The Effect of Temperature on Rheological Properties of Cement Slurry

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Abstract—*This experimental work reveals the effect of temperature on cement slurry rheological properties. Understanding cement slurry rheology is of critical importance for the design, execution and evaluation of oil or gas well cementing operations. The rheology depends on many factors which includes temperature. Temperature variations in oil and gas wells cause instability of rheological properties of cement slurries during cementing operations. The properties of the cement slurry investigated were plastic viscosity, yield point, gel strength, fluid loss and thickening time. In this research, 345.21ml of fresh water, 1g of Ensta antifoam, 0.5g of dispersant, 3g of Hydroxyl-Ethyl Cellulose (HEC), 0.1 gal/sk retarder concentration and 773.69g of cement were used to formulate the cement slurry. The behavior of the rheological properties was investigated at temperature range of 80ºF – 190ºF.Polynomial regression analysis was employed to study the behavior of rheological properties at different temperatures. An application (RP Predictor) was created with Visual Basic.NET and used to carry out theoretical analysis on the rheological properties of the cement. The results obtained showed that as the temperature increased from 80ºF – 190ºF, the rheological properties investigated decreased:plastic viscositytyfrom 105 – 90 (cp), yield point from 129 – 89 ((Ib/100ft^2), gel strength from 70 – 21 ((Ib/100ft^2), and fluid loss from 76 – 72 (ml/30min). However, the thickening time of the cement slurry increased from 2:50 – 19:58 (hr:min) with a rise in temperature confirming that adequate thickening time was required for a good cementing job. Also, the predictive models and application developed showed good prospects in predicting the behaviour of rheological properties at any given temperature.*

Index Terms—Cementing,Cement Slurry, Neat Cement, Enhanced Cement,Rheological Properties, Temperature, Rheological Properties Predictor (RP Predictor), Graphic User Interface (GUI), Regression Analysis.

1.0 Introduction

Cementing is a necessary aspect of the drilling oil process. Cementing in drilling engineering involves mixing cement, cement additives, and water (either fresh or salt) to obtain cement slurry based on designs. This is then pumped down-hole through the pipe to extremely important points in the space around the pipes or in the open hole below the casing string.

Rudimentary cementing of oil wells began as far back as the turn of the 19th century when few wells went deeper than 610 metres. Cementing operations were usually done by the rig crew. Today, specialist service companies routinely cement wells of 6,098 metres and deeper. Cementing operations are either primary (done in the course of drilling a well) or secondary/remedial (intended to correct deficiencies in primary cementing or alter the well completion for production) (Michaux *et al*., 1990).

Rheology is concerned with the study of the deformation of fluids and flow of matter. Understanding the rheology of cement slurry is of great importance for the planning, execution and assessment of oil or gas well cementing operations. The rheology depends on several factors including temperature, water-to-cement ratio, specific surface of the cement powder (shape and size of the grains of cement), chemical makeup of the cement, additives, the relative distribution of the components at the surface of the grains, mixing and testing procedures.

The Temperature effect on the rheological properties of the rheological properties of cement slurries is not well understood at very high temperatures because the standard oilfield equipment allows measurements to be performed at temperatures below 80˚C. Minimal experimental studies at higher temperatures insinuate the stability of cement slurry which is already a concern below 80˚C, is even more problematic at higher temperatures (Nelson and Guillot, 1990).

Significant numbers of research work have been carried out in cement technology to comprehend cement properties to increase the effectiveness of oil well production.

Shahriar (2011), investigated the rheology of oil well cement (OWC). The basic processes of the effects of additives on well cement the rheology were studied at various temperatures in the range of 23 to 60℃ making use of an advanced shear-stress/shear-strain controlled rheometer. From the study was found that, the well cement rheological properties largely rely on temperature, cement/water ratio, and additives present. Combined effects of additives and temperature caused a significant effect on the slurries rheological properties. The results showed that present data for chemical additives need be authenticated for cementing oil well; additives that demonstrated effectiveness in at moderate temperature in conventional cementing, may prove inefficient at large temperature in cementing of oil well.

