m(A) - 11 .

Conference on Petroleum Science, Vietnam Petroleum Institute, Hanoi, 1998

EFFECTS OF MUD CONTAMINATION TO CEMENT CASING BONDING

Ariffin Samsuri[*]
Surej Kumar Subbiah[+]
Petroleum Production Operation Research Group
Faculty of Chemical and Natural Resources Engineering
University Technology Malaysia

11

ABSTRACT

One of the failure in petroleum well cementing operations is due to the effect of mud contamination on cement slurry while displacement process. Mud material, especially mud additives have a great influence towards the cement-casing bonding and the cement compressive strength. Since then, it is necessary to observe the effect of the mud contamination to the cement bonding and strength.

Cement slurry which has been contaminated by the mud is then cured for 24 hours within the temperature range of 150 - 250 ^{O}F and pressure range of 2000 - 3000 psi before it is tested for the compressive strength and bonding. From the laboratory experiments, it was found that increasing in the mud rheologies especially yield point will reduced the cement bonding and compressive strength significantly and it is compulsory to control the mud rheologies to ensure the whole cementing operation reaches the optimum stage with the adequate cement strength.

INTRODUCTION

Cementing operation is an important activity in petroleum well completion process. If the cementing operation fails, the workover cost is tremendously critical and this has become a serious consideration among the researchers. As we know the cement plays an important role in sealing the annulus between the wall of the wellbore and the casing. The objectives of the cementing process are to provide zonal isolation, close the abnormal zone, protecting the casing from corrosion due to the formation fluid, as bonding agent between the casing and formation, and reduce the water cut for production well.

[*] PhD & Assoc.Prof , University Technology Malaysia
[+] Research Officer/MSc student, University Technology Malaysia

The drilling mud will be sticking at the annulus during the drilling activities. Therefore, one of the criteria for the optimum cementing operation is total displacement of the drilling mud during cementing. There are few methods used for the purpose. Some of them are, usage of flush water, additive in cement, mechanical gadgets and etc. Sometimes the turbulent flow also will give better displacement. The mud need to be displaced, in order to avoid the mud contamination to the cement slurry which will effect the bonding shear strength between cement and casing and also reduce the cement compressive strength.

Failing in doing a clean cementing operation will give problem to future well completion and stimulation activities. It may creates problem to the activities such as water flooding, hydraulic fracturing, acidizing and other stimulation activities. No doubt that the mud couldn't be displaced fully during the cementing operation. Thus, the additives play an important role in the mud contamination in cement. The mud rheology such as the mud density, gel strength, viscosity, yield point and plastic viscosity are the factors that should be considered and which effect the cement strength.

The shear strength is defined as the cement potential to support and hold the load of the casing mass. This potential is proportional to the surface area of cement-casing contact. In other word it can be defined as the resistance for the movement of cement and casing. This strength is important to support the casing load and optimum strength will be able to provide the safety and effectiveness of further development of the well.

BACKGROUND

Arthur found that the cement-casing shear bonding increases with temperature in the range of 100 ^{O}F and 250 ^{O}F. Whereas Evan said that the pumping pressure in the casing will reduced the cement-casing shear bonding. Davis concluded that the outer casing surface plays an important role and influences the bonding strength. Cement-casing shear bonding higher for rough surface compare to smooth surface. However, the bonding strength will decreases without the surface effects if the outer surface was coated with drilling mud. In general, the bonding strength is influenced by few factors, as shown Table 1.

LABORATORY WORKS

Drilling mud preparation

Correspondence to API Specification 13A, four types of mud system has been prepared to contaminate the cement. The same type of additive has been added into the mud systems (System A,B,C and D) but the quantity has been changed in order to get different mud rheology, as shown in Table 2.

Cement slurry preparation

The cement slurry prepared in laboratory correspondence to API Spec. 10. Four types of cement slurry had been used (E,F,G and H cement systems). The same type of additive added with different quantity in order to achieve different cement rheology. The details of the cement slurry shown in Table 3.

