Optimization of cement Manufacturing Process (cost reduction) :

A Case Study in Manufacturing Industry

Ggraduation Project (Design) for the degree of

Bachelor of engineering in industrial engineering

By

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Declaration

We hereby certify that this material, which we are now providing for evaluation in the study program leading to the award of the Bachelor of Engineering in Industrial Engineering, is our entire work, and that we have taken reasonable care to ensure that the work is original, and does not, to our knowledge, violate any copyright law, and it has not been taken from The work of others, with the exception and to the extent that this work was cited and recognized in the text of our work, and the work was done by Dr. Naif Al-Harbi, and he gave with us the tender in the shadow of Covid-19 disease, and we work remotely and I ask God to grant him success and us.

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Abstract

This project aims to prepare a study for the cement industry in Southern Cement Company. In this report, we will also review an overview of the cement product, how it is manufactured, its uses, machinery used, good planning, and work well in order to reduce the cost of production and work on the cohesion of the material in the cement. That makes the product good and can be purchased from customer as well as planning study. Production controls and control over preparation times. Regulations and planning restrictions. And study how to operate a factory for the production of cement or any other product, as this research for the project enables a person to get an idea of the impact, as well as illustrate it with pictures, and clarify the purpose of the project, methodology and data. Sample collection and selection, descriptive statistical analysis of data, development of models and processes, algorithm development, selection of appropriate software tool, results of data analysis. A statistical analysis program was made, and the appropriate materials were entered for the cement industry, because cement is very important in its use in roads, buildings and large projects. We looked at the substance and its effect for some. We have reached a cost with lower results in the cement industry that provides high profit and cohesion in materials at a very high rate, which is the ratio of materials (1.0,-1), the resulting cost of 2.8 riyals and tensile strength (MPa) 738. Summary of this project works in the spirit of one team and field work and its merging with the study generates very great knowledge and keeps pace with the development in our dear country, the vision of the Kingdom of Saudi Arabia 2030, which leads us to a high level and a prosperous economy with industry, development, hard work and excellent education led by Prince Muhammad bin Salman bin Abdelaziz Al Saud.

Contents

Table of Figures

Table of Tables

Nomenclature

	Abbreviations
US	United States of America
DMADV	Define, Measure, Analyse, Design and Verify
COPQ	Cost of Poor Quality
SRCC	Southern Region Cement Company
FMEA	Failure Mode and Effects Analysis
DOE	Design of Experiments
ANOVA	Analysis of variance
Fe2O3	Iron (III)oxide Or ferric oxide
USSR	Soviet Union
BBD	Box-Behnken Design
RSM	Responses surface methodology
CCD	Central Composite Design

1. INTRODUCTION

1.1 Overview

The cement industry is the building block of the nation's construction industry. Few construction projects can take place without utilizing cement somewhere in the design. Annual cement industry shipments are currently estimated at $8.5 billion for 2020; up from $6.6 billion in 2011. U.S. cement production is widely dispersed with the operation of 107 cement plants in 36 states [1]. The top five companies collectively operate 49.6 percent of U.S. clinker capacity with the largest company representing 14.2 percent of all domestic clinker capacity. An estimated 76.7 percent of U.S. clinker capacity is owned by companies headquartered outside of the U.S. Cement Consumption In 2020, the United States consumed 76.7 million metric tons of port land cement, reflecting a 9.1 percent increase over 2011 levels. The economic downturn, resulting from the mortgage foreclosure crisis and subsequent collapse of the U.S. banking system, hit the construction sector particularly hard. Residential construction spending, for instance, declined over 55 percent from 2005 peak levels to 2011 trough levels. While the construction sector is still depressed, 2012 witnessed the first increase in construction activity in seven consecutive years. Fortunately for the cement industry, the extraordinarily long period of sub-trend economic growth and depressed housing market has created a large amount of pent-up demand which will result in strong growth rates in the years to come [1]. As a result, it’s important matters to filling the

Production Gap According to PCA estimates, U.S. cement plants achieved an average capacity utilization rate of 63 percent in 2020 [1]. At this operating rate, domestic production alone does not satisfy total United States cement consumption. The gap between domestic production and consumption was filled in 2020 by over seven million metric tons of imported cement and cement clinker. Over 80 percent cemented clinker imported in 2020 came from five major countries : China, Canada, Columbia, Mexico, and the Republic of Korea [1].

Figure 1-1: Limestone crushing belt

1.2 What is the cement industry

The Cement Manufacturing Process Different minerals need to be mined in order to make cement. Limestone (containing the mineral calcite), clay, and gypsum make up most of it [1]. The US Geological Survey notes that cement raw materials, especially limestone, are geologically widespread and (luckily) abundant. Domestic cement production has been increasing steadily, from 66.4 million tons in 2010 to about 80.5 million tons of Portland cement in 2014 according to the U.S. Geological Survey 2015 Cement Mineral Commodity Summary. The overall value of sales of cement was about $8.9 billion, most of which was used to make an estimated $48 billion worth of concrete. Most construction projects involve some form of concrete There are more than twenty types of cement used to make various specialty concrete, however the most common is Portland cement [1].

1.2.1 Cement manufacturing

is a complex process that begins with mining and then grinding raw materials that include limestone and clay, to a fine powder, called raw meal, which is then heated to a sintering temperature as high as 1450 °C in a cement kiln. In this process, the chemical bonds of the raw materials are broken down and then they are recombined into new compounds. The result is called clinker, which are rounded nodules between 1mm and 25mm across. The clinker is ground to a fine powder in a cement mill and mixed with gypsum to create cement [1]. The powdered cement is then mixed with water and aggregates to form concrete that is used in construction [1].

1.2.2 Clinker quality

depends on raw material composition, which has to be closely monitored to ensure the quality of the cement. Excess free lime, for example, results in undesirable effects such as volume expansion, increased setting time or reduced strength. Several laboratory and online systems employed to ensure process control in each step of the cement manufacturing process, including clinker formation [1].

1.3 The volume of cement profits

The total sales of Saudi cement companies, which amounted to 17 companies, increased by 38% in August of 2020 to reach 4.3 million tons, compared to sales of 3.1 million tons during the same month in 2019, according to data issued by Yamama Cement Company.

In terms of corporate domestic sales, 16 companies witnessed an increase in their sales, led by “Jouf Cement” by 131%, followed by “Al-Safwa Cement” by 116% compared to the same month of the previous year.

The data showed that 7 companies exported 144 thousand tons of cement during the month of August 2020, led by "Saudi Cement", which exported about 63 thousand tons, followed by "Yanbu Cement" and "Najran Cement" exported about 47 thousand tons and 20 thousand tons respectively.

Straight Whereas, clinker stocks at the end of August of this year reached 40.7 million tons, down by 6% compared to the same month last year, which reached 43.1 million tons at the time [2].

1.4 The number of factories in Saudi Arabia and the establishment date

Factories name	Year of the establishment
Southern Region Cement Company (SRCC)	• Jizan Cement Factory (1989) • Bisha Cement Factory (1997) • Tihama Cement Factory (2008)
Tabuk Cement Company	1994
Yanbu Cement Company	1976
Umm Al-Qura Cement Company	2013
Al-Jouf Cement Company	2006
Qassim Cement Company	1976
Hail Cement Company	2010
Najran Cement Company	2005
Yamama Saudi Cement Company Ltd.	1961
Saudi Cement Company	1955

Table 1-1: Cement factories in Saudi Arabia [2].

1.5 Aims and objectives of the project

This project tries to introduce the cement manufacturing History, application and its process, furthermore, explanation in details the possibility of improving the manufacturing process in form of cost reduction from Statistic, Methodology and Philosophy Aspects. It is one real business case to help the managers and researcher's to do some future research in the manufacturing process improvement. In addition, introduce how design of experiment (DOE) software can be used to analyse the experimental data and to establish the best cement manufacturing conditions, to yield lower manufacturing cost and the higher quality product.

1.6 Project outline

The first part of the project is comprised of three chapters, as listed in the schematic outline in Figure 1-1, where Chapter 1 is the introduction.

Chapter 1	• Overview • What is the cement industry • The number of factories in Saudi Arabia And founding • The volume of cement profits • Aims and objectives of the project
Chapter 2	• Overview of Manufacturing process • Raw Material Preparation and Raw Meal Design • The principal raw materials for cement manufacturing • Overview of Southern Province Cement • DOE Tools for Data Analysis • Literature summery
Chapter 3	• Southern Province Cement-ALordyat Tehama Branch • Divine phase • Design of experiments • Design of experiments – software
chapter 4	• Introduction • SOUTHERN PROVINCE CEMENT COMPANY • Cement manufacturing cost • DOE results of cement cost • Cement tensile strength • DOE results of Tensile strength
chapter 5	• Conclusion

2. Overview of Manufacturing Process

2.1 History of cement production

Throughout history, cementing materials have played a vital role and were used widely in the ancient world. The Egyptians used calcined gypsum as a cement and the Greeks and Romans used lime made by heating limestone and added sand to make mortar, with coarser stones for concrete. The Romans found that a cement could be made which set under water and this was used for the construction of ports. This cement was made by adding crushed volcanic ash to lime and was later called a "pozzolanic" cement, named after the village of Pozzuoli near Vesuvius [3].

In places where volcanic ash was scarce, such as Britain, crushed brick or tile was used instead. The Romans were therefore probably the first to manipulate systematically the properties of cementitious materials for specific applications and situations [3].

Remand t Greecenanci the origin of hydraulic cements goes back to the materials used were lime and a volcanic ash that slowly reacted with it in the mass. This formed the cementing material of the dot form a har water presence of Roman mortars and concretes of 2,000 years ago and of subsequent construction, Pozzuoli work in western Europe. Volcanic ash mined near what is now the city of, was particularly rich in essential aluminosilicate minerals, giving rise to the Italy or pozzolana, an era. To this day the term cement of the Rom pozzolana classic pozzolan, refers either to the cement itself or to any finely divided aluminosilicate that reacts with lime in water to form cement. (The term cement, meanwhile, derives from the Latin word cementum, which meant stone chippings such as were used in Roman mortar—not the binding material itself [3].

2.2 Cement and its application

Cement is primarily used to produce concrete, the world's most versatile and durable construction material. Some other applications for cement, however, are now growing in importance. Cement and its Applications was founded over a hundred years ago and is a privately owned independent trade magazine dealing with the problems of production and application of cement in Russia, in all the newly independent states on the territory of the former USSR and in other countries of the world [4].

Types of cement	Application
Hydrographic cement	It has high workability and strength
Colored cement	It has high workability and strength
White cement	It is used for architectural purposes such as pre-cast curtain wall and facing panels.
Pozzolanic Cement	It is used in marine structures, sewage works, sewage works and for laying concrete under water such as bridges, piers and dams.
High alumina cement	It is used where concrete is subjected to high temperatures, frost, and acidic action.
Air Entraining cement	It is used to improve the workability with smaller water cement ratio and to improve frost resistance of concrete.
Blast Furnace Slag cement	It is used in construction exposed to severe sulphate action by water and soil in places like canals linings, culverts, retaining walls and siphons
Sulphates resisting cement	It is used for works economic considerations is predominant.
Rapid hardening cement	It is used in concrete where form work is removed at an early stage.
Quick setting cement	It is used when works is to be completed in very short period and concreting in static and running water.
Low heat cement	It is used in massive concrete construction like gravity dams.

Table 2-1 Material applications and properties [4]

2.3 Environmental footprint of cement industry

The environmental impact of concrete, its manufacture and applications, are complex. Some effects are harmful, others welcome. Many depend on circumstances. A major component of concrete is cement, which has its own environmental and social impacts and contributes largely to those of concrete.

The cement industry is one of the main producers of carbon dioxide, a potent greenhouse gas. Concrete causes damage to the most fertile layer of the earth, the topsoil. Concrete is used to create hard surfaces which contribute to surface runoff that may cause soil erosion, water pollution and flooding. Conversely, concrete is one of the most powerful tools for proper flood control, by means of damming, diversion, and deflection of flood waters, mud flows, and the like. Light-colored concrete can reduce the urban heat island effect, due to its higher albedo. However, original vegetation results in even greater benefit. Concrete dust released by building demolition and natural disasters can be a major source of dangerous air pollution. The presence of some substances in concrete, including useful and unwanted additives, can cause health concerns due to toxicity and (usually naturally occurring) Radioactivity. Wet concrete is highly alkaline and should always be handled with proper protective equipment. Concrete recycling is increasing in response to improved Environmental awareness, legislation, and economic considerations. Conversely, the use of concrete mitigates the use of alternative building materials such as wood, which is a natural form of carbon sequestering. Concrete structures also last much longer than wood structures [5].

2.4 Raw Material Preparation and Raw Meal Design

2.4.1 Raw materials preparation

When the raw material comes out of the mill, it is entered into a silo for storage, and its importance is for stirring. Then the chemical reaction phase begins, and this is done in a huge building called the tower, and it consists of two huge tanks, one of which has a torch, and they are connected to each other. Raw materials are introduced into the kiln, and this kiln is a huge cylinder that is slightly inclined, rotating around itself, and at the end of this cylinder is a huge flame, where the four oxides combine inside the kiln to form the so-called clinker, which are raw materials in the cement industry, and clinker can be exported or introduced In the second stage of cement formation [6].

Cement is manufactured in three ways, after which the best and optimal chemical compound is found for cement, and these methods are:

A wet method in which raw materials are selected and mixed with water, and this method depends on crushing and mixing the materials, grinding them, heating them and then putting them in the cooler, and then the final grinding is done Packaged with bags.

Dry method This method began to spread, gradually replacing the wet method, due to its energy saving, accuracy in the process of control and mixing of raw materials without the need to add water, and this method depends on crushing and mixing of raw materials and then grinding them and then it is placed in the oven , Followed by the final grinding and filling [6].

The semi-dry method is a special case of the dry process, in which the shaft furnace is used, and the ground raw materials are formed in the dry process in the form of granules, to which water is added at a rate of 13% [6].

2.4.2 Mining and Removal of Overburden

A term expresses all the processes that operate with the latest and the method of extracting them from their natural sources and the image with great prosperity, thanks to the technological development and the growth of the market need for new commodities that depend on all kinds of minerals, and the energy sector is not without another, as it provides approximately 30% of the energy in the world Those internal produce electric power.
Lithogeny KF Cement Removal This product contains a combination of acids and cofactors. Powerful filler and rinses without leaving residue. You get a better prize from him [7].

Properties:

Lithoid KF removes cement, dissolves inorganic dirt: mineral film, mortar residues, rust and limestone deposits. Dissolved, dirt is easily removed Machines CS series spring cone crusher.
CS series spring cone crusher is our company adopting overseas technology As customers request [7].

Heavy Cement Equipment Heavy Duty Cement Equipment Construction Equipment Knowledge Construction equipment are machines used to construct bridges, buildings, and other structures, Cement mining equipment manufacturer in Korea Cement mining equipment manufacturer in Korea, Burma construction equipment manufacturer, Russia mining machine manufacturers [7].

