بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Petroleum and Mining Engineering

Department of Petroleum Engineering

Project title:

Squeeze Cement Volume Estimation

(Case Study Hamra Field – Sudan)

تقدير حجم الاسمنت المضغوط

(دراسة حالة حقل هجليج النفطي -السودان)

Submitted in Partial Fulfillment of the Requirements of the Degree of B.Sc. in Petroleum Engineering

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November 2020

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Date: / / 2020

بسم الله الرحمن الرحيم

الإستهلال

سورة (الفاتحة) الجزء (١) صفحة (١)

سُورَةُ الفَاتِحَةِ

بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ ①
ٱلۡحَمۡدُ لِلَّهِ رَبِّ ٱلۡعَٰلَمِينَ ②
ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ ③ مَٰلِكِ يَوۡمِ ٱلدِّينِ ④
إِيَّاكَ نَعۡبُدُ وَإِيَّاكَ نَسۡتَعِينُ ⑤ ٱهۡدِنَا
ٱلصِّرَٰطَ ٱلۡمُسۡتَقِيمَ ⑥ صِرَٰطَ ٱلَّذِينَ أَنۡعَمۡتَ
عَلَيۡهِمۡ غَيۡرِ ٱلۡمَغۡضُوبِ عَلَيۡهِمۡ
وَلَا ٱلضَّآلِّينَ ⑦

Dedication

We would like to donate this unpretentious effort to

Our Parents;

Who have endless presence and for the never ending love and encouragement

Our brothers and sisters;

Who sustained us in our life and still

Our teachers;

Who lighted candle in our ways and provided us with light of knowledge

Finally; our best friends;

Our Classmates

Researchers…

Acknowledgements

Thanking to Allah before and after...

First and foremost; the greatest thanking to **our teachers** for their continuous support... and for their great efforts, they were the best guide and ad monitor...

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Finally; thanking to our colleagues and workers at College of Petroleum Engineering & Technology for their cooperation...

ABSTRACT

The volume of squeeze cementing process is a key factor for well intervention cost. In Sudanese oilfield, the estimation of squeeze volume has many limitations; this study is trying to estimate the optimum volume squeeze cement that depends on many operational factors.

In this study the squeeze volume has been divided into many portions, the most important part is to predict the squeezed volume inside the formations; this point had been achieved via statistical analysis method using Mini-Tab (statics software), the model that has been built can predict the value of squeezed volume with a R^2 value equal to 0.78 this value present the importance of the variable that did not taken in the model.

The study procedure found that, if the study had been utilized about 40% of cement slurry would not be mixed, therefore 1346 meter of cement would not be drilled at all.

Key Word:
Squeeze, Workover, secondary cement, statistical analysis, Screening Data, balance plug.

التجريد

الحجم اللازم لعملية الاسمنت المضغوط هو العامل الرئسي في تحديد التكلفة في البئر، في حقول النفط السودانية تحديد حجم الاسمنت المضغوط ذو محدودية ، تحاول هذه الدراسة تقدير الحجم الامثل للاسمنت المضغوط الذي يعتمد على العديد من العوامل التشغيلية .

في هذه الدراسه تم تقسيم حجم الاسمنت اللازم لعمليه الاسمنت المضغوط الى عده أجزاء، أهم جزء هو تقدير الحجم المضغوط داخل الطبقة ، تم تحقيق هذا الهدف عن طريق التحليل الاحصائي باستخدام (Mini-Tab) ، يمكن للمعادلة التي تم انشاؤها التنبؤ بقيمة حجم الاسمنت المضغوط بدلاله R^2 =0.78 هذه القيمه توضح أهمية المتغيرات الذي لم تؤخذ بالاعتبار.

في هذه الدراسة وجد انه اذا تم استخدام هذه المعادلة فلن يتم خلط حوالي 40% من حجم الاسمنت المخلوط وبالتالي لن يتم حفر 1346 متر من الاسمنت على الاطلاق.

كلمات مفتاحية :

المضغوط،تحليل احصائي،السمنته الاوليه،تصفية البيانات،الاسمنت المضغوط.

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NOMENCLATURE

STC	Saw Tooth Color
DCR	Drainable Cement Retainer
TOC	Top of Cement
TOP	Top of Top Perforation
BTM	Bottom of Bottom Perforation
GOR	Gas Oil Ratio
WOR	Water Oil Ratio

Chapter 1

Chapter One

Introduction

1.1 Introduction:

work over operations are more costly due to rig hire , tools and jobs , in squeeze operations The cement slurry usually represents less than 15% of the total job cost.

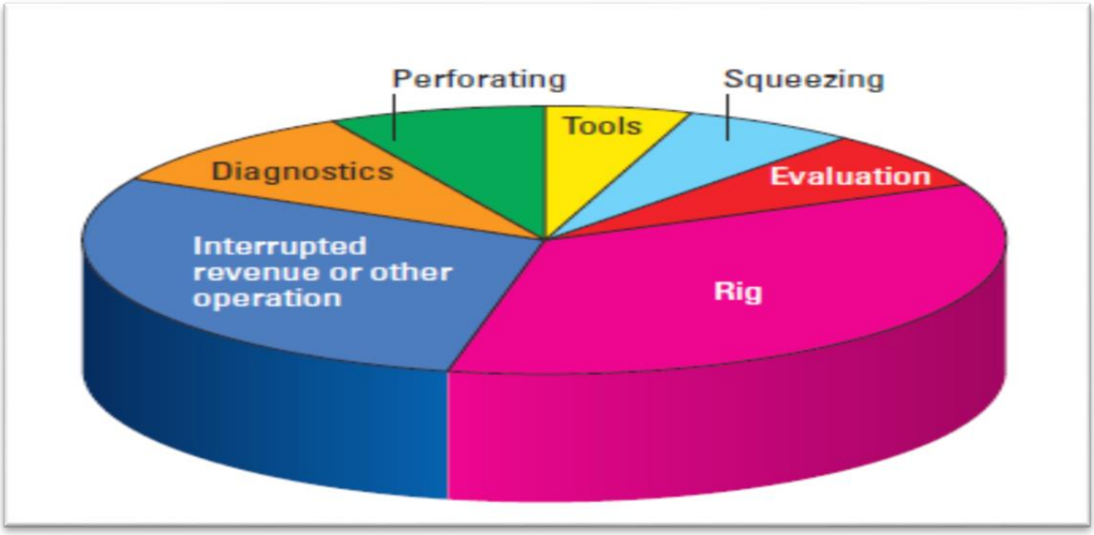


Fig (1.1): Total Cost Subdivision. (Erik B. Nelson and Dominique Guillot, 2006).

Squeeze cement is the process of forcing cement slurry into the perforations in the casing and behind the casing, Squeeze cement job usually applies in routine workover operation well.

It is commonly performed for the following purposes:

- Repair a primary cement job that failed.
- Repair casing leaks due to corrosion or split pipe.
- Sealing lost-circulation zones.
- Reducing the producing GOR or WOR by isolating the gas or water zones from adjacent oil intervals.

In this project, we will try to optimize squeeze cement volume to reduce total cost and prevent failure.

- When we pump volume, less than required, squeeze process may be fails.
- When we pump volume more than required, we need more time to drill it and more cost.

1. 2 Field Background:

Heglig oil field is one of the largest fields of oil and gas deposits in Sudan. It has been the site of conventional petroleum production for more than one decade (since 1999), but recently it has become producing water exceed the economic range. Heglig field is located in southeast and middle of Block 2B, Muglad Basin, discovered by Chevron. It consists of 10 fields (Heglig main, Toma, El Bakh, El Full, Laloba, Kanga, Barki, Hamra, Simbir East and Rihan). A general structure which follows average distance between fields is about 3 to 5 km. 8 layers are developed i.e., Aradeiba main, Aradeiba B, Aradeiba E, Aradeiba F, Bentiu-1, Bentiu-2 and Bentiu-3 and Abu Gabra. First Field Devolved Plan (FDP) was carried out in 1998. Last FDP was carried out in 2011. Field development started in June 1999 with development of 29 wells i.e., Heglig main (17), Toma (4), Barki (3),Hamra (2), El FulI (2)wells and El Bakh (1) well (Fatima - 2018).

1.3 Problem Statement:

Estimating the volume of squeeze cement slurry in Sudanese field has many limitations in calculate volume of cement slurry and it depend only on feed rate test.

this project attempt to determine the optimum volume of cement for squeeze cement job in Hamra field by Statistical analysis using mini-tab program.

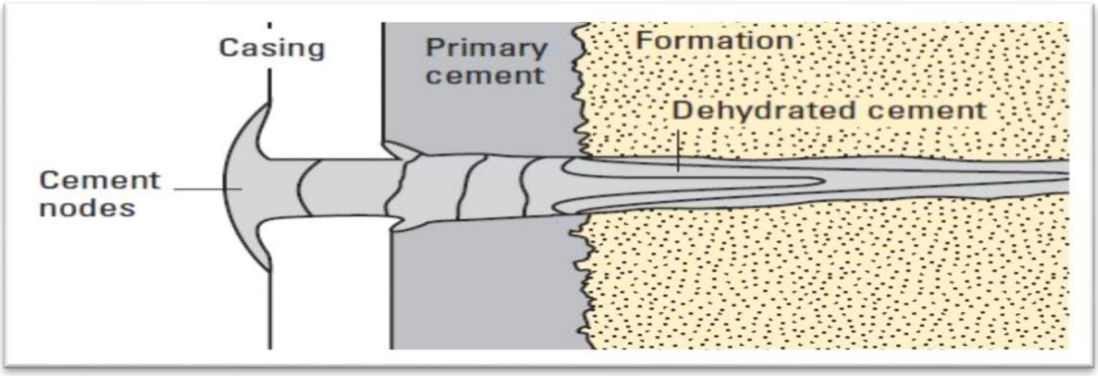


Fig (1.2): Distribution of Cement In Formation. (Erik B. Nelson and Dominique Guillot, 2006).

1.4 Methodology:

1. Data preparation and screening.
2. Statistical analysis using mini-tab program.
3. Make comparison.
4. Estimation of cost reduction.

1.5 Research Objectives:

The main objective of this work is the diagnosis of the squeeze cement jobs through different wells in Heglig oil field, which include:

1. Screening data from several reports.
2. Formulate an equation to estimate squeezed volume in Hamra field.
3. Determine optimum squeeze cement volume for each job.
4. Compare between optimum squeeze cement and actual squeeze cement volume for each case.

Chapter 2

Chapter Two

Theoretical Background and Literature Review

This chapter presents the background of cement & squeeze cement techniques along with literature review.

2.1 Theoretical Background:

2.1.1 Introduction:

When the well is while drilling, and set casing drilling engineering needs to make sure the well wall is stable and fluid from the formations does not penetrate into the well, this is done by techniques called cementing .the method of doing this is to pump cement down the inside of the casing and through the casing shoe into the annulus This operation is known as a primary cement job, Another type of cement job that is performed in oil and gas well operations is called a secondary or squeeze cement job. This type of cement job may have to be done at a later stage in the life of the well. (Heriot Watt, 2006).

2.1.2 Cementing:

Cementing is the process of placing a cement slurry in a well by mixing powdered cement additives, and water at the surface and pumping it by hydraulic displacement to the desired location, The drilling engineer is concerned with the selection of the best cement composition and placement technique for each required application. (Robert F. Mitchell ,Stefan Z. Miska,2011).

2.1.2.1 Functions of Cement:

There are many reasons for using cement in oil and gas well, the most important functions of a cement sheath between the casing and borehole are:

1. To prevent the movement of fluids from one formation to another or from the formations to surface through the annulus between the casing and borehole.
2. To support the casing string (specifically surface casing).
3. To protect the casing from corrosive fluids in the formations. (Heriot Watt, 2006).

