1977

The Manufacturing of Cement in Northern Iowa and the Strength of Selected Concrete Mixes Using Compression Testing

James E. Gephart
University of Northern Iowa

The Manufacturing of Cement in Northern Iowa and the Strength of Selected Concrete Mixes Using Compression Testing

THE MANUFACTURING OF

CEMENT IN NORTHERN IOWA

AND THE STRENGTH OF SELECTED

CONCRETE MIXES USING COMPRESSION TESTING

Approved by:

______________________________ June 30, 1977
Graduate Committee Chairman Date

THE MANUFACTURING OF CEMENT IN NORTHERN IOWA AND THE STRENGTH OF SELECTED CONCRETE MIXES USING COMPRESSION TESTING

A Report
Presented to the
Department of
Industrial Technology
University of Northern Iowa
Cedar Falls, Iowa

In Partial Fulfillment
of the Requirements for
Master of Arts Degree

---

by
James E. Gephart

ACKNOWLEDGMENTS

The writer wishes to express sincere appreciation to the following people for their assistance in the development of this report.

Mr. Peter Fauerby
Technical Service Engineer
Northwestern States Portland Cement Co.
Mason City, Iowa

for a personal tour of the Northwestern facility and for answering a multitude of questions.

Mr. Paul Peach, Branch Manager
Mr. Greg Owen, Geologist
Twin Cities Testing and Engineering Laboratory
Waterloo, Iowa

for providing storage space for the test cylinders, for providing capping material for the cylinders, and allowing this researcher to use the compression testing machine.

Mr. Robert Benton
Mr. Robert Berry
Benton's Ready Mixed Concrete
Cedar Falls, Iowa

for allowing this researcher to take comparative test samples of ready mixed concrete, and for loaning information concerning concrete.

Mr. Robert Mitchell, Production Mamager
C. W. Shirey Co.
Waterloo, Iowa

for loaning information concerned with concrete and for personal help.

Mr. Mez Austin
Mr. Dave Borchering

Waverly Gravel and Ready Mix
Waverly, Iowa

for printed material loaned and for a demonstration on testing cylinders

---

Mr. Jim Jensen
Martin-Marietta Cement, Northern Division
Davenport, Iowa

for providing information related to the topic.

Dr. Roger Betts
Department of Industrial Technology
University of Northern Iowa
Cedar Falls, Iowa

for answering questions and for the use of a slump cone.

Mr. Lynn Snodgrass
C. W. Shirey Co.

for information relating to the subject.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

THE PROBLEM

Concrete is one of the most widely used construction materials available today. Few, if any, structures are built today without using this material at some point in the building process. Portland cement is the principal ingredient of concrete.

Statement of the Problem

Cement manufacturing is a process that has been developed and refined during past centuries. The end result of this process, cement, is able to meet the demands of an ever increasing technological world. The research was made so that the writer would develop as complete an understanding of the processes involved in the manufacture of cement as was possible during the time allotted for this research.

Purpose of the Study

It is the purpose of this study to:

1. investigate the cement processing industry and to become knowledgeable of the procedures used to manufacture cement
2. perform compression tests on selected mixtures of concrete and to recognize why certain mixtures are preferred over other mixtures
3. investigate information related to the cement

industry

4. develop a unit of study involving the cement and concrete industries.

Importance of the Study

Industrial education teachers recognize the fact that students should be exposed to industry which plays such an important role in the world today. Students should become aware of their technological culture.

Construction is one of four major curriculum areas recognized at the junior high school level in The Iowa Guide for Curriculum Improvement in Industrial Arts, K-12. The guide specifically states the use of concrete in the broad curriculum of construction. Students should be aware of the origin of the material, cement, one of four basic ingredients used to formulate concrete. They should be aware of the raw materials and the processes these raw materials go through in order to produce cement, and they should be allowed the opportunity to use concrete in an industrial education laboratory or in a field situation. They should also recognize job opportunities in the cement industry, and how the material is utilized in construction.

Limitations of the Study

There are two different processes used in the manufacture of portland cement; the wet process and the dry process. Both processes are used in the state of Iowa. However, the wet process requires more energy to produce cement because it requires more energy to dry the slurry, one of the steps in the wet process. The cost of energy has increased rapidly in the past few years, and from all indications, it will continue to increase in cost. The dry process is used by a majority of the cement processors in this state and in the nation because less energy is required to produce the finished product. Therefore, this study will be limited to the dry process of cement manufacture.

Literature available at libraries dealing with cement processing was of a very general nature. No detailed information was available except for a few rigorous chemical analysis of formations of compounds that take place in cement processing and hydration of concrete. The chemistry background required to understand this was beyond the capacity of the writer since the writer has no background in chemistry. Understanding the chemistry involved in cement processing was not required to understand the process of cement manufacturing. If one understands that hydration of concrete must be controlled, a chemistry background for this is not necessary either. The writer has a desire to keep this research on a level that will be interesting to students.

Through a personal tour of a cement processing facility, question and answer sessions with professional people involved in cement and concrete, and an accumulation of knowledge and materials from these people, much valuable information was obtained.

The final limitation is in regard to financial costs incurred during testing of concrete mixtures. All of the materials necessary for testing, cement, sand, and three sizes of aggregate, and concrete test cylinders molds, involved a financial expenditure. The writer did not wish to exceed his expectations financially. The number of test cylinders was limited.

Definition of Terms

Aggregate . . . . any of several hard materials used for mixing with cement and water to form concrete.

Barrel (of cement) . . . . a quantity of cement equal to three hundred seventy six lbs. This quantity of measurement has been replaced with the short ton.

Cement . . . . a material capable of developing, after appropriate reactions have taken place, those adhesive and cohesive properties that make it possible to bond together mineral fragments to produce a hard continuous compact mass of masonry.

Cement kiln . . . . a long hollow tube with open ends, and elevated slightly. Raw cement mix enters at the upper end and is discharged at the opposite end as portland cement clinker.

Cement paste . . . . a mixture of water and cement used in the formulation of concrete; the same as water-cement ratio.

Charge (of a ball mill) . . the quantity of material placed inside a ball mill; varies according to the capacity of the ball mill.

Concrete . . . . a construction material made by combining cement, water and a mineral aggregate which causes the material to set and form a solid mass.

Finish ball milling. . . . . the final step in cement processing; a finish ball mill grinds cement clinker to a fineness greater than flour.

Hydration. . . . . the process of evaporation of water from concrete.

Portland Cement Association. an international organization working toward improving the quality of cement.

Portland cement clinker. . . material produced from raw mix as it passes through a cement kiln with heat present.

Primary ball milling . . . . crushed limestone and clay are ground in this machine in preparation for entry into the cement kiln.

Raw mix. . . . . composed of ground limestone and clay materials. Includes the raw ingredients of cement, but it has not passed through the cement kiln. Resembles cement in texture and in color.

Short ton. . . . . the term used to measure a quantity of cement; equals two thousand pounds.

Shot rock. . . . . rock that is blasted from an exposed face of a quarry with considerable variations in size.

Slump cone . . . . a piece of equipment used to determine the workability of concrete.

Surge pile . . . . a means of storing raw materials in a quarry operation.

Tire (on a cement kiln). . . support mechanism on a cement kiln. Composed of a ring of steel that surrounds the cement kiln at strategic points along the length of the kiln.

Trunion (on a cement kiln) . support for the tire on a cement kiln. Two trunions support each tire. Trunions are attached to foundations which support the weight of the kiln. (See figure 5).

Water-cement ratio . . . . the quantity of water in ratio to the quantity of cement; used in mixing concrete.

Chapter 2

HISTORICAL BACKGROUND

The history of cement can be traced to the early civilizations of the Babylonians, the Assyrians, the Egyptians, and the Romans. The word cement is more then two thousand years old. The cave man may have made the first accidental discovery of the process of producing a cementitious material when he accidentally burned limestone in his fire. Rainfall may have slaked this burned material, and when it rained, it turned hard again. Primitive man found this material to be superior to mud and used it for early masonry work which is disclosed in ruins that have been uncovered. The Egyptians used a gypsum binder when the pyramids were built.

The Romans

Of all of our predecessors, the Romans were the masters of cement. That was because they went farther then using cement as a binder; they were the first to use concrete. The Romans accomplished their enormous amount of building, according to the architectural writer Charles Henry Caffin, by systematizing the job, "and also by methods of construction which they invented: this was the extended use of concrete". (Portland Cement Association, 1966). Where the Greeks built solid walls of marble and stone, the more business-like Romans grasped the advantage of both speed and economy in using these materials for facings, while filling in the thickness of walls with small fragments of stone, intermixed with cement and lime. This became concrete.

This practice evolved after they discovered the properties of pozzuolana, a volcanic product found near the base of Mount Vesuvius. It lay in large quantities at Pozzuoli on the Bay of Naples. This volcanic ash, calcined by the heat of the volcano, was pulverized and mixed with slaked lime and a small amount of sand to form hydraulic mortar. (Hadley, 1945, p. 8-9).

Many of the structures built by the Romans continue standing today including the Pantheon constructed over eighteen hundred years ago, the Castle de San Angelo in Rome constructed in 138 A.D., many houses, and aquaducts, structures used to carry water.

Kilns used by the Romans to produce cement resembled cement kilns used in Holland for the same purpose. It has been established that the Holland kilns were used in approximately 1200 A.D..

The Origin of Portland Cement

The history of portland cement began in England in the eighteenth century. John Smeaton, an English engineer, did a considerable amount of experimenting to attempt to develop a durable mortar to be used in structures. He found that the properties of a specific limestone depended on the clay content of the stone and not on the color of the clay as his predecessors had believed. Smeaton found that a fifteen percent clay content was most favorable to the finished product. Smeaton did not publish his findings for thirty five years.

The most famous step in the development of portland cement occurred in 1824. Joseph Aspdin patented a process of artifically mixing clay and limestone that had been crushed, and then burned, to produce portland cement. Aspdin named the material "portland" cement because its color resembled a fine building stone quarried on the Isle of Portland just off of the coast of England. Aspdin built a cement plant in Wakefield, England. Cement produced at his plant was used to build a tunnel under the Thames River in 1828.

