COMPRESSIVE STRENGTH OF CONCRETE CAST IN FABRIC FORMS

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T.2. Performance of materials

ABSTRACT

Due to rapid developments in synthetic production and concrete pumping technology, fabric forms have become considered over the last decade a practical and economic alternative to the classic form materials (Wood & Steel). The fabric forms are permeable sheets made of synthetic fabrics, which when used in association with concrete, have the ability to hold, giving the concrete its final and required shape. Since synthetic fabrics are a bye-product of the petroleum industry, so using it in concrete applications in petroleum countries has positive economical and environmental impact and as well as adding value to concrete quality.

The permeability pore size relation is considered a key factor for fabric type selection in addition to application types and location. The drain ability of the forms allows an easy immigration for excess water - not required by the hydration process in the concrete mix and will solve the adverse effect of high water cement ration on concrete quality. This paper demonstrates a study carried out to compare the compressive strength of concrete obtained by using classic PVC forms and fabric forms. Two types of fabric forms have been used and denoted in the paper as (Type I and Type II). Four concrete mixes of aggregate cement ratio (A/C) of 5 and water cement ratio (W/C) of 0.5, 0.55, and 0.65 and 0.75 have been used.

KEYWORDS

Compressive Strength, Fabric Formwork, Structural Concrete Members

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1. INTRODUCTION

Fabric formwork has been in use since the mid-1960s to form concrete on the ground and under water for erosion control, cooling pond liners, and pile jackets. However, in the last decade Flexible formwork technology has advanced far beyond such early applications due to the expansion of computers in engineering practice, development in synthetic production and advances in concrete pumping technology '[Abdelgader et al. 2002] and [West 2003]'.

Fabric forms are permeable sheets made of synthetic fibers (typically nylon, polyesters or polypropylene) that are fabricated into containers to hold fresh concrete in place and produce the required final shape. The most common kinds of fabric formwork can be divided into four main groups: mattresses, sleeves, shuttering, and open troughs As shown in 'Figs 1,2,3,4 and 5', '[West et al. 2008]'.

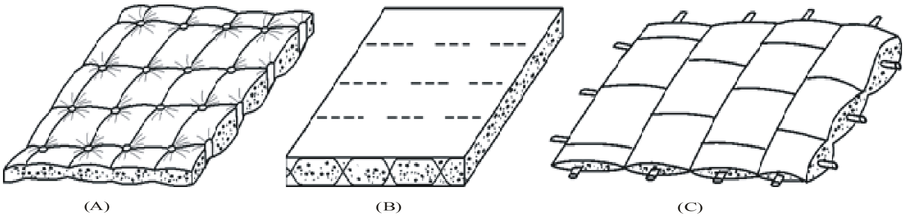

Figure 1. Mattress group of fabric forms :
(A)-Cobbled mattress, (B) Uniform mattress, (C) Articulated block

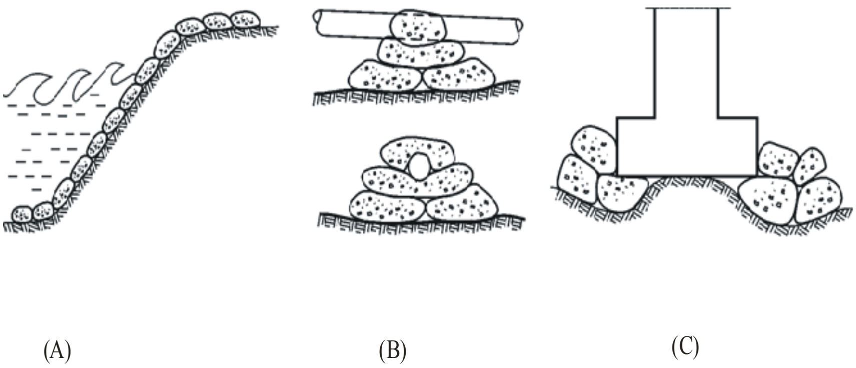

Figure 2. Fabric form bags application:
(A) Breakwaters , (B) Pipeline foundations , (C)Foundation supports