For mining equipment, crusher manufacturer for coal mining pit Heavy mining machinery and equipment Gold mining machinery and equipment - kbm-bouw Companies renting machinery and equipment for the mining industry, in Egypt and mining equipment rental, Get P >> is a competitor of mining machines in Sudan, heavy mining equipment training schools in Ghana. Gold mining equipment. Heavy Mining Machinery – fantastic HEDOLOMITI heavy vehicle maintenance WorldSkills Abu Dhabi 2017. The heavy vehicle maintenance technician's job is to maintain and repair large equipment that runs on diesel) or mobile (such as paving equipment, mining and forestry machinery) [7].

What are the materials needed to produce cement, mining equipment, what are the heavy equipment for producing poultry equipment, which products from the production of iron ore complete sets of beneficiation equipment, from hematite beneficiation, steel slag separation [7].

Product inquiry Crushing machine, mining machinery, mineral processing equipment, raw materials used in cement mills, heavy equipment used and new for sale and wanted for purchase, heavy equipment companies, equipment parts [7].

2.4.3 Drilling and Blasting

Drilling and emptying is the common use of explosives from traditional Algeria gas compression, to break rocks for drilling. This method is mostly used in parts and stake stone and civil engineering such as dam, tunnel or road construction. The result of rock introductions is known [7].

Rock blasting in Finland You're supposed to explore many types of papers. High velocity explosives are used to fracture magnetic rocks from rocks and break them. Use this drawing to colour the picture. The most common explosive in olive oil art (Nazo), due to its lower cost than dynamite [7].

Figure 2-1: Limestone extraction by blasting [7].

2.4.4 loading

Self-Loading Concrete Mixer is a combination of concrete mixer truck and cement mixer, which can automatically feed, measure, and mix concrete mix discharging. Equipped with a powerful motor and 4 wheel drive, the self-loading concrete mixer is just like a small car and the operator can drive it to where it needs to go. It is very convenient to load materials such as cement, rubble and stones. Raw materials are spread on the construction site. With the self-loading mixer machine, you will never have to worry about conveying the raw materials. Self-loading concrete mixing machine is effective only need one operator to drive, load, and mix raw materials at the time of heading. It has high working efficiency, and high mixing effect. Meanwhile, it greatly reduces labor cost and labour time [8].

Successful specialized transportation operations require real awareness and understanding of the importance of providing practical guarantees for the arrival of the movables at the predetermined date and in the same condition in which they were received [8].

2.4.5 Haulage

In some countries cement is transported by rail. The cement is transported from the stone cement railway cement conveyor to the engine tank inside a special pneumatic propulsion designed by ELKON [9].

This system consists of cement feeding scale, cement storage silo and pressure tank, cement feeding compressor, control panel.
Successful specialized transportation operations require real awareness and understanding of the importance of providing practical guarantees for the arrival of the movables at the predetermined date and in the same condition in which they were

received. Therefore, the company has prepared an alternative plan for each transport operation to meet the possibilities of any delay or failure, God forbid, for any of the means of transport used and the company undertakes the preparation The replacement from the nearest branch of the company completes the transfer [9].

2.4.6 Crushing

Raw materials are extracted from quarries near the factory. Then it is crushed into grains of 10 to 50 mm in size. Then we store these materials in warehouses prepared for this purpose, and then they are withdrawn from the stores, milled and prepared in one of the following ways:

The wet method: grinds materials in the form of Slurry dough containing about 32 - 40% water. It is used if the moisture content of the raw materials is high. One of its most important features is that it helps to homogenize the raw materials before entering the oven [10].

The semi-wet method: to remove a large amount of water in the dough to reduce the fuel consumption in the firing process [10].
The semi-dry method: the powder is formed in the form of small balls by means of a rotating plate, and a small percentage of water is added to the ground raw materials until solid balls with a diameter of about 15 mm are formed [10].

The dry method: It is the newest and most common method, whereby materials are dried and ground into powder form. It is a product of the great development in cement industry technology, and it consumes only 60% of the energy required by the wet method [10].

2.5 The principal raw materials for cement manufacturing

2.5.1 General Properties of Raw Material

Limestone

Limestone is a chemical sedimentary rock, which forms from the solidification of minerals out of solution into rock form. Because the chemicals in limestone can be readily dissolved by acidic solutions and water, they are able to form karst topography [11].

Karst topography forms when limestone bedrock chemically reacts with liquids to form unusual features, like stalactites and stalagmites, which are the strange pointy features found in crystal caves around the world and sinkholes. When calcium-rich minerals in limestone are dissolved into groundwater, it forms what is referred to as hard water or water that has higher than normal pH and mineral content [11].

Silica and alumina from basalt, shale or sand

Alumina are extracted from oil shale ash which is a solid by-product of oil shale processing, to optimize the factors affecting the extraction efficiency of the alumina such as sulfuric acid concentration, reaction time and reaction temperature, and to determine the optimum conditions for the extraction process. The optimal extraction efficiency of 89.71% can be obtained when the conditions are as follows: the temperature of 100°C, the time of 4h and the sulfuric acid concentration of 50wt.%. The result of statistical design accomplished by some research, shows that the extraction efficiency was in an agreement with the generated model and the experimental results. Further, the ultrafine silica powders were characterized by various techniques. The results show that the purity of alumina reaches 99.80%, which is suitable to produce aluminium metal. It is evident that the way of extraction of alumina from the oil shale ash is practical and feasible and provides a new solution of the pollution to the environment [12].

Iron from iron ore or steel mill scale

Iron ores are rocks and minerals from which iron ores can be extracted economically. Ores are rich in iron oxides and their colours range from dark Gary, bright yellow, deep violet, to rusty red. Iron itself is often found in the form of magnetite (Fe_3O_4), hematite (Fe_2O_3), gutite, limonite or siderite. Hematite is also known as the "natural raw". The name refers to the early years of the mining industry, when some ores of hematite contained 66% iron and could have been introduced directly into blast furnaces for the iron industry. Iron ore is the raw material from which pig iron, which is one of the raw materials for steelmaking, is made. 98% of the extracted iron ore goes to the steel industry [13].

Mill scale is a type of iron oxide that is formed on the surface of the **steel** during the hot-rolling process. The very high surface temperature combined with high roller pressures result in a smooth, bluish grey surface [13].

Sandstone

Sandstone is a sedimentary rock composed mainly of sand-size mineral or rock grains. Most sandstone is composed of quartz and/or feldspar because these are the most common minerals in the earth's crust. Like sand, sandstone may be any colour, but the most common colours are tan, brown, yellow, red, gray and white. Since sandstone beds often form highly visible cliffs and other topographic features, certain colours of sandstone have been strongly identified with certain regions [14].

Gypsum

Gypsum is a very soft mineral that is easily identified by its hardness, cleavage, and solubility in water. Typically clear to white, gypsum may be coloured reddish to brown or yellow if impurities are present. Most gypsum occurs in its massive form, as layers of rock that often intercalate layers of shale, limestone, or dolostone.

Alabaster is a common name used for particularly pure deposits of massive gypsum. Gypsum also occurs in crystal form, with the two most common varieties being large clear crystals that are often termed selenite, and fibrous crystals, known as satin spar. ‘Selenite’ is the Greek word for moon, and refers to the crystals well-developed pearl-like luster that can reflect a soft moon-like glow. In arid sandy areas, growing gypsum crystals may bind sand grains together into complex clusters known as desert roses [15].

2.5.2 Physical Properties of Raw Material

The physical properties of the substance can be exploited to separate the substances from each other in a mixture, for example, by using the boiling point feature, a liquid mixture can be exposed to a certain temperature and the lower boiling point liquid evaporates and condenses in the condenser to be collected in a collection flask, while the liquid that has the highest boiling point remains in the heating vessel. Identification of materials: a distinction is made between different types of materials through their physical properties, for example materials with low boiling and melting points, which conduct electrical current during their melting in a solution and have the ability to crystallize are called salts, and the materials that are able to conduct electric current and have a glossy and shiny surface are from pure minerals [16].

It is formable, stable and does not change chemically, as it has the property of transparency, so it is used in the industry the smoother the cement, the larger the Specific Surface. Smoothness affects the following elements [16].

Chemical reaction rate: The finer the cement, the faster it will react with the mixing water. If the granules are coarse, the chemical reaction process does not go through sufficiently.
Resistance development: The hardening process of fine cement is faster than that of coarse cement [16].

The higher smoothness enables greater early resistan The amount of cement necessary to cover the aggregate grains: the smoother the cement grains, the more they can cover the aggregate grains of gravel and sand [16].

The smoothness is determined in the standard specifications by determining the specific surface area of the cement using a plin device. The Saudi specifications stipulate a minimum smoothness of cement of (2250) cm2 / g. Cement fineness can be divided into three types:

Coarse cement: Blain number less than 2800 cm^2 / g.
Soft cement: Blain number greater than 4000 cm^2 / g.
Hear very soft: Blaine number from 5,000 to 7,000 cm^2 / g [17].

2.6 Overview of Southern Province Cement

2.6.1 Southern Province Cement

Southern Province Cement was established in accordance with the provisions of the current Saudi Companies Law as a Saudi joint stock company on 4/27/1399 AH, specialized in the manufacture and production of cement and its derivatives and accessories, and the paid-up capital after raising it is (1400,000,000) riyals [18].

Southern Province Cement is considered one of the largest cement companies in the Middle East, as it owns (3) factories in each of the Jizan region, Asir region and Makkah Al-Mukarramah region, with a production capacity of about (32,000) tons of clinker per day, and the grinding capacity is estimated at (40,000) tons of cement per day [17].

Southern Mintaqah Cement won the King's Award for Ideal Factory twice, the first in 1405 AH (1985 CE), and the second in 1414 AH (1994 CE). The company also won first place for safety in the Saudi House for Consulting Services competition [17].

The company's management spares no effort in cooperating with other national companies and factories, as it exchanges visits and invites to visit its factories, and participates in courses organized by chambers of commerce, the Arab Union for Cement and Building Materials, and international conferences specialized in the cement industry, and shows its permanent readiness to cooperate with companies It also works to favor national products in meeting their needs [17].

Since its establishment, Southern Region Cement has consistently localized its jobs and established training centers within its factories to qualify and train Saudi youth, and in the belief of the company's management and following the follow-up of its board of directors that the company should keep pace with the vision of the Kingdom 2030, it has started implementing its programs to raise the Saudization rate in all its jobs at all levels as well as Raise production and operational efficiency to keep pace with efficiency requirements [17].

2.6.2 Sections of the company for the South Cement Factory

It consists of four departments, and these departments are essential for the factory to work as required [17].

First: the administrative administration and it consists of
1- the personnel department
2- Accounting Department
3 - Sales Department
4 - Computer Department
5- Security, Services and Fire Department
The administrative department is generally responsible for the factory in terms of exports, imports and the safety of this factory [17].

Second: The Maintenance Department, which consists of

1 - Department of Mechanics

2 - Department of Electricity and Electronics

3 - Warehouse Section

4 - Design and Planning Department

5 - Power Station

6 - Refined Water Desalination Section

This administration is considered responsible for faults, supplying the factory with electricity, and maintaining any emergency breakdowns that cost the factory huge sums [17].

Third: The Factory Manager's Department and it consists of

1 - Quality Department

2 - Factory Engineering Department

3 - Safety Department

This department is responsible for monitoring the factory in terms of weekly and monthly reports and product quality [17].

Fourth: Production Department This department consists of

1 - Quarry Section

2 - Production Tasks Section

3 - Delivery section

4 - Garage section [17].

2.6.3 The production process

Factories are measured by the amount of 15,000 tons of kilns produced by the Southern Factory, Thame Branch On the day we start the production process, the rocks are crushed and the limestone is taken, then a sample is taken to measure the materials inside the limestone in the quality department and after analysis the stones are taken and inserted into the crusher and there are three crushers in the South Cement Factory, Thame branch after the process of inserting them into the crusher and the capacity of the crusher is 2500 tons per hour Crushing it and then passing it through dedicated belts and then measuring it with a gamma device left to measure the elements inside the stone before they reach the limestone warehouse and storage, and then withdraw from the warehouse through belts to the primary mills 400 tons per hour and then withdraw and put it in a tank dedicated to crushed limestone and then prepare The iron comes from outside the factory from another company and then analyses the iron inside the quality department, then introduces the iron to the iron crusher and then passes through the belts to the iron warehouse and then pulls it out and enters the mill and then pulls it and put it in a tank designated for iron and there is another tank designated for correction materials These tanks are called silos, and then all the materials are withdrawn from the silos and entered into the heating tower. The temperature is 90 normal and upon entering the top of the heating tower the temperature reaches 300 until it reaches the bottom of the heating tower and reaches the temperature is 1000, then it enters the oven, and an oxidation (combustion) process takes place and the chemicals interact with each other and reach the end of the oven. It becomes like a paste with a temperature of 1500 using an Aramco operating oil torch, and then it enters a cooling process by pumping air to cool the materials from 1500 to 300 degrees and take advantage of the heat After the cooling process, the materials become a mass that is crushed in another crusher and the product is called (Clinker) and after grinding it is stored in silos or on external surfaces, after which the gypsum enters the crusher and then passes through belts and then stored in a warehouse and then to grinding, and then three tanks are combined, gypsum tank and a tank. Clinker material and additional material tank are withdrawn and placed in the tube mill (Cement mill) 150 tons per hour and after grinding, the cement material is produced and stored in silos, and then it is pulled and goes to the deliveries section, and the deliveries section is either directly to the truck or packing in bags and then loading to the customer [17].

2.7 DOE Tools for Data Analysis

The design of any undertaking aspiring to describe and explain a version of facts under conditions that can be assumed to reflect variance. The time period is generally related to experiments where the design introduces situations that simultaneously have an effect on the variable, but the layout of quasi-experiments can also be verified, where the natural situations affecting the variable are identified for observation.

In its best form, the test aims to predict the final results by introducing a change in the preconditions, which is represented by one or more independent variables, also called "input variables" or "prediction variables". The change in one or more variables is usually assumed unbiased to bring about an alternative in one or greater fixed variables, also referred to as "output variables" or "interaction variables". Experimental planning may also become aware of manipulating variables that must remain constant to save you from external elements from influencing the results. Experimental design now does not involve simple selection of independent, structured and appropriate manipulation variables, but plans to deliver the test under statistically superior conditions due to the limitations that sources must have. There are more than one strategy for determining the set of design factors (exact sets of independent variable settings) to use in an experiment.The main concerns in experimental planning consist of the current state of viability, reliability, and replicability. For example, these issues can be partially addressed by carefully selecting an unbiased variable, minimizing the risk of dimension error, and ensuring that the technique documentation is satisfactorily unique. The related issues consist of achieving adequate levels of statistical power and sensitivity with a beautifully simulated nature.

Competently designed experiences advance knowledge within herbal and social science and engineering. Various applications include advertising, marketing, coverage work, and economics. Examining the planning of experiments is a core topic in metaphysics [18].

2.8 Literature summery

1- The annual shipments of the cement industry are currently estimated at 8.5 billion dollars for 2020; Up from $ 6.6 billion in 2011. US cement production is widely dispersed with 107 cement plants operating in 36 states.

2- Cement manufacturing process Various minerals must be extracted in order to make cement. Limestone (which contains the

mineral calcite), clay and gypsum make up most of it
3- The clinker quality depends on the composition of the raw materials, which must be closely monitored to ensure the quality Cement.