Shahriar and Nehdi (2013), developed an artificial intelligence model for rheological properties of oil well cement slurries. Supplementary cementitious materials (SCM) such as fly ash, rice husk ash, silica fume, and metakaolin were incorporated. Experiment was carried out to create the database used for training the model. The rheological properties of the slurries were carried out at of 23 to 60ºC temperature range using an advanced shear-stress/shear-strain controlled rheometer. The data got experimentally were used to create a predictive model based on feed-forward back-propagation artificial neural networks. The results obtained showed that the developed model effectively predict the effect of key variables such as temperature and amount of SCM on OWC rheological properties with an absolute error of less than 7%.

John (2017), investigated the effect of temperature on cement slurry using fluid loss additives. The study was to ascertain the effect of temperature on cement slurry using various fluid control additives (Starch, XC-Polymer, PAC-R, and CMC). The filtration properties (mud weight, filtrate volume, and cake thickness) of the cement slurry were analyzed at 82°F to 176°Ftemperature range with 10g to 30g of various fluid loss control additives concentration. The study found that cement slurry responded differently to various fluid loss control additives at various temperatures, and an increase in temperature caused a decrease in the filtrate volume. The results indicated that neat cement slurry had a higher fluid loss rate as compared with cement mixed with additive slurry. Also, for all temperatures tested, PAC-R showed the most ability to reduce fluid loss when used as an additive as compared to others.

Umekafor and Joel (2010), presented modeling of cement thickening time at high temperatures with different retarder concentrations. 36 thickening time tests were conducted for a 5 inches high temperature liner cementing jobs done at 230 °F to 284 °F temperatures. They also developed a mathematic model that predicts the thickening time at various retarder concentrations and temperature. The results got deduced that the thickening time predicted is 10% less than the experimental results. They concluded that adequate thickening time was needed for a correct cement job.

This work covers the investigation on the effect of temperature on rheological properties (plastic viscosity, yield stress, gel strength, fluid loss and thickening time) of cement slurry; development of predictive model showing the relationship between rheological properties of cement slurry and temperature; and creating an application for future prediction of the effect of temperature on rheological properties of cement slurry.

2.0 MATERIALS AND METHODS

The experimental materials and apparatus used for this work consists of the following: Hamilton Beach Mixer, Hamilton Beach Mixer Cup, Rheometer, Rheometer cup, Atmospheric Consistometer, Consistometer, Electronic Balance, API Filter Press, HPHT Filtter Press, Water, Cement and additives.

2.1 Cement Slurry Formulation

345.21 ml of water was added into an hamilton beach mixer cup and allowed to stir for a minute. Ensta antifoam (1 gram) was added and allowed to stir for 5 mins. At 5 minutes Interval, dispersant and HEC of 0.5 gram and 3grams was added to the mixture respectively. After the elapsed of 5 mins, the cement was added at 2 mins for low, 3 mins for high and 5mins for higher speeds.

The cement slurry was ready for analysis. Mudweight was taken and transferred to a consistometer for different temperatures regulations at 120 ºF, 150 ºF and 190 ºF while 80 ºF was taken without a consistometer at room temperature. After each regulations, the slurry was transferred to the rheometer were rheological readings were taken and recorded.

2.2 Rheological Properties Determination

i. About 150ml of the cement slurry was transferred into the rheometer cup and stirred for 10 seconds and heated to a working temperature (80℉).
ii. The motor was started by placing the switch in a high-speed position. Readings were taken at 300RPM. The gear of the motor was changed while the motor was running to try for other speeds (200, 100, 60, 30, 6, and 3 RPM).
iii. Step 2 was repeated at 120℉, 150℉, and 190℉.
iv. Readings were taken to determine:Plastic viscosity (cP), Yieldpoint (lb/100ft^2), Gel strength (lb/100ft^2).