The specimen preparation

Fill the cube mould with the mud and then pour the cement system till the cement displacement the mud in the cube mould. The cement is then allowed to set in the pressurized chamber for 24 hours at 150 - 250 ^{O}F and pressure of 2000 - 3000 psi.

Compressive strength and shear bonding test

The compressive strength test was carried out correspond to the API Spec. 10A by using the compressive strength tester. The shear bonding test followed the same procedure as the compressive strength test but the position of the specimen is different.

RESULTS AND DISCUSSION

Effect of Mud Gel Strength

Figure 1 shows the relationship between the mud gel strength due to the used of bentonite and cement shear bonding and compressive strength. It shows that increasing in the mud gel strength due to increase in the amount of bentonite added to the mud which contaminated the cement will increased the void within the cement particle and will reduced the cement shear bonding and compressive strength. This is understandable since bentonite will absorbed water and expand. During contamination, the expanded bentonite particle will mixed with cement particle and shrinked, resulting in increasing of void within the set cement. The results show that 66 % increase in the mud gel strength will reduced 12 % of shear bonding and 9 % of compressive strength.

Effect of mud yield point

Increasing of bentonite contain in the mud will also increase the mud yield point, so as shown in Figure 2, mud yield point increases will reduced the cement shear bonding and compressive strength. It can be seen that 66 % increase in mud yield point will reduced shear bonding by 43 % and compressive strength by 28 %.

Effect of Mud Viscosity

Organic material used to increase the mud viscosity, such as IDFLO, IDVIS. IDPAC and IDBOND, contains the HO-C-H group which will be absorb by the cement particle when the mud contamination occurred. This phenomena will produced thin film which will prevent the complete reaction between cement particle and water, resulting in higher thickening time of the cement, which in turn will reduced the shear bonding and compressive strength of the set cement. Figure 3 shows that increasing in the mud plastic viscosity will reduced cement shear bonding and compressive strength. It can be seen that 66 % increase in the mud plastic viscosity will reduced the cement shear bonding by 29 % and compressive strength by 21 %. In addition, Figure 4 shows that 66 % increase in the mud apparent viscosity will reduced the cement shear bonding by 21 % and compressive strength by 16 %.

Effect of Barite

Mud density was increased by adding the Barite ($BaSO_4$). The specific gravity of Barite is 4.2 times more than water and 1.6 times heavier than clay. Barite normally could not dissolve in water and won't react with clay material.

As the mud contamination occurred in the cement slurry, Barite in the mud system suppose to increase the cement strength since the density of cement slurry will increase.

However, Fig 5 shows that increase in the mud density will reduced the cement strength due to others mud rheologicaleffects such as increasingin the yield point, gel strength, plastic viscosity and apparent mud viscosity.

Effects of Temperature

Fig 6 and Fig 7 show that the yield point of mud to the cement strength at various temperature. It was found that, as the temperature decreased from $250^{O}F$ to $150^{O}F$, the shear bonding strength reduced 22% and the compressive strength reduced up to 17%. This is in agreement with Davies et.al where they found that reduction of temperature will reduces the cement strength. This is due to the process where the yield point of the mud will be increased. Furthermore, increase in the mud yield point will reduced the cement strength.

Effect of pressure

Fig 8 and Fig 9 show the effects of mud's yield point on the cement strength at various pressure. It was found that, as the pressure increased from 2000 psi to 3000 psi, the shear strength also increased up to 8% and the cement compressive strength increased to 22%. The phenomenon due to, increment of pressure will reduced the mud yield point.

Effect of water cement ratio

Fig 10 and Fig 11 show the effects of mud yield point to cement strength for various water-cement ratio. The E cement system has the lowest ratio (0.42) compare to H cement system (0.55). It was found that, as the water-cement ratio increased (0.42 to 0.55), the shear strength reduced up to 25% and the cement compressive strength also reduced up to 28%. This is due to excessive water usage for H cement system which required longer thickening time. Therefore, the exposure of mud and cement will be longer and the mud contamination occurred for longer period.