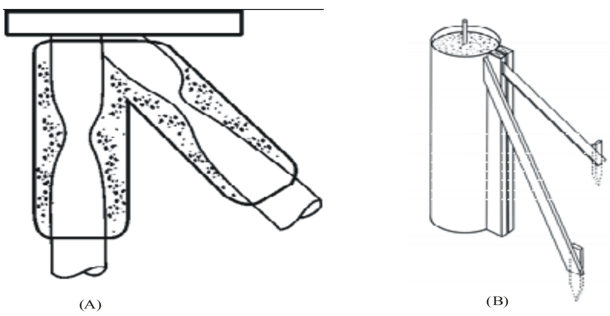

Figure 3. The sleeve group of fabric forms:
(A)-Pile jackets (B)-Column formwork

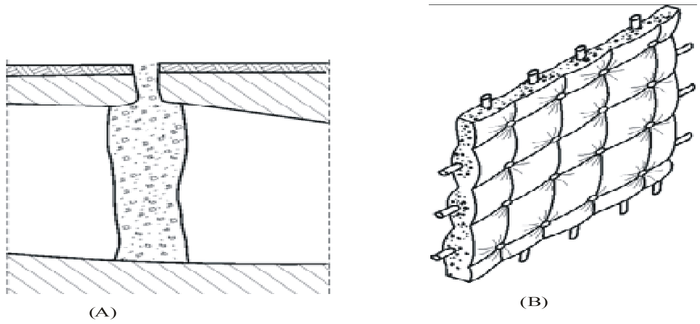

Figure 4. The shuttering group of fabric forms:
(A)- Earth cavities (B)- Quilted wall

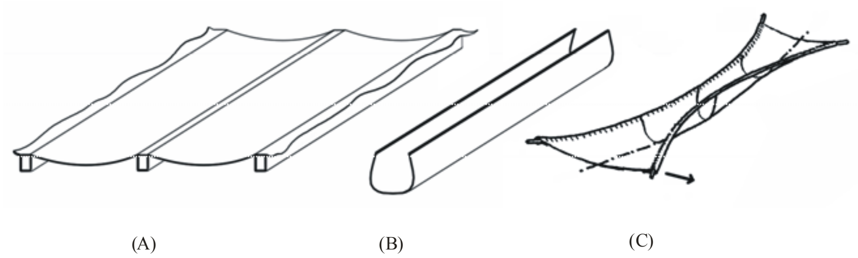

Figure 5. The open through group of fabric forms :
(A)-Tilt-up panels, (B) Precast columns, (C) Precast variable-section beams

Fabric form offer a porous wall to the fresh concrete, improving concrete's strength, durability, and finish quality. When formwork membranes are made of permeable fabrics, they acts as filters allowing air bubbles and excess mixing water to bleed out, leaving an unblemished, cement rich paste at the concrete surface. This loss of water can significantly improve the water to cement ratio (W/C) at the member's surface providing a dense and significantly stronger "case hardened" concrete '[Lamberton 1989]; [West 2003] and [Abdelgader et al. 2006]'. With flexible formwork, the final geometry of the cast member is the result of the interaction between the flexible tension membrane and the fresh concrete it contains. Unlike conventional rigid formworks, members of high complexity can be cast from simple flat formwork membranes that are allowed to deflect under the weight of fresh concrete. Furthermore, one such form can be used multiple times to form a multitude of differently shaped and dimensioned members, simply by altering the manner in which the formwork is rigged.