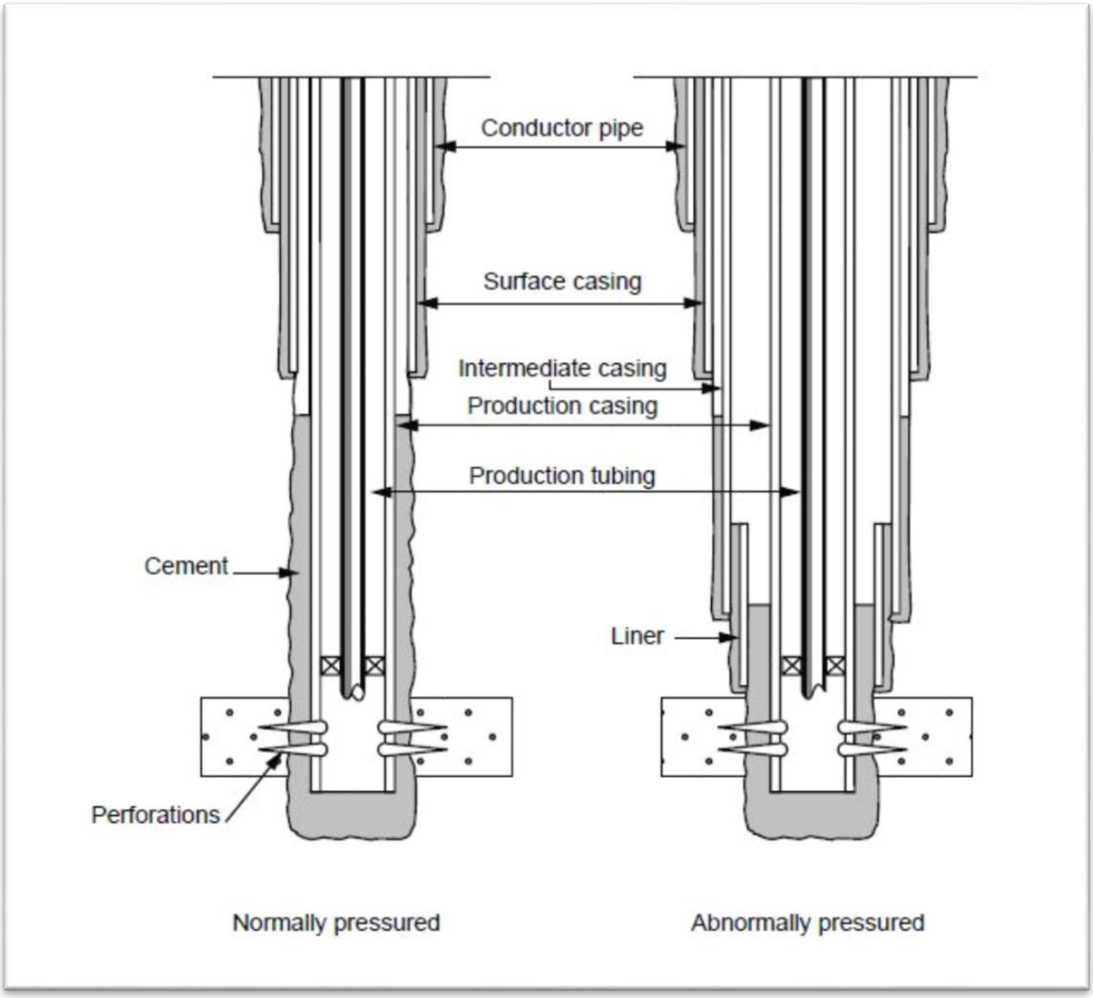
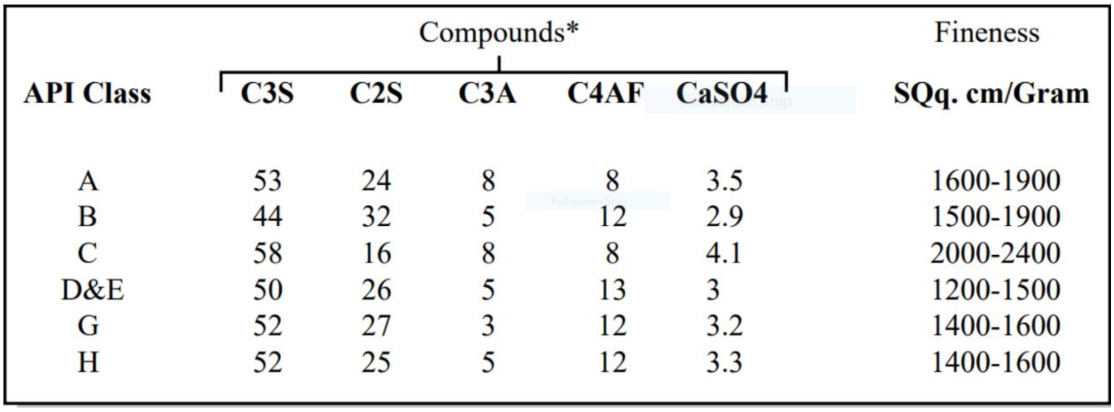


Fig 2.1: Function of Primary Cementing (Heriot Watt, 2006).

2.1.2.2 Composition of Cements:

The cement slurry is made up from cement powder; water; and chemical additives. There are many different grades of cement powder manufactured and each has particular attributes, which make it suitable for a particular type of operation. The water used may be fresh or salt water. The chemical additives, which are mixed into the cement slurry, alter the properties of both the cement slurry and the hardened cement. (Heriot Watt, 2006).



	Compounds*					Fineness
API Class	C3S	C2S	C3A	C4AF	CaSO4	SQq. cm/Gram
A	53	24	8	8	3.5	1600-1900
B	44	32	5	12	2.9	1500-1900
C	58	16	8	8	4.1	2000-2400
D&E	50	26	5	13	3	1200-1500
G	52	27	3	12	3.2	1400-1600
H	52	25	5	12	3.3	1400-1600

Fig 2.2: Composition of API Cements (Heriot Watt, 2006).

Each cement job must be carefully planned to ensure that the correct cement and additives are being used, and that a suitable placement technique is being employed for that particular application.

There are several classes of cement powder, which are approved for oil well drilling applications, by the American Petroleum Institute – API:

Classes A and B: These cements are generally cheaper than other classes of cement and can only be used at shallow depths, where there are no special requirements. Class B has a higher resistance to sulphate than Class A.

Class C: This cement has a high C3S content and therefore becomes hard relatively quickly.

Classes D, E and F: These are known as retarded cements since they take a much longer time to set hard than the other classes of cement powder.

This retardation is due to a coarser grind. These cement powders are however more expensive than the other classes of cement and their increased cost must be justified by their ability to work satisfactorily in deep wells at higher temperatures and pressures.

Class G: Used over a wide range of temperature and pressure and the most common type of cement.

Class H: Has a coarser grind than Class G and gives better retarding properties in deeper wells. (Heriot Watt, 2006).

2.1.2.3 Cement Additives:

Most cement slurries will contain some additives, to modify the properties of the slurry and optimize the cement job. Most additives are known by the trade names used by the cement service companies. Cement additives can be used to:

1. Vary the slurry density.
2. Change the compressive strength.
3. Accelerate or retard the setting time.
4. Control filtration and fluid loss.
5. Reduce slurry viscosity.

- **Several Additives:**

1- Accelerators: Accelerators are added to the cement slurry to shorten the time taken for the cement to set. These are used when the setting time for the cement would be much longer than that required to mix and place the slurry.

2- Fluid loss additives: Fluid loss additives are used to prevent dehydration of the cement slurry and premature setting.

3- Heavyweight additives: Heavyweight additives are used when cementing through over pressured zones.

4- Lightweight additives (Extenders): Extenders are used to reduce slurry density for jobs where the hydrostatic head of the cement slurry may exceed the fracture strength of certain formations.

2.1.2.4 Cement Parameters (properties):

The properties of specific cement slurry will depend on the particular reason for using the cement; however, there are fundamental properties, which must be considered when designing any cement slurry.

- **Compressive Strength:** The casing shoe should not be drilled out until the cement sheath has reached a compressive strength of about 500 psi. This is generally considered to be enough to support a casing string and to allow drilling to proceed without the hardened cement sheath, disintegrating, due to vibration.
- **Thickening Time (pump ability):** The thickening time of cement slurry is the time during which the cement slurry can be pumped and displaced into the annulus.
- **Water Loss:** The amount of water loss that can be tolerated depends on the type of cement job and the cement slurry formulation.
- **Corrosion Resistance:** Formation water contains certain corrosive elements which may cause deterioration of the cement sheath.
- **Permeability:** After the cement has hardened the permeability is very low (<0.1 mille Darcy). This is much lower than most producing formations. However if the cement is disturbed during setting (e.g. by gas intrusion) higher permeability channels (5 - 10 Darcie’s) may be created during the placement operation.
- **Fluid Loss:** Fluid-loss tests are designed to measure the slurry dehydration during, and immediately after cement placement. Under simulated wellbore conditions.

- **Rheology:** Ensuring that the rheological behavior of the slurry downhole is similar to that specified in the design is essential for effective cement placement.(H.rabia,2001).

2.1.2.5 Types Of Cementing Operation:

2.1.2.5.1 Single Stage Cementing Operation:

The single stage procedure can be summarized as follows:

1. Circulate the casing and annulus clean with mud (one casing volume pumped).
2. Release wiper plug.
3. Pump spacer.
4. Pump cement.
5. Release shut-off plug.
6. Displace with displacing fluid (generally mud) until the shut-off plug lands on the float collar.
7. Pressure tests the casing. (Heriot Watt, 2006).

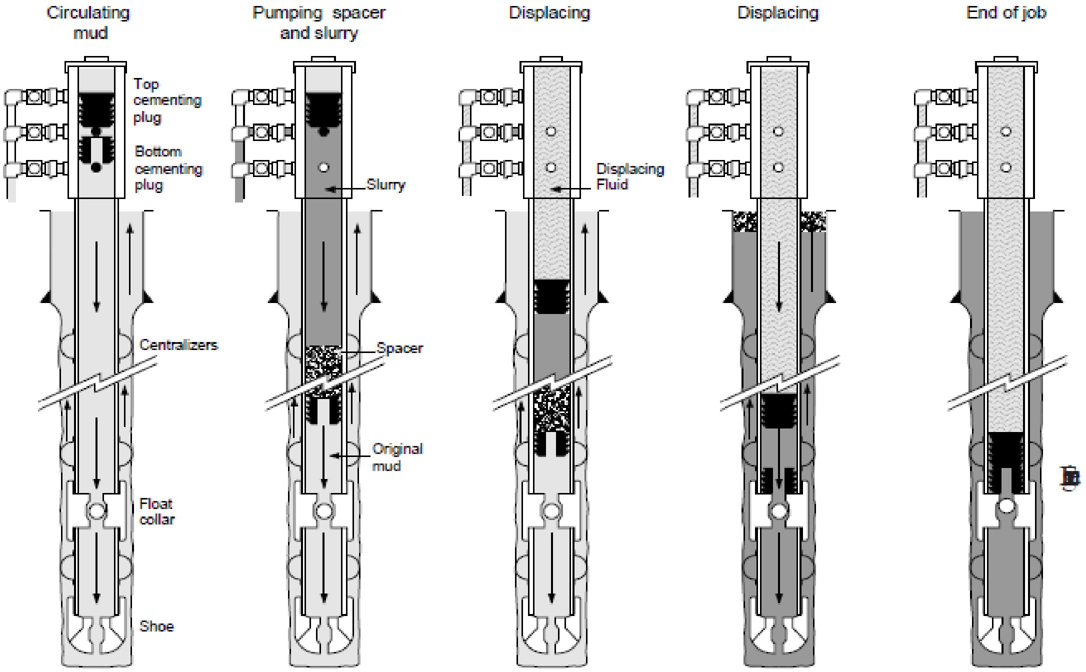


Fig (2.3): Single Stage Cementing Operation (Heriot Watt, 2006).

2.1.2.5.2 Multi-Stage Cementing Operation:

When a long intermediate string of casing is to be cemented it is sometimes necessary to split the cement sheath in the annulus into two, with one sheath extending from the casing shoe to some point above potentially troublesome formations at the bottom of the hole, and the second sheath covering shallower troublesome formations. (Heriot Watt, 2006).

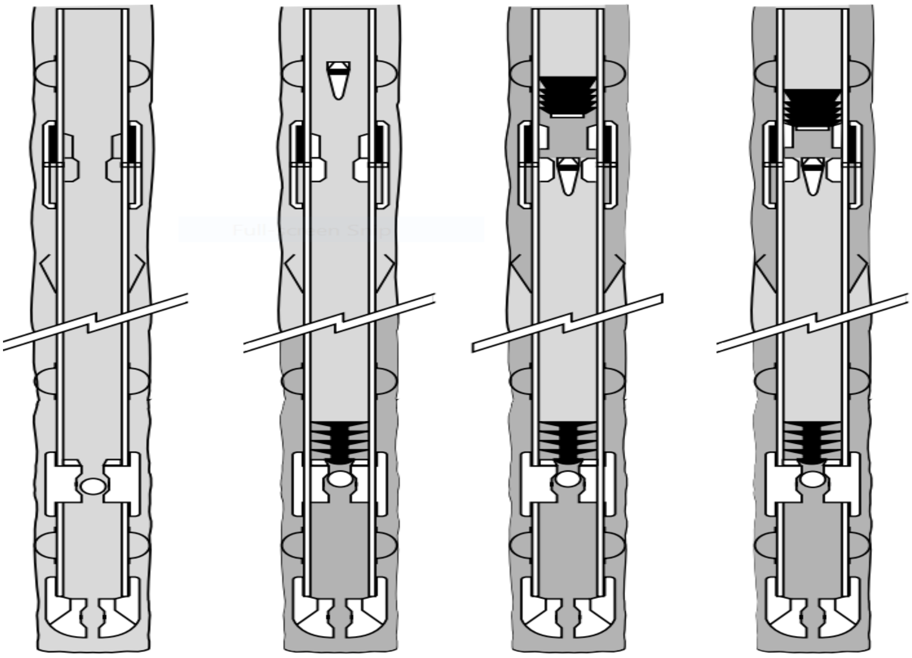


Fig (2.4): Multi-Stage Cementing Operation (Heriot Watt, 2006).

The procedure for conducting a multi-stage operation is as follows:

First stage: The procedure for the first stage of the operation is similar to that described in single stage above, except that a wiper plug is not used and only a liquid spacer is pumped ahead of the cement slurry. The conventional shut-off plug is replaced by a plug with flexible blades. This type of shut-off plug is used because it has to pass through the stage-cementing collar, which will be discussed below. It is worth noting that a smaller volume of cement slurry is used, since only the lower part of the annulus is to be cemented. The height of this cemented part of the annulus will depend on the fracture gradient of the formations which are exposed in the annulus (height of 3000' - 4000' above the shoe is common).

Second stage: The second stage of the operation involves the use of a special tool known as a stage collar, which is made up into the casing string at a pre-determined position. The position often corresponds to the depth of the previous casing shoe. The ports in the stage collar are initially sealed off by the inner sleeve. This sleeves held in place by retaining pins. After the first stage is complete a special dart is released form surface which lands in the inner sleeve of the stage collar. When a pressure of 1000 - 1500 psi is applied to the casing above the dart, and therefore to the dart, the retaining pins on the inner sleeve are sheared and the sleeve moves down, uncovering the ports in the outer mandrel. Circulation is established through the stage collar before the second stage slurry is pumped. (Heriot Watt, 2006).

2.1.3 Squeeze Cement:

Squeeze cementing is the process by which hydraulic pressure is used to force cement slurry through holes in the casing and into the annulus and/or the formation. Squeeze cement jobs are often used to carry out remedial operations during a workover on the well. (Heriot Watt, 2006).

2.1.3.1 Application of Squeeze Cement:

According to Erick B. Nelson (2006) as mentioned earlier, squeeze cementing has many applications:

1. Repairing a primary cement job that has failed because of mud channeling or insufficient cement height in the annulus.
2. Eliminating water intrusion from above, below, or within the hydrocarbon-producing zone.
3. Reducing the producing GOR or WOR by isolating the gas or water zones from adjacent oil intervals.
4. Repairing casing leaks caused by corroded or split Pipe.