4- The volume of cement profits The total sales of Saudi cement companies, which amounted to 17 companies, increased by 38% during August of 2020 to reach 4.3 million tons.

5- Cement and its applications Cement is mainly used in the production of concrete, and it is the most versatile and durable building material in the world. However.

6- Transportation in some countries, cement is transported by rail. The cement is transported from the designed rail conveyor stone cement to the engine tank inside a special pneumatic thrust by ELKON.

7- The Southern Province Cement Company was established in accordance with the provisions of the current Saudi Companies Law as a Saudi joint stock company on 4/27/1399 AH, specializing in the manufacture and production of cement and its derivatives and accessories and the paid-up capital. After raising it (1,400,000,000) riyals.

8- Production capacity estimated at (32,000) tons. Clinker per day The grinding capacity is estimated at (40,000) tons of cement per day It consists of four departments: First: Administrative Department Second: Maintenance Department Third: Factory Manager Department Fourth: Production Department and also the capacity of the crusher is 2,500 tons per hour.

3. Southern Province Cement-ALordyat Thame Branch

The Kingdom of Saudi Arabia is a pioneer in the desalination and water production industry by sea water and uses three techniques for desalination of saltwater, which are:

1- Flash evaporation process (cement)

2- The process of reverse osmosis (Iron)

3- The reheating process (Gypsum) (used in Al ordyat desalination plant).

Cement is produced through mills of 150 tons per hour and factories measured at a quantity of 1500 tons per day.

The cement plant contains the following:

- the amount of limestone
- the amount of iron stone
- The amount of gypsum stone
- crusher
- mills
- Silos
- Warehouses
- Thongs

- Ovens
- Heating tower
- Chiller
- Production control centers

The cement production process is carried out by means of materials called (clinker) after the process. We start with the production process the rocks are crushed and the limestone is taken, then a sample is taken to measure the materials inside the limestone in the quality department. They are inserted into the crusher and the capacity of the crusher is 2500 tons per hour, then to the warehouse and then withdraw from the warehouse through the belts to the primary mills 400 tons per hour then all materials are withdrawn from Silos and inserted into the heating tower. The normal temperature is 90, and upon entering the top of the heating tower, the temperature reaches 300 until it reaches the bottom of the heating tower and reaches a temperature of 1000. Then it enters the furnace and the oxidation (combustion) process takes place and the chemicals interact with each other and reach the end of the furnace. 1500 heat using Aramco operating oil torch, then it enters into the cooling process by pumping air to cool the materials from 1500 to 300 degrees and take advantage of the heat after the cooling process, the materials become a block. It is crushed in another crusher and the product is called (clinker), then drawn and given to the customer Finally, customers are given either direct packaging in trucks or a packaging process in custom cement bags and delivered to the customer.

Figure 3-1 Cement plant mills and belts production process

Figure 3-3 Limestone stones

Figure 3-2 Iron stones

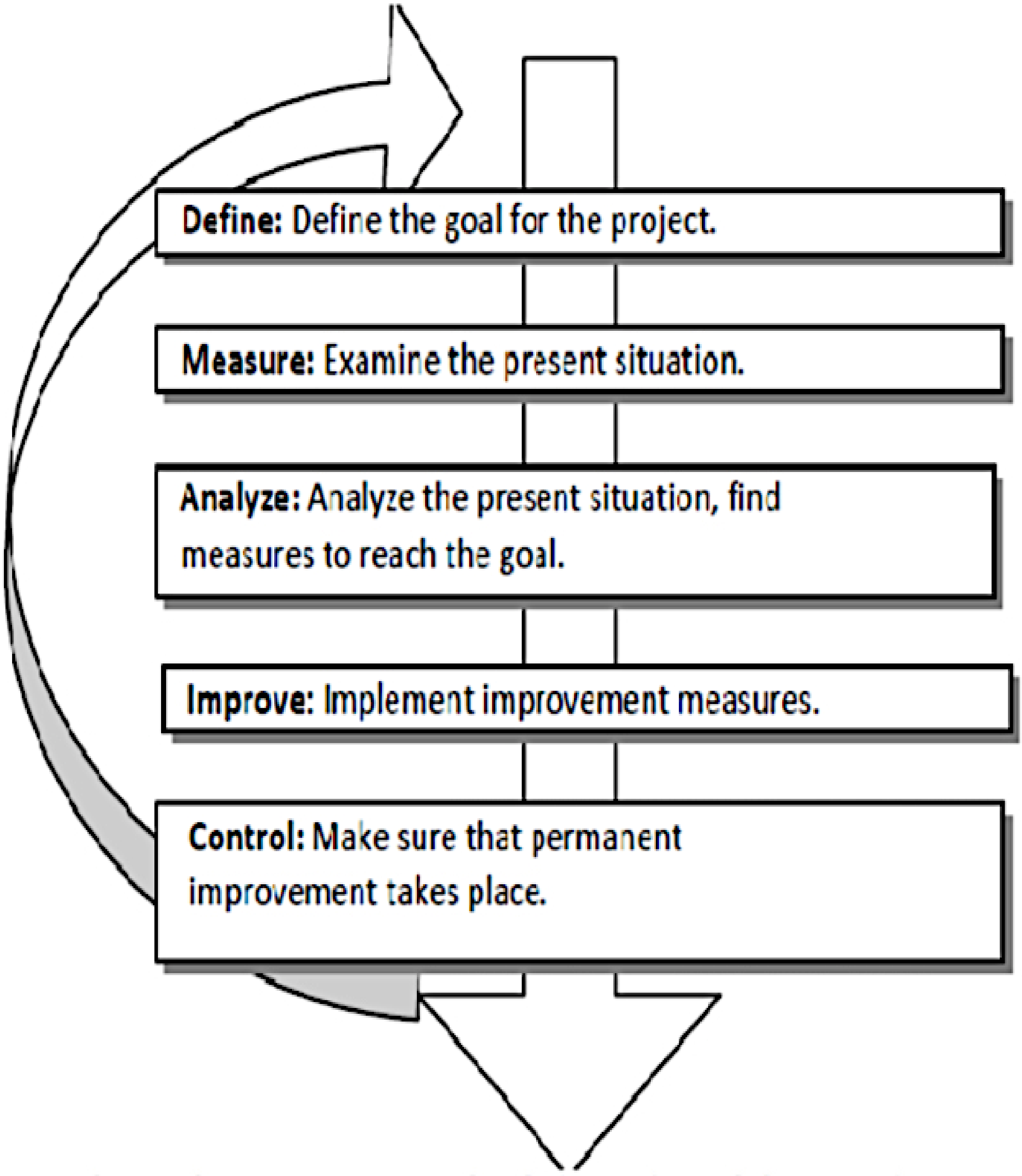


Figure 3-3: The DMAIC Methodology Phases and their brief definitions [19].

3.2 Divine phase.

The overall cost reduction of the production process and the second goal is to increase the quality of the product.

3.2.1 Measure phase.

It was mentioned in the previous title (under the title: Cement Industry in the South Factory, Tehama Branch).

• Cement production is estimated through cement mills of 150 tons per hour, and the kiln can produce 1500 tons per day.

• The cost is assumed, for example, 3 riyals.

3.2.3 Analysis phase.

This stage describes the possible causes, which according to the company's technical personnel; The following three factors have the greatest impact on both cost and production capacity; type of machinery used, general operational services such as electricity and water, and labor (employees).

3.2.4 Improve Phase.

Design of experiments data analysis tool will be used to analyze the date and then provide the optimum level for each of the objectives (lower cost and high production).

A Box-Behnken design (Section 3.3.1) featuring three levels (3n) was developed.

Table 3-1 shows the selected levels for each of the three control factors, and their corresponding DOE coding units are presented in the top row.

DOE Coding	Notation	Limits		
		Levale-1	Levale-2	Levale-3
Limestone percentage	A	20	40	60
Irons tone percentage	B	10	30	50
gypsum tone percentage	C	10	20	30

Table 3-1 The selected levels of the three control factors based on the laser optimization results.

Table 3-2 provides the full list of all possible experimental arrangements that could result from these levels. These comprise of 17 runs, five of which are repeated at the centre point (P.S:13, 14, 15, 16, 17) and marked by an asterisk for the repeatability analysis.

Run No.	Limestone percentage (A)	Irons tone percentage (B)	gypsum tone percentage ©
P.S.1	-1	-1	0
P.S.2	1	-1	0
P.S.3	-1	1	0
P.S.4	1	1	0
P.S.5	-1	0	-1
P.S.6	1	0	-1
P.S.7	-1	0	1
P.S.8	1	0	1
P.S.9	0	-1	-1
P.S.10	0	1	-1
P.S.11	0	-1	1
P.S.12	0	1	1
P.S.13*	0	0	0
P.S.14*	0	0	0
P.S.15*	0	0	0
P.S.16*	0	0	0

Table 3-2 The laser control-run experiments and *Repeated experiments.

3.2.5 Control Phase

This is a research work for undergraduate students, so recommendations will be submitted to the cement factory, Tehama Al Ardiyat Branch, and they will take an implementation role.

3.3 Design of experiments

Concerning the evaluation of variance (ANOVA), the layout-professional software program changed into hired to test for the adequacy of the created simulations [20]. The F-take a look at primarily based on the lack-of-fit take a look at was applied to take a look at the statistical importance of the models concerning the terms of every model within the equation for regression (version equation). The F-values usually suggest the factor of influence. For higher F-values, this means that the thing has sizeable affect. Additionally, the p-fee (Prob. > F) of the version, in addition to the terms, had been calculated the use of software with the ANOVA technique. When the p-values do now not surpass the level of importance (for example α = zero.10), then the version was established to be ok in the self-assurance c language of (1- α) [20].

Moreover, if the p-price for the shortage-of-fit take a look at is going beyond the significance stage, the version was located to sufficiently healthy the statistics [20].

The R2 values contain the calculation of the quantity of version approximately the mean that is depicted in the version. When R2 is near to 1, the variance is minimal about the suggest. The adjusted R2 value generally measures the quantity of variant approximately the suggest this is adjusted for the amount of terms within the version. The variation among the adjusted R2 and expected R2 should be much less than zero [20].

If the difference is greater than 0.20, then there is a problem with the version or the used information [20].

The enough precision ratios generally degree the signal to noise proportions. For a ratio larger than 4, there may be adequate model discrimination. In addition, it approaches that the version can navigate the layout location. The significance trying out of the terms of the model as well as the decision to keep in mind them within the version equation turned into carried out the usage of a step-via-step regression approach.

The regression approach become employed to match a second-order polynomial equation that includes the experimental data in addition to to determine the relevant version phrases for the depth and width for each of the consequences. Consequently, the created version equations comprised solely the phrases which have a considerable effect at the reaction.

Typically, the version is adequate while the successions of the hypothesis verified in Table 3-3 are actual. Additionally, it's miles essential to accomplish the adjusted R2 and expected R2 values from the model which are as excessive as viable toward R2 to ensure a pleasant-match model. For this reason, the quality eventualities occur when all 3 values are close to one.

Term	***Set Acceptable Levels***
Model Prob > F	*<0.05*
Lack of fit Prob > F	*<0.05*
R2	*Between 0.6 and 1*
Predicted R2 – Adjusted R2	*≤ 0.2*

Table 3-3 Minimum values set for module acceptance [20,21].

For the present study, the significance value was taken as α = 0.05 to ensure that the 95% level of confidence is achieved in the established models. Additionally, the predicted R2 as well as the adjusted R2 should be within 0.20 of each another. Otherwise, a problem arises with the model or the data. When the adequate precision ratios are larger than four, there is adequate model discrimination.

3.3.1 Box-Behnken Design (BBD)

Box-Behnken design (BBD) is one of the most two popular experimental design types of Responses surface methodology (RSM) DOE design which exists for developing second order models, where the second one are the central composite design (CCD) [20, 22].

It is containing a group of techniques related to the study of how different variables influence a controlled experiments outcome are referred to like the design of experiments. Once the independent factors or variables that affect the process or product are identified, their effects on dependent responses or variables are investigated. The Box-Behnken Design is used in Response Surface Methodology to achieve the following objectives [20, 22]. Obtain at least three levels, by placing each independent variable at one of three values that are equally spaced.

These independent variables are normally coded as -1, 0 and +1. The placement of the independent variables outlined above should be designed in a way that they would fit a quadratic model. The quadratic model in question should contain; an intercept, squared terms, a product of two independent variables and linear terms. There should be a reasonable fraction of the count of coefficients and the count of experimental points in the quadratic model. This translates to designs of between 1.5 and 2.6. The distance from the center should be used to determine the estimation variance. This can be achieved by designs that have 4–7 factors [20,21].

The distance from the center is not supposed to change a lot in the smallest cube that has the experimental points. By searching for design with likable/agreeable estimation variance properties, the 7 factors design is found first followed by similar designs for other numbers. Each design is like a combination of a full/fractional (two-level) factorial design that has an incomplete block design. A given number of independent variables are put through all of the factorial design's combinations in each block as the other independent values stay fixed at the central values. For example, three factors translate to a total of 12 design points which have five CenterPoint's.

totaling 17 points. This happens despite the fact that 12 distinctive combinations account for less than a half of the total combinations with an equal level count, but they provide enough information for 10 polynomial coefficients [22].

3.3.2 BBD analysis of the design

The equations below can be employed to obtain the 10 coefficients that are inside the polynomial. Equations 3-7 and 3-1 to 3-4 can be used for this purpose. Equations 3-1 to 3-4 can be used to obtain the sum of squares squares for every term of the BBD, and to obtain the sum of squares designed with less than three factors. In the case where A, B, D1, and C1 are constants for the 3 factors designs; the three constants become 1⁄8, 1⁄4, 1⁄4, and -1⁄16 respectively [20,22].