A third person, Isaac Johnson, had ideas similar to Smeaton's and Aspdin's. He proportioned clay and lime materials much as is done today to produce cement. Johnson did his work nearly one hundred years ago, after Smeaton began his work. Aspdin is recognized as the person who patented the process of producing cement. Therefore, he is recognized as the inventor of cement in a form very similar to what is produced in cement processing facilities today.

An engineering and construction project that established the superiority of portland cement as a building material was the construction of the London sewer system. It was built in the early 1860's. The project used approximately 370,000 barrels of cement, a considerable quantity considering the time at which the project was completed.

The first shipment of portland cement arrived in the United States in 1868 from Europe, but the United States already had a prospering cement industry in its infant stages. The natural cement industry was stimulated by the canal building that was taking place in this country in the early 1800's. A natural cement rock was discovered in the Rosendale District of the state of New York in 1818. The natural cement rock contained proportions of limestone and clay that were needed to produce cement. To process the rock, it simply had to be mined, crushed, and burned. Cement produced from this rock was of excellent quality. Two other natural cement rock areas were developed in the United States. They were the Lehigh Valley in Pennsylvania and the Louisville, Kentucky area. Other areas containing natural cement rock were discovered, but they were considerably smaller than the above mentioned areas.

At approximately this same time, cement manufacturers in Europe (England, France, and Germany) were realizing the increased use of cement in the United States for construction purposes. European manufacturers began to ship cement to this country as ballast in ships. They were able to ship the product at very low rates and could compete with American manufacturers. The quantity of foreign cement shipped to this country reached a peak of two and one-half million barrels a year very quickly. European portland cement was preferred to American produced natural cement. David Saylor, a natural cement producer in the United States, thought that he could produce a cement similar to European portland cement. He began his experiments in Coplay, Pennsylvania in the Lehigh Valley. He used natural cement rock and burned this to produce natural cement clinker. That particular rock was high in lime and low in magnesia and iron, desirable characteristics in the production of cement, and very comparable to the imported cement. The cement clinker was then ground. The cement that Saylor produced was very quickly considered to be of the same quality as the European cements being shipped to this country. Saylor claimed his process to be new and dirrerent, and he applied for a patent on the process. The patent was applied for in 1871. This date is considered as the birthdate of the portland cement industry in the United States. Two additional early cement manufacturers in this country were Thomas Miller who experimented with materials in the South Bend, Indiana area and John Shinn who was able to produce a cement product at Wampum, Pennsylvania. A cement processing facility was begun at Oglesby, Illinois and was the parent company of the Marquette Cement Company, which today has a cement plant in Des Moines, Iowa.

Early Cement Kilns

Kilns used to burn cement rock were of various shapes and sizes. Some were round, some square in shape. Some early kilns were considerably high for their diameter and were referred to as vertical kilns. Other kilns were referred to as shaft kilns. The rotary kiln is standard in present day cement processing plants. The rotary kiln was patented by Frederick Ransome, an Englishman. The earliest kilns were fired with various fuels, but Ransome's kiln was gas fired. His kiln was a failure because he did not understand that fusion of the silica in the clay could not take place. He allowed this to happen and the interior of the kiln caked with limestone and clay. Two American inventors, Hurry and Seaman, employees of the Atlas Cement Company, developed a rotary kiln that was successful. They realized that the limestone and clay could only be burned until incipient fusion of the materials took place. The advent of the rotary kiln increased the quantity of cement produced and decreased costs. The rotary kiln is still in use today in the cement industry.

The Portland Cement Association

The major cement manufacturers of the Eastern United States gathered for a meeting in 1902 to solve industry-wide problems. It was decided at this first meeting to form an organization that would work to solve future problems in the cement and concrete industries. The group was called the Association of Portland Cement Manufacturers when it was officially formed in 1916. Specifications for cement manufacture was one of the major problems that this organization attempted to solve early in their existence. They worked in cooperation with such groups as the American Society of Civil Engineers and the American Society for Testing Materials to solve this problem plus improving reinforced concrete construction and scientific research. This organization later changed its name to the Portland Cement

Association, and is very active in the cement industry today.

The cement manufacturing industry continued to grow as new manufacturing processes and larger, better, and more efficient equipment was introduced to the industry. As more cement was being used for construction in this country, more cement processing facilities were built. Today, the United States utilizes more cement than any other country in the world. (Portland Cement Association, 1966).

The Northwestern States Portland Cement Company

The writer visited the Northwestern States Portland Cement Company in Mason City, Iowa, and was able to accumulate a short history of that facility. Mason City, Iowa was the first area in the Upper Midwest to begin processing cement. Raw materials were readily available in abundance and there was a good market potential in the area. Construction on the original facility was begun in 1906. The first cement to be shipped from Mason City occurred in February, 1908. In 1912, the original company found that it was in financial difficulties. The company was sold at that time. The new owners were Mr. C. M. McNider and six other investors. These seven owners were financially successful. The current president of the company is the grandson of Mr. C. M. McNider. Decendents of the other six investors are members of the board of directors of Northwestern States Portland Cement Company today. There are in excess of 2,700 shares of stock in the company. Approximately twenty per cent of this stock is owned by decendents of Mr. McNider.

Chapter 3

RELATED INFORMATION

This chapter deals with geographical and occupational information, and with financial trends in the cement industry. Each of the five cement processors in the state of Iowa received an introductory letter from the writer. (Appendix C). Responses were received from four of the processors. A field trip was made to the Northwestern States Portland Cement Company in Mason City, Iowa. Six hours were spent with Mr. Peter Fauerby, Technical Service Engineer for Northwestern States Portland Cement Company. A great deal of information was received from Mr. Fauerby. A written appreciation was made after completion of the field trip. (Appendix D).

Geographical Information

There are five cement processing companies with facilities located in the state of Iowa. They are:

Lehigh Portland Cement Company
700 25th Street N.W.
Mailing address:
Box 1068
Mason City, Iowa 50401

Marquette Cement Mfg. Company
52nd & Park Avenue
Mailing address:
P. O. Box 1377
Des Moines, Iowa 50305

Martin-Marietta Cement, Northern Division
Highway 22
Mailing address:
P. O. Box 4288
Davenport, Iowa 52808

Northwestern States Portland Cement Co.
2100 North Federal
Mailing address:
12 2nd Street N. E.
Mason City, Iowa 50401

Penn-Dixie Industries, Inc.
Cement Division
13th & Railroad
Mailing address:
P. O. Box 190
West Des Moines, Iowa 50265

(See Figure 1).

Two of these facilities use the wet process of producing cement. They are the Marquette Cement Mfg. Company and Martin-Marietta Cement, Northern Division. The wet process requires more energy to dry the material. Today, no wet processing plants are being built due to the increased costs of fuel to dry the material.

Cement manufacturing processors sell their product to over 350 ready mix concrete plants in the state of Iowa and states surrounding Iowa geographically. An additional 150 customers in this state purchase cement to use in manufacturing concrete building block, concrete silos, burial vaults, precast and poststressed members, septic tanks, cattle feeding bunks, drain tile, patio blocks, hog feeders, and outdoor ornaments.

Because of their geographical locations, these companies also market their product in states that border Iowa such as Illinois, Wisconsin, Minnesota, and North Dakota. The Lehigh Portland Cement Co. transports cement to Cedar Rapids, Iowa and Burnsville, Minnesota where it is stored at transfer terminals until it is delivered to a

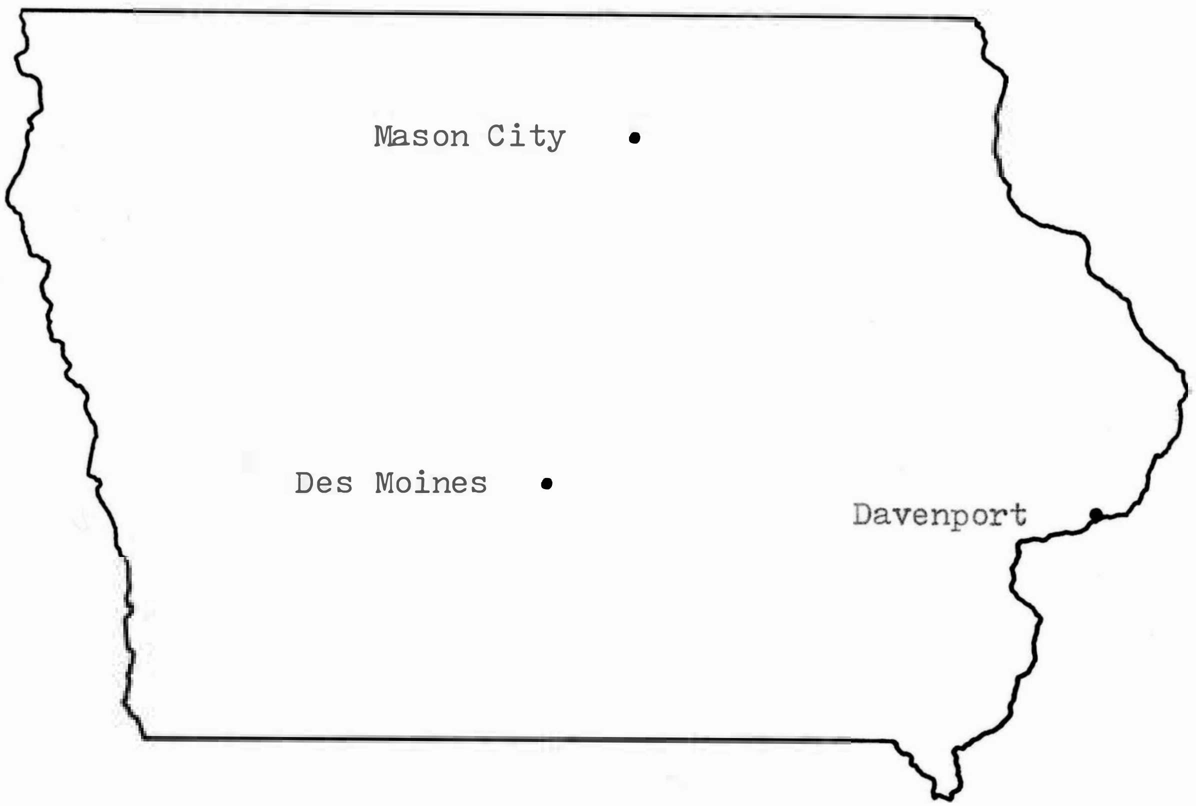

Figure 1

Location of Cement Manufacturing Facilities in Iowa customer. The Northwestern States Portland Cement Co. owns transfer terminals located at Cedar Rapids, Iowa, Burnsville, Minnesota, and Fargo, North Dakota. The location of Martin-Marietta Cement, Northern Division transfer terminals include St. Paul, Minnesota and Madison, Wisconsin. The Marquette Cement Mfg. Co. and Penn-Dixie Industries, Inc. do not operate transfer terminals.