Fluid Loss Determination

The following procedures shows how slurry fluid loss was determined:

i. The cement slurry was placed in the API filter-press cup to about 2/3 volume, inserted and tightened;
ii. The CO_2 cartridge was placed in the filter-press;
iii. The knob was pressed in for pressure to build up;
iv. The pressure was maintained at 100 psi.
v. The filtrate was collected in a 10ml cylinder within 30mins.
vi. Then, the filtrate collected was measured and recorded.
vii. The above procedure was repeated for higher temperatures using the HPHT filter-press.

Thickening Time Determination

Thickening time is the time in which cement slurry remains in liquid state and has the ability of being pumped. It is assessed under replicated downhole conditions with the help of a consistometer.

The following procedures shows how slurry thickening time was determined:

- To ascertain the thickening time of cement slurry at different temperature conditions a high pressure high temperature consistometer is employed.
- The slurry cup assembly contained the cement slurry.
- The slurry cup was put into the test vessel and the pressure was raised via an air-driven hydraulic pump.
- A temperature controller regulated the internal heater which maintained the required temperature profile, while the magnetic drive mechanism turned the slurry cup assembly at 150 rpm.
- A potentiometer controlled the output voltage.
- The dual channel strip chart recorder registered and displayed the cement consistency and temperature as a function of time. And the readings were taken;
- The test ended when the slurry reached a consistency of 100 BC (Beardon Consistency).

2.3 Predictive Models for the Rheological Properties of Cement Slurry

Polynomial regression statistical analysis was employed in creating the mathematical models for predicting plastic viscosity (PV), yield point (YP), gel strength (GS), fluid loss (FL), and thickening time (TT) at different temperature conditions.

Polynomial Regression Statistical Model is given as:

$$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 \qquad (1.1)$$

where y is the dependent variables (rheological properties); x is the independent variable (temperature); $a_0,\ a_1,\ a_2\ and\ a_3$ are constants.

The system of linear equations used to get the constants are given as:

$$na_0 + a_1 \sum x + a_2 \sum x^2 + a_3 \sum x^3 = \sum y \qquad (1.2)$$

$$a_0 \sum x + a_1 \sum x^2 + a_2 \sum x^3 + a_3 \sum x^4 = \sum xy \qquad (1.3)$$

$$a_0 \sum x^2 + a_1 \sum x^3 + a_2 \sum x^4 + a_3 \sum x^5 = \sum x^2 y \qquad (1.4)$$

$$a_0 \sum x^3 + a_1 \sum x^4 + a_2 \sum x^5 + a_3 \sum x^6 = \sum x^3 y \qquad (1.5)$$

The plastic viscosity rheological property of cement slurry is given as:

$$PV = 112.6154 + 0.02589T - 0.00206T^2 + 6.87814 \times 10^{-6} T^3 \qquad (1.6)$$

$R^2 = 0.977$

The yield point rheological property of cement slurry is given as:

$$YP = 146.07493 + 0.317502T - 0.0090876T^2 + 0.000030952T^3 \qquad (1.7)$$

$R^2 = 0.933$

The gel strength rheological property of cement slurry is given as:

$$GelS = 68.4932 + 0.0461T + 0.0003677T^2 - 0.000010317T^3 \qquad (1.8)$$

$R^2 = 0.940$

The fluid loss rheological property of cement slurry is given as:

$$FL = 83.1663 - 0.12118T + 0.00046003T^2 + 6.87814 \times 10^{-7} T^3 \qquad (1.9)$$

$R^2 = 0.979$

The thickening time rheological property of cement slurry is given as:

$$TT = 2.5688316 - 0.0400273989T + (4.053037 \times 10^{-4} T^2) + 1.49944 \times 10^{-6} T^3 \qquad (1.10)$$

$R^2 = 0.965$

The rotational speed at given temperature is given as:

$$N_{\theta 300} = 258.69034 + 0.3433902T - 0.0111474T^2 + 0.00003783T^3 \qquad (1.11)$$

$R^2 = 0.947$

where T (°F) is the temperature.