Effect of cement thickening time

Fig 12 and Fig 13 show the effect of mud yield point of the cement strength for various cement thickening time. It was found that, as the thickening time increased from 120 to 170 minutes, the shear strength reduced up to 30% and cement strength to 35%.

This phenomenon is due to longer period of mud contamination occurred for higher thickening time.

CONCLUSION

From the experimental results and discussion, it can be concluded that :-

1) Bentonite will increased the mud yield point which in turn will reduced the cement shear and compressive strength.

2) Increasing mud density by adding Bentonite will reduced the cement shear and compressive strength.

3) Increasing mud viscosity will reduced the cement shear and compressive strength.

4) Effect of mud yield point in reducing the cement shear and compressive strength is very significant, followed by mud viscosity and gel strength.

Table 1- Factors that influences the bonding strength.

Factors	Descriptions
Water-cement ratio	Low ratio will increase the cement slurry density and will increase the bonding strength
Mud base	Oil base mud which acting as wetting agent at the outer surface of casing will reduce the bonding strength and vice versa for water base mud.
Mud contamination	Mud contamination reacts with cement slurry and reduce the bonding strength
Casing surface	Rough surface relatively gives higher bonding strength compare to smooth casing.

Table 2 - The additives added and the mud rheology

Composition	System A	System B	System C	System D
Caustic Soda	0.45 g	0.45 g	0.5 g	0.5 g
Barite	70.00 g	71.00 g	75.39 g	76.00 g
IDVIS	0.45 g	0.48 g	0.50 g	0.52 g
IDPACXL	0.50 g	0.60 g	1.00 g	1.20 g
IDPAC	0.65 g	0.70 g	1.00 g	1.20 g
IDFLO	2.30 g	2.50 g	3.00 g	3.50 g
Water	214.88 g	214.88 g	214.88 g	214.88 g
KCL	17.00 g	17.00 g	17.00 g	17.00 g
IDBOND	0.43 g	0.45 g	0.50 g	0.80 g
Bentonite	60.00 g	80.00 g	100.00 g	112.00 g
MUD RHEOLOGY				
Density (ppg)	9.9	10.2	10.4	10.8
Gel Strength 10s (lb/100ft2)	3.0	5.0	10.4	10.8
Gel Strength 10m (lb/100ft2)	16.00	23.00	35.00	40.00
Plastic Viscosity (cp)	16.00	18.00	24.00	30.00
Yield Point (lb/ft2)	2.0	8.0	24.00	25.00
Absolute Viscosity (cp)	17.00	22.00	36.00	43.00

Table 3 - Cement System

Composition	System E	System F	System G	System H
Barite (gram)	15	20	25	30
	1.58	1.59	1.6	1.65
Fluid Loss Agent (gram)	7.92	7.80	7.90	7.95
Extended (gram)	7.92	7.80	7.90	7.95
Cement (gram)	792	792	792	792
Water (gram)	316.8	354.0	396.0	435.6
CEMENT RHEOLOGY				
Water content (gps)	4.74	5.08	5.65	6.21
Slurry Density (ppg)	12	14	14.5	15
Thickening time 70 BC (min)	120	210	240	270