The Portland Cement Association is comprised of 40 member companies. These 40 companies own 139 cement plants in the United States. (Portland Cement Association, 1975).

Ten per cent of all cement production in the United States is located within a 50 mile diameter of the Lehigh Valley in Pennsylvania. (Portland Cement Association, 1975). Nearly every major cement company in this country has a plant located in this area.

In Iowa, the Lehigh Portland Cement Co., Martin-Marietta Cement, Northern Division, and Northwestern States Portland Cement Co. own quarries from which raw materials are removed within short distances of their respective processing facilities. The Marquette Cement Mfg. Co. orginally located at Des Moines, Iowa because of an available source of raw materials near their plant. That resource has been depleted and raw materials for that operation are now located near Winterset, Iowa. For the same reasons, Penn-Dixie Industries, Inc. procure raw materials from Gilmore City, Iowa.

Occupational Information

Occupational opportunities in the cement industry are many and of a wide variety. Considering the substancial physical size of a cement processing plant, there are not that many employees found at such a plant. The typical cement plant will employ approximately 250 employees with 200 people in the processing plant and 50 people in the main office.

The following list includes the classifications of job opportunities at a cement plant.

- Administrative
- Marketing
- Engineers (civil)
- Technical Service
- Purchasing
- Chemists
- Geologists
- Laboratory technicians
- Sales
- Safety Engineer
- Management
- Electricians
- Maintenance
- Mechanics
- Heavy equipment operator
- Office employees
    - clerical
    - bookkeeping
- Truck drivers
- Mill laborers

The organizational structure of a typical cement processing facility is shown in Figure 2.

Financial Trends

Financial trends in the cement industry are not due to the supply of raw materials as is true in so many other industries. Raw materials, limestone, clay, and

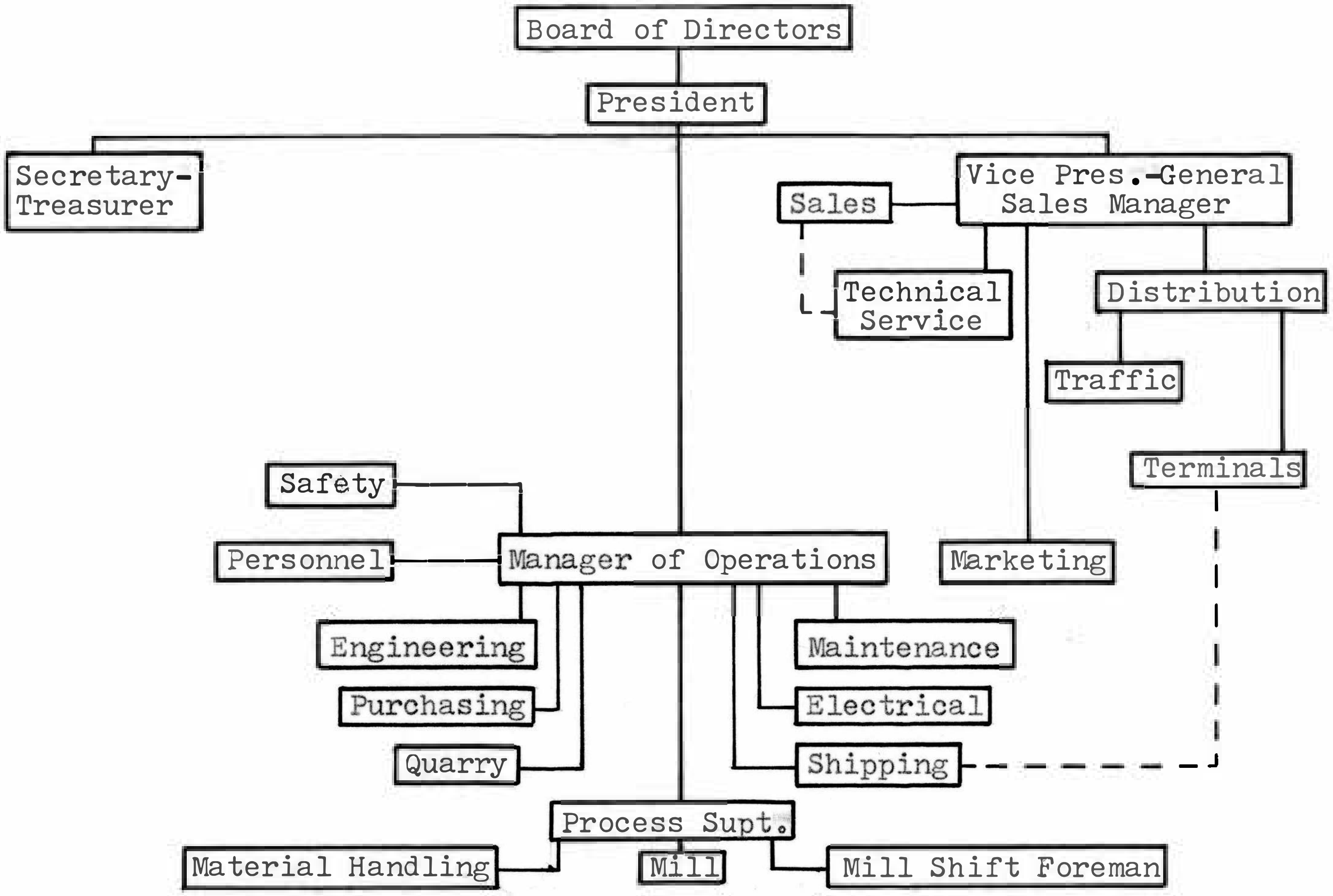

Figure 2

Organizational Structure of a Cement Processing Facility gypsum, are found in ample supply wherever cement processors are located since this is a basic criteria when the location of a facility is decided.

Rather, financial trends are correlated, among other things, to the amount of construction that is taking place since cement is basic to almost all types of construction. Below is a list, including the years 1948 through 1973, that includes the percentage of increase or decrease of cement production in the United States.

1948	+9.6%	1961	-7.5%
1949	+1.9%	1962	+2.4%
1950	+11.8%	1963	+4.7%
1951	+5.3%	1964	+4.3%
1952	+4.1%	1965	+2.0%
1953	+4.0%	1966	+1.6%
1954	+5.7%	1967	-2.3%
1955	+7.9%	1968	+6.5%
1956	+7.9%	1969	+3.3%
1957	+5.3%	1970	-4.5%
1958	-6.3%	1971	+7.5%
1959	+5.9%	1972	+3.5%
1960	+10.1%	1973	+7.0%

(Portland Cement Association, 1974).

Below is a list, including the years 1948 through 1973, that includes the percentage od increase or decrease of cement production in the state of Iowa.

1948	+2.0%	1961	-3.9%
1949	+13.4%	1962	-4.3%
1950	-.4%	1963	+5.6%
1951	+2.4%	1964	+11.7%
1952	+ .5%	1965	+6.0%
1953	+1.0%	1966	+8.5%
1954	+17.5%	1967	+2.9%
1955	+1.0%	1968	-10.5%
1956	+13.3%	1969	+9.5%
1957	-14.2%	1970	-4.4%
1958	+33.3%	1971	+1.2%
1959	-2.2%	1972	- .8%
1960	-9.5%	1973	+8.9%

(Portland Cement Association, 1974).

By studying these figures, it is obvious that the cement industry has not had constant financial success. There was a boom in the cement industry in the 1950's, but in the early 1960's cement processing in the state of Iowa was in the doldrums. There was an overcapacity of cement produced. This forced some manufacturers to close plants. This action brought supply-demand back to where it should probably have been for the industry to show growth. There was some overexpansion in the early 1970's. Production in the past few years has kept in step with the increased construction that is now taking place.

A newspaper article that appeared in the Des Moines Register describes recent growth in the cement manufacturing industry. (Figure 3). The use of cement for agricultural uses was responsible for a majority of the increased demand of cement.

Mason City cement firm's sales, profit up sharply

From The Register's Wire Services

Northwestern States Portland Cement Co., Mason City, had a 56.8 per cent gain in profit for the second fiscal quarter ended May 31, as sales jumped 73 per cent above the like period a year ago.

In an interim report to stockholders, Jack MacNider, president and general manager, said second quarter shipments of cement products improved because of an early spring and strengthening demand in the agricultural sector.

He said weak spots "persist" in major metropolitan markets as industrial and commercial activity remains depressed, but there are "tentative signals of a reversal in these negative trends," and that he expects "excellent" demand for the company's products during the balance of the year.

In the latest quarter Northwestern States earned $849,455, or 85 cents a share, up from $541,683, or 54 cents a

share, in the like period a year ago. Gross sales rose to $6.4 million from $3.7 million, the report says.

For the first half of the fiscal year the company's earnings were $641,411, or 64 cents a share, up 27.4 per cent from $503,541, or 51 cents a share, a year earlier. Sales in the latest six months reached $8.8 million, up 57.1 per cent from $5.6 million a year ago.

MacNider said the company's new finish mill complex is in operation, completing the firm's recent manufacturing expansion project. Work on additional storage and truck loading solos is expected to be completed by late fall, he said.

