development of Concrete Shrinkage Performance*. Virginia Polytechnic Institute: Doctor of Philosophy Thesis in Civil and Environmental Engineering,

Manohar, S. N. (1967). The Production, Properties and Applications of Colcrete. *Indian Concrete Journal. 41 (No. 7, pp. 262-275 (July).)*

Nasser, K. and A. Al-Manaseer (1986). "Shrinkage and creep of concrete containing 50 percent lignite fly ash at different stress-strength ratios." *ACI Special Publication 91.*

Nipatsat, N. and S. Tangtermsirikul (2000). "Compressive strength prediction model for fly ash concrete." *Thammasat International Journal of Science and Technology* 11: 1-7.

Neville, A.M. (1964). Creep of concrete as a function of its cement paste content. *Magazine of concrete research. 16 (46): 21-30.*

Neville, A.M. (1970). *Creep of Concrete: Plain, Reinforced and Prestressed*. Netherlands: North-Holland Publishing Company-Amsterdam.

Neville, A. M. (1971). Creep of concrete: plain, reinforced, and prestressed.

Neville, A.M. (1975). *Properties of Concrete*. Pitman Publishing Ltd.

Neville, A.M. (1981). *Properties of Concrete.* 3rd ed. England: Longman Group UK Ltd.

Neville, A.M., Dilger, W.H. and Brooks, J.J. (1983). *Creep of plain and structural concrete*. United State of America: Longman Inc., New York.

Neville, A.M. and Brooks, J.J. (1990). *Concrete Technology*. England: Longman Group UK Ltd.

Orchard, D. F. (1973). *Concrete Technology*. 3rd Ed., Vol.2, Applied Science Publishers Ltd, London, pp. 409-416.:

Tang, C. K. (1977). *Properties of Prepacked Concrete. M. Eng. Sc. Thesis, University of Melbourne.*

Tadros, et al. (2002). *Prestress Loss in Pretensioned High Strength Concrete Bridge Girders*. Final Report.

Taylor, W. H. (1965). *Concrete technology and practice.* Angus and Robertson, pp 357-358.

Townsend, B.D. (2003). *Creep and Shrinkage of a High Strength Concrete Mixture*. Virginia Polytechnic Institute: Master of Science Thesis in Civil Engineering.

Vincent, Edward C., (2003). *Compressive Creep of a Lightweight, High Strength Concrete Mixture.* Virginia Polytechnic Institute: Master of Science Thesis in Civil Engineering.