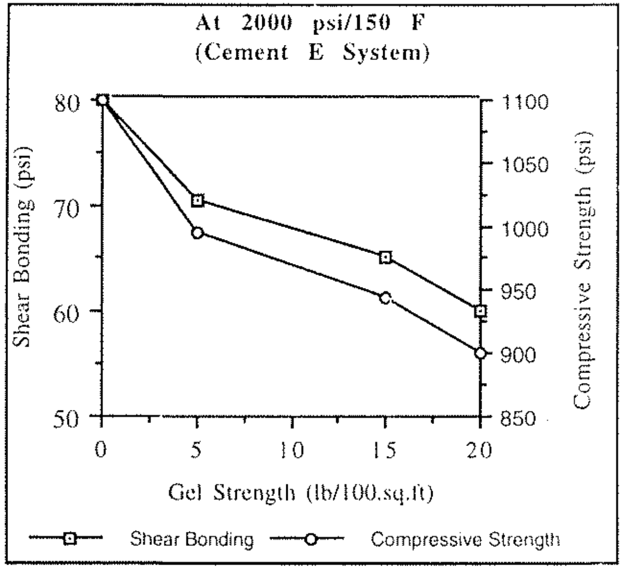

Fig 1 Effects of Gel Strength on shear bonding and cement strength.

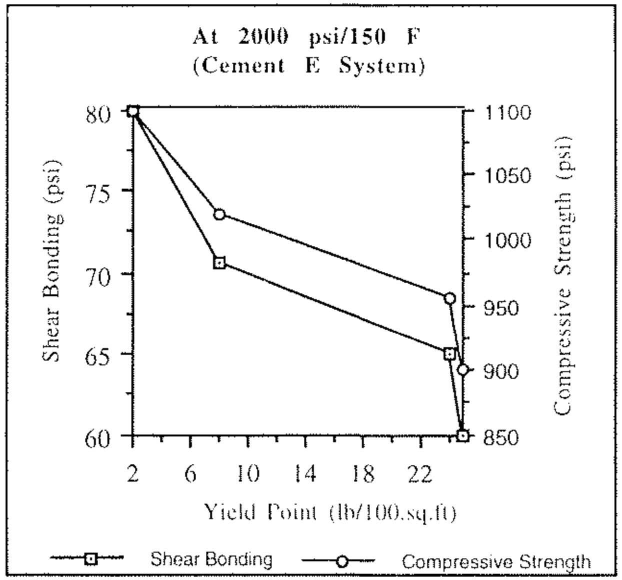

Fig 2 Effects of Mud Yield Point on shear bonding and cement strength.

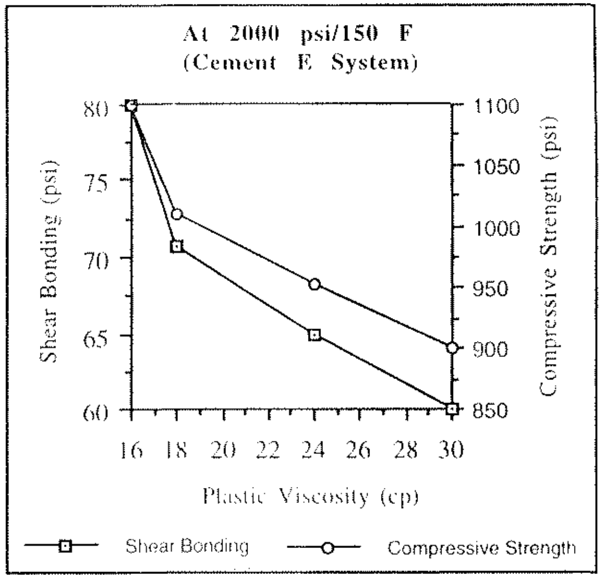

Fig 3 Effects of Plastic Viscosity on shear bonding and cement strength.