Figure 3

An Example of Recent Growth in the Cement Manufacturing Industry

Chapter 4

TECHNICAL INFORMATION

On Tuesday afternoon, July 6, 1976, the writer was the guest of the Nothwestern States Portland Cement Company located in Mason City, Iowa. Mr. Peter Fauerby, a technical service engineer employed by Northwestern States Portland Cement Company was the host of a tour given to the writer.

Quarry Operations

Limestone. This resource is one of the primary raw materials needed for the manufacture of cement. The Northwestern States Portland Cement Company began operations in their present location because of the hugh quantities of limestone that were available close to the surface of the earth in that area. The location of the limestone quarry that is presently being quarried is approximately four miles west of the manufacturing facility.

Drilling rigs drill holes along and on top of the exposed face of the quarry to a depth of forty feet. These holes are charged with an explosive and are then set off. Each explosion takes place, one at a time, with a delay in milliseconds between each succeeding explosion and the last explosion that took place. This allows the limestone to fall into the already mined area of the quarry in such a way that it is more accessible for loading. Charges are set off on the face of the quarry every fourth day, on the average. The limestone that has been dislodged from the quarry face is referred to as shot rock. This material is loaded into heavy duty off highway quarry trucks and is transported approximately one-fourth to one-half mile. Each truck is able to move ninety tons of shot rock on each delivery. The shot rock is dumped into a hopper which conveys this material to a primary crusher which is located in the quarry. When the shot rock has passed through the primary crusher, each piece has a maximum size of six inches. The crushed material is then stored in a surge pile. The surge pile contains thousands of tons of crushed limestone and provides easier loading of the stone into open-topped semi-trucks. The surge pile consists of a large pile of stone with a tunnel made of corrugated steel in a circular shape. The end of the tunnel extends out of the pile approximately forty feet. Inside the tunnel is a conveyor used to load the stone into the trucks which transport the crushed limestone to the processing facility. Trucks simply pass under the end of the conveyor and material is placed in the trucks.

The Northwestern plant has, at this time, in excess of 2,000 acres of limestone under its control. This is equal to a supply of approximately sixty years.

Clay. The second raw material needed in the manufacture of cement is a clayey material. Large deposits of suitable clay can also be found in close proximity to the cement plant. Two clay pits are utilized in clay mining for use in cement production. One of the clay pits is located four miles south and one-half mile east of the plant. The second clay pit is located directly west of the plant.

The clay in each of the pits contain different amounts of potassium; yet, the potassium content in the clay at each pit is suitable for manufacturing cement. Clay from the two pits is usually blended together to achieve a more acceptable potassium ratio in the clay. The clay is mined from the pit, it is loaded into open-topped semi-trucks and is transported to the manufacturing plant. It is stockpiled until needed. Motor scrapers remove the clay from the stock-pile to a conveyor which carries the material inside the plant.

The cement company has in excess of 460 acres of clay deposits desirable for use in cement manufacturing under its control. The total clay reserves of the company exceed limestone reserves by many times.

Gypsum. This is the third raw material needed to produce cement. Northwestern States Portland Cement Company purchases all of the raw gypsum needed for the plant. This material is transported by rail to the plant from the Fort Dodge, Iowa area where hugh deposits of gypsum are located.

The quantity of raw gypsum needed to produce cement equals approximately four to five per cent of the total raw materials needed. Clay represents approximately fifteen per cent of the raw materials needed. Limestone represents the remaining eighty per cent of raw materials.

Plant Processing

Limestone is transported from the quarry by truck and is dumped into a hopper which feeds the raw material onto a conveyor. Clay is removed from the stockpile by motor scraper and is dumped into a separate hopper which feeds this material onto another conveyor. Both materials are conveyed inside the plant to separate secondary crushers. After both materials emerge from secondary crushing operations, the maximum size of the materials is one and one-fourth inches. Both materials are flash dried. Moisture content does not exceed one-half of one per cent. Each material is then transported to separate storage silos where they will be stored until needed.

Primary Ball Milling

When the crushed raw materials are needed for further processing, they are weighed out of the storage silos proportionally and blended together as they enter a conveyor to be transported to the primary ball mill. One charge of a primary ball mill will consist of eighty five per cent crushed limestone and fifteen per cent crushed clay. The ball mill pulverizes these materials to a consistency of a medium coarse powder. Each primary ball mill requires 2,500 horsepower to rotate the mill. Electric motors provide the power. Inside of each mill are 108 tons of steel balls, circular in shape, and varying from five-eights to six inches in diameter. The ball mill is a steel cylinder suspended on its side, with both ends closed, and it is mounted on a shaft on which it rotates. The mill is approximately twelve feet in diameter and twenty five feet long. There is one opening on each end of the mill to which is attached a pipe. The crushed raw materials are placed in and removed from the mill through the pipes.

Fastened to the inside of the mill through the use of bolts are sections of corrugated steel. As the mill rotates, the steel balls are carried up the side of the mill while caught by the corrugated sections. When the side of the mill reaches a height where the corrugated sections will no longer hold the balls in position, the balls fall to the bottom of the mill crushing the materials which are in the bottom of the mill. (See Figure 4).

When the limestone and clay have been crushed to a consistency of coarse powder, they are removed from the ball

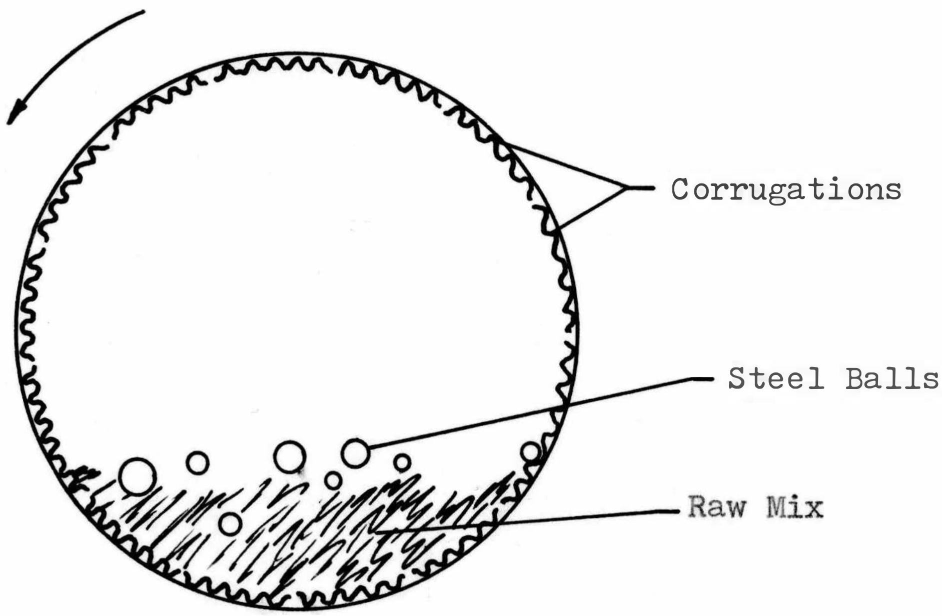

Figure 4

End View of the Interior of a Ball Mill

mill through the introduction of air. When air is introduced to the material, it mixes with the air and will flow through a pipe much like a fluid. Air carries the material which is now known as raw mix to a storage silo. Air is constantly entering the storage silo to further blend the raw mix. This process is known as homogenizing.

The Cement Kiln

The processing of raw materials up to this time has had one purpose: to crush and blend these materials for entry into the cement kiln. The cement kiln is recognized as the second largest piece of moving industrial equipment in the world being exceeded in size by ocean traveling ships. Cement kilns being used in the cement industry today are several hundred feet long. The three kilns producing cement at the facility referred to are 400, 500, and 600 feet long with diameters of 14, 15, and 18 feet. The kilns are made of steel and vary from one inch thick on the cool end to one and one-fourth inches thick on the hot end. The kilns are resting in place with a pitch of six degrees. The upper end is the cool end. Raw mix is placed in the upper end of the kiln.

The 600 foot long kiln is supported at ten equally spaced points, including each end by massive foundations. Attached to the kiln above each of the foundations is a tire. The tire consists of a ring of steel six inches thick and eighteen inches wide. The tire is permanently attached to the kiln. As the kiln rotates, so does the tire rotate.

The tire rides on two trunions at each supported point. Each pair of trunions is attached to the foundation which supports the tremendous weight of the kiln. (See Figure 5).