5. Abandoning a nonproductive or depleted zone.
6. Plugging one or more zones in a multi zone injection well to direct the injection into the desired intervals.
7. Sealing lost-circulation zones.
8. Protecting against fluid migration into a producing Zone.

2.1.3.2 Squeeze Cementing Techniques:

There are two traditional and fundamentally different squeeze job classifications:

- Low-pressure squeeze: The bottom hole treating pressure is maintained below the formation fracturing pressure, the cement-slurry volume is usually small. Because no slurry is actually pumped into the formation, in low-pressure squeezes, it is essential that perforations and channels be clear of mud or other solids.
- High-pressure squeeze: The bottom hole treating pressure exceeds the formation fracturing pressure, in some cases; a low-pressure squeeze of the perforations will not accomplish the job objective. The channels behind the casing may not be directly connected to the perforations. (Erik B. Nelson and Dominique Guillot, 2006).

2.1.3.3 Placement Techniques:

There are three main placement techniques for carrying out a squeeze:

1. Bradenhead placement.
2. Retrievable squeeze packer.
3. Drillable cement retainer.

1. **Bradenhead Squeeze (no packer):** The Bradenhead squeeze technique is a low-pressure squeeze technique practiced when there are no doubts concerning the casing’s ability to withstand the squeeze pressure. No special tools are involved, although a bridge plug may be required to isolate other open perforations farther downhole. Open-

ended tubing is run to the bottom of the zone to be cemented. Blowout preventer (BOP) rams are closed over the tubing, and an injection test is performed. The cement slurry is subsequently spotted in front of the perforations. Once the cement is in place, the tubing is pulled out to a point above the cement top, the BOPs are closed, and pressure is applied through the tubing. The Bradenhead squeeze is popular because of its simplicity. (Erik B. Nelson and Dominique Guillot, 2006).

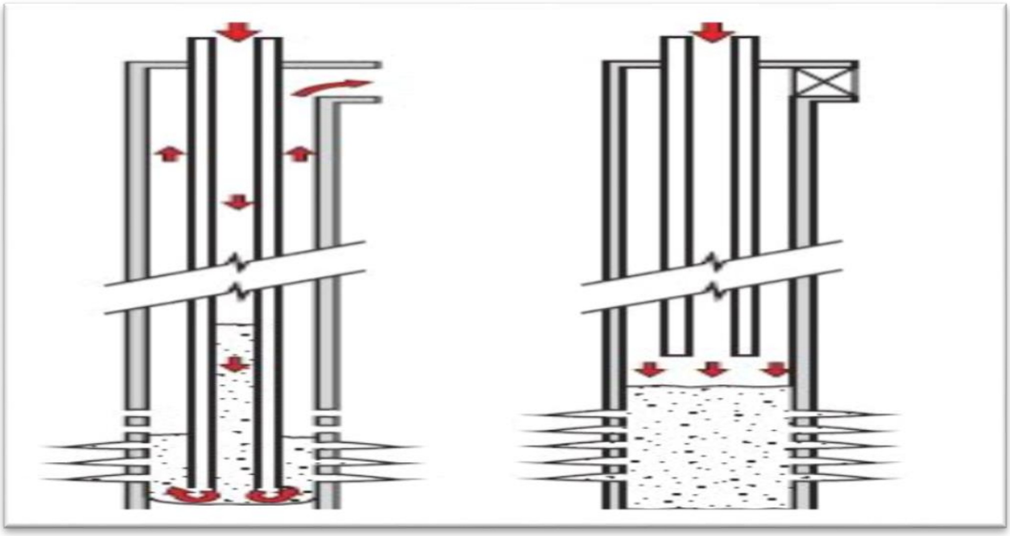


Fig (2.5): Bradenhead Squeeze Technique (Erik B. Nelson and Dominique Guillot, 2006).

2. **Retrievable Squeeze Packer:** The main objective of using a packer is to isolate the casing and wellhead while high pressure is applied downhole. The advantage of the retrievable packer is the fact that it can be set and released many times Retrievable squeeze packers can be either compression set or tension set. Compression set packers are generally preferable based on industry experience.

   Squeeze packers have a by-pass valve to allow circulation of fluids while running in and pulling out of the hole (to prevent high swab and surge pressures) and also when the packer has been set (for reversing out of excess cement without excessive pressures).

3. **Drillable Cement Retainer:** Cement retainers are drillable packers provided with a two-way valve that prevents flow in either or both directions. The valve is operated by a stinger run at the end of a work string. Drillable cement retainers run on wireline are used instead of packers to prevent backflow when no dehydration of cement is expected, or when high negative differential pressures may disturb the cement cake, when cementing multiple zones, the cement retainer isolates the lower perforations and subsequent zone squeezing can be carried out without having to wait for the cement to set. (H.rabia, 2001).

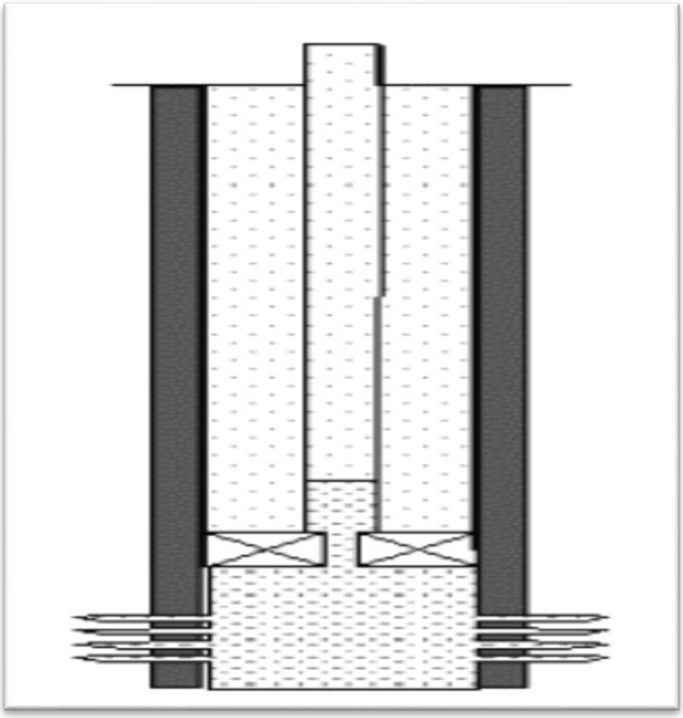


Fig2.6: Drillable Cement Retainer (H.rabia, 2001).

2.1.3.4 Evaluation of Squeeze Job:

According to Nelson 2006, the extent to which one must evaluate the results of a squeeze job depends on the requirements of the subsequent operations to be performed on the well. As a preliminary step before an evaluation, the state of the wellbore is checked to detect the presence of cement nodes that may restrict passage of downhole tools. An under reaming operation is eventually performed. Also, the rat hole is checked for the presence of cement:

1. Temperature Log: When a high-pressure squeeze job is performed to ensure that a subsequent fracturing treatment will stimulate a target zone, a temperature log can locate the cement and indicate if any slurry was injected outside of the perforated interval (Krause and Reem, 1992).

Goolsby (1969) evaluated squeeze results on water injection wells by comparing pre- and post squeeze temperature profiles. By logging the well temperature after a post squeeze injection test, he was able to demonstrate that the well accepted the injection water at the planned location.

2. Positive And Negative Pressure Tests: Plugged perforations are evaluated by performing a positive or negative pressure test. A positive pressure test subjects the well to a given pressure and determines whether fluid can be injected into the formation. A negative pressure test, also known as an inflow test, subjects the well to a pressure reduction and is used to determine how effectively the plugged perforations prevent the ingress of fluids from the formation. The test pressure is usually that which the well is expected to experience during injection or production; it is determined during the job-design phase (Walker et al., 1992).

The negative pressure test is performed as follows:

- Placing a light brine across the perforations.
- Swabbing the well.
- Running a dry test.

3. Production Changes: One of the most common ways to evaluate a remedial treatment is to compare the well production rates before and after the treatment.

4. Cement Hardness: If well cleanup was not performed after the squeeze, the cement in the wellbore is drilled out. For such jobs,Suman and Ellis (1977) reported that a good indication of success is the nature of the cuttings. If the cement is hard throughout, the results are usually good. However, soft spots or voids are not necessarily indicative of a failure.

5. Radioactive Tracers: Radioactive materials may be added to the cement slurry, and subsequent tracer surveys can indicate whether the cement is placed in the desired interval. The isotopes 131I, 192 Ir, and 46Sc are appropriate because of their short half-lives—8 days, 75 days, and 85 days respectively. The iridium and scandium radioisotopes are preferable, because iodine (present as iodide) is soluble and may be squeezed out of the cement with the filtrate.

6. Acoustic Logs: When the objective of the squeeze is to repair a primary cementing job, cement logs should be run to evaluate the effectiveness of the repair by comparing pre squeeze and post squeeze.

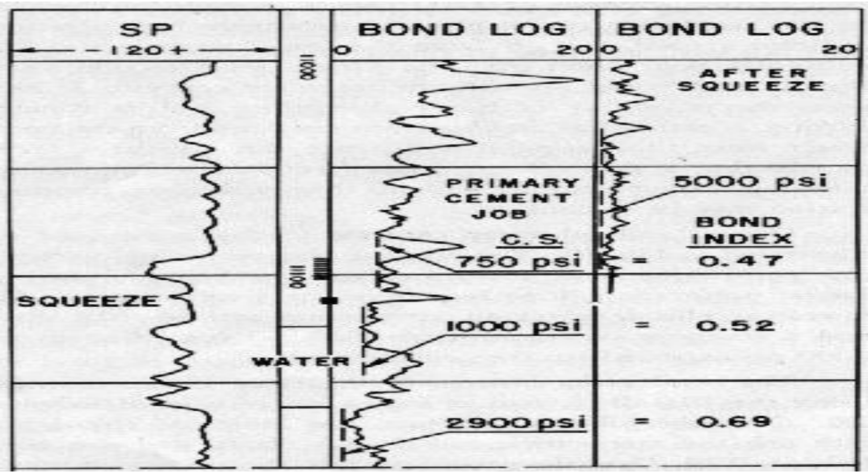


Fig (2.7): Acoustic logs (Walker et al, 1992).

2.1.3.5 Reasons for Squeeze Cementing Failures:

Whenever a squeeze treatment fails to meet its objectives, a thorough investigation must be conducted to analyze the job, understand why a failure occurred, and improve the design of subsequent treatments. Squeeze failures may originate from misconceptions of what a squeeze treatment is and what actually happens downhole.

- **Common Reason For Failure:**

1. Improper Slurry Selection: The cement slurry does not penetrate the pores of the rock. Only the mix-water and dissolved substances penetrate the pores, while the solids accumulate at the formation face and form the filter cake. It would require a permeability higher than 100 D for solids from a conventional Class G cement to penetrate a sandstone matrix. Even micro fine cements have limited penetration, if any, through porous media. The only way for a slurry to penetrate a formation is through fissures, fractures, and large holes (vugs).

2. Excessive Final Squeeze Pressure: A high final squeeze pressure does not increase the chance of success; on the contrary, it increases the chance of fracturing the formation and losing control of the cement-slurry placement. Once created, a fracture may extend across various zones, and open unwanted channels of communication between previously isolated zones. It is important that a “think downhole” attitude be developed among all personnel involved in this operation.

3. Plugged Perforations: Another common misconception concerning squeeze cementing is that all perforation holes are open and receptive to fluids (Rike and Rike, 1981). Such an assumption can lead to failure. The mud filter cake, which is capable of withstanding a large differential pressure when applied from the wellbore toward the formation, cleans up easily when submitted to a differential pressure in the other direction. In addition to mud cake, debris, scale, paraffin, formation sand, pipe dope, rust, and paint can accumulate and plug the perforations. Goodwin (1984) reported that, in a producing well, the upper perforations are usually open, while the plugged perforations are generally found in the lower zones. Squeezing under such conditions will not fill all of the perforations with cement. Following the treatment, the perforations not plugged with cement will allow entry of formation fluids into the well. Perforation washing before the squeeze job helps to render all perforations receptive to the squeeze cement slurry.

4. Improper Packer Location: If the packer is set too high above the perforations, the cement slurry will become contaminated as it channels through the mud completion fluid Slurry properties such as fluid loss, thickening time, and viscosity are adversely affected by contamination, and slurry placement results are altered.

2.1.3.6 Squeeze Cementing for Perforation Theory:

During most squeeze cementing treatments, the particles in the cement slurry are too large to enter the formation matrix. As a result, an external cement filter cake accumulates, fills the perforations, and forms nodes that protrude into the wellbore. When a volume of slurry, V slurry, containing a solid volume fraction, f sv, is forced against a porous medium, a liquid filtrate of volume V filt passes into the medium. The solids that remain behind produce a filter cake of porosity φ. mathematically, this is written as follows.

- Solids volume fraction:

$$\mathrm{fsv} = \frac{\mathrm{V_{solids}}}{\mathrm{V_{slurry}}} \tag{2.1}$$

- Conservation of volume:

$$\mathrm{V_{slurry}} = \mathrm{V_{filt}} + \mathrm{V_{f}} \tag{2.2}$$

Where:

V_{fc}= filter cake volume

- Cake porosity:

$$\mathrm{V_{fc}} = (\emptyset \times \mathrm{V_{fc}}) + \mathrm{V_{solids}} \tag{2.3}$$

$$\mathrm{V_{fc}} = \frac{\mathrm{f_{sv}}}{1 - \mathrm{f_{sv}} - \emptyset} \mathrm{V_{filt}} = \mathrm{wV_{filt}} \tag{2.4}$$

The factor $\left(\frac{f_{sv}}{1-f_{sv}-\emptyset}\right)$ is called the deposition factor, *w*. It corresponds to the ratio of the filter cake volume to the filtrate volume and can be measured by a standard American Petroleum Institute (API) or International Organization for Standardization (ISO) fluid-loss test. Experimentally, one observes that this factor is almost constant when the differential pressure is varied, indicating that cement filter cakes are incompressible. A neat 15.8-lbm/gal [1,900-kg/m3] cement slurry has a solids volume fraction of 40%. The porosity of cement filter cakes from this system is usually about 30%. Thus, a typical value for the deposition factor is about 1.3.