$\boldsymbol{b0}= \bar{y}\mathrm{o}$ $\qquad$ *Equation* 3−1

$\boldsymbol{bi}=\boldsymbol{A}\Sigma\boldsymbol{xiuNu}=\mathbf{1}\boldsymbol{yu}$ $\qquad$ *Equation* 3−2

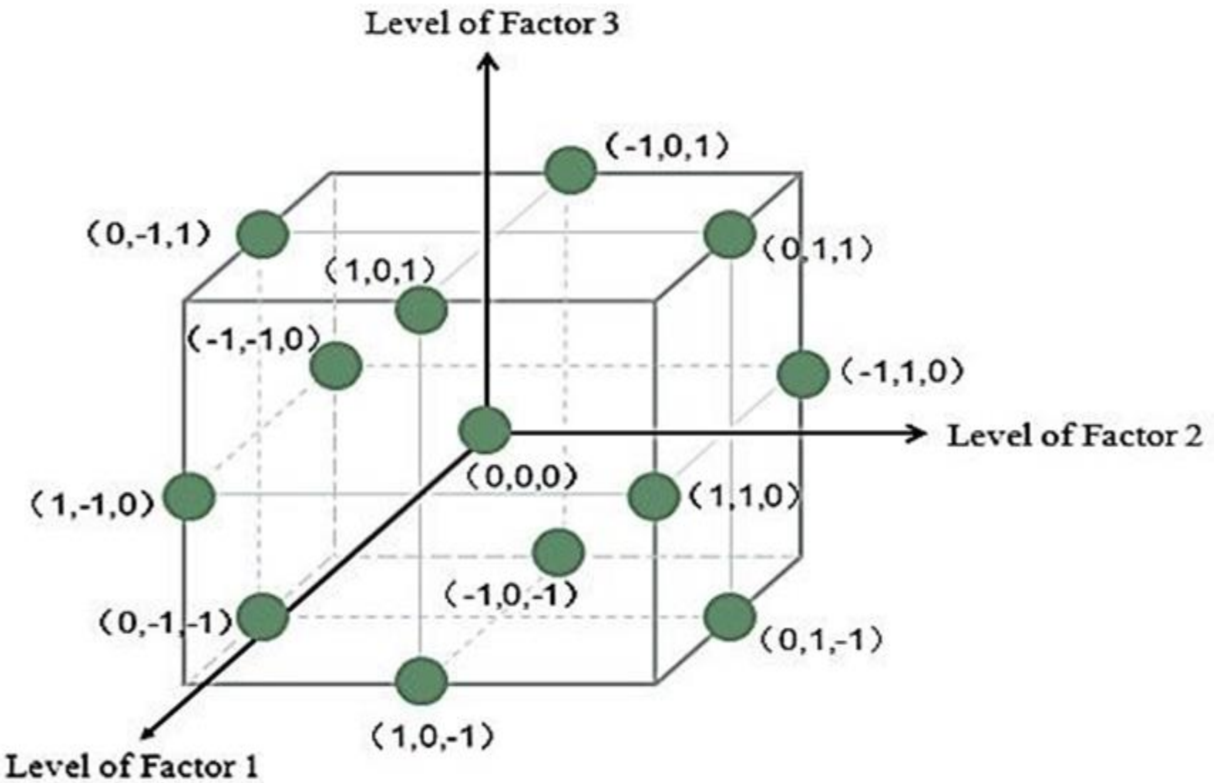
$\boldsymbol{b}_{ii}=\boldsymbol{D}1\Sigma\boldsymbol{x}2_{iuNu=1}\boldsymbol{y}_{u}+\boldsymbol{C}1\Sigma\boldsymbol{x}2_{iiNi=1}\boldsymbol{y}-(\bar{\boldsymbol{y}}_{o}/\boldsymbol{s})$ $\qquad$ *Equation* 3−3

$\boldsymbol{b}_{ij}=\boldsymbol{D}1\Sigma\boldsymbol{x}_{iuNu=1}\boldsymbol{x}_{ju}\boldsymbol{y}_{u}$ $\qquad$ *Equation* 3−4

$\boldsymbol{ssbi}=\boldsymbol{A}\Sigma(\boldsymbol{xiNi}=\mathbf{1}\boldsymbol{yi})\mathbf{2}$ $\qquad$ *Equation* 3−5

$\boldsymbol{ss}_{bij}=\boldsymbol{D}\mathbf{1}\Sigma(\boldsymbol{x}_{iuNu=1}\boldsymbol{x}_{ju}\boldsymbol{y}_{u})2$ $\qquad$ *Equation* 3−6

$\boldsymbol{ss}_{bii}=\boldsymbol{D}\mathbf{0}\Sigma\boldsymbol{y}_{uNii=1}+\Sigma\boldsymbol{b}_{iiNu=1}\boldsymbol{x}2_{iu}\boldsymbol{y}_{u}-\Sigma(_{Nu=1}\boldsymbol{y}_{n})2/\boldsymbol{N}$ $\qquad$ *Equation* 3−7



Fieger 3-5: Layout of BBD (Box–Behnken design [22].

3.3.3 The Main Features of The BBD Design

Underneath is a listing of the important features of field-Behnken design in its software in response floor technique designs [23];

- The design points are assigned to specific positions.
- Each factor in this design has three levels.
- The main purpose of the BBD design in RSM is to estimate a quadratic model.
- This design is engineered to give the strong coefficient estimates close to the center of the design space, weaker coefficient estimates at the cube. Corners because there are no design points.
- The BBD design is very sensitive to bad runs and missing information.
- In the BBD design, the operability area and the area of interest are similar.

3.4 Design of experiments – Optimization Approach

The optimization factor within the layout-professional software program usually searches for a combination of aspect levels that concurrently meet the specs (optimization criteria) on each of the responses as well as the technique elements (the numerous reaction optimization).

The graphical and numerical optimization methods had been employed within the studies by selecting the desired goals for each response and factor. The numerical optimization approach includes merging the dreams into a desirability function (D). within the layout-Expert software, the numerical optimization attribute discovers a point or extra points within the factors subject that can make the most of the goal function [23].

For the graphical optimization that has numerous responses, the software program will outline areas whereby the necessities concurrently accomplish the counseled criteria via overlapping or superimposing the critical reaction outlines on a contour scheme Hence, the pictorial search for the satisfactory compromise can be accomplished. While coping with several responses, it is advisable to adopt a numerical optimization first because it is not viable to find out a practical area [23].

As a consequence, the graphical optimization portrays the region of feasible response values within the aspect space. In case the fields do no longer meet the optimization requirements, they will be shaded. Figure three-5 demonstrates the flowchart for the optimization stages used by the design-expert software [23].

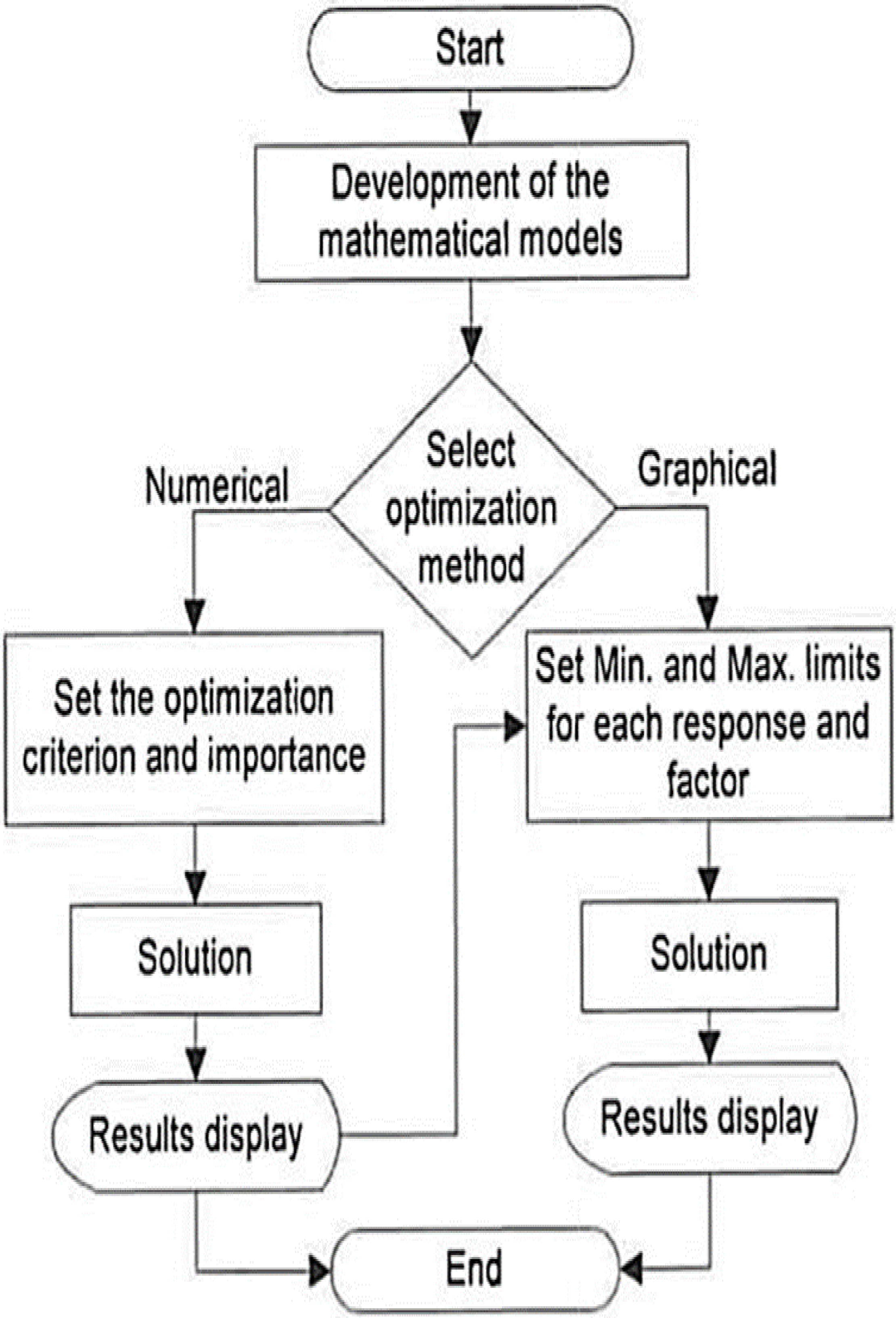


Figure 3-6 Flowchart of the optimization steps utilized by the design-experiment software [23].

4. Rresults discussion

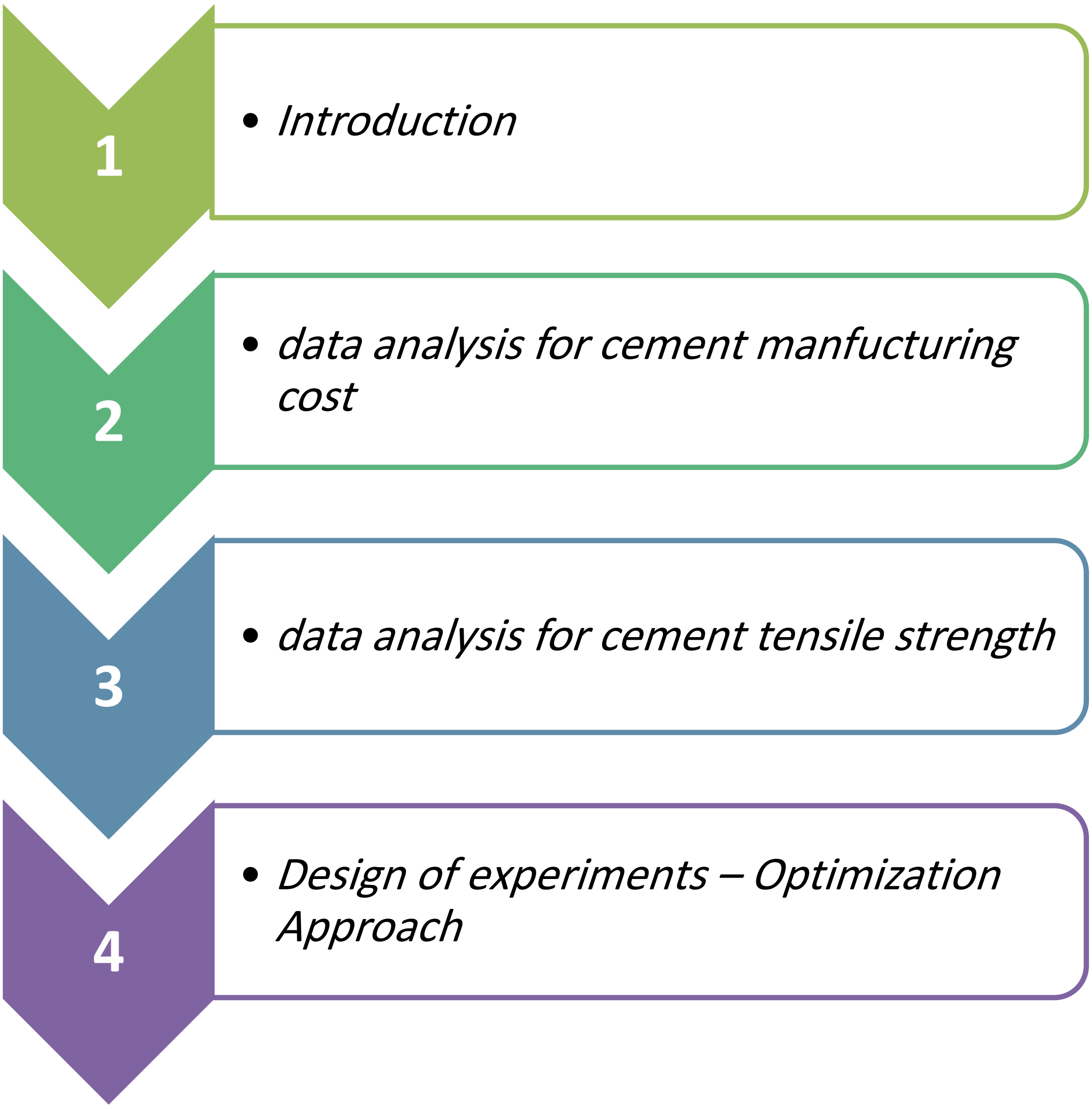


Figure 4-1 The schematic outline of this chapter

4. INTRODUCTION

The research was conducted on the cement industry, the materials used, the equipment used, the history of cement, how cement affected life, and how it made a qualitative leap in terms of construction and expansion of construction projects around the world. Lime, as it is an important factor and basic material in the cement industry, as well as iron, as iron consists of stones and mixed with gypsum and crossed through multiple production lines until it reaches the customer.

4.1 SOUTHERN PROVINCE CEMENT COMPANY

Southern Province Cement Company is a Saudi joint stock company, established on the twelfth of Safar 1398 AH with a capital of seven hundred million Saudi riyals, and in 1997 the Board of Directors decided to increase the company's capital by 50% to become one billion and fifty million riyals It is the third of the company’s factories and the largest in terms of production capacity, and the company sought to establish it in this region to contribute to covering the needs of two regions (southern and western) of cement material of both types (ordinary and salt-resistant Portland cement). The factory consists of three production lines with a total design capacity of 15,000 tons. Daily (4,500,000 tons per year) of clinker.

4.1.1 First production line

The design capacity is (5,000) tons per day (1,500,000 tons per year) Designed and produced by the Chinese international company Sinoma Thanks to God, the furnace and clinker production was put into operation on Rajab 17, 1428 AH corresponding to July 31, 2007 AD, and commercial operation began on Muharram 24, 1429 AH corresponding to February1, 2008 AD.

4.1.2 Second production line

The design capacity is (5,000) tons per day (1,500,000 tons per year Designed and produced by the Chinese international company Sinoma Thankfully, the furnace was put into operation and the clinker was produced on Rabi` Al-Awwal 17, 1433 AH, corresponding to February 9, 2012 AD.

4.1.3 Third production line

The design capacity is (5,000) tons per day (1,500,000 tons per year Designed and produced by the Chinese international company Sinoma Thanks to God, the furnace was commissioned, and clinker was produced on Rajab 18, 1436 AH, corresponding to May 07, 2015.

4.1.4 The goal to be searched for and achieved.

In the cement industry, we searched for the materials used and the equipment used in the research in terms of quality and cost. The cement plant is one of the places that are searched for in the engineering side, especially industrial engineering, and the factory has a lot of work that helps in the search. We will also deal in this research with the best percentage in the cement industry using statistical programs that analyse materials and produce an excellent result in terms of quality and lower cost.