Because fabric formworks are extraordinarily light, they can be shipped by air freight to any construction site across the world; that freedom opens up new possibilities for how the constraints of a construction project are conceived, as explained in '[West et al. 2008]'. Because concrete is the most widely used construction material in the world, improvements in the economy and durability of concrete structures has significant implications worldwide. Thus, there has been increasing interest in the use of fabric formwork as an alternative to the conventional formwork. This is particularly true in situations where the cost of conventional formwork represents a high percent of the total cost of the structure or when the project conditions are difficult '[Abdelgader et al. 2002] and [West 2003]'.

In fact, the rapid growth of fabric form applications is paralleled by heavily patents; consequently there is a scarcity of related scientific publications and technical reports. Most of the available publications are constricted in the case history of fabric form applications and the economic benefits gained, '[West et al. 2008]'. This paper demonstrates a study carried out to compare the compressive strength of concrete obtained by using classic PVC forms and fabric forms.

2. EXPERMINTAL PROGRAM

The laboratory experiment program was designed to carry out a comparison investigation to measure the effect of fabric forms having different porosity on the compressive strength of normal concrete mixes. Concrete mixes of constant aggregate cement ratio (A/C) and ranged water cement ratio (W/C) to give different degrees of workability have been prepared. Then, Fresh concrete was moulded in both classic PVC and fabric forms. Two types of fabric forms have been used (denoted in the paper as “Type I” and “Type II”). Commercially available local materials have been used in all mixes, while the fabric forms have been imported. Details for the materials used, Mix proportions, mixing and testing procedures of fresh and hardened concrete are given in the following subtitles.

2.1 Materials

Ordinary Portland cement produced by Zletin factory (150 KM east of Tripoli) has been used in all the concrete mixes through out this research. The cement was investigated to confirm its quality according to British standards ‘[BS-12 -1991]’. Fine aggregate was natural dry sand having a specific gravity of 2.66, imported from Zletin sand dunes. Its grading complies to zone IV of British standards ‘[BS-882-1985]’ grading limits, while other physical properties also conform to the same standard. Coarse aggregate was round gravel of maximum size of 14 mm, imported from local dunes. Its grading, other physical and mechanical characteristics were confirmed to the requirements of British standards ‘[BS-882 -1995]’. Both fine and coarse aggregate were clean and free from any impurities and used in the mixes with percentage of 20% and 80% respectively. The combined aggregate grading curves are shown in ‘Fig. 6’. Ordinary drinkable water was being used. It is known to contain less than 1000 p.p.m. of dissolved solids, hence satisfy the requirements of British standards [BS-3148 -1989].

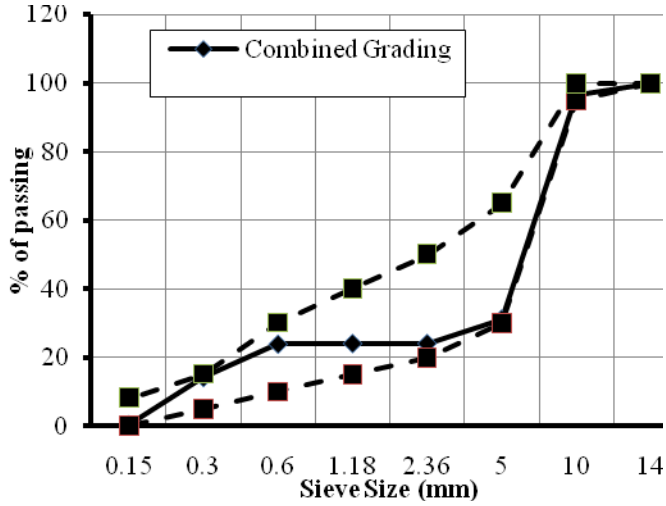

Figure 6. Combined aggregate grading curves

2.2 Mixes

Four concrete mixes of aggregate cement ratio (A/C) of 5 and water cement ratio (W/C) of 0.5, 0.55, and 0.65 and 0.75 have been prepared and molded in both classic PVC and fabric forms. American concrete institute (ACI) mix design method was employed to calculate mix proportions of desired strength and acceptable workability, ‘[Neville 1991]’. The mixes and their proportions are shown in Table 1. All mixes were performed in the laboratory using a rotary electrical mixer of 0.3 m^3 capacity and vertical rotation axis. Standardized mixing procedure was used in which cement and sand being mixed first and then the water and coarse aggregate added. The complete mixing time was about 5 minutes and subsequently some of the fresh concrete properties were also measured such as the slump. Standard slump cone results were recorded for all mixes.