To determine the time required to build a filter cake of given height h_{fc} under a constant filtration pressure, Δp, Darcy's law is frequently used under the assumption that the pressure drop is constant throughout the cake. The following relationship is obtained where the cake Permeability is K_{fc} and the filtrate viscosity is μ_{filt}:

$$h_{fc} = \sqrt{\frac{2K_{fc}\times w\times\Delta p}{\mu_{filt}}}\times\sqrt{t}\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(2.5)}$$

Expressed in terms of the API/ISO fluid loss of the slurry, *VAPI*, the cake height is:

$$h_{fc} = w\times\frac{V_{API}}{A_{API}}\times\sqrt{\frac{\Delta p}{\Delta p_{API}}}\times\sqrt{\frac{t}{t_{API}}}\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(2.6)}$$

Where the subscript API refers to API/ISO conditions:

A_{API} = 3.5 in2, Δp_{API} = 1000 psi, and t_{API} = 30 min.

The time required to build a cake of height $h_{fc}$is therefore:

$$t = t_{API}(h_{fc}\frac{A_{API}}{wV_{API}})^2\,\frac{\Delta p_{API}}{\Delta p} \approx \frac{6.1\times10^7}{\Delta p}\,(\frac{h_{fc}}{wV_{API}})^2\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(2.7)}$$

It is important for the reader to realize that the above equations provide an approximate model to determine the relative orders of magnitude of relevant squeeze cementing parameters. Some caution should be exercised when attempting to use these equations to describe real downhole conditions.

The squeezing process is divided into three successive steps:

1. Filling of perforation tunnels located inside the formation
2. Filling of perforation tunnels crossing the casing and cement sheath.
3. Building cement nodes.

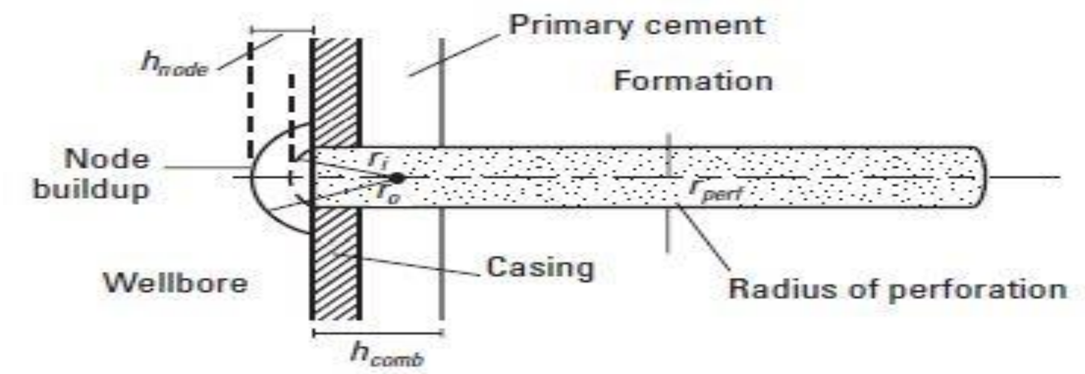


Fig (2.8):Node Buildup (Erik B. Nelson and Dominique Guillot, 2006).

2.1.3.6.1 Displacement Volume For A Squeeze Operation:

The maximum displacement volume for a cement squeeze operation corresponds to the volume from the surface down to the top perforations to be squeezed. Safety margin is added, usually a few barrels. Like balanced plugs, the maximum displacement volume for squeeze operations may be uncertain owing to factors such as pump efficiency, variability of the internal pipe volume, and fluid compressibility.

The pressure attained during a squeeze operation is much greater than that attained during primary cementing, so fluid compressibility plays a larger role. When the squeeze is performed in an open hole section, the formation has a tendency to expand, leading to a hole-volume increase.

The duration of a squeeze operation can be long, and the cement-slurry temperature will have more time to equilibrate with the formation temperature.

2.1.3.6.2 Injection Test:

Before mixing and pumping the cement slurry, an injection testis performed. This procedure consists of pumping a fluid, typically water, into the well.

The injection testis performed for several reasons:

1. To ensure that the perforations are open and ready to accept fluids (for small leaks, an injection test helps determine whether it will be possible to inject a fluid, and the expected treatment pressure and rate.
2. To obtain an estimate of the proper cement-slurry injection rate.
3. To estimate the pressure at which the squeeze job will be performed.
4. To estimate the volume of slurry to be used volume.

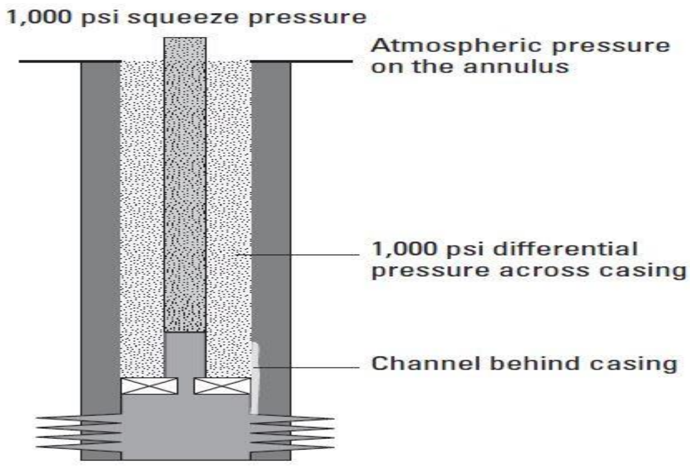


Fig (2.9): Injection Test (Erik B. Nelson and Dominique Guillot, 2006).

The most important factors to consider are the following:

1. The friction pressure developed as the fluid flows through the pipe should be calculated and subtracted from the pump pressure. If possible, monitor the annular pressure.

2. To prevent perforation plugging, the injected fluids must be clean, and the wellbore should be circulated before injection.
3. The injection should proceed until the pressure stabilizes, typically 10–15 min.
4. The injection rate should be maintained below the fracturing pressure.
5. Operational procedures should be consistent between different wells in the same field to obtain meaningful comparisons.
6. A fluid with a viscosity between 50 and 200 cp should be used. The tighter the formation, the lower the viscosity should be. The viscosity should be measured at the anticipated treatment temperature.
7. The fluid should be clean to facilitate flow through the formation. Fully hydrated biozan, xanthan, or polyacrylamide fluids are suitable. (Erik B. Nelson and Dominique Guillot, 2006).

2.1.3.6.3 Determination of injection pressure and rate:

The goal of the injectivity test is to collect data about the expected pressure to be applied during a low-pressure squeeze treatment. Depending on the measured pressure, a perforation wash treatment may be applied before the squeeze job to increase injectivity or the squeeze-fluid composition may be altered. The test consists of injecting a fluid such as water through the perforations for several minutes at a rate close. (Erik B. Nelson and Dominique Guillot, 2006).

2.2 Literature Review:

J.L.RIKE 1973 they provided a review of fundamental principles of squeeze cement process; they discussed impact of squeeze pressure in cement slurry volume required.

A high-pressure squeeze requires mixing relatively large cement volumes, usually100 to 500 sacks.

At low pressure squeeze in many squeeze operations it has required lees than a barrel.

TOOR 1983 they discussed factor effecting in squeeze cement job. Studded effect of location of squeeze packer relative to the interval from squeeze packer to the zone will account for the volume of fluid that has to be squeezed ahead of cement slurry. Also it reflects the footage of cement that has to be drilled after the job is over, Vertical formation permeability, formation porosity, shot density, cement slurry filtration behavior and well bore geometry etc. are such things that play an important role in the depth of penetration of cement slurry into the formation.

GOODWIN 1984 he discusses the purpose of squeeze cementing. Then he touched the operation problems, where that effect on the success of a squeeze operation include plugged perforations, lost circulation problems encountered during drilling, and strong water cross flows. After that, he discusses the selection of cement slurry, where the selection depends on the purpose of the squeeze, the bottom hole circulating temperature and expected job time, the volume of the cement slurry, and subsequent pressures and temperatures the cement will be exposed.

Squeeze slurry volumes should be determined by the annular volume between the casing and the open hole, plus sufficient volume to fill the casing across the perforations, plus 25 feet (7.62m) above the top perforation.

Henry Lopez 1998 the idea was to increase Efficiency and Reduces Costs for squeeze cement matrix in Wlckett Field.

The Wlckett Field in the Permian Basin, located 40 miles West of Odessa in Ward County, Texas, is a mature field where squeeze operations occur approximately once per week on each workover rig. Successful cement squeezing generally has been defined by the industry primarily through trial and error, this methodology requires the accounting of many critical items that routinely vary from job to job, these include cement chemistries and volumes, surface and subsurface tools, and on-site pump methods and rates. Squeeze pressures and “shut in” times ban also vary according to individual preference.

Cowan 2007 he discuss Correlations and practices that improve squeeze-cementing success in a wide range of applications were developed from a series of field studies.

He use Statistical analysis of data for successful first attempt squeeze operations from this database identified practices and correlations that significantly improved the success rate for squeeze-cementing operations , in Prejob injection test data can be used to select basic cement type, recommended cement volume, and cement fluid loss based upon correlations developed from these studies.

Guidelines for placement procedures and pumping techniques were developed from successful field operations, the Data from service company treating reports and workover operations morning reports were collected and put into an electronic database , the parameter which used are Well type (producer or injector), age of the well, mechanical configuration, formation type, type of leak being squeezed, squeeze interval length, squeeze technique, presqueeze injection pressure and injection rate, cement type and volume, final squeeze pressure, waiting-on-cement time, and post-squeeze test pressure , Two types of statistical analysis were performed on the data. First, a general descriptive analysis of the data providing averages, minimums and maximums, and standard deviations for each variable in the database was performed. The second analysis was determination of correlation coefficients for each variable to squeeze-cementing success, He found relationship between injection pressure and injection rate, He spot light in the relationship between injection pressure and injection rate.

Cowan calculate the volume of cement by the following equation:

If the cement is micro fine ⇒

$$V_{CO} = 1225 \times \text{Interval length} \times 3.28 \times \left(\frac{Q}{P}\right) \qquad \textbf{(2.8)}$$

If the cement is class G ⇒

$$V_{CO} = 1018 \times \text{Interval length} \times 3.28 \times \left(\frac{Q}{P}\right) \qquad \textbf{(2.9)}$$

Where:

V_{co} = Volume of cement according to Cowan (bbl.).

Q = Pump flow rate for feed rate test (BPM).

P = The pressure for feed rate test (psi).

Chapter 3

Chapter Three

The Methodology

In this project, the study beginning by obtains the data, then screening it, and calculates all the volume of cement use in the job.

3.1 Introduction:

As was previously mentioned, the process of squeeze cementing is routine and calculating the optimum volume of cement is very important, as it reduces time and cost in an excellent way and there are many problems facing the Sudanese oil fields in calculating the optimum volume of squeeze cement in various maintenance and completion operations, in this project, the optimum volume of cement will be estimate to reach this level. The flow chart Fig.**3.1** below has been followed.

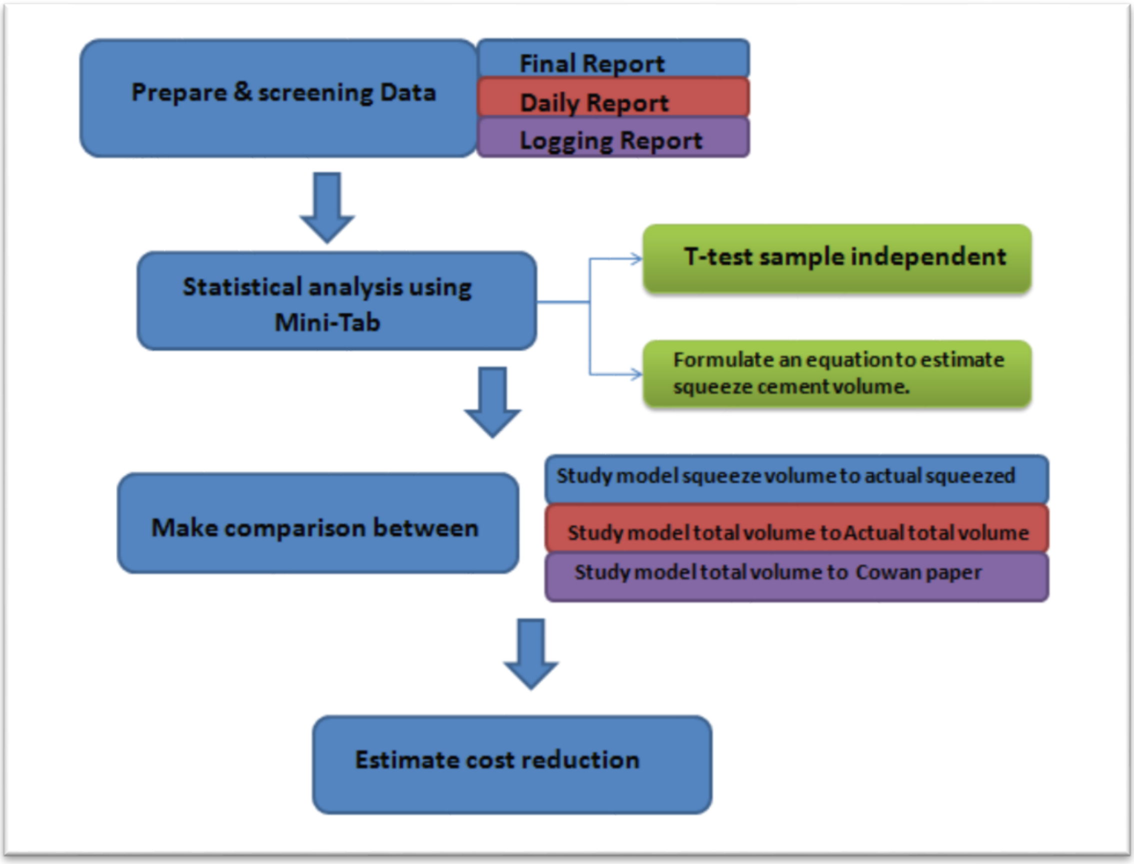


Fig (3.1): Flow Chart of Methodology

3.2 Data Preparation:

The data collected of several reports form Hamra field; this reports are:

1.Final Workover Report: These reports are summarized and covered a large portion of the data described the maintenance process, completed in a specific time period, Summary and sequence of action in well, Sketch of the well showing the open and closed layers and download tools, Details of the pump that was lowered into the well & pump tally and Most of the operation data was obtained from the final workover report.