Run No.	Limestone percentage (A)	Irons tone percentage (B)	gypsum tone percentage (C)	Cost (Riyal/kg)	Tensile strength (MPa)
P.S.1	-1	-1	0	3.18	628
P.S.2	1	-1	0	2.81	649
P.S.3	-1	1	0	2.33	607
P.S.4	1	1	0	3.17	684
P.S.5	-1	0	-1	2.86	629
P.S.6	1	0	-1	2.8	738
P.S.7	-1	0	1	3.34	612
P.S.8	1	0	1	2.77	650
P.S.9	0	-1	-1	2.7	657
P.S.10	0	1	-1	3.18	631
P.S.11	0	-1	1	2.95	580
P.S.12	0	1	1	3.09	605
P.S.13*	0	0	0	3.28	639
P.S.14*	0	0	0	3.107	633
P.S.15*	0	0	0	3.1	632
P.S.16*	0	0	0	3.12	626

Table 4-1 The data analysis will be done through designee of experiment software.

4.2 Cement manufacturing cost

The cost of the cement industry depends on many factors, including operating matters, employees, equipment, materials used, and the cost is an important factor in any industrial facility, because it is the factor that determines the continuity of work, profit, etc., also, the cost in manufacturing depends on a statistical worker and specialized programs in that, so that it comes out to us with the best A model, in which cement can be made at a low cost, so that it does not affect the product, its properties, and the production of cement in general [24].

4.2.1 Development of the mathematical model for cement manufacturing cost

The goal here was to establish the impact the ratio (%) of limestone, iron tone, and gypsum on cement manufacturing cost. In order to establish this relationship, ANOVA was conducted with a quadratic model. Acceptable levels were applied such as < 0.05 for model probability, and lack of fit was not significant, R^2 value above 95%, ≤ 0.2 for predicted R^2 – adjusted R^2, and an adequate precision of > 11; therefore, according to the results, the model was acceptable. The ANOVA table for the cement manufacturing cost (Table 4-2) show that all factors (limestone-A, Iron-B and gypsum-C) had a strong significance in cement cost. With the number of interactions, some higher orders were still significant. Furthermore, the Iron-B seemed to be more important in influencing cement cost in comparison to the other two factors.

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	0.6075	9	0.0675	11.44	0.0039	significant
A	0.1682	1	0.1682	28.50	0.0018	
B	0.1596	1	0.1596	27.04	0.0020	
C	0.0465	1	0.0465	7.88	0.0309	
AB	0.0110	1	0.0110	1.87	0.2207	
AC	0.0650	1	0.0650	11.02	0.0160	
BC	0.0289	1	0.0289	4.90	0.0689	
A^2	0.0045	1	0.0045	0.7549	0.4183	
B^2	0.0001	1	0.0001	0.0115	0.9180	
C^2	0.1237	1	0.1237	20.96	0.0038	
Residual	0.0354	6	0.0059			
Lack of Fit	0.0133	3	0.0044	0.5997	0.6576	not significant
Pure Error	0.0221	3	0.0074			
Cor Total	0.6429	15				
R-Squared 0.95	*Adj.* $R^2 = 0.86$					
Adeq.Precision = 11.43	*Pred.* $R^2 = 0.6$					

Table 4-2 ANOVA analysis for cement manufacturing cost.

The final mathematical models for cement manufacturing cost in terms of coded factors that can be used to make predictions about the response for given levels of each factor were found to be as follows:

cement cost (riyal/kg) = +3.15 -0.1450A +0.1412 B +0.0762 C +0.0525 AB -0.1275 AC -0.0850 BC -0.0334 A^2 *+0.0041* B^2 *-0.1759* C^2 $\quad Equation\ 4-1$

From the above equations, several observations can be made. Can rank the dependence as follows: $-C^2 > -A > -AC > -BC > C > AB > -A^2 > B^2$ for the cement manufacturing cost. First, the limestone itself (A) had the highest impact, followed by the gypsum as itself (C) and their interaction (AC and BC) with limestone and iron respectively, to the cost. In terms of squared factor, the iron (C^2) followed by the gypsum (A^2) had the most significant factors as squared cement manufacturing cost.

Figure 4-2 is the relationship between the actual and predicted value was linear, indicating that the difference between them was small as shown in the Figure.

The final mathematical model determined by the DOE software for cement manufacturing to be used to predict the optimized cost for cement response, with regards to actual factors is given in Equation 4-2.

*Cost = +3.15175 -0.145000 A +0.141250 iron tone +0.076250 gypsum tone +0.052500 A * iron tone -0.127500 A * gypsum tone -0.085000 iron tone * gypsum tone -0.033375* A^2 *+0.004125 iron* $tone^2$ *-0.175875 gypsum* $tone^2$ $\quad Equation\ 4-2$

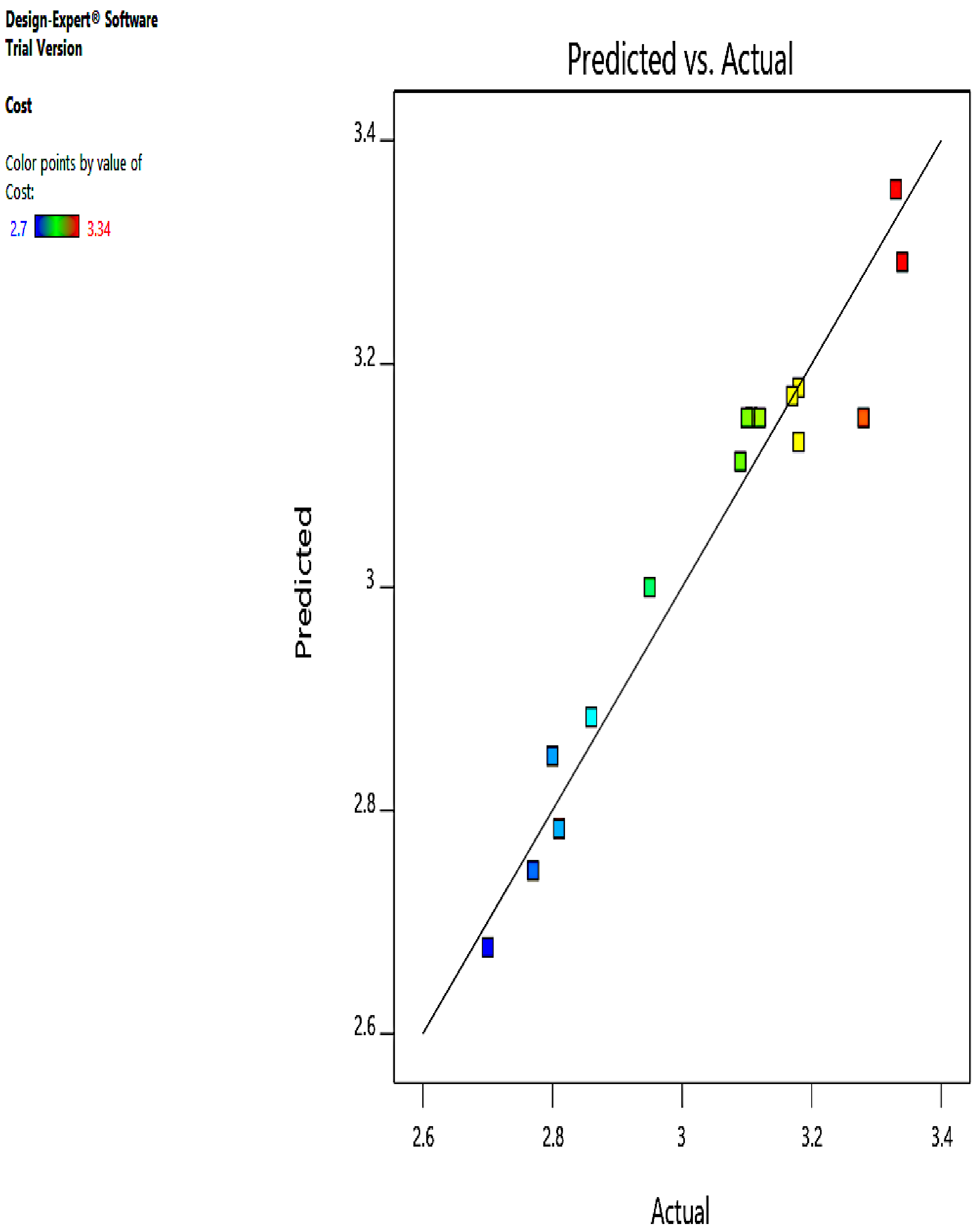


Figure 4-2 Predicted versus actual plot for cement manufacturing cost.

4.2.2 DOE results of cement cost

There are some statistical analyzes and graphs of the results of statistical work on cement, limestone, gypsum, and iron and how they affect each other in terms of cost. Explained on Design Expert-13, the results are very beautiful and distinct, and there are colors for setting materials and their effect [24].

Figure 4-3: The name of the statistical program is Design Experiment-13

In the figure 4-4, we notice 3 lines, A,B and C, so if we consider each one as an individual from the another factors, we will say that A means "Limestone", if we increase it, we will decrease the cost, B means "IRON", if we increase it, we will increase the cost, C means "GYPSYM" ,its variable, that have a part that increase cost and the another part decrease cost.

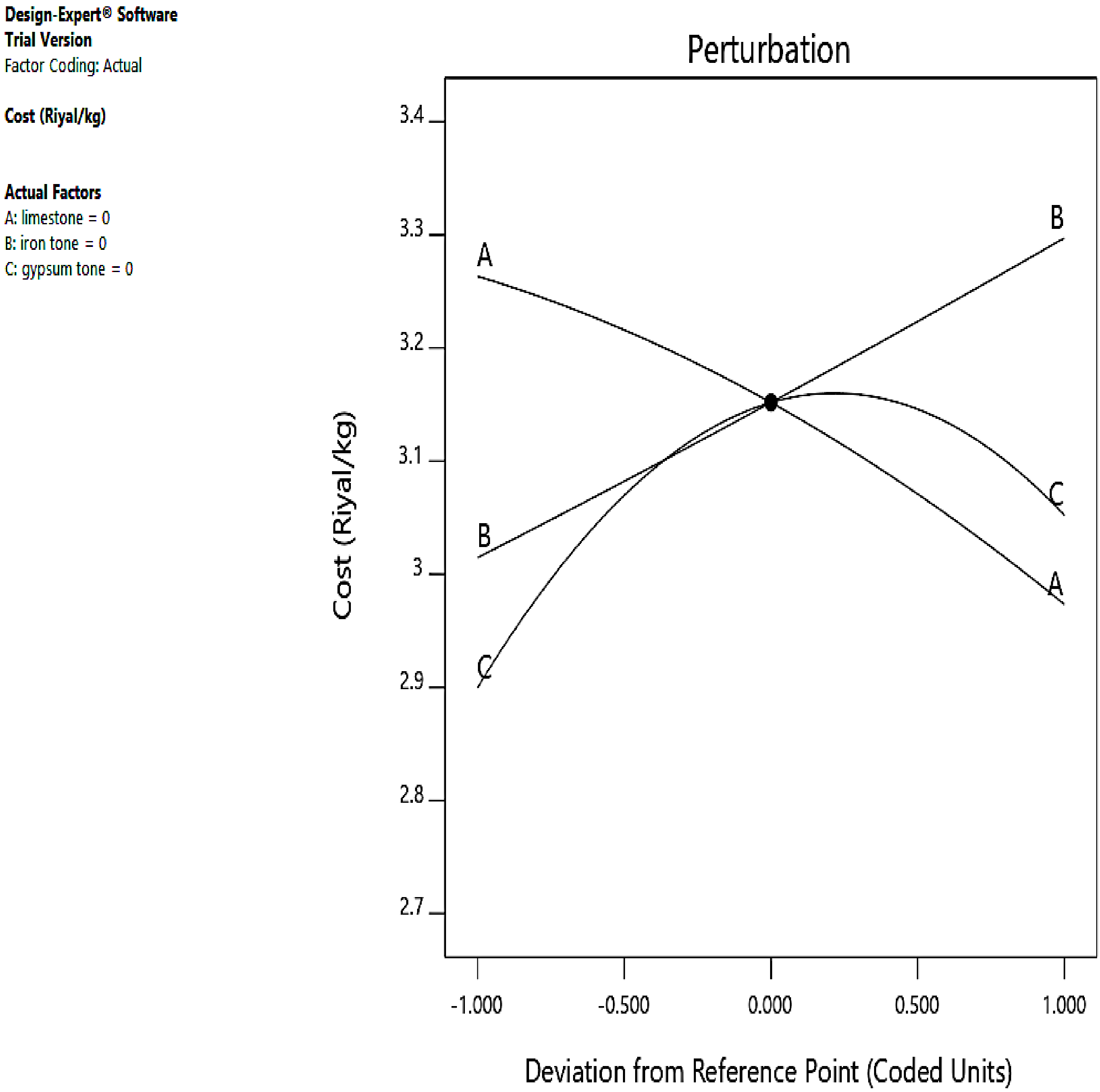


Figure 4-4: Perturbation plot for cement manufacturing cost.

In figure 4-5 called contour , it is a relationship between 2 factors, that describe increasing and decreasing in cost , this figure got 2 important factors , the first one in the X axis, called "Limestone", its start from the left, by the minimum coded value -1, which equal to 20% , and ends in the right by the highest coded value 1, which equal to 60% , the another factor in the Y axis is called "Iron", its start from the bottom, by lowest coded value -1, which equal to 10% and ends up, by the highest coded value 1, which equal to 50% , So we notice in this figure that if we increase the "Iron", that would cause an increasing in cost and vice versa, and we notice that if we increase "Limestone", that would cause decreasing in cost , on other way we could notice colours if its red that mean the cost is high and the blue mean that the cost is low.