Average absolute error is given as:

$$AAE = \frac{1}{n} \sum_{i=1}^{n} \left(\frac{Y_{measure} - Y_{predicted}}{Y_{measured}} \right) \qquad (1.12)$$

where y is the dependent variable measured or predicted with either the mathematical model or RP predictor (the developed application software).

2.4 Rheological Properties Predictor (RP Predictor)

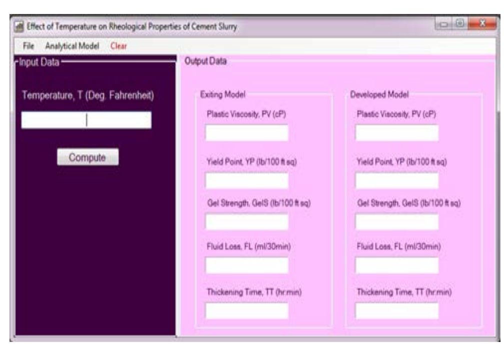

Figure 1: GUI for RP Predictor

The effect of temperature on cement slurry rheological properties can be analysed in different ways. It can be experimental or theoretical. The temperature effect on the rheological properties of cement slurry was analysed experimentally and theoretically by using the application (RP Predictor) created. The GUI of the software is depicted in figure 1. This application was created using data from the rheological properties of cement slurry with rheological enhancer, existing models, and predictive models.

3.0 RESULTS AND DISCUSSION

3.1 RESULTS

The experiment was first conducted using neat cement slurry as a control and then for cement slurry with rheological enhancers. The results obtained from the experimental studies to determine the effect of temperature on the rheological properties of cement slurry for both neat slurry and cement slurry with rheological enhancers are presented in Appendix A, Tables A.1-A.4. The experimental results showed that as temperature increased, the rheological properties (plastic viscosity, yield stress, and gel strength) decreased but for the thickening time which increased with increased temperature.
The result obtained from the predictive models developed via RP predictor is shown in Table A.5 of Appendix A. A comparison of the results obtained from the experiment, predictive models (RP predictor) and existing models have been displayed in Table A.6, Appendix A.

3.2 Comparative Simulation of Rheological Properties at Different Temperatures

Here, the results obtained from the experiment conducted, predictive models (RP predictor) and existing model were simulated and the plots obtained.

3.2.1 Comparative Effect of Temperature on Plastic Viscosity

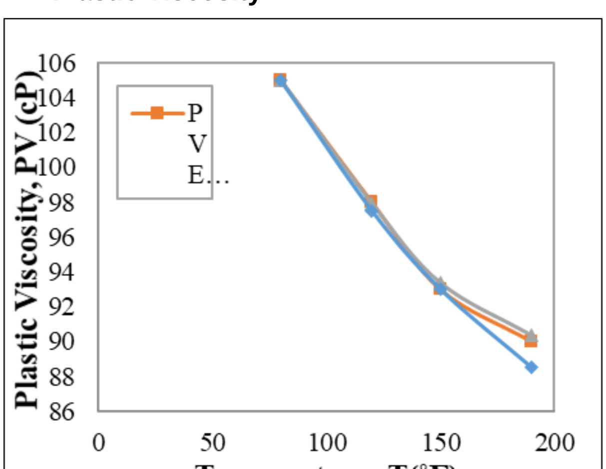

Figure 1: Comparative Temperature Effect on Plastic Viscosity of the Models

Figure 1 demonstrates the effect of temperature on plastic viscosity of cement slurry for the three cases at different temperatures. It was observed that, in the three cases, increase in temperature of the cement slurry led to decrease in the plastic viscocity of the cement slurry signifying that the resistance to flow of the slurry decreases with rise in temperature.
Also, this confirms that, the predictive model and analytical application predicts the effect of temperature on plastic viscosity of cement slurry.