2.Daily Report : This reports located on the field staff at the end of the day , to log information about the work that done in hour by hour .The study completed the missing data in the final reports from daily reports.

3.Well Logging Report: Is a record of the formations and any event that are encountered in the drilling process, it tellsyou what you pass through as you are drilling deeper and deeper. In addition, this report gives the petrophysical data.

After viewing of all reports, the data collected from the reports are filtered according to the following criteria:

1. The report contains squeeze cement job.
2. The report contains successful squeeze cement job.
3. Availability of sufficient data in the report.
4. Modern reports.

The data has been screened and collected from the reports are illustrated in the following Table.**3.1**:

Table (3.1): Data Screened From Reports

General data	• Field name . • well number . • Date of squeeze . • Workover type .
Tublar data	• Casing specification . • Tubing specification . • Tubing depth . • Drillable cement retainer depth(DCR) or saw tooth collar depth(STC) .
Cement data	• Cement technique (Balance or DCR) • Cement volume mixed and pumped . • Actual top of cement (TOC) . • Feed rate test . • Type of cement . • Reason to stop cement . • Actual cement squeezed into formation .
Formation data	• Formation name . • Top and bottome of formation . • Petrophysical properties (porosity& permeability).

3.3 Cement Volume Estimation:

In order to estimate the optimum cement volume for squeeze process, the cement volume which required divided into number of sections according to the cement technology used (balance technique or drillable cement retainer (DCR)).

- When using the balance technique (saw tooth color (STC)), the cement divided into three sections:

- **Section (A):** this is the cement, which mixed with wellbore fluid (Contaminate).
- **Section (B):** this is the cement inside the well and opposite the perforated layers.
- **Section (C):** this is the cement inside perforated layers.

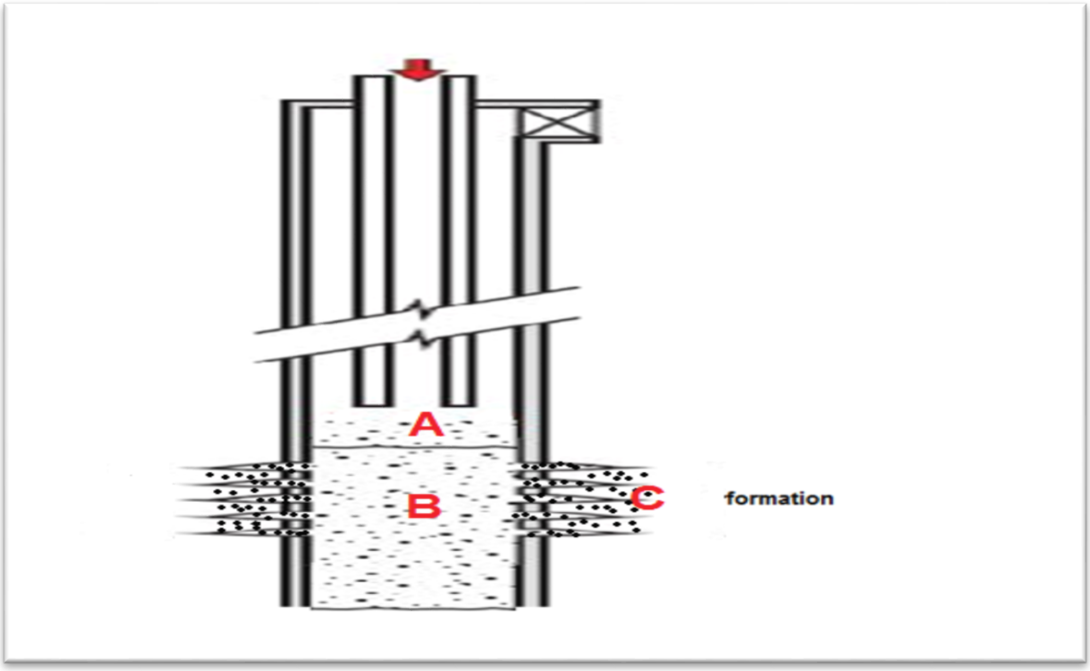


Fig (3.3): Cement volumes in balance technique.

- When using drillable cement retainer (DCR) technique, the cement divided into two sections:
  - **Section (B):** this is the cement inside the well and opposite the perforated layers.
  - **Section (C):** this is the cement inside perforated layers.

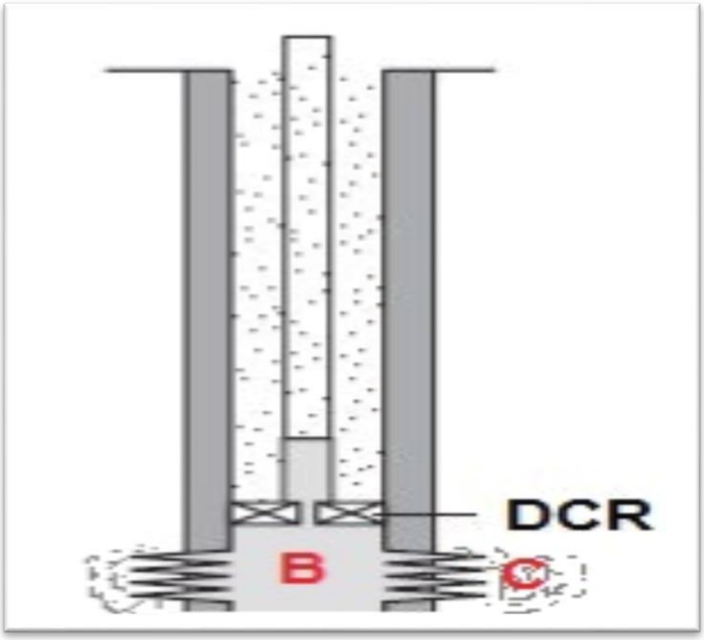


Fig: (3.4): Cement volumes in DCR Technique

The volume of the contaminate cement (A), volume of cement inside the wellbore (B) and the volume of cement inside layers (C) has been calculated ,Then estimate the volume of cement required in the squeeze process (A+B+C).

3.3.1 Estimation the Volume of Contaminate Cement (A):

Is located above perforation zone (for safety from wellbore fluid) , also called the contaminate cement section (A) Fig.**3.2**, through the study and research of information to reach the volume of the contaminate cement, the study find it can be calculated by calculation the theoretical top of cement (TOC) and knowing the actual cement top of cement. By following Equation (**3.1, 3.2** and **3.3**):

$$\mathrm{TOC_{th}} = \mathrm{STC} - \frac{\mathrm{CM_{ac}} - \mathrm{CZ_{ac}} / 6.28}{\mathrm{A_g}} \qquad (3.1)$$

$$\mathrm{A_g} = \frac{(\mathrm{ID}^2 \times 3.28)}{(1029.4 \times 6.2895)} \qquad (3.2)$$

$$\mathrm{V_A} = \mathrm{A_g} \times (\mathrm{TOC_{ac}} - \mathrm{TOC_{th}}) \qquad (3.3)$$

Where:

TOC_{th}≡ Theoretical top of cement (m).

STC≡Saw tooth collar depth (m)

ID ≡ Casing diameter (in).

CM_{ac} ≡ actual total cement mixed (bbl).

CZ_{ac}≡ Actually cement squeezed (bbl).

A_g≡ Casing capacity (m^3/m).

TOC_{ac}≡ actually top of cement (m).

V_A≡ Volume of contaminate cement (m3).

Assumption: The study assumes that the section of fine cement (A) is not present when using drillable cement retainer technique (DCR).

3.3.2 Estimation the Volume of Cement inside Wellbore (B):

This cement located inside the well bore between bottom of bottom perforation and top of top perforation section (B) Fig (**3.2,3.3)**, calculated from geometry of wellbore. Followed the Equation **(3.2, 3.4 and3.5):**

- If use DCR→

$$V_B = A_g \times (\mathrm{Btm} - \mathrm{DCR}) \qquad \textbf{(3.4)}$$

- If use STC→

$$V_B = A_g \times (\mathrm{STC} - \mathrm{Top}) \qquad \textbf{(3.5)}$$

Where:

V_B ≡ Volume of cement inside the well (m^3).

DCR ≡ Drillable cement retainer depth (m).

Btm ≡ TOP ≡ Top of top perforation depth (m).

Bottom of bottom perforation depth (m).

STC ≡ Saw tooth collar depth (m).

3.3.3 Estimation the Volume of Cement inside Formation:

To estimate volume of squeezed cement in formation located inside the layer through the perforation zone section (C) Fig.**3.2** and Fig.**3.3** analytical procedure using min-tab has been followed.

- **Minitab Program:** Minitab is a statistical package that provides a broad range of basic and advanced data analysis techniques.

The procedure that use for estimate the volume of (C):

- Preparation of data.
- Use the T-Test Sample Independent.
- Formulate an Equation.

1. Preparation of Data:

To be suitable to the analysis program, assumption has been obtained:

- **Assumption:**
  1. There is no cross flow between layers.
  2. The flow regime follows Darcy low.

According to this assumption the feed rate test (which done in job before squeezing to knowing the pressure and flow rate which layer will carrying) was divided for each comingle job (squeezing more than one layer in one job) for each layer by Equation **(3.6).**

$$Q_i = \frac{K_i h_i}{\sum_{i=1}^{n} K_i h_i} Q \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.6)$$

By same way actual squeezed cement volume in comingle job by Equation 3.7 for each layer in comingle

$$C_i = \frac{K_i h_i}{\sum_{i=1}^{n} K_i h_i} C \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.7)$$

Where:

Q_i≡ The feed rate test (BPM).

Q_i≡ The feed rate test for single layer (BPM).

K_i≡ Permeability of single layer (md).

$h_i \equiv$ The thickness of single layer (m) .

$V_{ci} \equiv$ The volume of cement for single layer (m^3).

$V_c \equiv$ The volume of cement inside layer (m^3).

$n \equiv$ The number of layer.

After this, the actual squeezed cement for each layer divided by unit of depth (bbl/m).

2. T-Test Sample Independent:

After data was prepared t-test sample independent was done this test shows the relationship between the averages between a variable and two types of data. From this test, you can find out whether the data changes equally or differently with the variable.

3. Formulate an Equation:

This equation are created for calculate the volume of cement in the formation, by using regression analysis in Minitab program regression and it mean a statistical method attempts to determine the strength and character of the relationship between one dependent variable (in this project squeezed cement volume per unit of depth) and a series of other variables known as independent (formation , cement technique , cement type ,thickness ,permeability ,porosity ,feed rate test and pressure).

3.3.4 The total Study volume of cement:

After calculated volume of A, B and C total cement volume calculated by Equation **3.8**.

$$V_T = V_A + V_B + V_C \quad \text{……………………………………..…….. (3.8)}$$

Where:

$V_T \equiv$ the total volume of cement (m^3).

3.3.5 The comparison:

After calculate total volume of cement and the volume of (C), compare:

3.3.5.1 Study volume inside formation to actual volume inside formation:

After calculating volume of cement inside formation compare to actual cement volume inside formation

3.3.5.2 Study Total Volume to Actual Total Volume:

Comparing between the actual volume of cement in field data and the total volume of study model Equation 3.8, by using the actual total cement mixed and the estimated cement volume Equation (3.9).

$$The\ difference = V_{ac} - V_T \ldots\ldots\ldots\ldots\ldots \quad (3.9)$$

Where:

V_{ac}≡the volume of actual cement mixed in filed (m^3).

3.3.5.3 Study Model to (Cowan) 2007 Model:

Calculate the total volume by using Cowan (2007) model by Equation (2.8, 2.9) Compare it to total volume study model.

3.3.6 Estimation Volume Reduction:

The amount of volume reduction is the surplus between actual total volume of cement in field and the total study volume, it has been calculated by equation **(3.8&3.9).**

Chapter 4

Chapter Four

Results and discussion

4.1 Introduction:

The statistics analysis was chosen to solve problem of inappropriate cement volume in squeeze cement operation lead to costly maintenance operation.

4.2 Data Preparation:

Data was taken from several files from these file data integrated together to form full data base for analytical statistic general data obtained in table.**4.1** and table.**4.2**.