Table 1. Concrete mix details

Mix No.	W/C	A/C	Cement	Water	Fine Agg.	Coarse Agg.
			Kg/m^3			
1	0.5	5	370	185	444	1407
2	0.55	5	364	200	436	1382
3	0.65	5	351	228	421	1333
4	0.75	5	339	254	407	1288

2.3 Sample Preparations

A total of 36 samples of standard cylindrical size (150mmx300mm) have been prepared through out this research. For each mix 9 samples were prepared (3 using classic PVC moulds, 3 using fabric form moulds type I, and 3 using fabric form moulds type II). Table 2 demonstrates some physical and mechanical properties of the fabric sheets used in the manufacturing of the fabric moulds. Compaction using standard manual method was used for concrete mixes having a slump more than 180 mm, while electrical vibrating tables were used for those having slump of less than 180 mm. All specimens were covered with plastic sheets and wet cloths to prevent surface water evaporation and kept in their moulds at the laboratory environment for 24 hours.

Table 2. Some physical and mechanical properties of the fabric sheets used

Type	Weight	Thickness	Permeability (m/s)		Tensile Strength (MPa)		Extension
	(gm/m^2)	(mm)	Air	Water	Parallel	Vertical	(%)
I PT 48-100	486	0.88	0.2	0.0018	550	300	48
II PT 79-160	460	0.7	0.065	0.0005	600	400	42

2.4 Curing

Immediately after demoulding samples were stored in a water tank, saturated with lime at 20 ^{0}C until testing after 28 days. Samples from fabric moulds kept in their mould during the first 2 weeks of the curing regime. After 2 weeks of curing the fabric sheets were removed and cores of 100 mm diameter and height of 300 mm were extracted, using an electric coring machine. Cores were then adjusted to 200 mm height using an electric saw, and returned to water tanks to complete the curing period.

2.5 Compressive Strength Testing

The compressive strength testing was carried out for a total of 36 samples after they have been water cured for 28 days as detailed above. A steady state hydraulic loading machine of 500 ton capacity was used. Samples were tested in vertical direction and subjected to a uniform stresses. The test was performed according to standards '[BS-1881-1983] and [ASTM-C39- 1986]' and a capping was applied in both upper and lower faces to a void partial stress concentration. Test results are shown in Table 3.

Table 3. Compressive strength results

W/C	fc' (MPa)		
	Classic	Type-I-	Type-II-
0.5	25.09	25.29	27.54
0.55	22.03	23.25	22.64
0.65	22.64	11.63	14.28
0.75	13.87	14.28	13.05

3. RESULTS AND DISCUSSION

It is well known that concrete compressive strength is affected by many factors such as, W/C, A/C, proportions and properties of constituents, age, curing, compaction, environment conditions ………..etc.'[Neville 1981] and [Neville et al. 1991]'. In order to study the effect of water cement ratio on compressive strength using different kinds of mould material, all other factors were intentionally kept constant. W/C ratio versus compressive strength for both traditional and fabric moulds are demonstrated in 'Figs 7, 8, and 9'. a comparison between results obtained using the three kind of mould materials are shown in 'Fig. 10'. A discussing of those relations are explained in the following subtitles.

3.1 Effect of W/C Ratio on Compressive Strength When PVC Forms Were Used

'Figure 7', demonstrates the relation between water-cement ratio (W/C), and Compressive strength (**Fc`**). The relation is a typical one as expected. Results showed a reduction in strength of about 12% over the W/C ratio range 0.5-0.55, while that reduction increased to a value of 44% over the W/C ratio range 0.65-0.75.