3.2.2 Comparative Effect of Temperature on Yield Point

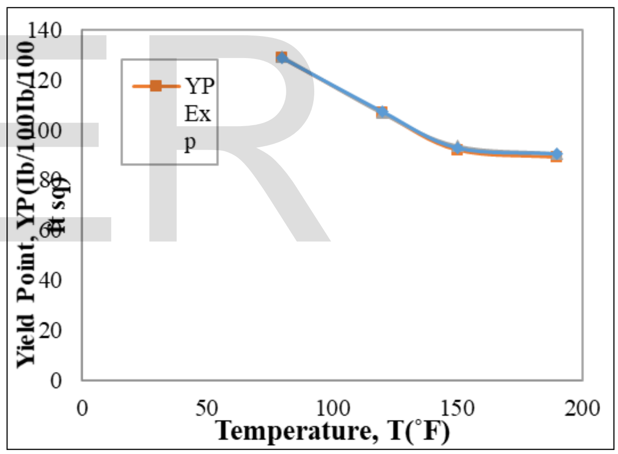

Figure 2: Comparative Temperature Effect on Yield Point

Figure 2 shows the effect of temperature on yield point of cement slurry for the three cases at different temperature. It was observed that, in the three cases, increase in temperature of the cement slurry led to decrease in the yield point of the cement slurry signifying that the electrochremical forces within the cement slurry reduced with rise in temperature. Also, this confirms that, the predictive model and analytical application predicts the effect of temperature on yield point of cement slurry.

3.2.3 Comparative Effect of Temperature on Gel Strength

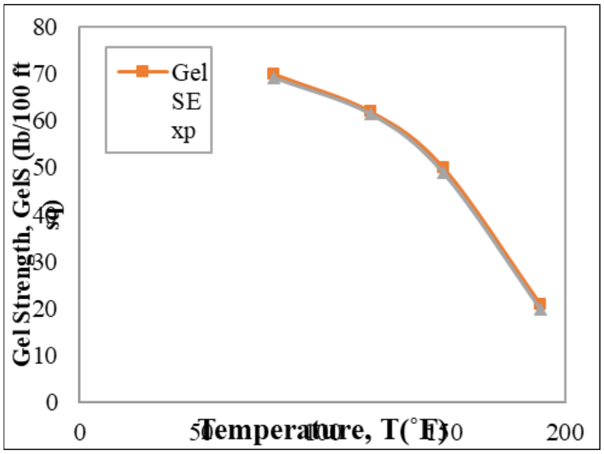

Figure 3: Comparative Temperature Effect on Gel Strength

Gel strength is a property of cement slurries that describes the attractive forces that exist between particles suspended within the mixture. It develops as the slurry remains under static conditions. The effect of temperature on gel strength of cement slurry for the three cases at different temperature values has been simulated and diplayed in Figure 3 below. From the simulation carried out, as the temperature of the cement slurry increased, the gel strength of the cement slurry decreased continously. This signifies the ability of the cement slurry to resist gas invasion after pumping operations have ceased.