Table (4.1): General Date Screening

Field Name	Csg Spec ppf	Formation Name	cement type	Cement Tech	Feed Rate Test	
					(Psi)	(BPM)
Ha E	9 ⅝ - 47	Bentui	Micro	Balance	1000	0.4
Ha	9 ⅝ - 47	Comingle	Class G	Balance	200	5
Ha	9 ⅝ - 47	Bentui	Micro	DCR	750	1.5
Ha E	9 ⅝ - 47	Arad	Class G	Balance	1300	0.655
Ha E	9 ⅝ - 47	Comingle	Micro	Balance	1300	0.389
Ha E	9 ⅝ - 47	Comingle	Class G	DCR	650	0.5
Ha	9 ⅝ -43.5	Arad	Micro	Balance	375	1
Ha C	7- 29	Bentui	Class G	Balance	1000	1.5
Ha E	7- 29	Comingle	Class G	Balance	200	1.5
Ha E	7- 29	Arad	Class G	Balance	1000	_
Ha E	7- 29	Arad	Class G	DCR	1000	_
Ha E	7- 29	Comingle	Class G	Balance	180	2
Ha E	7- 29	Comingle	Micro	Balance	1000	0.7

Ha E	9 ⅝ - 47	Comingle	Class G	Balance	1000	3
Ha E	9 ⅝ - 47	Comingle	Micro	Balance	1000	0.5
Ham	7- 26	_	Class G	Balance	500	4.7
Ha AG	9 ⅝ - 47	Comingle	Class G	Balance	880	1.75
Ha AG	9 ⅝ - 47	Bentui	Micro	DCR	_	_
Ha C	7- 29	Arad	Micro	DCR	1600	0.3
Ha C	7- 29	Comingle	Class G	Balance	_	_
	7- 29	Comingle	Class G	Balance	800	2
Ha	7- 29	Bentui	Class G	Balance	_	_
Ha C	7- 29	Comingle	Class G	DCR	150	2
Ha E	7- 29	Comingle	Class G	Balance	750	2
Ha E	7- 29	Comingle	Class G	Balance	700	2
Ha SW	9 ⅝ - 47	Ghazal	Micro	Balance	1000	0.377

Table (4.2): General Date Screening

Formation Name	**Date**	**permeability**	**Porosity**
Bentui	23/02/13	60.60	0.24
Comingle	05/07/15	13.16	0.21
Bentui	12/07/15	279.02	0.27
Arad	01/03/14	0.62	0.15
Comingle	04/02/14	167.72	0.26
Comingle	21/02/15	3555.57	0.32
Arad	25/02/14	100.81	0.25
Bentui	05/06/17	100.81	0.25
Comingle	12/05/17	21.90	0.22
Arad	24/04/17	0.62	0.15

Arad	18/04/17	0.37	0.14
Comingle	23/03/14	21.90	0.22
Comingle	19/03/14	13.16	0.21
Comingle	09/06/13	614.14	0.28
Comingle	04/01/13	60.60	0.24
Bentui	11/07/07	279.02	0.27
Comingle	12/06/15	0.00	0.15
Bentui	06/12/15	0.62	0.22
Arad	16/12/11	21.90	0.23
Comingle	23/12/12	36.43	0.19
Comingle	18/04/14	4.76	0.23
Bentui	10/12/12	36.43	0.22
Comingle	25/01/14	21.90	0.22
Comingle	10/09/18	21.90	0.26
Comingle	01/10/18	167.72	0.26

4.2.1 Statistical Description:

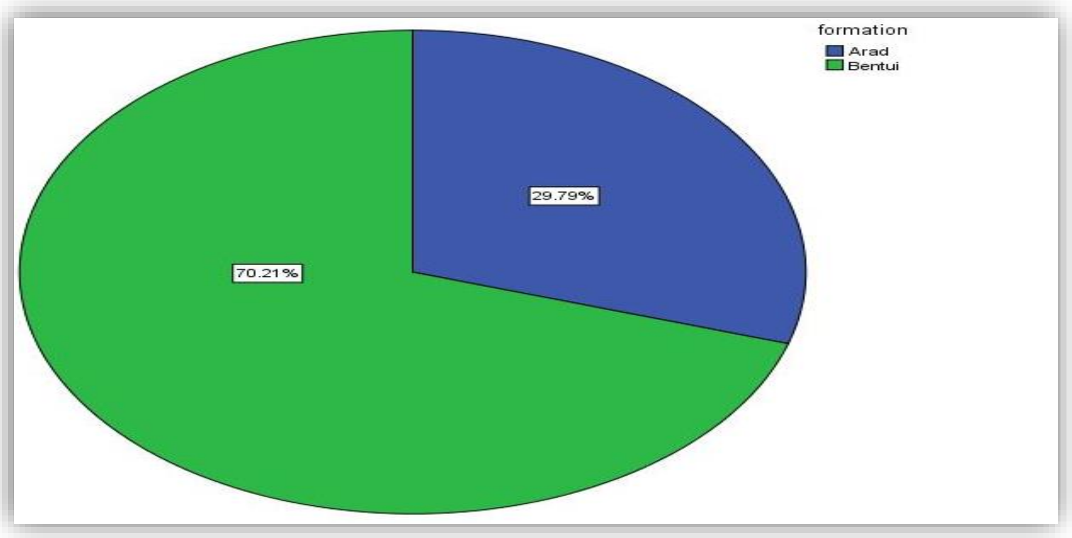


Fig (4.1): Distribution of Formation in Case Study

According to the graph, a Bentui formation represents 70% of the total formation, Arad represents 29.8%.

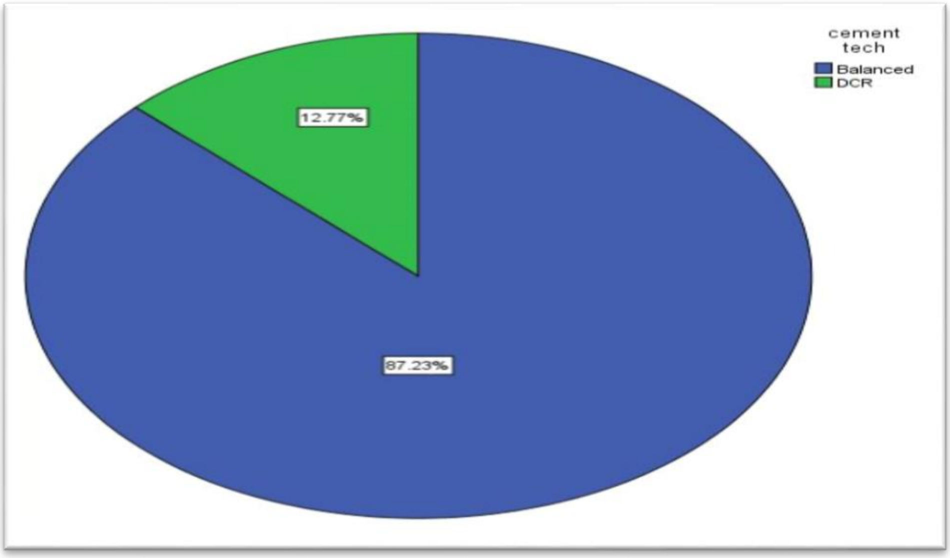


Fig (4.2): Distribution of Cement Techniques in Case Study.

From the fig**.4.2** it can said that most of operation in the field under study were in balance technique and this indicates that the majority of cementation operations were for single layer or number of combined layers close to each other with no risk of putting pressure on the casing.

Table (4.3): Type of Formation and Technique.

Formation name	cement techniques type	
	Balance	DCR
Bentui	13	4
Arad	5	2

Table (4.3) shows the the number of using the balanceplug & DCR techniques in formations.

Table (4.4): Type of Formation and Type of Cement.

Formation name	cement type	
	Glass G	Micro fine
Bentui	12	5
Arad	5	3

Table shows the types of cement that using in formation.

Noted: that the Class G was used in Bentui formation more than micro fine.

Table (4.5): Total Volume And Total Squeezed.

	Actual total cement mixed	**Volume actual squeezed**
Mean	21 BBL	4.8 BBL
Sum	508 BBL	110 BBL

4.3 Cement Volume Estimation

As was previously mention the cement divided to many section depending on the cement technique:

- When using (STC) the cement divided into three section **Fig.3.2:**

Section (A): This is the contaminate cement above perforation zone (for safety).

Section (B): This is the cement inside the well and opposite the perforated layers.

Section (C): This is the cement inside perforated layers.

- When using drillable cement retainer (DCR) technique, the cement divided into two sections **Fig.3.1:**

Section (B): This is the cement inside the well and opposite the perforated layers.

Section (C): This is the cement inside perforated layers.

- Whereas the section (A) is not present in this type of cement , due to the DCR technology is a retainer , which in turn traps the fluids above it , so as prevent the cement from mixing with well bore fluid , and the little mixed is disposed of by sliding it down or inside the perforation .
- Also because the contaminate cement affected by the contact area, it is relatively small when using the balance technique and very small when using the drillable cement retainer technique.

4.3.1 Estimation the Volume of Contaminate Cement (A):

This type of cement appears when using the balance technique, as it represents the intermediate stage between the cement that must solidify and the completion fluid (water).

Volume of contaminate (A) calculated by equation (**3.3)** and result showed in table**.4.6**.

Table (4.6): Contaminate Cement Volume.

Formation Name	Cmt Tech.	Theoretical TOC (m)	Actual TOC (m)	Contaminate Cement (m^3)
Bentui	Balance	1751	1700.17	-1.943
Comingle	Balance	1707	1632.09	-2.903
Bentui	DCR	1785	1784.5	0
Arad	Balance	1527	1582	8.000
Comingle	Balance	1566	1603	1.408
Comingle	DCR	1701	1701	0
Arad	Balance	1518	1446	-2.791
Bentui	Balance	1548	1545	-0.067

Comingle	Balance	1573	1537	-0.705
Arad	Balance	1483	1453	-0.573
Arad	DCR	1668	1668	0
Comingle	Balance	1573	1598.72	0.497
Comingle	Balance	1620	1620.09	-0.007
Comingle	Balance	1667	1656.5	-0.388
Comingle	Balance	1710	1715	0.207
Bentui	Balance	1589	1566.08	-0.464
Comingle	Balance	1636	1582.45	-2.029
Bentui	DCR	2587	2587	0
Arad	DCR	1581	1581	0
Comingle	Balance	1539	1532.78	-0.129
Comingle	Balance	1546	1555.23	0.182
Bentui	Balance	1545	1503	-0.823
Comingle	DCR	1686	1686	0
Comingle	Balance	1553	1525.07	-0.533
Comingle	Balance	1555	1539.18	-0.311

It has been appear that the work in field done by not standard criteria because of native value this mean actual top of cement rise up above theoretical top of cement Fig**.4.3** shown that.

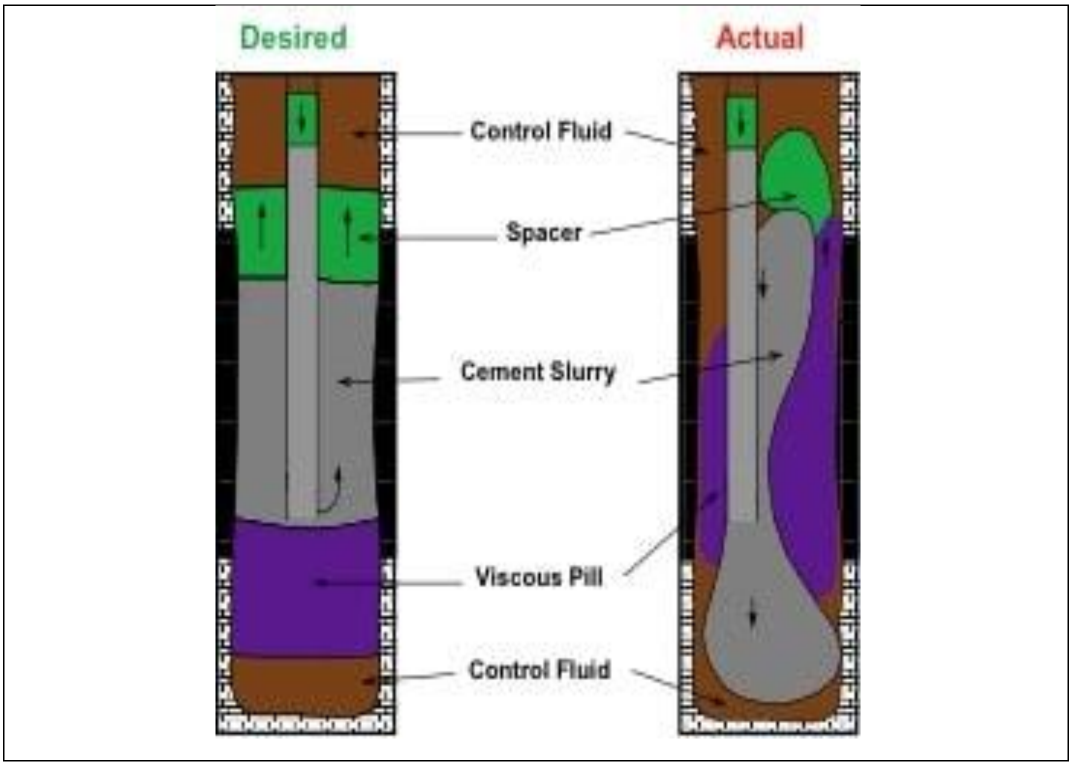


Fig (4.3): Ideal and Actual Behavior of Contaminate Cement.

This problem appears due to the following reason:

1. Different density.
2. Rheological properties.
3. Heterogeneity in cement distribution.
4. Displacement velocity.

It has to calculate this volume by another method because no way to ignore all volumes of (A) which carry negative value since it representing 57% of total values.

The distance between STC and bottom of bottom perforation is good thick to prevent contaminate cement to inter formation from bottom while squeezing thus same thick is approach to the top.

All balance job revised to sureness about its operation typical and founded that there are one job which doesn't sufficient the work(#job**(1)**), then remainder jobs takes its average value of distance between STC and bottom of bottom perforation then Volume (A) calculated by following equation

$$\mathrm{V_A} = \mathrm{A_g} * \mathrm{avg(stc - btm)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \textbf{(4.1)}$$

$$(STC - BTM)_{Avg} = 13.48\, m$$

Where:

STC≡ saw tooth color depth (m).

BTM ≡ bottom of bottom perforation (m)

$\mathrm{A_g}$ ≡ casing capacity (m^3/m$^/$).

$\mathrm{V_A}$≡ volume of contaminate cement (m^3).