3.2 Effect of W/C Ratio on Compressive Strength When Fabric Forms Type -I- Were Used

'Figure 8', shows the graphical presentation of compressive strength obtained from samples using Type I fabric form moulds. The relation is similar to that obtained using classic PVC moulds. 18% reduction in quantity was recorded over the w/c range 0.5 to 0.55, increasing to 43% as w/c reached 0.75.

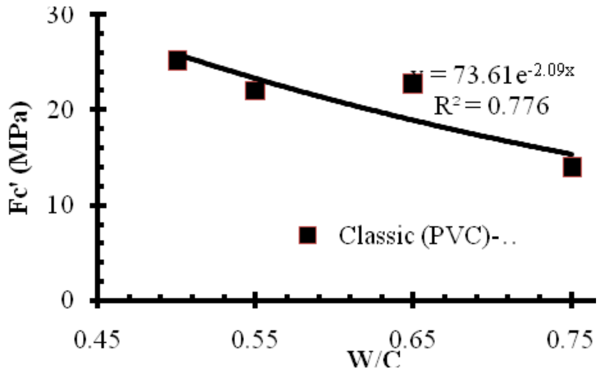

Figure 7. Compressive strength results using classic PVC moulds

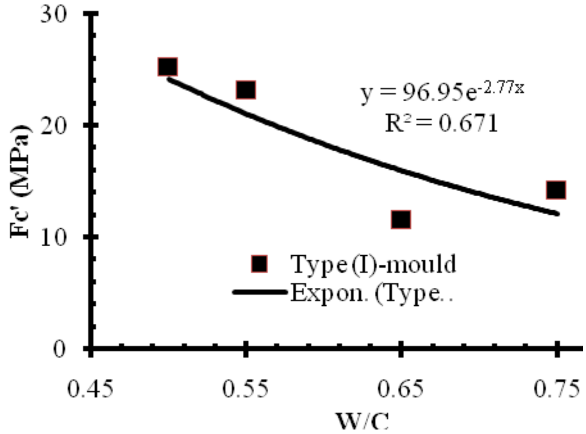

Figure 8. Compressive strength results using classic type I moulds

3.3 Effect of W/C Ratio on Compressive Strength When Fabric Forms Type -II- Were Used

'Figure 9', shows the graphical presentation of compressive strength obtained from samples using Type II fabric form moulds. A reduction in strength of about 18% was calculated over the w/c range 0.5 to 0.55. As w/c increased to a value of 0.75 the reduction in strength reaches a value of 53%. From 'Figure 10', It is obvious that the rate of decrease in strength using Type II moulds is smaller than that obtained using Type I and classic PVC moulds.