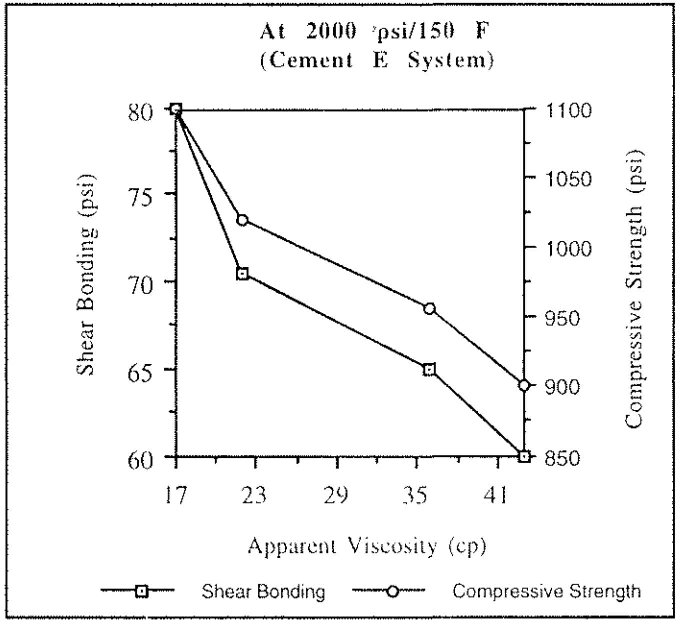

Fig 4 Effects of Apparent Viscosity on shear bonding and cement strength.

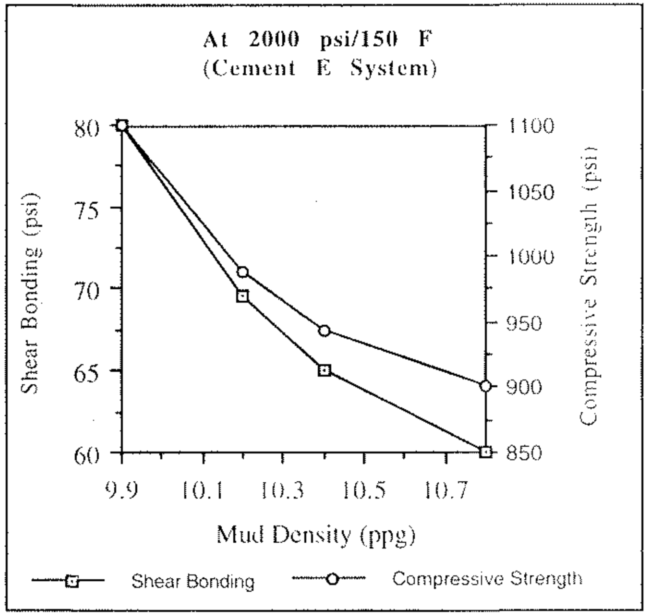

Fig 5 Effects of Mud Density on shear bonding and cement strength.