New values of ($\mathrm{V_A}$) shown in Table **(4.4)**

Table (4.7): Contaminate Cement Volume. Adjusted

Job	Cement Tech	casing capacity	STC depth (m)	Btm of btm perf (m)	Difference	Contaminate Cement (m^3)
1	Balance	0.0382	1784.55	1725	59.55	0.515
2	Balance	0.0388	1812.58	1790	22.58	0.523
3	DCR	0.0388	-	1790	-	-
4	Balance	0.0382	1585	1574.5	10.5	0.515
5	Balance	0.0382	1736.3	1728	8.3	0.515
6	DCR	0.0382	-	1722	-	-
7	Balance	0.0388	1585	1575	10	0.523
8	Balance	0.0194	1730	1716.5	13.5	0.262
9	Balance	0.0194	1759	1739	20	0.262
10	Balance	0.0194	1595	1592	3	0.262
11	DCR	0.0194	-	1717	-	-
12	Balance	0.0194	1762.85	1739	23.85	0.262
13	Balance	0.0194	1760.75	1739	21.75	0.262
14	Balance	0.0382	1754.7	1745	9.7	0.515
15	Balance	0.0382	1754.2	1744.5	9.7	0.515
16	Balance	0.02	1674.46	1663	11.46	0.270
17	Balance	0.0382	1677.16	1659	18.16	0.515
18	DCR	0.0382	-	2603	-	-
19	DCR	0.0194	-	1597	-	-

20	Balance	0.0194	1730	1720	10	0.262
21	Balance	0.02	1664.3	1652.5	11.8	0.270
22	Balance	0.0194	1731	1724.5	6.5	0.262
23	DCR	0.0194	-	1716	-	-
24	Balance	0.0194	1730	1714	16	0.262
25	Balance	0.0194	1745	1730.5	14.5	0.262

Total contaminate volume = 7.54 m^3

4.3.2 Estimation the Volume of Cement inside Wellbore (B):

It’s the volume of cement in the casing between bottom of bottom perforation and top of top perforation in balanced plug cement technology, or the volume of cement between bottom of bottom perforation and DCR depth in DCR technology calculate by equations (**3.4** and **3.5**.)

Table (4.8): Cement Volume In Wellbore.

Job	**Cement Tech**	**casing capacity**	**STC depth (m)**	**Btm of btm perf**	**TOP of top perf**	**DCR depth (m)**	**V_B (m^3)**
1	Balance	0.0382	1784.55	1725	1723	-	2.35
2	Balance	0.0388	1812.58	1790	1741	-	2.78
3	DCR	0.0388	-	1790	1787	1784.5	0.21
4	Balance	0.0382	1585	1574.5	1568	-	0.65
5	Balance	0.0382	1736.3	1728	1627	-	4.17
6	DCR	0.0382	-	1722	1704	1701	0.802
7	Balance	0.0388	1585	1575	1554	-	1.203
8	Balance	0.0194	1730	1716.5	1710	-	0.4
9	Balance	0.0194	1759	1739	1698	-	1.183
10	Balance	0.0194	1595	1592	1589	-	0.12

11	DCR	0.0194	-	1717	1713	1668	0.951
12	Balance	0.0194	1762.85	1739	1698	-	1.26
13	Balance	0.0194	1760.75	1739	1720	-	4.67
14	Balance	0.0382	1754.7	1745	1710	-	1.707
15	Balance	0.0382	1754.2	1744.5	1735	-	0.733
16	Balance	0.02	1674.46	1663	1660	-	0.3
17	Balance	0.0382	1677.16	1659	1640	-	1.42
18	DCR	0.0382	-	2603	2598	2587	0.6112
19	DCR	0.0194	-	1597	1591	1581	0.31
20	Balance	0.0194	1730	1720	1702	-	0.54
21	Balance	0.02	1664.3	1652.5	1630	-	0.7
22	Balance	0.0194	1731	1724.5	1718	-	0.25
23	DCR	0.0194	-	1716	1695	1686	0.582
24	Balance	0.0194	1730	1714	1697	-	0.64
25	Balance	0.0194	1745	1730.5	1719	-	0.504

Total cement (B) = 24.55m^3

4.3.3 Estimate the Volume of Cement Inside Formation Section (C):

4.3.3.1 Preparation of Data:

Volume (C) is the optimum squeezed cement into formations. In the comingle jobs, the cement was distributed via equation **(3.6),** based on the assumption that the flow system follows Darcy's law and there is no cross flow between the layers. Thus the formations in the comingle jobs was considered as separated job. Accordingly, the number of jobs has increased from 25 to 49 jobs.

Feed rate test (Q) estimated by the same way as the volume © distribution by (Equation **3.7),** the pressure for each layer is constant the value of C & Q for each shown in table **4.9**.

Table (4.9): Squeeze Cement and Feed Rate for Each Layer.

#	**Formation**	**H**	**K**	**Q before**	**Vc before**	**Q after**	**Vc after**
Bentui	Bentui	2	60.60	0.4	5.024	0.40	5.02
Comingle	Arad E	5	1.72	5	5.625	0.03	0.04
	Arad F	8	2.86			0.09	0.10
	Bentui1A	7	60.60			1.64	1.85
	Bentui 1B	3	279.02			3.24	3.64
Bentui 1B	Bentui 1B	3	279.02	1.5	4	1.50	4.00
Arad	Arad	11.5	0.62	0.655	5.024	0.66	5.02
Comingle	Arad D	10.5	772.22	0.389	3.14	0.10	0.79
	Arad D1	6.5	7.91			0.00	0.01
	Arad E	7	2.86			0.00	0.00
	Arad F	6	36.43			0.00	0.02
	Bentui 1A	6	2137.2			0.16	1.26
	Bentui 1B	14	772.22			0.13	1.06
Comingle	Bentui1A	6	3555.5	0.5	6.2	0.21	2.66
	Bentui 1B	8	3555.5			0.29	3.54
Arad	Arad	21	100.81	1	2.5	1.00	2.50
Bentui	Bentui	6.5	100.81	1.5	3	1.50	3.00
Comingle	Bentui1A	12	60.60	1.5	2.5	1.17	1.95
	Bentui1A	8	21.90			0.28	0.47
	Bentui 1B	6	4.76			0.05	0.08

Arad	Arad	3	0.62	0.19	2	0.19	2.00
Arad	Arad	3.5	0.37	0.19	12	0.19	12.00
Comingle	Bentui 1A	12	60.60	2	2	1.56	1.56
	Bentui 1A	8	21.90			0.38	0.38
	Bentui 1B	6	4.76			0.06	0.06
Comingle	Bentui1A	8	21.90	0.7	3	0.60	2.58
	Bentui 1B	6	4.76			0.10	0.42
Comingle	Arad	7	60.60	3	4	0.05	0.06
	Bentiu1A	12	2137.2			2.73	3.64
	Bentiu1A	1	2137.2			0.23	0.30
Comingle	Bentiu	1	60.60	0.5	3.3	0.25	1.65
	Bentiu	1	60.60			0.25	1.65
	Bentiu	3	279.02	4.7	5	4.70	5.00
Comingle	Arad F	6	0.22	1.75	12	0.00	0.03
	Bentui1A	6	100.81			1.75	11.97
	Bentui	5	0.62	-	8.5	1.00	8.50
	Arad	6	21.90	0.3	7.5	0.30	7.50
Comingle	Bentui1A	6	36.43	2	1.9	1.00	-
	Bentui1A	11	36.43			1.00	-
Comingle	Arad F	7	1.03	2	4	0.10	0.19
	Bentui1A	4	13.16			0.70	1.40
	Bentui 1B	2.5	36.43			1.21	2.41
Bentui	Bentui	6.5	36.43	1	2.512	1.00	2.51
Comingle	Bentui1A	4.5	21.90	2	3.5	0.64	1.13
	Benui 1A	9.5	21.90			1.36	2.38

4.3.3.2 T-Test Sample Independent:

After the data is been ready, it adjusted by selecting the data on which the analyze and tests will be performed. This data includes two types of inputs.

- **Categorical Data:**
  1- Formation type.
  2- Cement technique.
  3- Cement type.
- **Numerical Data:**
  1- Thickness (h).
  2- Porosity (ϕ).
  3- Permeability (K).
  4- Feed rate (Q) and pressure (P).
  5- Peripheral space.

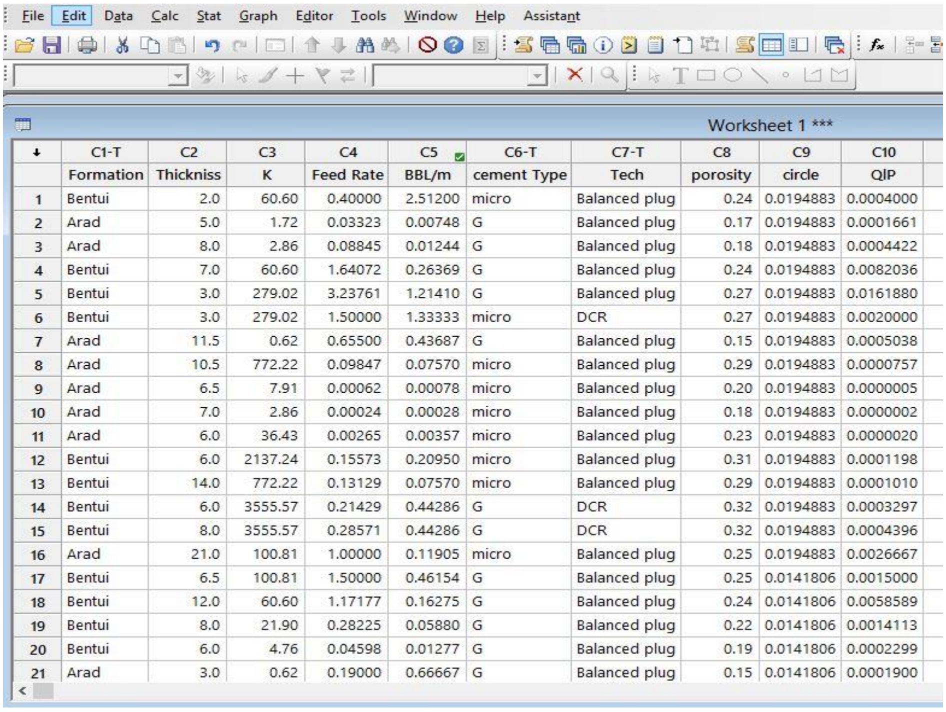
In addition to this date (K*H) & (Q/P) was added, and all this data shown in table **4.10.**

Table (4.10): Mini-tab Data.

Formation	H	K	Q	Bbl/m	Cement type	Tech	ϕ	circle
Bentui	2	61	0.4	2.5120	micro	Balance	0.24	0.019
Arad	5	2	0.033	0.0075	G	Balance	0.17	0.019
Arad	8	3	0.088	0.0124	G	Balance	0.18	0.019
Bentui	7	61	1.641	0.2637	G	Balance	0.24	0.019
Bentui	3	279	3.238	1.2141	G	Balance	0.27	0.019
Bentui	3	279	1.5	1.3333	micro	DCR	0.27	0.019
Arad	11.5	1	0.655	0.4369	G	Balance	0.15	0.019
Arad	10.5	772	0.0985	0.0757	micro	Balance	0.29	0.019
Arad	6.5	8	0.0006	0.0008	micro	Balance	0.2	0.019
Arad	7	3	0.0002	0.0003	micro	Balance	0.18	0.019

Arad	6	36	0.0027	0.0036	micro	Balance	0.23	0.019
Bentui	6	2137	0.1557	0.2095	micro	Balance	0.31	0.019
Bentui	14	772	0.1313	0.0757	micro	Balance	0.29	0.019
Bentui	6	3556	0.2143	0.4429	G	DCR	0.32	0.019
Bentui	8	3556	0.2857	0.4429	G	DCR	0.32	0.019
Arad	21	101	1	0.1190	micro	Balance	0.25	0.019
Bentui	6.5	101	1.5	0.4615	G	Balance	0.25	0.014
Bentui	12	61	1.17177	0.1627	G	Balance	0.24	0.014
Bentui	8	22	0.282	0.0588	G	Balance	0.22	0.014
Bentui	6	5	0.046	0.0128	G	Balance	0.19	0.014
Arad	3	1	0.19	0.6667	G	Balance	0.15	0.014
Arad	3.5	0	0.19	3.4286	G	DCR	0.14	0.014
Bentui	12	61	1.56236	0.1302	G	Balance	0.24	0.014
Bentui	8	22	0.376	0.0470	G	Balance	0.22	0.014
Bentui	6	5	0.061	0.0102	G	Balance	0.19	0.014
Bentui	8	22	0.602	0.3225	micro	Balance	0.22	0.014
Bentui	6	5	0.098	0.0700	micro	Balance	0.19	0.014
Arad	7	61	0.045	0.0086	G	Balance	0.24	0.019
Bentui	12	2137	2.728	0.3031	G	Balance	0.31	0.019
Bentui	1	2137	0.227	0.3031	G	Balance	0.31	0.019
Bentui	1	61	0.25	1.6500	micro	Balance	0.24	0.019
Bentui	1	61	0.25	1.6500	micro	Balance	0.24	0.019
Bentui	3	279	4.7	1.6666	G	Balance	0.27	0.014
Arad	6	0	0.004	0.0044	G	Balance	0.13	0.019
Bentui	6	101	1.746	1.9956	G	Balance	0.25	0.019
Bentui	5	1	1	1.7000	micro	DCR	0.15	0.019
Arad	6	22	0.3	1.2500	micro	DCR	0.22	0.014
Bentui	6	36	1	0.1110	G	Balance	0.23	0.014
Bentui	11	36	1	0.1110	G	Balance	0.23	0.014
Arad	7	1	0.096	0.0274	G	Balance	0.16	0.014
Bentui	4	13	0.698	0.3488	G	Balance	0.21	0.014
Bentui	2.5	36	1.207	0.9653	G	Balance	0.23	0.014

Bentui	6.5	36	1	0.3864	G	Balance	0.23	0.014
Bentui	4.5	22	0.643	0.2500	G	Balance	0.22	0.014
Bentui	9.5	22	1.357	0.2500	G	Balance	0.22	0.014
Bentui	7	168	1.333	0.1905	G	Balance	0.26	0.014
Bentui	3.5	168	0.667	0.1905	G	Balance	0.26	0.014