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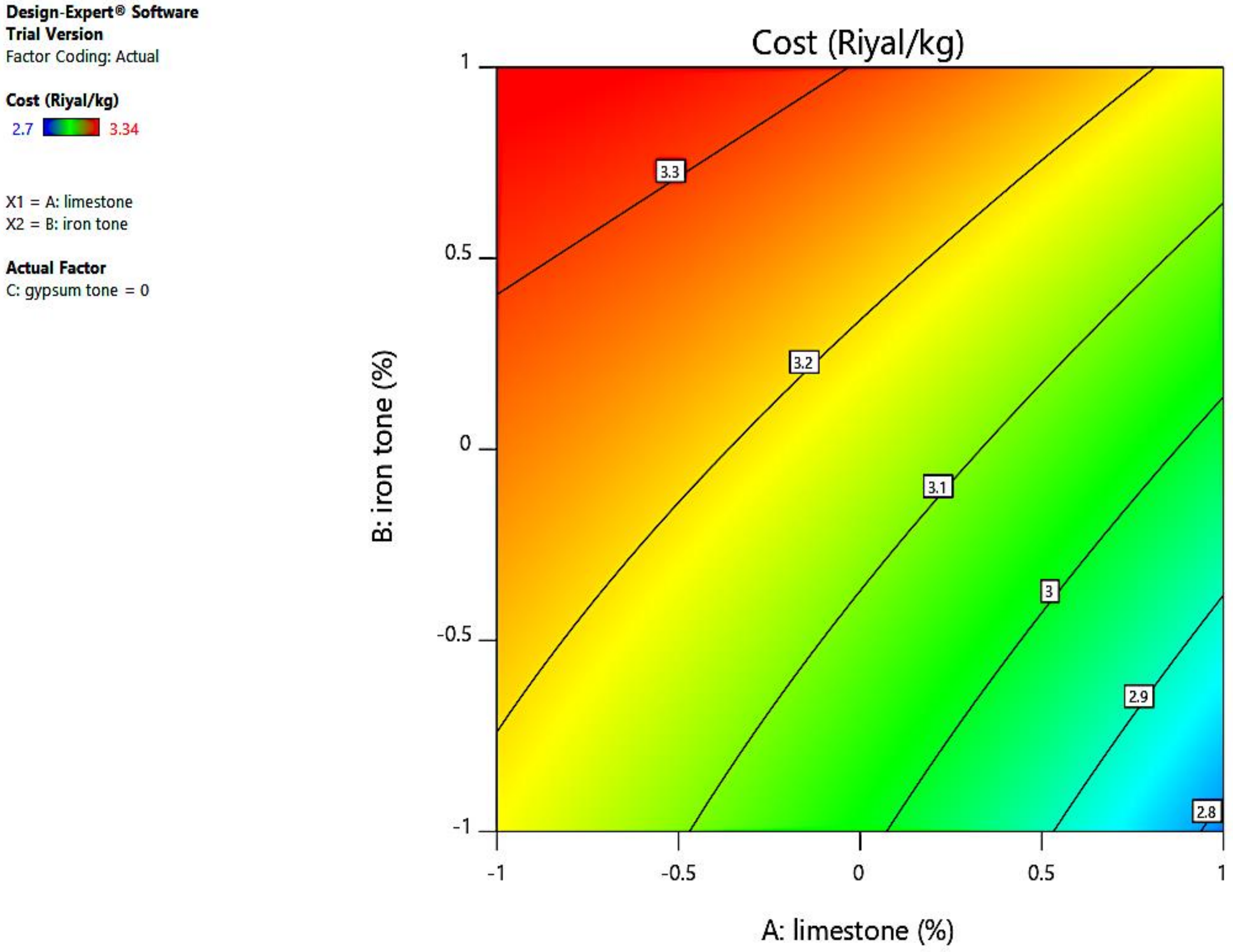

Figure 4-5: Contour plot of the cement cost for the limestone versus the iron.

In the figure4-6 called contour also, it is a relationship between 2 factors, that describe increasing and decreasing in cost , this figure also got 2 important factors , the first one in the X axis called "IRON", its start from the left, by the minimum coded value -1,which equal to 10% , and ends in the right, by the highest coded value 1, which equal to 50% , the another factor in the Y axis is called "GYPSEM", its start from the bottom, by lowest coded value -1,which equal to 10% ,and ends up by the highest coded value 1,which equal to 30% , So we notice in this figure, that if we increase the "Iron", that would cause increasing in cost and vice versa, and we notice that, if we increase "GYPSUM", that would cause increasing in cost also, on other way we could notice colours, if its red that mean the cost is high and the blue mean that the cost is low.

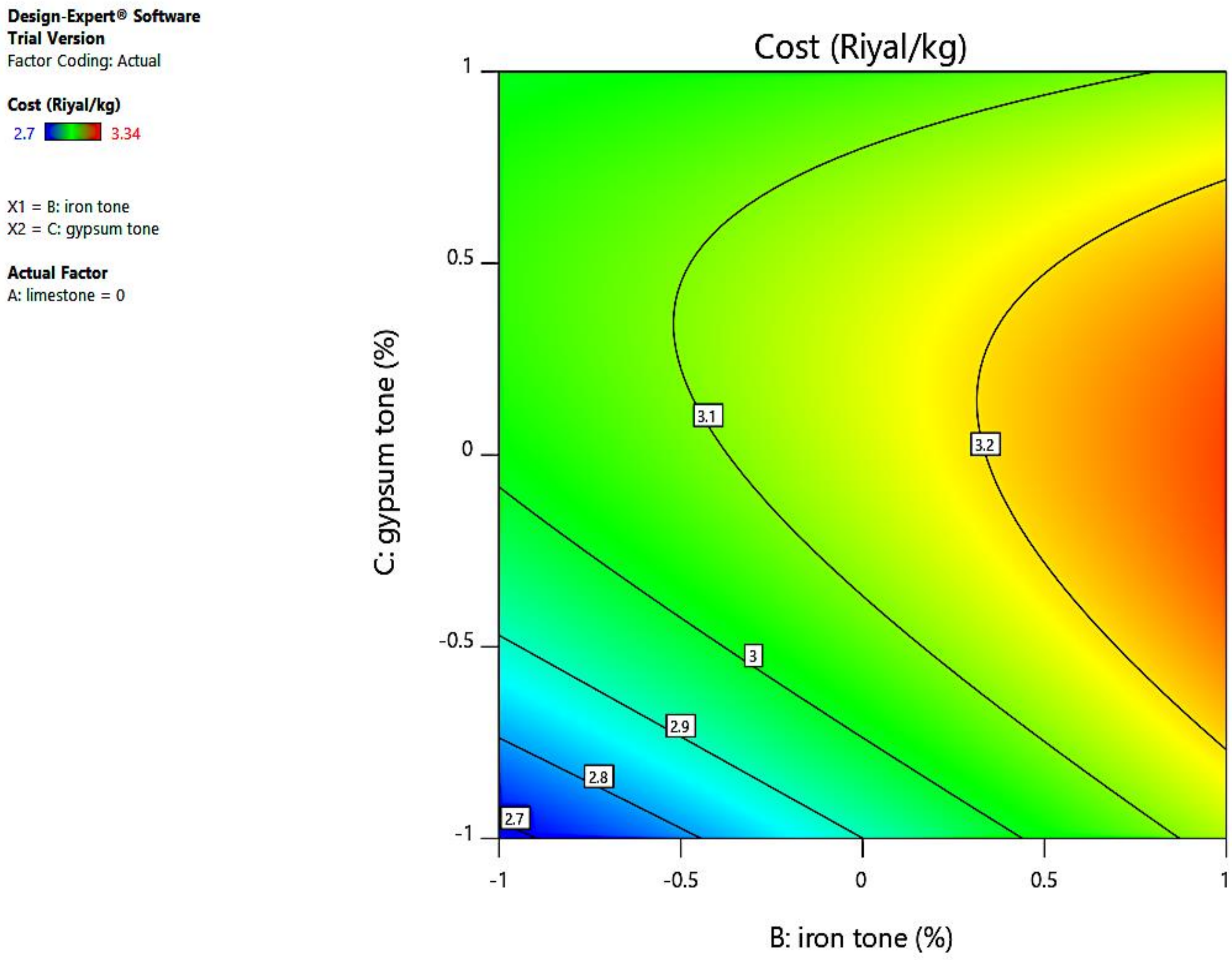

Figure 4-6: Contour plot of the cement cost for the iron versus the gypsum.

In the figure 4-7 ,there are some statistical analyzes and graphs of the results of the statistical work on cement, between "Limestone" and "Gypsum" , and there are influences that are considered materials in their effect on some materials with a material considered, A and C in the cost of cement, Here, in this 3D model called "contour plot" we explain the relationship between two influences in the high and low cost in the graphs, and show that A by the highest coded value 1, which equal to 60% and by the minimum coded value -1, which equal to 20% the more it exceeds (1) the higher the cost, and also in c, by the highest coded value 1, which equal to 30%, and. by the minimum coded value -1, which equal to 10%, We can also notice the colors if the red means the cost is high, while the blue means the cost is low.

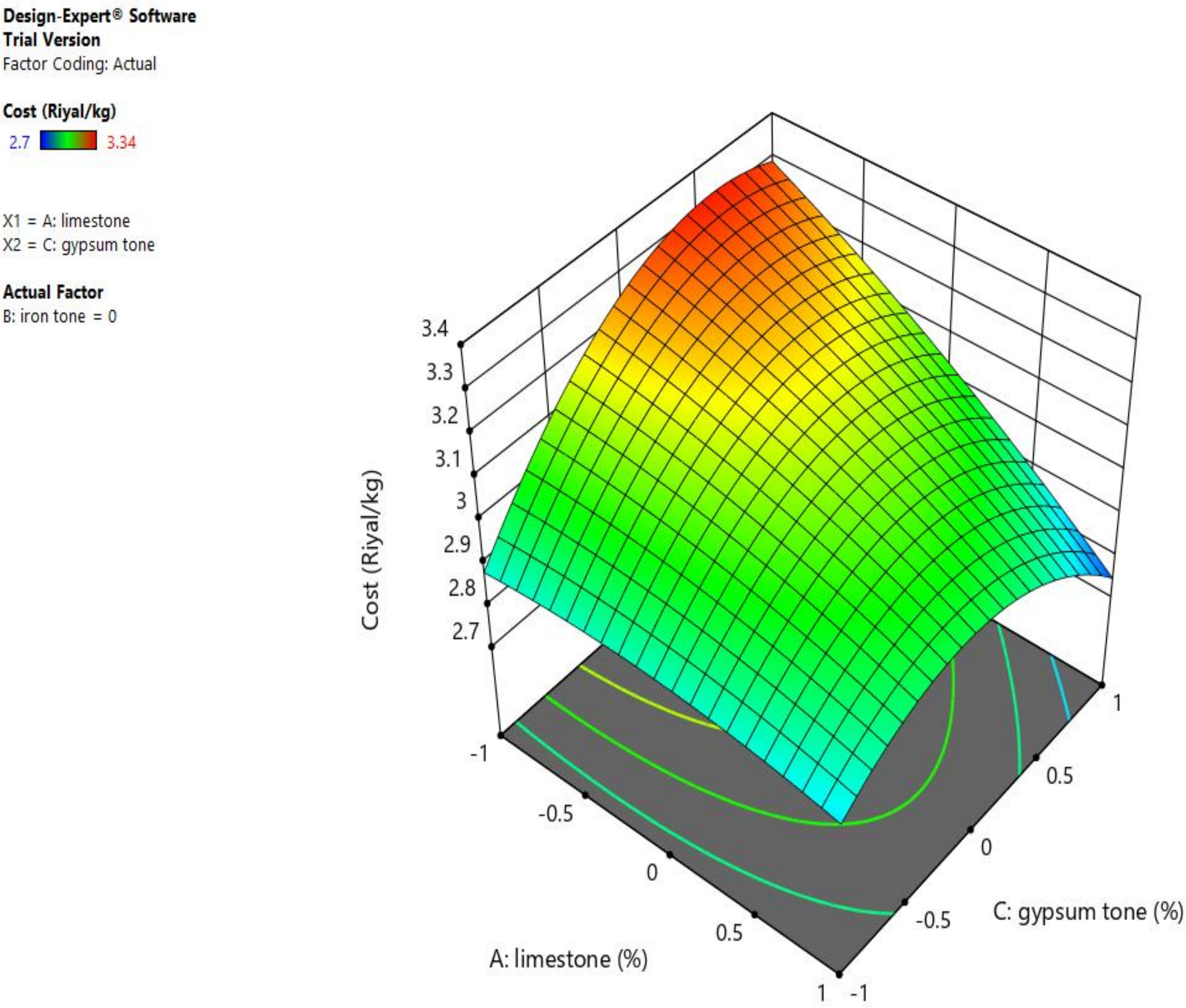

Figure 4-7: 3D Contour plot of the cement cost for the limestone versus the gypsum.

4.3 Cement tensile strength

Tensile strength is very important , as it proves to us the extent of the quality of the product and the quality depends on the strength of the cohesion of the material in the cement industry, as the quality in the product is an important factor in earning a large profit for a company and it is an important goal for every company that produces a specific product and also care must be taken carefully until the cement is processed and to achieve the best quality of cement. This is done after pouring and tapping the cement. Cement may need to be moistened and environmentally controlled to obtain full strength and quality, which is essential. The cement mixture hardens over time, at first being liquid, then it becomes solid, albeit very weak, and strengthens in the following days and weeks. After about 3 weeks, more than 90% of its final strength is usually reached [25].

4.3.1 Development of the mathematical model for cement tensile strength

Similarly, to what was carried out for the cement cost, the design of experiment (DOE) analysis was used to derive the mathematical model to show the effects of considered input factors—namely, gypsum, iron and limestone ratio—on the tensile strength of the cement product. The quadratic model, which was selected to fit the data, showed R^2 value of 0.95 for the cement. To determine the modules to be used in the analysis, several acceptable levels were set up as follows: the model probability and lack of fit probability, R^2, and the differences between the predicted R^2, adjusted R^2, and adequate precision. For this study, all of these were above the minimum level set for module acceptance, as clarified in the two AVOVA table (see Table 4.3). As can be seen from the Prob>F value in the AVOVA tables, the gypsum (C) and limestone (A), had the most significant effects on the cement tensile strength, whereas the iron (B), showed that this factor had only secondary effects. Furthermore, significant interactions took place up to the second order for all factors in the cement tensile strength. This indicates that the response is not linear and is highly sensitive to changes in the levels of these factors.

Source	*Sum of Squares*	*df*	*Mean Square*	*F-value*	*p-value*	
Model	18850.25	9	2094.47	30.37	0.0003	significant
A	7503.12	1	7503.12	108.81	< 0.0001	
B	21.13	1	21.13	0.3063	0.5999	
C	5408.00	1	5408.00	78.42	0.0001	
AB	784.00	1	784.00	11.37	0.0150	
AC	1260.25	1	1260.25	18.28	0.0052	
BC	650.25	1	650.25	9.43	0.0219	
A^2	2352.25	1	2352.25	34.11	0.0011	
B^2	870.25	1	870.25	12.62	0.0120	
C^2	1.0000	1	1.0000	0.0145	0.9081	
Residual	413.75	6	68.96			
Lack of Fit	328.75	3	109.58	3.87	0.1479	not significant
Pure Error	85.00	3	28.33			
Cor Total	19264.00	15				
R-Squared 0.9785	*Adj.R^2 = 0.94*					
Adeq.Precision = 23.45	*Pred.R^2 = 0.71*					

Table 4-3 ANOVA analysis for cement manufacturing cost.

The final mathematical models for cement tensile strength in terms of coded factors that can be used to make predictions about the response for given levels of each factor were found to be as follows:

Tensile strength (Mpa) = +632.50 +30.63 A +1.62 B -26.00 C +14.00 AB -17.75 AC +12.75 BC +24.25 A^2 *-14.75* B^2 *+0.5000* C^2 $Equation\ 4-3$

Based on the above equations, several observations can be made. Can rank the dependence as follows: A > -C > $-A^2$ > -AC > $-B^2$ > AB > BC > $-C^2$ for the cement manufacturing tensile strength. First, the limestone (A) itself (A) and as a interaction with gypsum (C) had the highest impact in tensile strength, followed by the gypsum as itself (C). In terms of squared factor, the gypsum (A^2) followed by the iron (B^2) had the most significant factors as squared cement manufacturing tensile strength.

The relationship between the actual and predicted value was linear, indicating that the difference between them was small as shown in the Figure 4-4.