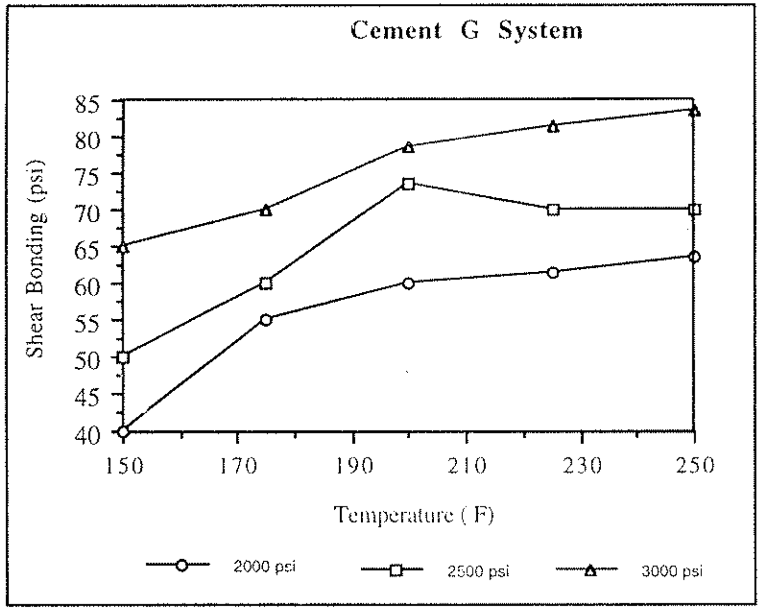

Fig 6 Effects of temperature on shear bonding

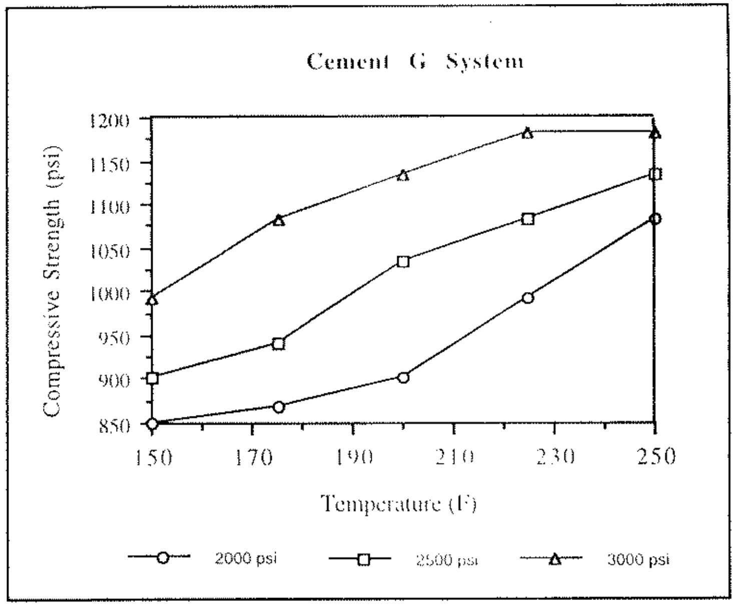

Fig 7 Effects of temperature on cement strength

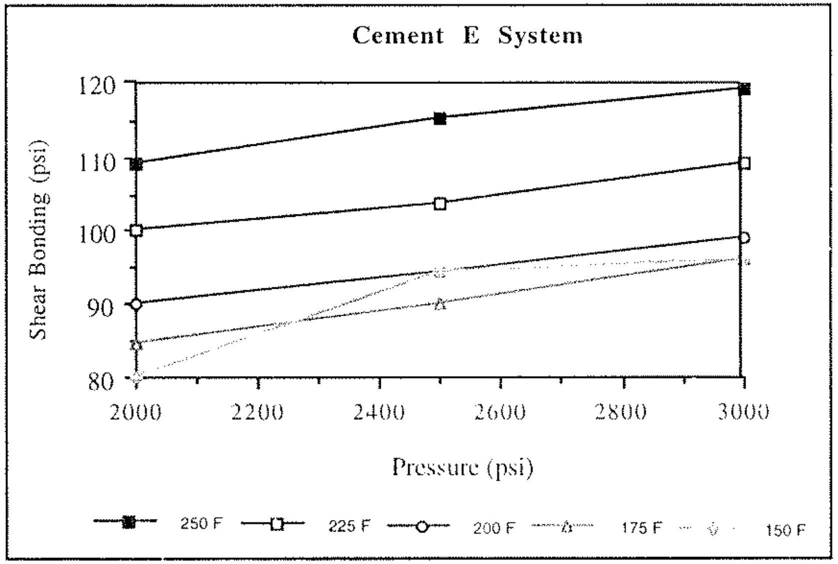

Fig 8 Effects of pressure on maximum shear bonding.