↓	C1-T	C2	C3	C4	C5	C6-T	C7-T	C8	C9	C10
	Formation	Thickniss	K	Feed Rate	BBL/m	cement Type	Tech	porosity	circle	QIP
1	Bentui	2.0	60.60	0.40000	2.51200	micro	Balanced plug	0.24	0.0194883	0.0004000
2	Arad	5.0	1.72	0.03323	0.00748	G	Balanced plug	0.17	0.0194883	0.0001661
3	Arad	8.0	2.86	0.08845	0.01244	G	Balanced plug	0.18	0.0194883	0.0004422
4	Bentui	7.0	60.60	1.64072	0.26369	G	Balanced plug	0.24	0.0194883	0.0082036
5	Bentui	3.0	279.02	3.23761	1.21410	G	Balanced plug	0.27	0.0194883	0.0161880
6	Bentui	3.0	279.02	1.50000	1.33333	micro	DCR	0.27	0.0194883	0.0020000
7	Arad	11.5	0.62	0.65500	0.43687	G	Balanced plug	0.15	0.0194883	0.0005038
8	Arad	10.5	772.22	0.09847	0.07570	micro	Balanced plug	0.29	0.0194883	0.0000757
9	Arad	6.5	7.91	0.00062	0.00078	micro	Balanced plug	0.20	0.0194883	0.0000005
10	Arad	7.0	2.86	0.00024	0.00028	micro	Balanced plug	0.18	0.0194883	0.0000002
11	Arad	6.0	36.43	0.00265	0.00357	micro	Balanced plug	0.23	0.0194883	0.0000020
12	Bentui	6.0	2137.24	0.15573	0.20950	micro	Balanced plug	0.31	0.0194883	0.0001198
13	Bentui	14.0	772.22	0.13129	0.07570	micro	Balanced plug	0.29	0.0194883	0.0001010
14	Bentui	6.0	3555.57	0.21429	0.44286	G	DCR	0.32	0.0194883	0.0003297
15	Bentui	8.0	3555.57	0.28571	0.44286	G	DCR	0.32	0.0194883	0.0004396
16	Arad	21.0	100.81	1.00000	0.11905	micro	Balanced plug	0.25	0.0194883	0.0026667
17	Bentui	6.5	100.81	1.50000	0.46154	G	Balanced plug	0.25	0.0141806	0.0015000
18	Bentui	12.0	60.60	1.17177	0.16275	G	Balanced plug	0.24	0.0141806	0.0058589
19	Bentui	8.0	21.90	0.28225	0.05880	G	Balanced plug	0.22	0.0141806	0.0014113
20	Bentui	6.0	4.76	0.04598	0.01277	G	Balanced plug	0.19	0.0141806	0.0002299
21	Arad	3.0	0.62	0.19000	0.66667	G	Balanced plug	0.15	0.0141806	0.0001900

Fig (4.4): Data in mini-tab

At the beginning of the analyzes using the mini-tab program, a two test sample independent was done , This test shows the relationship between the averages between a variable and two types of data, such as the students ’scores for females and males. From this test, you can find out whether the data changes equally or differently with the variable ‹It produces a “p-value”, which can be used to decide whether there is evidence of a difference between the two population means p-value ranges from **(0-1)** and when be small indicates that the error coefficient is small.

- **Two test Sample, which was Done:**

Squeezed cement volume per unit of depth (bbl/m) with:

1- Formation type (Bantiu, Aradiba) .

2- Cement technique (Balance,DCR) .

3- Cement type (Glass G, Micro fine).

The result from this test shown on table **(4.11).**

Table (4.11): T- test Sample Independent Result.

Parameter	**t-test**
Formation	P-Value = 0.548
cement type	P-Value = 0.079
cement tech	P-Value = 0.306

From the result, it is clear that the means are different, meaning that there is no relationship between Bentiu and Ardiba in terms of formation, as well as in both the technique and the type of cement.

Cement technique have lowest p-value that indicate the best for the c correlation estimation.

4.3.3.3 Formulate an Equation:

The second analysis that was conducted is regression and it mean a statistical method attempts to determine the strength and character of the relationship between one dependent variable (in this project squeezed cement volume per unit of depth) and a series of other variables known as independent (formation, cement technique, cement type, thickness, permeability, porosity, feed rate test and pressure), the result from this test is of correlation international (r square).

- **Multiple linear regressions:**

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + \cdots + b_tX_t + u$$

Y= the variable that you are trying to predict (dependent variable).

X= the variable that you are using to predict Y (independent variable).

a = the intercept.

b = the slope.

u = the regression residual.

Regression (0.00 - 1) values are accepted from 0.7 and above the closer to one indicate the stronger equation, the result from this test shown in table **4.12.**

Table (4.12): Regression Analysis Result.

Parameter	**R^2**
Formation	62%
cement type	50%
cement tech	78%

As mentioned in t- test sample that cement technique have the strong chance the regression confirmed with it and the equations is shown below:

- **For balance technique→**

$$V_C = -1.285 + 0.004h - 0.000778K + 0.2533Q + 168.6C + 0.01109h^2 + 0.000076K^2 - 17.14C \ldots\ldots \mathbf{(4.2)}$$

- **For DCR technique→**

$$V_C = 3.14 - 0.398h - 0.000778K - 1.741Q + 168.6C + 0.01109h^2 + 0.000076h \times K + 17.14h \times C \ldots\ldots \mathbf{(4.3)}$$

Where:

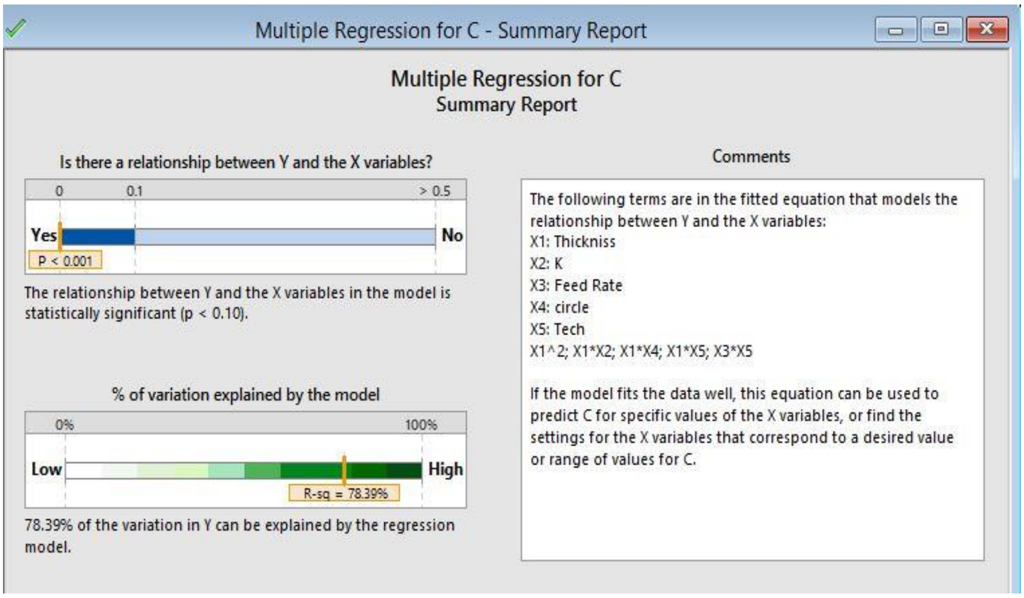
V_C = the volume of cement inside formation per unit length (m^3/m).

h = the formation thickness (m).

K = the permeability of formation (md).

Q = the feed rate test (BPM).

C = the circumference of casing (m).



Multiple Regression for C - Summary Report

Multiple Regression for C
Summary Report

Is there a relationship between Y and the X variables?

The relationship between Y and the X variables in the model is statistically significant (p < 0.10).

% of variation explained by the model

78.39% of the variation in Y can be explained by the regression model.

Comments

The following terms are in the fitted equation that models the relationship between Y and the X variables:
X1: Thickniss
X2: K
X3: Feed Rate
X4: circle
X5: Tech
X1^2; X1*X2; X1*X4; X1*X5; X3*X5

If the model fits the data well, this equation can be used to predict C for specific values of the X variables, or find the settings for the X variables that correspond to a desired value or range of values for C.

Fig (4.5): Multi Regression for C.

4.4 The Total Study Volume of Cement:

Calculated by equation **(3.8)** shown in Table **(4.13)**

Table 4.13: Total Study Model And Total Actual Field.

Formation	Total study volume (m^3)	Total actual volume(m^3)
Bentui	3.327	2.08
Comingle	5.480	5
Bentui	0.961	1.5
Arad	1.164	3
Comingle	5.674	7
Comingle	1.902	3
Arad	2.718	3
Bentui	1.034	4

Comingle	1.788	4
Arad	0.634	2.5
Arad	2.673	4
Comingle	2.055	4
Comingle	1.208	3.2
Comingle	3.692	4
Comingle	1.791	2.23
Bentui	1.288	2.5
Comingle	3.129	3.5
Bentui	1.647	1.5
Arad	1.796	2
Comingle	1.232	4
Comingle	1.616	3
Bentui	0.786	4

4.5 The compression:

4.5.1 Study Model Volume to Sctual Field Folume:

1. Total study volume (calculated by equation **3.8**) and total actual volume has been option in Table **4.13**.
2. And the compression of estimated squeeze cement to actual squeeze cements option in table **4.14**.

Table 4.14: Estimated Squeeze Volume To Actual Squeeze Volume.

Formation	Vc total m^3	Vc field m^3
Bentui	0.461	0.8
Comingle	2.17	0.9
Bentui	0.747	0.636

Arad	0	0.8
Comingle	0.984	0.5
Comingle	1.100	0.987
Arad	0.992	0.398
Bentui	0.385	0.478
Comingle	0.343	0.398
Arad	0.256	0.318
Arad	1.723	1.911
Comingle	0.536	0.318
Comingle	0.156	0.478
Comingle	1.469	0.637
Comingle	0.542	0.525
Bentui	0.729	0.796
Comingle	1.195	1.911
Bentui	1.036	1.354
Arad	1.485	1.194
Comingle	0.427	0.303
Comingle	0.660	0.637
Bentui	0.273	0.400
Comingle	0.562	0.557
Comingle	0.576	0.318

4.5.2 Total Study Volume to (Cowan) 2007:

Cowan (2007) estimated volume calculated by equation (**2.8 & 2.9)** Table 4.15 shown the difference between the two models.

Table 4.15: Total Study Model and Total Cowan Volume

Formation	Total Study Volume (m^3)	Total Cown Volume (m^3)
Bentui	3.327	0.512
Comingle	5.480	305.724
Bentui	0.961	3.839
Arad	1.164	1.741
Comingle	5.674	8.232
Comingle	1.902	5.726
Arad	2.718	35.829
Bentui	1.034	5.184
Comingle	1.788	103.680
Arad	0.634	0.303
Arad	2.673	0.354
Comingle	2.055	153.601
Comingle	1.208	6.270
Comingle	3.692	31.902
Comingle	1.791	0.640
Bentui	1.288	14.994
Comingle	3.129	12.688
Bentui	1.647	4.570
Arad	1.796	0.720
Comingle	1.232	12.913
Comingle	1.616	17.945
Bentui	0.786	4.937
Comingle	1.464	19.850
Comingle	1.341	15.951

4.6 Estimate Volume Reduction:

Reducing the volume of cement is one of the objectives of the project, and it will be reduce by calculating the surplus between the actual volume of cement in field data and the total volume of study equation (**3.8**)Table **4.16** shown the volume that are reduction.

Table (4.16): The Volume Reduction.

Formation	Total Study Volume (m^3)	Total Actual Volume (m^3)	Volume reduction |(m^3)
Bentui	3.327	2.08	-1.247
Comingle	5.480	5	-0.480
Bentui	0.961	1.5	0.539
Arad	1.164	3	1.836
Comingle	5.674	7	1.326
Comingle	1.902	3	1.098
Arad	2.718	3	0.283
Bentui	1.034	4	2.966
Comingle	1.788	4	2.212
Arad	0.634	2.5	1.866
Arad	2.673	4	1.327
Comingle	2.055	4	1.945
Comingle	1.208	3.2	1.992
Comingle	3.692	4	0.308
Comingle	1.791	2.23	0.439
Bentui	1.288	2.5	1.213
Comingle	3.129	3.5	0.371
Bentui	1.647	1.5	-0.147

Arad	1.796	2	0.205
Comingle	1.232	4	2.768
Comingle	1.616	3	1.384
Bentui	0.786	4	3.214
Comingle	1.464	4	2.536
Comingle	1.341	4	2.659

From the result the volume reduction for Micro fine and Class G cement type in table **4.17.**

Table (4.17): All Volume Reduction.

	Cement type	
	Class G	Micro fine
volume reduction	27.22 m^3	3.38 m^3

- **Noted:** The result explained the height of cement that are wasted in the well, and this height equal 1346 m.

Chapter 5

Chapter Five

Conclusions and Recommendations

5.1 Conclusion:

1- From the study it is Cleary found out that the process squeeze cement depend basically on type of technique which used.

2-after deep follow up the reports figure out the average difference between the STC depth and the bottom of bottom perforation is 13.48 which is agree and stick the standards and regulation**.**

3-if the study this study utilized about 40% of slurry volume will be reduced and 1346 m of cement would not be drilled at all.

5.2 Recommendations:

The recommendations of this project that showed during the study, analysis, tests and results are illustrated below:

1-Cement type: For determine the cement type which used in job , the study specified that for Aradeiba layers which famous by bad clay used Micro Fine cement type, and for Bentui layers used Class G cement type.

Also cement type can be determine by the feed rate test ,where the layers that has rate below 1.5 BPM used Micro Fine cement type , and layers that has rate between 1.5-5 BPM used Class G cement type .

2-Contaminate cement: To overcome the problems that makes the contaminate cement does not behave the ideal behavior, the study recommends a replacement the fluid in the well by fluid has density high than water and low than cement like spacer, used centerlizer for centering the tube in the well , and pump the displacement fluid at suitable velocity.

References:

1- Erik B. Nelson and Dominique Guillo (2006), well cementing, Schlumberger.

2- I.A. Toor (1983), Problems in Squeeze Cementing, Society of Petroleum Engineers held in Manama.

3- J. L. Rik (1973), obtaining successful squeeze-cementing results, Society of Petroleum Engineers held in Las Vegas.

4- K.J, Goodwin (1948), Principles of Squeeze Cementing, .society of Petroleum Engineers of AIME.

5- Mitchell R.F, Miska (2011), Fundamentals of Drilling Engineering ,Society of Petroleum Engineers.

6- George C.Howard (1950),Squeeze Cementing Operations, society of Petroleum Engineers of AIME.

7- Michael Cowan (2007),Field Study Result Improve Squeeze cementing success, Society of Petroleum Engineers.