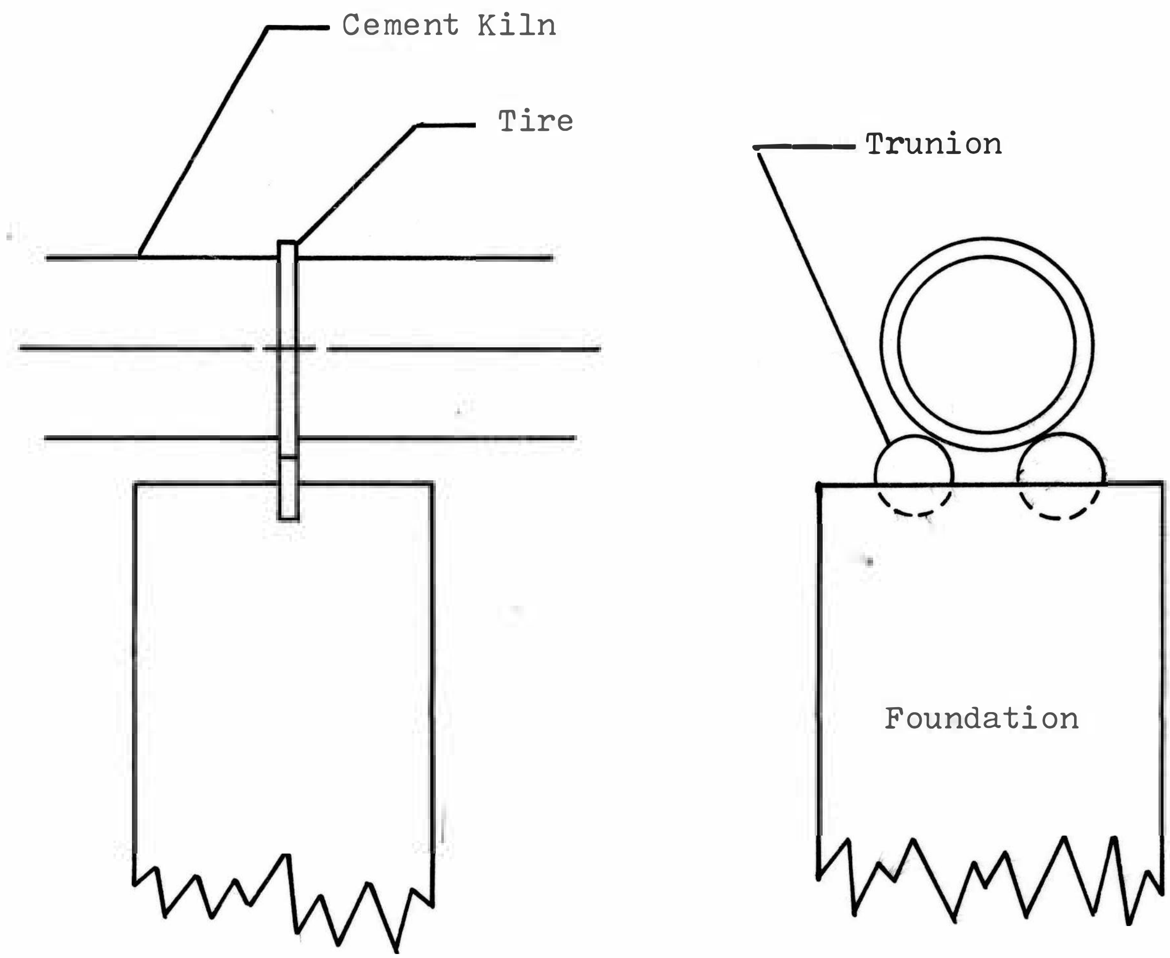

Figure 5

Tire and Trunions That Support the Cement Kiln

Two hundred feet from either end of the kiln is located a drive house. At these two points is located the power needed to rotate the kiln. One electric motor in each drive house with a potential of 350 horsepower rotates the combined weight of the kiln and the cement charge. The use of one bull gear and two helical-cut gears aid each of the electric motors in rotating the kiln. The gears provide gear reduction. The rate of rotation of the kiln is seventy revolutions per hour.

Raw mix is removed from the homogenizing silo and is conveyed to the upper end of the cement kiln. Raw mix is continuously placed inside the kiln. As the kiln rotates, raw mix is carried up the side of the kiln and then falls to the bottom of the kiln. This process continues throughout the entire length of the kiln. Since the kiln has a pitch of six degrees, each time raw mix falls to the bottom, it moves laterally toward the lower end of the kiln.

The temperature at the upper end of the kiln is approximately 500 degrees Fahrenheit. Thirty five feet from the low end of the kiln the maximum temperature is reached which varies from 2,700 degrees Fahrenheit to 3,200 degrees Fahrenheit. As raw mix moves the length of the kiln, it increases in temperature. Maximum temperature is reached at the apex of the flame which is heating the kiln. When the material passes the apex of the flame, it begins to cool slightly. From the time the mix enters the kiln until it reaches the apex of the flame, it is progressing toward the heat source.

While the raw mix is inside the cement kiln and as it approaches the apex of the flame, the raw mix is being heated and it slowly changes from a solid to a molten liquid. The mix changes to a molten state at approximately 2,500 degrees Fahrenheit. While the material is changing to a molten state, four chemical compounds are being formed. These are diacalcium silicate, tricalcium aluminate, tricalcium silicate, and tetracalcium aluminoferrite. As the mix passes the maximum temperature of the kiln, the material begins to cool. The rotating motion of the kiln rolls the cooling mix. Portland cement clinker is formed.

Portland cement clinker is a relatively round rock, and while still in the kiln and exposed to high temperature, is white in color. It varies in size from one and one-half inches in diameter to one-half inch in diameter. The cement mix requires four hours to travel the length of the kiln.

The kiln operation is controlled by an operator in a control room. Panels of switches, indicating lights, a television monitor, and a computer inform the operator of all aspects of the kiln operation such as the speed at which the kiln is rotating, information concerning temperatures of the kiln at preselected strategic points along its length, power consumption, the quantities of fuel and air that are being burned, chemical composition of exhaust gases, production rate of the kiln, and the amount of raw mix entering the kiln. Temperatures of the kiln at many points along its length are continuously checked through the use of several optical pyrometers mounted along side each kiln.

The 600 foot long kiln referred to has a production capacity of 500,000 tons of portland cement clinker per year. The combined production rate of the three kilns is 1,000,000 tons of clinker per year.

Refractory of the Kiln

A cement processing plant operates 365 days a year, seven days a week, twenty four hours a day. Constant operation is a necessity because of large expenses incurred in the operation of the kilns.

Because of the high temperatures at which the kilns operate, they must be refractored twice each year. The upper end of the kiln is refractored with a material called Kilncast 23. Nine inch firebrick is used in the lower end where higher temperatures occur.

A cement kiln provides approximately 320 days of operation per year. Approximately twenty one days are required to clean the kiln and to refractor it.

Air Quenching

When the portland cement clinker has traveled to the end of the kiln, a grate removes the clinker and places it in an air quencher. The temperature of the clinker is in excess of 2,000 degrees Fahrenheit when it is removed from the kiln. It is cooled to approximately 150 degrees Fahrenheit in a time period of ten minutes. Vast amounts of air are circulated around the clinker to accomplish this. The reason for cooling the clinker in such a short period of time is to stop the four compounds that were formed in the kiln from breaking down chemically. The shorter the period of time in cooling the clinker, the fewer the number of molecules that will revert to their original form.

The air that is used to quench the clinker has increased in temperature by accepting heat from the clinker. This heated air is then recovered and forced into the kiln to feed the flame that is firing the kiln. Substancial fuel costs are saved by doing this.

The portland cement clinker is blackish-gray after having been cooled in the air quencher.

Power Failure

A cement processing plant relies on the constant use of large quantities of utilities. The cement kiln is the most important consideration if a power failure should occur.

The kiln operates at high temperatures. If a power failure occurs, the kiln would stop rotating. Hot material would stop in the bottom of the kiln. This area could stay hot for a long period of time. The top of the kiln would cool faster then the bottom. Therefore, the kiln could warp. Hot material in the bottom of the kiln could burn through the refractory material and cause expensive repairs. As the kiln cooled, it could shrink and force the foundations which support the kiln to be destroyed. This could also cause destruction of the kiln.

The kiln is worth several million dollars. If a power failure should occur for more then thirty minutes, the kiln is "inched" to keep the molten material from sitting in one position in the kiln for too long a period of time. Diesel engines are used as a power source to accomplish this.

Fuel

Just a few years ago, natural gas was used to fire the cement kilns. Since the apparent natural gas shortage has occurred in this country, cement manufacturers were forced to find an alternative source of fuel.

Coal is the primary source of fuel now used. At the present time, it is mined in Wyoming and shipped to the cement processor where it is crushed into a powder. It is then burned in the kiln. If natural gas can be purchased, it is burned in conjunction with the coal.

Petroleum coke is often burned with the coal in a powdered form. The combination of coal and petroleum coke is a very efficient fuel to burn in the kilns. Within the next few years, coal and coke will provide the entire fuel source for firing the kilns.

Finish Ball Milling

Portland cement clinker is conveyed to the finish ball mill. It is weighed while it is moving on the conveyer. As a finish ball milling machine is charged with clinker, raw gypsum is being proportioned with the clinker at the rate of four to five per cent of the charge weight. Raw gypsum is milled with the clinker for the specific purpose of controlling the initial set time of the cement when it is used to mix concrete.

The finish ball mill resembles the primary ball mill, although it may be larger in size . (See Figure 4). Three finish ball mills are used at the Northwestern cement facility. Two of them are rotated using 2,000 horsepower electric motors, one for each mill. The third mill is rotated with one 4,400 horsepower motor.

The finish cement mill is divided into three compartments. The initial grinding takes place in the first compartment. When the clinker-gypsum combination has been ground fine enough to pass through a screen mounted parallel to the ends of the mill and one-third of the length from one end, it is ground to a greater blane fineness in the second compartment. When the material is ground fine enough to pass through a second screen of greater blane fineness and into a third compartment, it has been ground to the required blane fineness for finished cement.

The finished cement is then moved to storage silos by injecting air with the cement. The cement is stored in the silos until it is transported to a customer.

Transportation of the Finished Product

The finished product is transported in any of three different ways. A majority of the cement is transported in highway tankers. To load the truck, it is driven under the storage silos. Cement is weighed and transferred into the truck. The truck is then driven to its destination. Generally, the destination is a ready mix concrete plant.

A second transportation system is by railroad. Bulk rail tankers are loaded in the same way that highway tankers are loaded. Most of the rail tankers are transported to cement terminals that are owned by the company. Rail tankers are unloaded at their destinations and the cement is again stored in a silo until it is delivered to a customer.

A third means of shipping is by bag. The cement is bagged at the cement plant and is generally shipped by truck. One bag of cement weighs 94 pounds. The original technique of measuring cement was by the barrel. One barrel of cement weighed 376 pounds. Four bags of cement equalled one barrel. In recent years, cement has been measured by the short ton (English ton), but cement is still bagged according to barrel weight.

Costs of Production

One of the major costs of operating a cement processing plant are the utilities. Utilities for the plant referred to average $135,000 per month. The majority of this figure is used to purchase electrical energy.

The cost of producing one short ton of cement is $23.50 to $24.00. This figure includes direct manufacturing costs. It does not include general and administrative expenses, sales expenses, or transportation expenses.