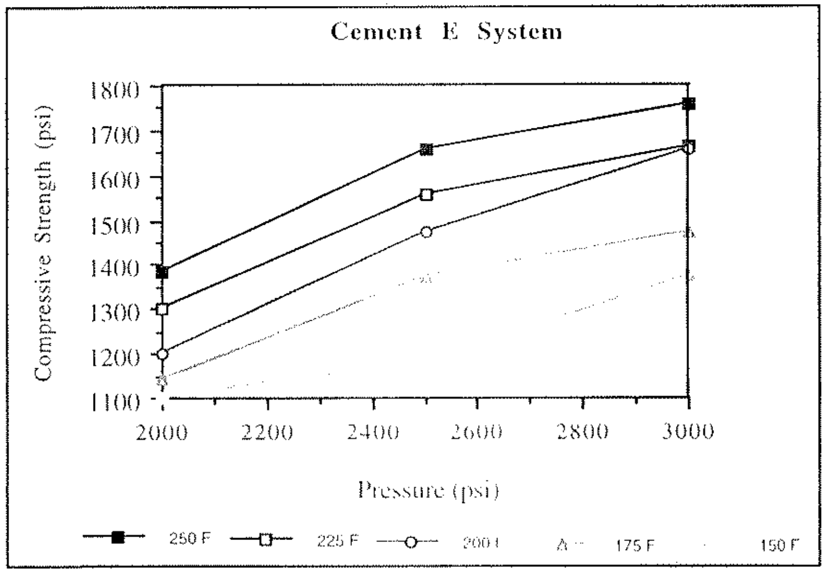

Fig 9 Effects of pressure on maximum cement compressive strength.

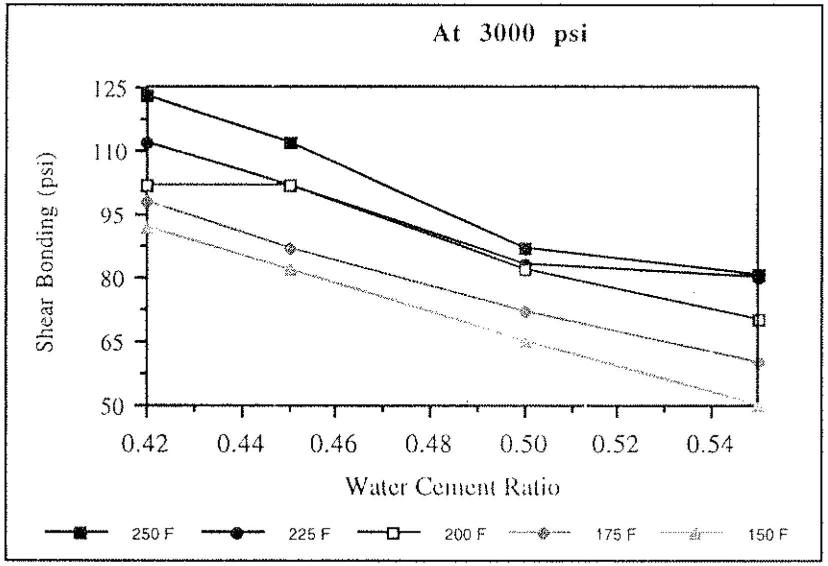

Fig 10 Effects of water-cement ratio on maximum shear bonding.

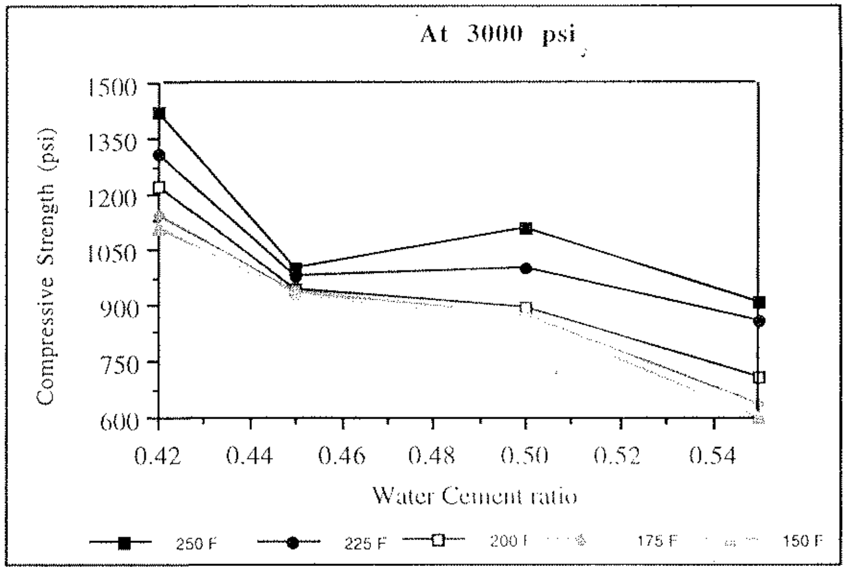

Fig 11 Effects of water-cement ratio on compressive strength.