The final mathematical model determined by the DOE software for cement manufacturing to be used to predict the optimized cost for cement tensile strength response, with regards to actual factors is given in Equation 4-5.

*Tensile strength (Mpa) = +632.50000 +30.62500 limestone +1.62500 iron tone -26.00000 gypsum tone +14.00000 limestone * iron tone -17.75000 limestone * gypsum tone +12.75000 iron tone * gypsum tone +24.25000* $limestone^2$ *-14.75000* $iron\ tone^2$. $Equation\ 4-5$

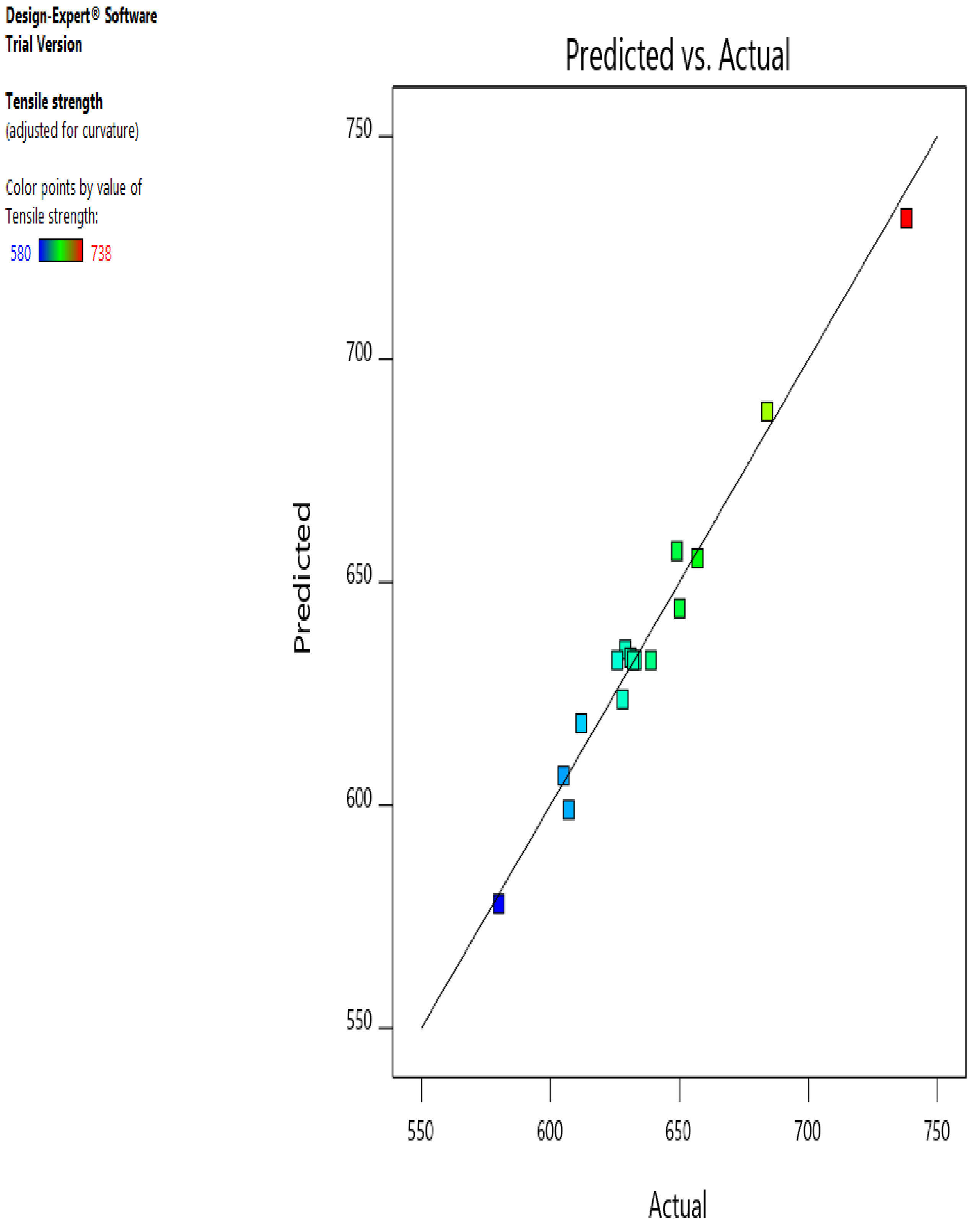

Figure 3-8: Predicted versus actual plot for cement manufacturing Tensile strength.

4.2.2 DOE results of cement Tensile strength

In the figure4–9, we notice 3 lines, A,B and C, so if we consider each one as an individual from the another factors, we will say that A means "Limestone", if we increase it, we will increase the tensile strength, B means "IRON", its variable, that have a part that increase tensile strength and the another part decrease it, C means "GYPSYM" , if we increase it, we will decrease the tensile strength.

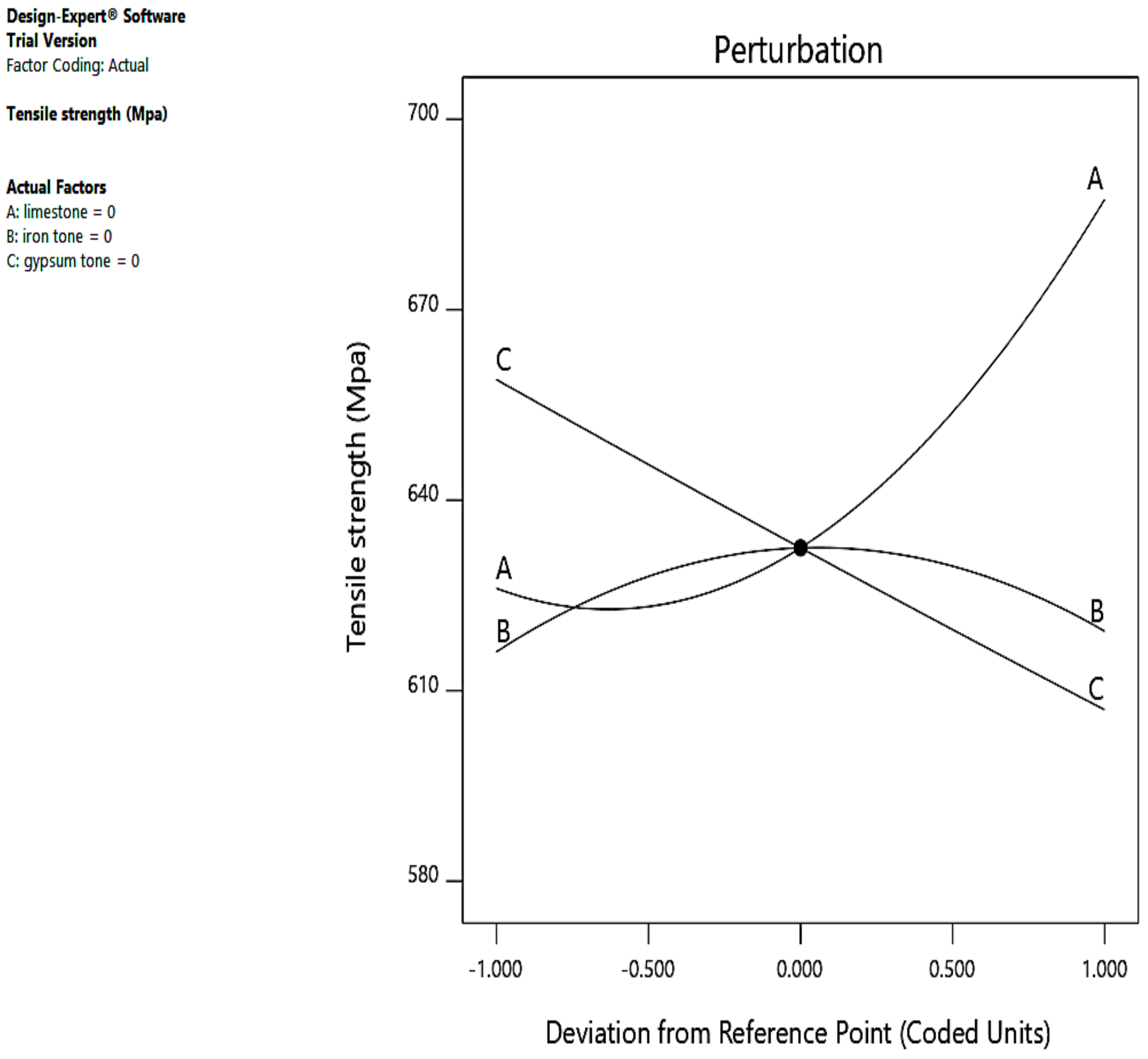

Figure 4-9: Perturbation plot for cement manufacturing Tensile strength.

In figure 4–10 called tensile strength , it is a relationship between 2 factors, that describe increasing and decreasing in tensile strength, this figure got 2 important factors , the first one in the X axis, called "Limestone", its start from the left, by the minimum coded value -1, which equal to 20% , and ends in the right by the highest coded value 1, which equal to 60% , the another factor in the Y axis is called "Iron", its start from the bottom, by lowest coded value -1, which equal to 10% and ends up, by the highest coded value 1, which equal to 50% , So we notice in this figure that if we increase the "Iron", that would cause an decreasing in tensile strength and vice versa, and we notice that if we increase "Limestone", that would cause increasing in tensile strength, on other way we could notice colours if its red that mean the tensile strength is high and the blue mean that the tensile strength is low.

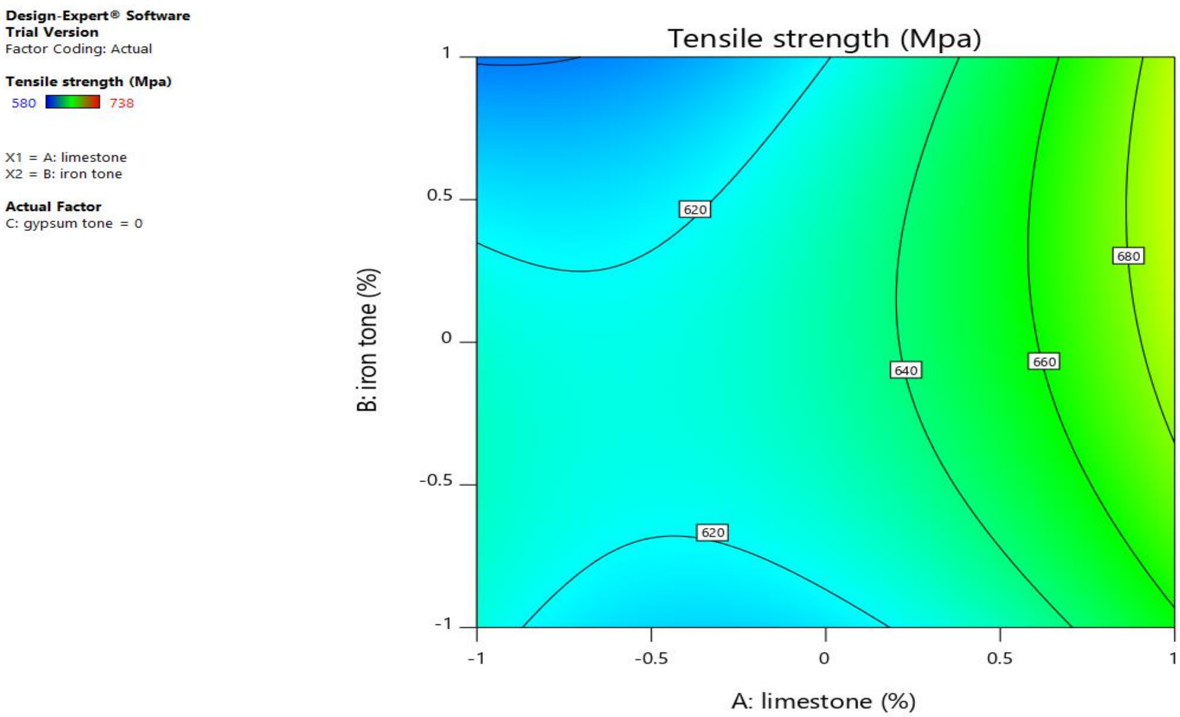

Figure 4-10: Contour plot of the cement cost for the limestone versus the iron.

In Figure 4-11 we find that the tension line is a connection of the relationship between two factors describing the amount of increase and decrease in the tension line, and we find that we have two important functions, the first in the x-axis from (-1) to 1 to the y-axis and it is called "GYPSUM" and it becomes the lowest value at (-1) which It is equal to 20% and the largest is at 1 which equals 60% the fewer the elements below, the less cohesion, and the more "GYPSUM", the more cohesion.

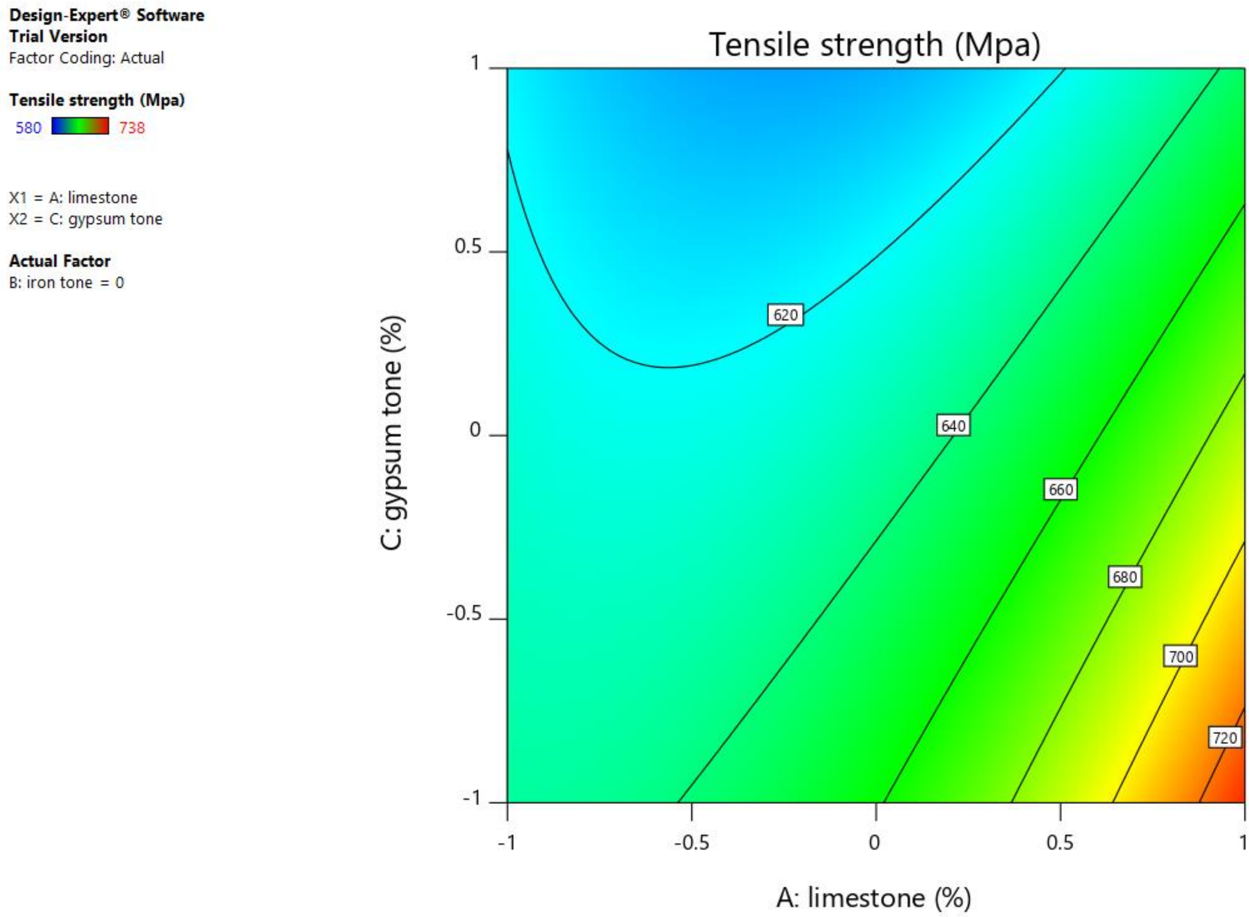

Figure 4-11: Contour plot of the cement cost for the limestone versus the gypsum.