3.2.4 Comparative Effect of Temperature on Fluid Loss

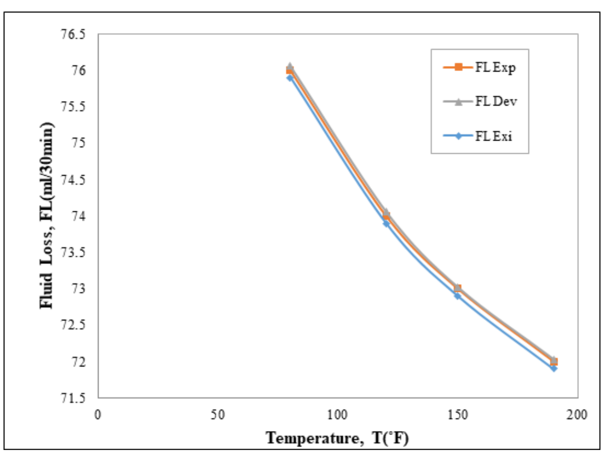

Figure 4: Comparative Temperature Effect on fluid loss

Fluid loss agents are used in cement slurries to minimize cement dehydration in the annulus, reduce gas migration, improve bonding, and minimize formation damage. Figure 4 demonstrates the effect of temperature on fluid loss of cement slurry for the three cases at different temperature values. It was observed that, in the three cases, increase in temperature of the cement slurry lead to decrease in the fluid loss from the cement slurry signifying that the water content of the cement slurry decreases with rise in temperature.

3.2.5 Comparative Effect of Temperature on Thickening Time

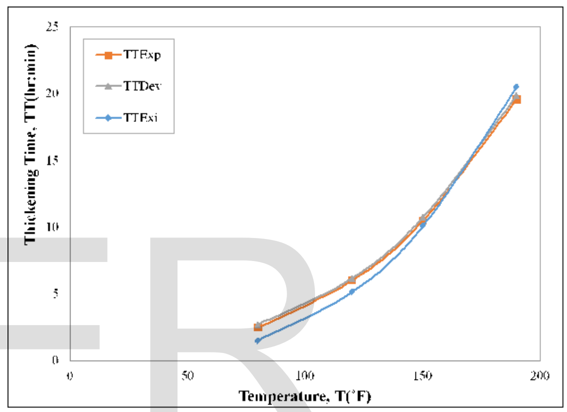

Figure 5: Comparative Temperature Effect on Thickening Time

Thickening time is the time in which cement slurry remains in a fluid state and is capable of being pumped. The simultion displayed in Figure 5 indicates that, with 0.1gal/sk retarder concentration, thickening time increased with rise in temperature of the cement slurry for the three cases considered in this study. This confirms that for a good cementing job, adequate thickening time is required (Umeokafor and Joel, 2010).

The simulations carried out and the results obtained confirmed that, the developed predictive models and analytical application efficiently predicts the effect of temperature on rheological properties of cement slurry with absolute error less than 5% of the experimental result.

4.0 Conclusion

Based on the results obtained from the laboratory experiment conducted, theoretical analysis done through the application created and existing models of rheological properties, the conclusions drawn are as follows:

i. The rheological properties of cement slurry (such as plastic viscosity, yield point, gel strength and fluid loss) decreases as temperature increases.

ii. The flow resistance of the cement decreases with rise in temperature.

iii. Adequate thickening time is required for a good cementing job.

iv. The predictive models developed can be used to carry out theoretical analysis on the rheological properties of cement slurry with temperature variation.

v. The application created serves as an alternative to experiment on the effect of temperature on rheological properties of cement slurry of the same composition used in this study. It saves time and costs associated with laboratory experiment.

vi. The temperature of the well is a determining factor of any cementing job to be done. So, it should put into consideration when preparing the cement slurry.

5.0 Appendices

Appendix A

The results obtained from the experiments conducted at Pollution Control and Environmental Management (POCEMA) LTD are displayed in Tables A.1 – A.4.

Table A.1: Rheology of Neat Cement @ Different Temperatures

RPM	@ 80°F	@ 120°F	@ 150°F	@ 190°F
Θ300	108	113	126	151
Θ200	78	109	102	126
Θ100	65	80	91	122
Θ60	60	73	84	90
Θ30	57	68	81	83
Θ6	27	41	61	75
Θ3	26	30	52	65
PV (cP)	65	50	53	44
YP (lb/100ft²)	43	63	73	107
Density (ppg)	15.0	15.0	15.0	15.0
Free fluid (ml)	1.4	0	0	0