Chapter 5

PROJECT ACTIVITY INFORMATION

For the past few years, the writer has been more involved with the use of concrete then ever before. The question "What are the changes in the strength of concrete that take place when the formula used for the concrete is varied?" has always interested the writer. This research provided the opportunity to find the answer to this question.

The first decision that had to be made was how the concrete mixtures would be tested. After checking several references and after having discussed the situation with five professional people in the concrete industry, it was decided that the compression test of concrete cylinders would be used to test the mixture design chosen and its variations.

Concrete Formula

The next decision was what concrete formula would be used. The mixture design was based on one cubic yard of concrete.

This formula meets the range of proportions stated in the Design and Control of Concrete Mixtures by the Portland Cement Association. (Portland Cement Association, 1968, p. 7). Cement paste ordinarily constitutes twenty five to forty per cent of the total volume of concrete. (Portland Cement Association, 1968, p. 7). Since the percentage of cement paste in the design formula is twenty seven and four-

Table 1

Concrete Formula Design

%	Ingredients	Amount of Ingredient	Volume in Cubic Feet
8.8	Cement	470 lbs.	2.39
18.6	Water	38 gallons	5.03
28.6	Sand	1282 lbs.	7.73
40.8	Coarse Aggregate	1833 lbs.	11.04
3.0	Assumed Moisture		
100.0			27.00

tenths per cent, the mixture design was satisfactory according to the Portland Cement Association reccommendations. This concrete formula was not found in any book. It was designed for this research project.

Determination of the ingredients to vary and the ingredients to hold constant was the next step in designing the formula. It was decided to increase and to decrease at the rate of ten per cent the quantity of water used, and to increase and to decrease at the rate of ten per cent the quantity of coarse aggregate used. The quantities of sand and cement would be held constant. Varying the water content of the mixture design would directly change the cement paste and the aggregate ratio which should vary the strength of the concrete. When the quantity of water was increased, the amount of cement paste was increased. The decrease in water decreased the amount of cement paste. When the quantity of aggregate was increased, it provided more surface area of the aggregate to be coated with cement paste, therefore decreasing the strength of the concrete. When the quantity of aggregate was decreased, there was less surface area of aggregate to be coated by the cement paste, therefore increasing the strength of the concrete. These statements were based on theory, and it was hoped that these statements would be proven to be true using the test results to do so.

Three sizes of aggregate were used in the test. They were:

Aggregate A - $1\frac{1}{4}$" maximum size

Aggregate B - 3/4"maximum size

Aggregate C - 1/2"maximum size

The quantity of water and the quantity of each aggregate size was varied one at a time, and never more then one quantity was varied in any one concrete test cylinder.

Materials

The ingredients, aggregates in sizes A, B, and C, washed sand, and cement, were purchased from local suppliers. Cylinder molds were purchased from a testing laboratory. These molds are made of heavy paper, and are coated with wax on the inside to prevent loss of moisture of the concrete specimen. Each mold measured six inches inside diameter and twelve inches in height. The bottom is closed with metal. The top is open so that concrete can be placed in the mold. A.S.T.M. standard C 470 was followed.

A tamping rod five-eights inch in diameter and twenty four inches in length with one end rounded to a hemispherical tip was used to tamp concrete after it was placed in the mold. A.S.T.M. standard C 31 was followed when this rod was made.

Other equipment used included a clean mortar box and hoe to mix concrete, a shovel to handle materials, a scale to weigh materials, a slump cone to measure the slump of the particular formula being tested, and a ruler to measure the actual slump of the concrete.

Procedure

The formulas were mixed at an air temperature of 71 degrees Fahrenheit. Each ingredient was weighed according to a predetermined figure. Water was measured in a cylinder with measurements marked on its side. Sand, coarse aggregate, and cement were throughly mixed together in the mortar box using a hoe. The measured quantity of water was then added to the other ingredients, and all ingredients were throughly mixed together unit it was felt that the cement paste had adequately coated the aggregate. Next, a slump test was performed. One-third of the slump cone was filled with concrete and was rodded with the prescribed rod twenty five times. The second one-third of the slump cone was filled and it was also rodded twenty five times. The same procedure was followed with the final one-third of the slump cone. Excess concrete was removed from the top of the cone so that the cone was level on the top. The slump cone was pulled upward immediately, leaving the exposed concrete standing by itself. The height of the concrete was then measured from its existing height to the height it occupied while it was in the slump cone. The measurement arrived at is considered to be the slump of the concrete.

The next procedure was to fill the cylinder mold. A.S.T.M. standard C 31 was followed. Using a scoop that would fit inside the mold, the bottom one-third of the mold was filled with concrete and the prescribed rod was used to rod the concrete in the mold twenty five times, being careful not to touch the bottom of the mold with the rod. The purpose of all rodding of test specimens is to remove as many air voids as is possible. The second one-third of the mold was filled with concrete and, again, the material was rodded twenty five times, being careful not to insert the rod into the previously placed concrete. The final one-third of the mold was filled with concrete and the rodding was performed on this material in the same procedure as before. The top of the cylinder was leveled and a plastic bag was placed over the cylinder. The purpose of the bag is to retain the moisture in the concrete. The molds were stored for twenty four hours at a temperature of 69 degrees Fahrenheit.

At the end of the twenty four hour period, the concrete in the molds had achieved an initial set. All concrete test specimens were placed in a tank of water after the plastic bag and the paper mold had had been removed from each cylinder. The concrete cylinders were stored submerged in water for seven days at a temperature of 80 degrees Fahrenheit. A.S.T.M. standard C 31 was followed.

Two test cylinders were taken from ready mix concrete trucks. Fifteen different cylinder tests were conducted, each cylinder being a slightly different formula because of the increase or decrease of water or coarse aggregate. (Table 2). All of the cylinder molds were filled on the same day so that all concrete formulas were exposed to identical atmospheric conditions.

On the seventh day, all of the test cylinders were capped using a sulfer compound. The purpose of capping the cylinders is to establish two surfaces which are flat, smooth, and parallel to each other. The caps must also be perpendicular to the sides of the test cylinders. Both ends of every cylinder were capped. A.S.T.M. standard 617 was followed.

Each cylinder was then compressed in a compression testing machine. By using a pre-established table, the total compressive strength of each individual cylinder can be converted to the pounds per square inch of pressure that the cylinder was able to withstand before it fractured. Pounds of pressure per square inch determines the strength of the concrete that was being tested. (Appendix A).

<u>Additional Information</u>

It has been established, according to professional people in the concrete industry, that the percentage of strength of concrete cylinders will vary from as little as twenty or thirty per cent to one hundred per cent in a time period of seven days depending on the formula that was used to mix the concrete. If an established formula was used, the strength will be reasonably close to or exceed seventy per cent. If an unacceptable formula was used, the strength at seven days will vary according to the formula. (Ready mix concrete plants usually overdesign a formula so that if additional water is added at the customer's request, the formula will still meet the minimum strength requirement. To overdesign a formula, additional cement is added to the mix). Examples of typical failures of concrete test cylinders can be seen in Figure 6.

Each of the seventeen formulas were based on 3,000 pound concrete. Two test cylinders of ready mixed concrete were used to establish a basis for 3,000 pound concrete, and to provide a comparison between ready mixed concrete and hand mixed concrete. No 3,000 pound concrete using C aggregate from a ready mix truck was available the day the test cylinders were filled with concrete. Therefore, no comparison can be made of that formula. No air entrainment was used in any of the hand mixed test formulas.

Results of Testing

Before any testing of concrete cylinders was begun, the writer considered the per cent of strength that would be gained by the test cylinders at the end of seven days. The estimate that was made was a gain in strength of the formulas used varying from forty to one hundred per cent.It is