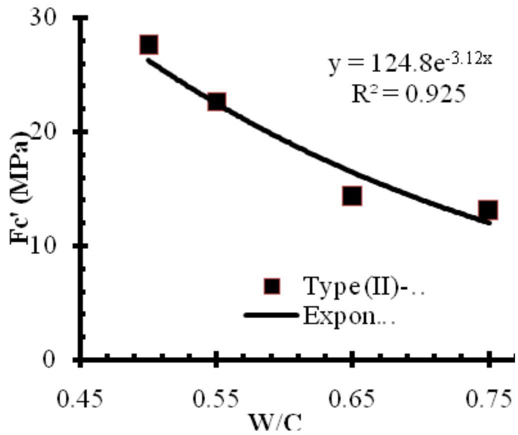

Figure 9. Compressive strength results using classic type II moulds

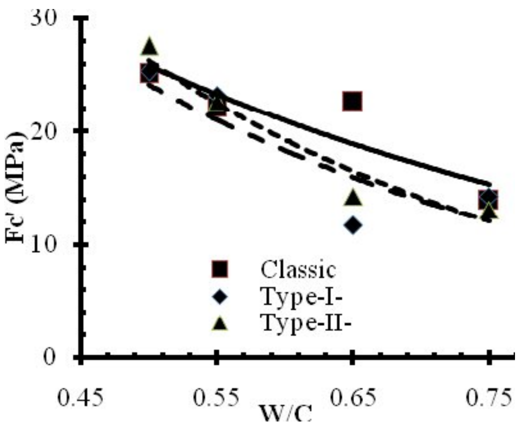

Figure 10. Compressive strength results using the three kinds of moulds

4. CONCLUSIONS

1. Relative to classic moulds the fabric forms slightly improve the strength of concrete at lower w/c ratio (0.5-0.55).
2. Improvement of compressive strength using Type II fabric moulds could be related to the increased permeability of the fabric sheets used to manufacture the moulds.
3. High permeability value of Type I fabric moulds, causes both some water and cement paste being lost from the mould, which considerably reduced the strength.
4. Compressive strength results obtained using fabric forms are generally, comparable to those obtained using classic PVC forms.
5. The relationships between w/c and Fc` are typical for all results and fit the general exponential function with high correlation coefficients.
6. The rate of strength decrease using Type II fabric moulds is smaller than that using other two kinds of moulds used in this research.

5. REFRENCES

West M., Abdelgader H.S. & Gorski J., ‘ State of the art report on fabric form work ‘ Proc., Int. Conference on Precast Concrete: Towards Lean Construction, Dundee, Scotland, 2008, pp.109-120.

Abdelgader H.S. & and Fhema A.H.,.’ Concrete using fabric forms ’ Proc. The Third National Conference on Construction Materials and Structural Engineering, Musrata, Libya, 2006, pp.116-125.

Bindhoff E.W. & King J.C. 1982. ‘Wold’s largest installation of fabric-formed pile jackets ‘ *Civil Engineering*, ASCE, pp. 68-70.

Lamberton B.A. 1989, ‘ Fabric formwork for concrete. ‘ *Concrete International*, 11(12), pp. 58-67.

GHAIB M.A. & Gorski J. 2001, ‘ Mechanical properties of concrete cast in fabric formworks ‘ , *Cement and Concrete Research* , 31, pp.1459-1465.

WEST M. 2003, **‘** Fabric-formed concrete members ’ , *Concrete International*, 25(10), pp. 55-60.

Abdelgader H.S , GHAIB M.A. & Gorski J. 2002, ‘ Concrete elements cast in fabric forms ‘ , *Betonwerk + Fertigteil-Technik*, 8, pp. 24-32.

Neville A. & Brook J.J. 1991, *Concrete technology* , Longman, London.

Neville A.M. 1981, *Properties of concrete*, Pitman, London.

BS-12- 1991, ‘ *Ordinary and rapid-hardening portland cements* ‘ , British Standard Institution, London, UK.

BS-882- 1985, ‘ *Testing aggregates: specification for aggregate from natural sources for concrete* ‘ , British Standard Institution, London, UK.

BS-812- 1985, '*Testing aggregates: method for determination of particle size distribution* ' British Standard Institution, London, UK.

BS-812- 1985, '*Testing aggregates: method for determination of physical properties* ' , British Standard Institution, London, UK.

BS-3148- 1980, ' *Water for making concrete* ' British Standard Institution, London, UK.

BS-1881: Part 102- 1983, '*Testing concrete: method for determination of slump* ' , British Standard Institution, London, UK.

BS-1881: Part 120- 1983, '*Testing concrete: method for determination of the compressive strength of concrete cores* ' , British Standard Institution, London, UK.

BS-1881: Part 107 - 1983, '*Testing concrete: method for determination density of compacted fresh concrete* ' , British Standard Institution, London, UK.

C 39-86- 1986, ' *Test for compressive strength of cylindrical concrete specimens* ' , American Society For Testing and Materials, USA.