Free fluid (%)	0.56	0	0	0

Source: Pollution Control and Environmental Management (POCEMA) LTD (2018)

Table A.2: Rheological Properties of Cement Slurry with Rheology Enhancer @ Different Temperatures

RPM @ 80°F	80°F Ramp down	80°F Ramp up	Aver-age @ 80°F	120°F Ramp down	120°F Ramp Up	Aver-age @ 120°F	150°F Ramp Down	150°F Ramp up	Aver-age @ 150°F	190°F Ramp down
Θ300(cP)	229	239	234	199	210	205	183	187	185	183
Θ200(cP)	202	202	202	201	201	201	178	178	178	157
Θ100(cP)	160	168	164	138	142	140	129	134	123	118
Θ6(cP)	100	111	110	98	102	100	72	88	80	32
Θ3(cP)	70	-	70	62	-	62	50	-	50	21
PV (cP)	-	-	105	-	-	98	-	-	93	-
YP (lb/100ft²)	-	-	129	-	-	107	-	-	92	-
Slurry weight (ppg)	15.0	-	15.0	-	-	15.0	-	-	15.0	-
Free fluid (ml)		-	0	-	-	0	-	-	0	-
Free fluid (%)	-		0	-	-	0	-	-	0	-

Source: Pollution Control and Environmental Management (POCEMA) LTD (2018)

Table A.3: Result of Thickening Time Test of Neat Cement Slurry

S/N	Temperature, °F	Thickening Time, Hrs: min
1	80	5.01
2	120	4.71
3	150	3.35
4	190	2.31

Source: Pollution Control and Environmental Management (POCEMA) LTD (2018)

Table A.4: Result of Thickening Time Test of Cement Slurry with 0.1% of Rheological Enhancer

S/N	Temperature, °F	Thickening Time ,Hrs: min
1	80	2.50
2	120	6.02
3	150	10.48
4	190	19.58

Source: Pollution Control and Environmental Management (POCEMA) LTD (2018)

Table A.5: Rheological Properties of Cement Slurry at

ISSN 2229-5518

Different Temperatures

Slurry	Temperature (°F)	Density (ppg)	Temperature (°F)	PV (cP)	YP (lb/100ft²)	Gel Strength (lb/100ft²)	Fluid loss (ml/30min)	Thickening Time (hr: min)
1	80	15.00	80	105.03	129.16	69.25	76.06	2.73
2	120	15.00	120	97.95	104.24	61.49	74.06	6.19
3	150	15.00	150	93.37	94.28	48.86	73.02	10.74
4	190	15.00	190	90.35	90.68	19.76	72.03	19.88

Source: Developed Application Software (RP Predictor)

Table A.6: Comparison of Rheological Properties of Cement Slurry obtained at Different Temperatures

Rheological Properties of Cement Slurry	Temperature (°F)	Experimental Result	Theoretical Result (RP Predictor)	Result from Existing Models
PV (cP)	80	105	105.03	105
YP (lb/100ft²)		129	129.16	128.92
GelS (lb/100ft²)		70	69.25	N/A
FL (ml/30min)		76	76.06	75.9
TT (hr:min)		2.50	2.73	1.53
PV (cP)	120	98	97.95	97.5
YP (lb/100ft²)		107	106.80	107.5
GelS (lb/100ft²)		62	61.49	N/A
FL (ml/30min)		74	74.06	73.9
TT (hr:min)		6.02	6.19	5.17
PV (cP)	150	93	93.37	93
YP (lb/100ft²)		92	93.69	92.89
GelS (lb/100ft²)		50	48.86	N/A
FL (ml/30min)		73	73.02	72.9
TT (hr:min)		10.48	10.74	10.09
PV (cP)	190	90	90.35	88.5
YP (lb/100ft²)		89	90.64	90.5
GelS (lb/100ft²)		21	19.76	N/A
FL (ml/30min)		72	72.03	71.9
TT (hr:min)		19.58	19.88	20.49