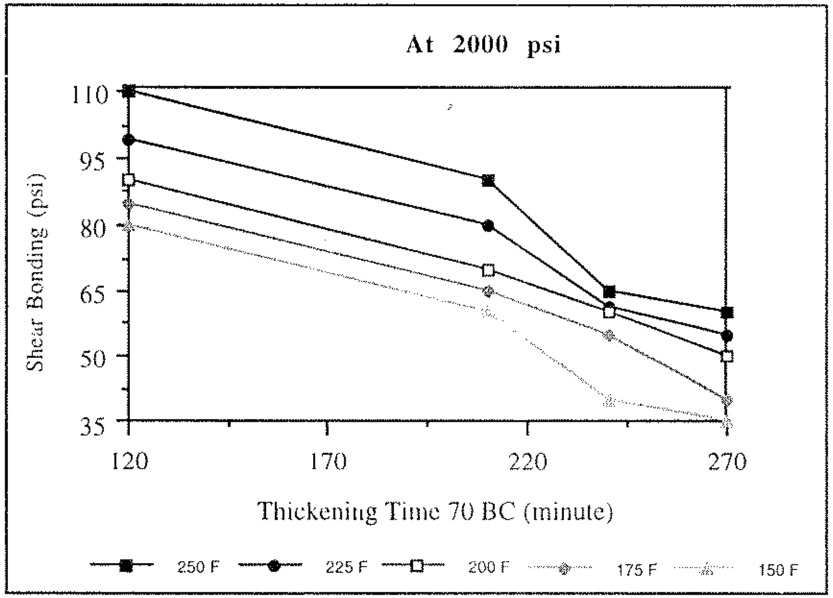

Fig 12 Effects of thickening time on maximum shear bonding.

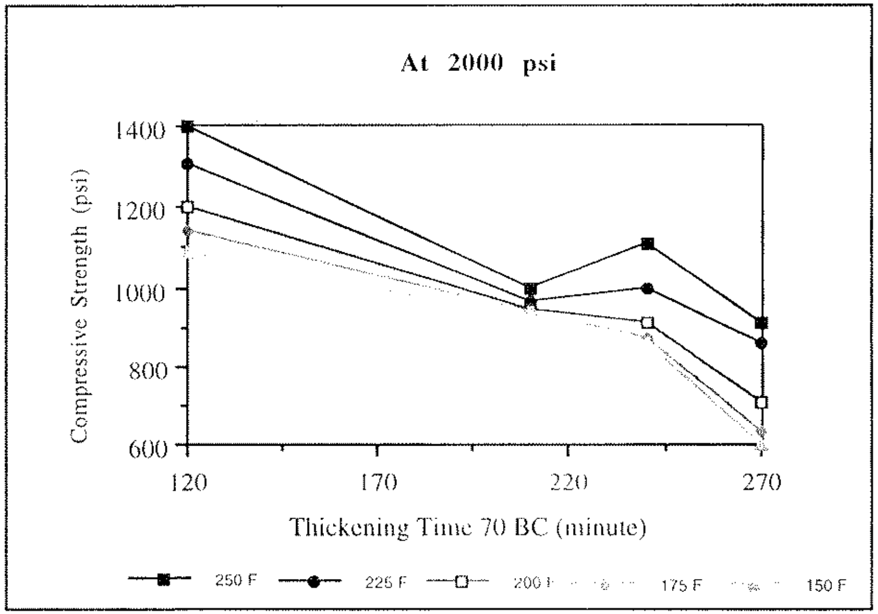

Fig 13 Effects of thickening time on maximum compressive strength.