In Figure 4-12 We find that some graphs and statistical analyses have some impacts on Cohesion between materials taking into account B_C in cohesion and in the 3D histogram Demonstrates the relationship between two influences in high and low cohesion in the graph and shows that C - The more "GYPSUM" the greater the cohesion (1), i.e. by 60%, and the fewer the elements below it Cohesion (-1) i.e. 20%. We note that "GYPSUM" increases cohesion and gives better results.

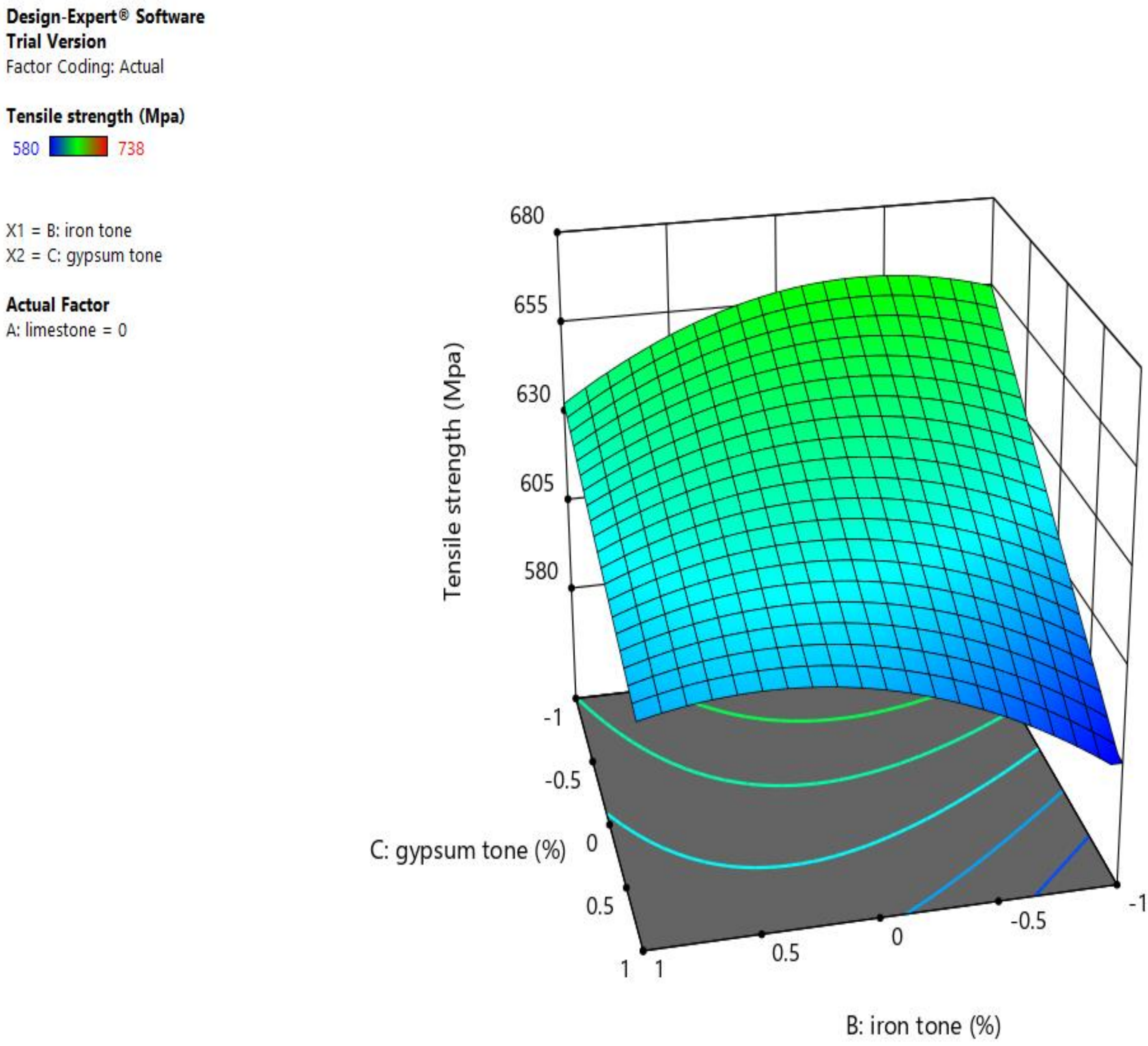

Figure 4-12: 3D Contour plot of the cement cost for the iron versus the gypsum.

4.4 Numerical Optimisation of cement product

In Figure 4-13 Interested in cost, ignoring the power of cohesion. We chose 5 stars in this diagram, we are analysing the cost and setting the goal and objective here to reduce the cost. The lowest specific percentages of the three substances affecting the cement industry analysis are set out in the drawings as shown before graph "limestone" the appropriate ratio between -1 and 1 is 60% and graph "iron" between -1 and 1 is 10% and graph "gypsum "is between -1 and 1, which is 30% and the result is given that the resulting cost is 2.66793 SR/kg and the tensile of the Cement material is 600.547 MPa.

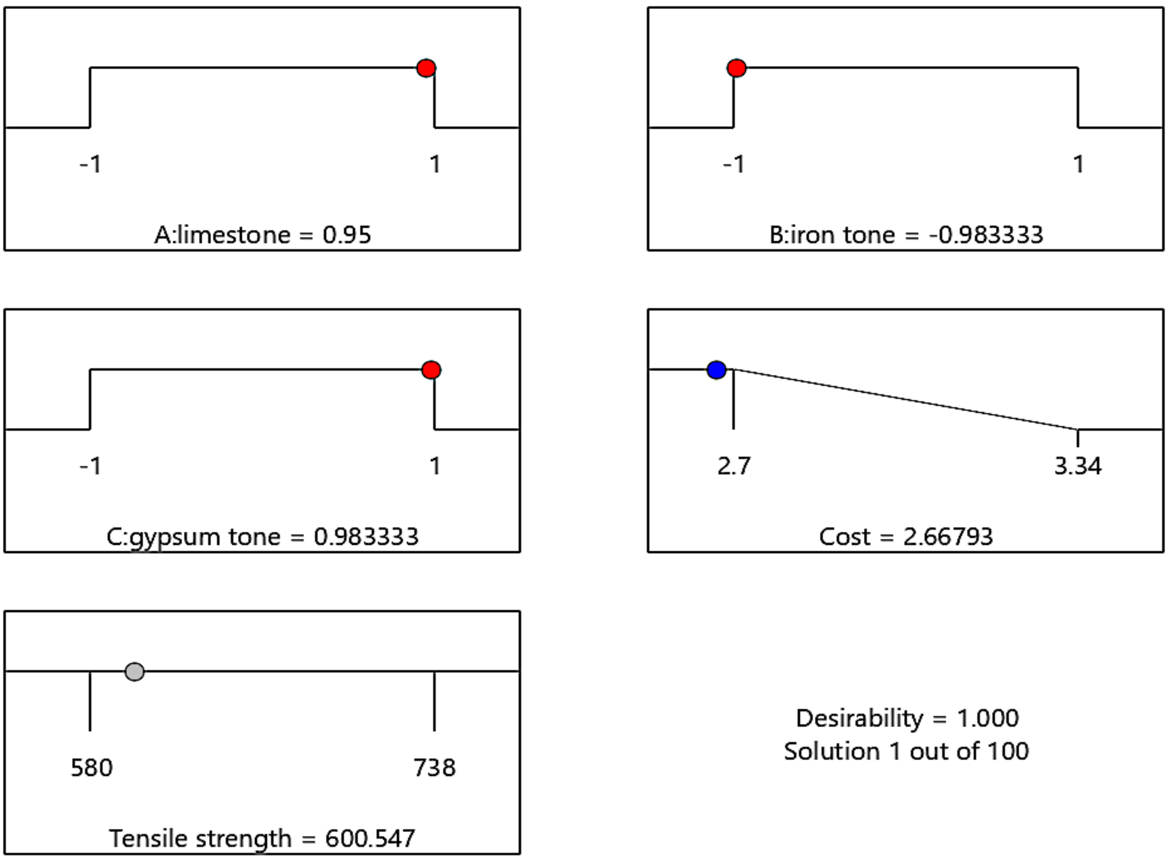

Figure 4-13: Optimal cement conditions as obtained by Design-Expert for cost criterion.

In Figure 4-8 Interested in the power of cohesion, ignoring CostIn this graph, we chose 5 stars we analyze the cohesion of materials and set the goal and the goal here is to raise the highest material cohesion in the cement industry. The coherence of the three materials is illustrated in the diagrams as shown by graph "limestone" The appropriate ratio for the cohesion of limestone between -1 and 1 is 60% and graph "iron" the appropriate ratio for the cohesion of "iron" between -1 and 1 is 50% graph "gypsum" The appropriate ratio for the cohesion of "gypsum" between - 1 and 1 is 10% and also considering the result that the resulting cost is 2.789 SR/Kg and the consistency of the cement materials is 731.765 MPa.

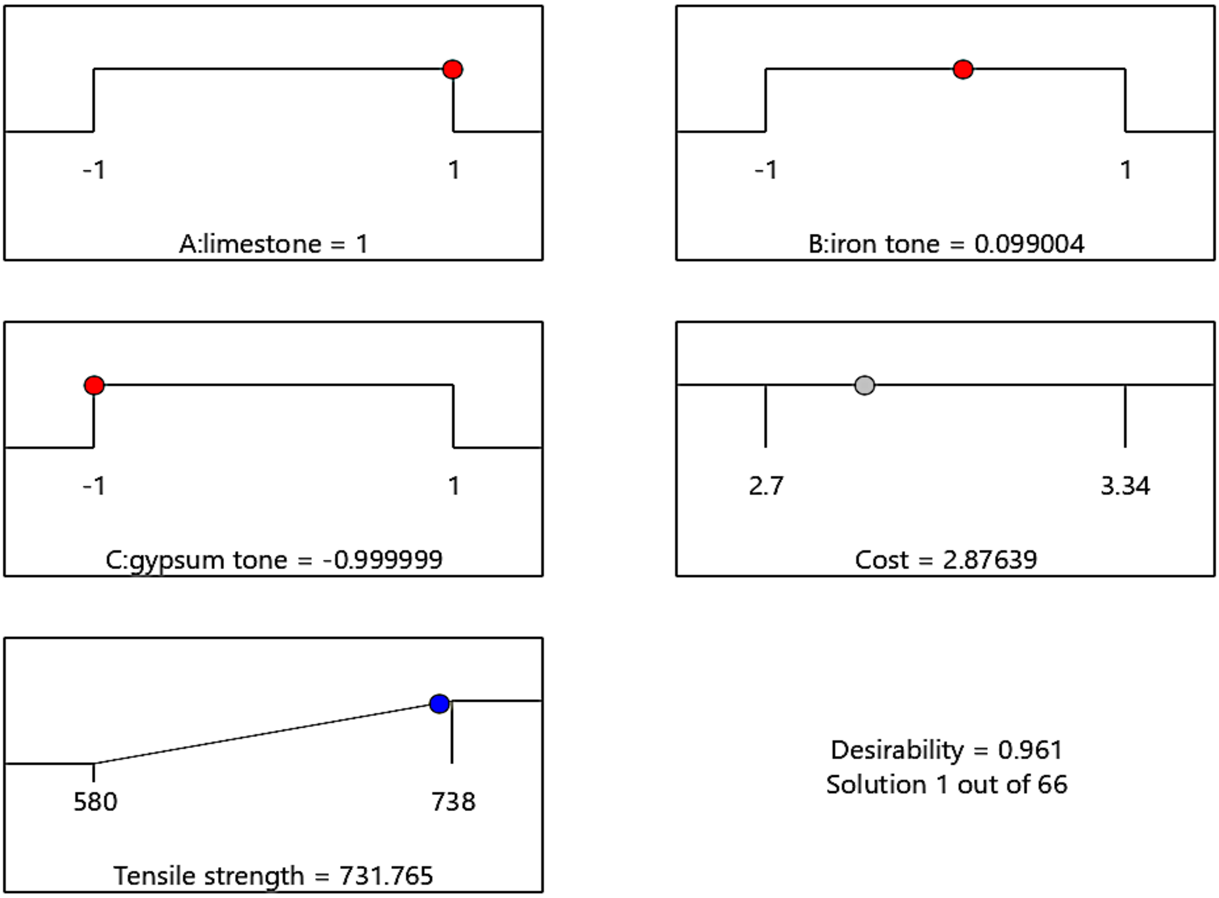

Figure 4-14: Optimal cement conditions as obtained by Design-Expert for tensile strength criterion.

5. Conclusion

Work was done on the cement project and how cement was made. Cement and its effects were also studied. The machines used in the cement industry were also identified, and how tables were created for the proportions of the amount of cement used. Two goals were set, namely, reducing the cost of cement, and secondly, consistency of cement with high quality. Completion of the work. In a statistical program for measuring cement, how to reduce cost and high quality, and also work was done in the spirit of one team, how to keep up with the study and field work, and also excellent experience was gained in the analysis and how the information was obtained.

1-It was concluded that the materials used in the predictive cement industry in the following ratios (0, -1, 1) provide a lower cost of 2.8 riyals / kg and the strength of 738 materials (MP).

2-The influences we showed were measured in terms of cost and in terms of consistency, and the results showed above how the proportions between them are limestone, gypsum, and iron.

3-cement cost (riyal/kg) = $+3.15 -0.1450A +0.1412 B +0.0762 C +0.0525 AB -0.1275 AC -0.0850 BC -0.0334 A^2 +0.0041 B^2 -0.1759 C^2$

4-Tensile strength (Mpa) = $+632.50 +30.63 A +1.62 B -26.00 C +14.00 AB -17.75 AC +12.75 BC +24.25 A^2 -14.75 B^2 +0.5000 C^2$

5-Optimum cement conditions as obtained by Design-Expert for cost standard with the result that the resulting cost is *2.66 riyal /kg,* and the stability of the three materials is 600.547Mpa.

6-Optimal cement conditions as obtained by Design-Expert for tensile strength criterion with the result that the resulting cost is 2.87 riyal /kg, and the stability of the three materials is *731.765 Mpa.*

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