Appendix B

B.1: Visual Basic.NET Code for Investigating the Effect of Temperature on Rheological Properties of Cement Slurry:

```
'Dimensioning section'
Dim YP AsDouble
Dim PV AsDouble
Dim θ AsDouble
DimPVeAsDouble
Dim PVe1 AsDouble
DimYPeAsDouble
Dim YPe1 AsDouble
DimGelSeAsDouble
DimFLeAsDouble
DimThickTeAsDouble
DimPVdAsDouble
DimYPdAsDouble
DimGelSdAsDecimal
DimFLdAsDouble
DimThickTdAsDouble
Dim T1 AsDouble
Dim V30 AsDouble
Dim Theta AsDouble

IftxtTemp.Text = ""Then
MsgBox("Enter the value of the tempera-
ture")
txtTemp.Focus()
Return
ElseIftxtRPM.Text = ""Then
MsgBox("Specify the input value at
300RPM")
txtRPM.Focus()
Return
ElseIftxtPVI.Text = ""Then
MsgBox("Specify the value of the plastic
viscosity")
txtPVI.Focus()
Return
ElseIf txtV30.Text = ""Then
MsgBox("Specify the volume of filtrate
collected at 30 min")
txtV30.Focus()
Return
EndIf
'Definition or assignment section
        T = txtTemp.Text.ToString()
        Theta = txtPVI.Text.ToString
        θ = txtRPM.Text.ToString
        V30 = txtV30.Text.ToString

'Computation Section'
'For the existing model'
PVe = (θ - theta) * 1.5
YPe = (θ - PVe)
FLe = 10.954 * (V30 / Math.Sqrt(30))

'For the developed model'
       PVd = 112.61541150196 +
       (0.0258883172427886 * T) -
       (0.0020597869461767 * (T ^ 2))  +
       (0.00000687814062183545 * (T ^ 3))
```

```
 YPd = 146.074932023534 +
(0.317501877121686 * T) -
(0.00908757625589374 * (T ^ 2)) +
(0.0000309516327978154 * (T ^ 3))
 GelSd = 68.4931787355454 +
(0.0461007799531217 * T) +
(0.000367705397650298 * (T ^ 2)) -
(0.00001031721093325034 * (T ^ 3))
 FLd = 83.16627122 - (0.121182602 *
T) + (0.00046003 * (T ^ 2)) -
(6.87814 * (10 ^ -7) * (T ^ 3))
 ThickTd = -0.217046635 +
(0.154412985 * T) - (0.0013065 * (T
^ 2)) + (3.03326 * (10 ^ -6) * (T ^
3))

'Output section'
lblPVE.Text = Math.Round(PVe, 4).ToString
lblYPE.Text = Math.Round(YPe, 4).ToString
lblFLE.Text = Math.Round(FLe, 4).ToString
lblGelSE.Text = "Not Available For Now"
lblThickTE.Text = "Not Available For Now"

lblPVD.Text = Math.Round(PVd,
4).ToString()
lblYPD.Text = Math.Round(YPd, 4).ToString
lblGelSD.Text = Math.Round(GelSd,
4).ToString
lblFLD.Text = Math.Round(FLd, 4).ToString
lblThickTD.Text = Math.Round(ThickTd,
4).ToString

       txtPVI.Clear()
txtTemp.Clear()
txtRPM.Clear()
txtV30.Clear()
lblPVD.Text = ""
lblPVE.Text = ""
lblYPD.Text = ""
lblYPE.Text = ""
lblGelSD.Text = ""
lblGelSE.Text = ""
lblFLD.Text = ""
lblFLE.Text = ""
lblThickTD.Text = ""
lblThickTE.Text = ""
txtTemp.Focus()
```

ACKNOWLEDGMENT

My gratitude goes to Mr. Sam Victor for his unending support in the course of this work.

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