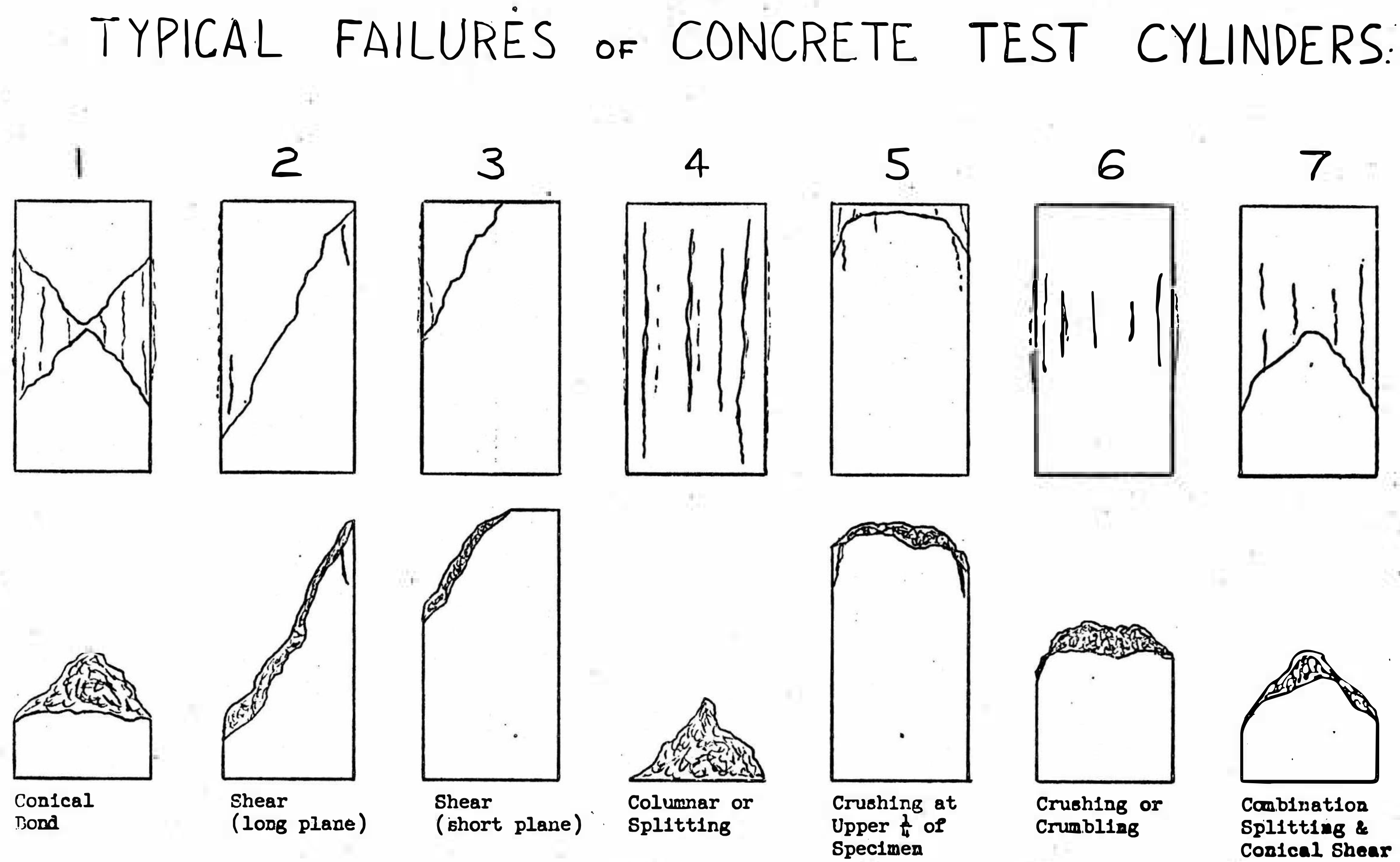

Figure 6

Typical Failures of Concrete Test Cylinders interesting to note that only one cylinder failed to meet this estimate. That cylinder had an excessive amount of water added to it which diluted the water-cement ratio therefore decreasing the strength of the concrete. One cylinder failed to gain fifty per cent of its strength. Four cylinders failed to gain sixty per cent of maximum strength. Only eight cylinders failed to gain seventy per cent of their maximum strength. It must be remembered that twelve of these cylinders were formulated with existing adverse mixtures. This indicates that an acceptable formula was used. Because of a limitation of time, cylinders were broken only at seven days. The total compressive strength of the concrete test cylinders was obtained from prepared industry-accepted conversion tables. (Appendix A).

Water-cement ratio is the most critical proportion in determining a formula for concrete. If too much water is introduced to the formula, the ratio will be too high. Although there will be a larger quantity of cement paste to cover the aggregate used in the mixture, its strength will have been decreased due to the addition of the extra water. In short, when additional water is added to a mixture, the concrete will have been diluted. The only advantage to a formula that has had an excessive amount of water is the workability of the concrete.

The opposite is also true, but not to the same degree, as can be seen in Figures 7 and 8. If the water content is reduced, the quantity of the cement paste is also reduced, but the existing cement paste is stronger then the

Table 2

Results of Testing

Cylinder Letter	Water	Cement	Sand	Aggregate Size	Slump in Inches	Total Compressive Strength In Pounds	Strength of Concrete in P.S.I.	Per Cent of Strength At 7 Days	Set Number
A	Ready Mixed Concrete		Ready Mixed Concrete		-	84,500	3010	100.0	-
B	Ready Mixed Concrete		Ready Mixed Concrete		-	81,500	2900	96.6	-
C	Constant	Constant	Constant	A-Constant	1½	68,500	2440	81.3	1
D	Constant	Constant	Constant	B-Constant	2½	79,500	2830	94.3	1
E	Constant	Constant	Constant	C-Constant	3½	70,500	2510	83.6	1
F	Increase	Constant	Constant	A-Constant	4	47,000	1670	55.6	2
G	Increase	Constant	Constant	B-Constant	5	46,500	1660	55.3	2
H	Increase	Constant	Constant	C-Constant	6	35,000	1250	41.6	2
I	Decrease	Constant	Constant	A-Constant	1	85,000	3030	101.0	3
J	Decrease	Constant	Constant	B-Constant	2	86,500	3080	102.0	3
K	Decrease	Constant	Constant	C-Constant	3	59,000	2100	70.0	3
L	Constant	Constant	Constant	A-Increase	2	54,500	1940	64.6	4
M	Constant	Constant	Constant	B-Increase	2½	50,750	1810	60.0	4
N	Constant	Constant	Constant	C-Increase	3	59,500	2120	70.6	4
O	Constant	Constant	Constant	A-Decrease	2	47,000	1670	56.0	5
P	Constant	Constant	Constant	B-Decrease	2½	58,000	2060	69.0	5
Q	Constant	Constant	Constant	C-Decrease	3	56,500	2010	67.0	5

Increase = 10% Increase   Decrease = 10% Decrease

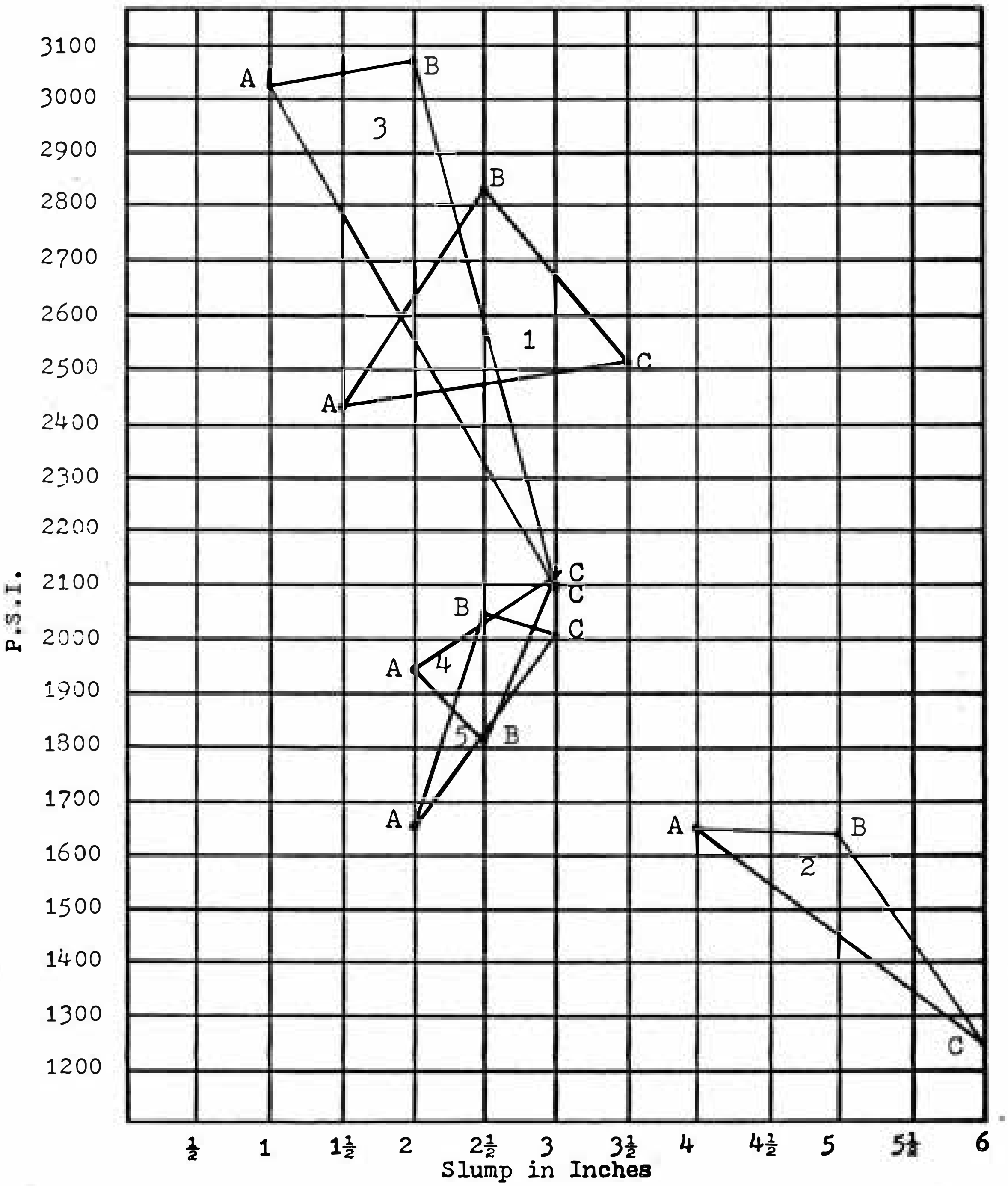

Figure 7

Results of Testing

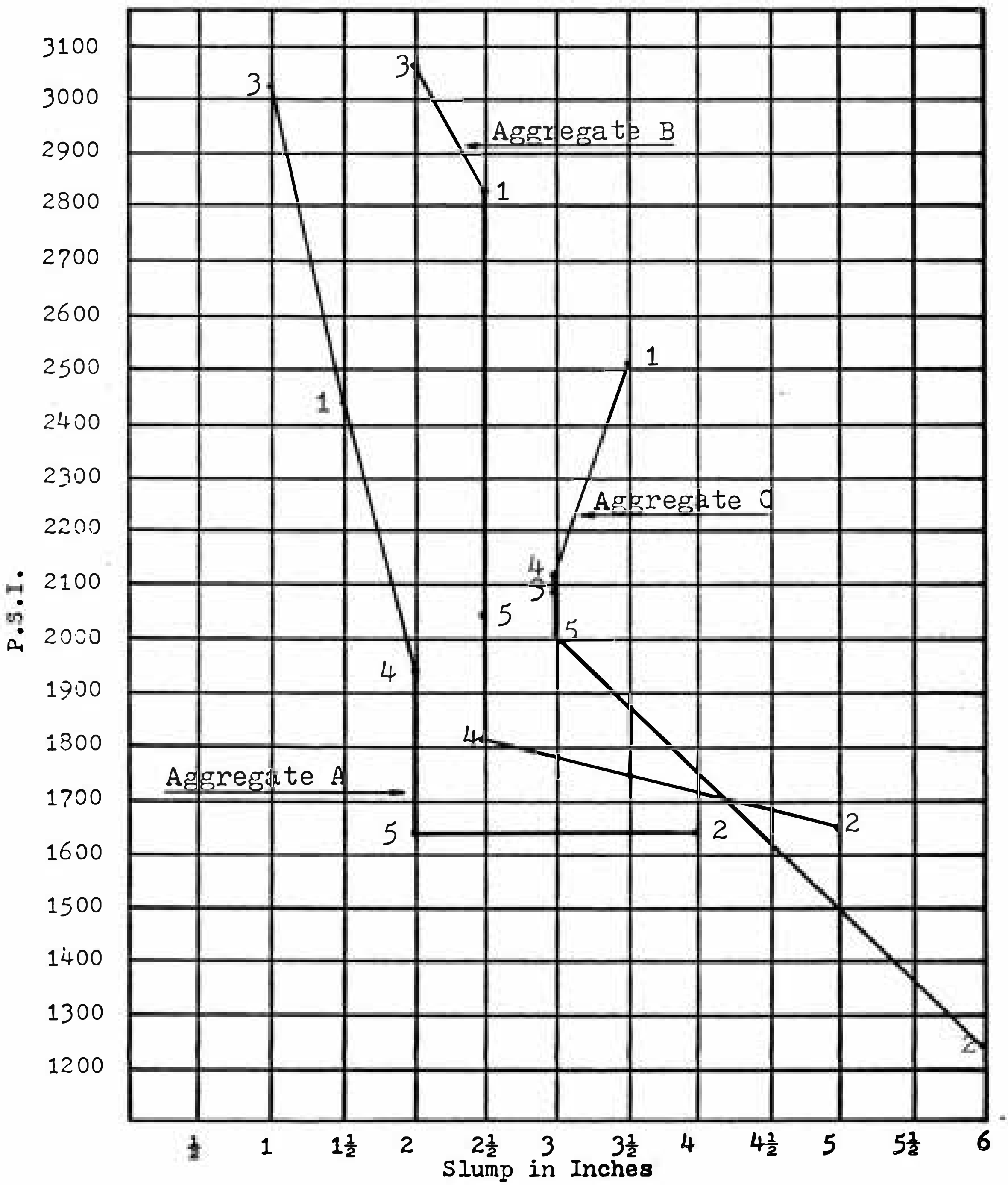

Figure 8

Results of Testing

formula for which it was designed. More mixing is required to cover the aggregate used in the formula, but a noticeable increase in strength is also apparent. With a reduction in the prescribed quantity of water, a harsh mix is the result. In other words, the mix does not possess the desired workability for placing the concrete.

It is obvious that as slump of concrete increases, workability increases, and strength is decreased, and that as slump decreases strength increases and workability decreases. Workability, required properties of hardened concrete, and economy are the three criteria to consider when designing a concrete formula. The formula used for this research produced very workable concrete. When the concrete was tested for maximum strength, the results were very favorable. A minimum water-cement ratio was used when the formula was designed, and this proved to be both economical, and yet the formula produced concrete that possessed adequate strength.

Chapter 6

AN INSTRUCTIONAL UNIT IN CEMENT/CONCRETE

It is not the intended purpose of this writer to develop an extensive unit of instruction in cement and concrete. Rather, the writer wishes to integrate these areas into the broad concept of construction as is suggested in The Iowa Guide for Curriculum Improvement in Industrial Arts, K-12.

Unit Objectives

Upon successful completion of this unit, the student should be able to demonstrate a knowledge of:

1. the history of portland cement
2. the major cement processors in the state of Iowa
3. the occupational opportunities in the cement industry
4. the major steps in the processing of portland cement
5. the transportation methods employed by the cement industry
6. the necessary ingredients to mix concrete
7. the approximate proportions of the necessary ingredients in mixing concrete
8. the correct procedure for making a test cylinder of concrete
9. the method of testing concrete cylinders
10. the importance of cement and concrete in the construction industry

Unit Outline

I. Introduction to the cement industry

   A. A widely utilized construction material

   B. Few buildings are constructed without using cement in one of many ways

II. Background information

   A. Different processes used in the manufacture of cement

   B. Defining terms used in cement processing

III. The history of cement

   A. Early developments

   B. The Romans

   C. The origin of portland cement

   D. Early cement kilns

   E. The Portland Cement Association

IV. The process of cement manufacturing

   A. Quarry operations

   B. Plant processing

   C. Primary ball milling

   D. The cement kiln

   E. Refractory of the kiln

   F. Air quenching

   G. Power failure

   H. Fuel

   I. Finish ball milling

   J. Transportation of the finished product

   K. Costs of production

V. Cement processors in the state of Iowa

A. Lehigh Portland Cement Co.

B. Marquette Cement Mfg. Co.

C. Martin-Marietta Cement, Northern Division

D. Northwestern States Portland Cement Co.

E. Penn-Dixie Industries, Inc.

VI. Occupational information

A. Employment opportunities

B. Requirements for employment

VII. Quantities of cement production

A. Brief history of production in the United States and in Iowa

B. Costs of production

VIII. Ingredients of concrete and correct proportioning

A. Cement

B. Water

C. Sand

D. Aggregate

E. Quantities required of each ingredient

IX. Mixing cement

A. Hand method

B. Mechanical mixer method

X. Testing concrete cylinders

A. Seven day tests

B. Expectations and potential results

Laboratory Activities

1. Inspection of all ingredients of concrete

2. Proportioning the ingredients to be used in concrete
3. Actual mixing of concrete
4. Filling test cylinders and forms for the concrete project
5. Testing the concrete cylinders using a compression testing machine

Sample Lesson Plan

IV. The process of cement manufacturing

A. Quarry operations
   1. Limestone
   2. Clay
   3. Gypsum

B. Plant processing
   1. Transporting material
   2. Flash drying

C. Primary ball milling
   1. Physical size of the primary ball mill
   2. What primary ball milling is and why

D. The cement kiln
   1. Physical properties of the kiln
   2. The interior of the kiln

E. Refractory of the kiln
   1. Upper one-half
   2. Lower one-half

F. Air quenching
   1. The reason for air quenching

2. Recovering heated air

G. Power failures

1. Why it must not happen

2. What is done when it occurs

H. Fuel

1. Coal and coke

2. Natural gas

I. Finish ball milling

1. Grinding the clinker

2. Moving the material

J. Transportation of the finished product

1. Semi-tanker

2. Rail

K. Costs of production

1. Current costs

2. Future costs

Software Materials

Textbooks. Since the unit in cement and concrete would be relatively short, a textbook would not be necessary. The unit can be taught using this research and instructional sheets prepared by the individual teacher.

Films. The writer was unable to locate any films for use at the junior high school level. The writer intends to pursue the availability of films by attempting to have the Area Seven Educational Media Center order films relating to the subject matter if any are available.

Reference Materials. Refer to the Cement and Concrete

Reference Catalog by the Portland Cement Association. This catalog will provide extensive information relating to cement and concrete.

Slides. The researcher has prepared an excellent set of slides pertaining to the cement processing industry. These slides are available for duplication.

Hardware Materials

Cement. Almost all lumberyards sell cement by the bag. Type I cement is preferred, which is standard cement.

Aggregate. Three sizes of aggregate are used in concrete. Aggregate and washed sand can be purchased at four locations in the Waterloo-Cedar Falls area. These are:

Assink Brothers, Inc.
Highway 218
Cedar Falls, Iowa

Earl Hansen Excavating Co.
710 River Forest Road
Evansdale, Iowa

Hawkeye Sand and Gravel
RR #4
Waterloo, Iowa

Martin-Marietta Central Division
1800 West Donald
Waterloo, Iowa

Field Trips. There are three ready mix concrete plants in the Waterloo-Cedar Falls area. Arrangements should be made in advance with the particular plant at which a field trip may be desired. Refer to the Iowa Manufacturers Guide for a complete list of these facilities in the state of Iowa.

There are five cement processing facilities in the state of Iowa. If one of these facilities is within a reasonable distance, contact one of them for the opportunity to tour a production facility. These manufacturers are listed on pages 14 and 15 of this research.

Materials Required to Perform Cylinder Tests.

Cylinder molds can be purchased from:

Twin City Testing and Engineering Laboratory, Inc.
529 Logan
Waterloo, Iowa

Patzig Testing Laboratory, Inc.
2215 Ingersoll Avenue
Des Moines, Iowa

Brodhead-Garrett
4560 East 71st Street
Cleveland, Ohio

The steel rod used while filling the cylinder molds should be made to exact specifications. The following materials can be gathered from many sources.

Shovel

Small trowel to place concrete in the mold

Mortar box in which to mix concrete

Hoe to mix concrete

Scale to weigh material

Compression machine to break cylinders. This machine can be found at a testing laboratory or ready mix concrete plant

Safety Precautions

Safety precautions must be established for any operation preformed. Every operation should be performed with all safety rules remembered at all times.

1. Safety glasses and/or goggles must be worn

during any laboratory activity. The lime in cement can injure eyes. They should also be worn when cylinders are broken since concrete chips can fly out of the testing machine.

2. The floor may be damp or wet. Sand may make the floor a hazardous surface to work on. Keep it as dry and clean as is possible
3. Wear proper clothing.
4. Follow all safety rules while working in the laboratory.

Chapter 7

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

This study has been very elightening for the writer. The experiences encountered throughout this study have been interesting and educational.

Summary

This research was conducted for the purposes of investigating the cement processing industry and to become knowledgeable of those processes, and to design a concrete formula and to perform compression tests using the design formula to determine strengths and weaknesses of the mix. Additional purposes included investigating information related to the cement industry, and to develop a unit of study involving the cement and concrete industries. Construction is a major curriculum area in The Iowa Guide for Curriculum Improvement in Industrial Arts, K-12, and cement plays an increasingly important role in current construction practices.

This research traces the raw materials involved in cement production from the moment they are removed as natural resources through the total operations of the processing facility, and continues with transportation of the finished product. Costs of production are also included in that chapter.

The historical significance of cement was developed from the era of the cave man, the Romans, and the origin of portland cement, to the formation of the Portland Cement

Association. The related information includes geographical locations, occupational information, and financial trends in the industry.

There are four principal ingredients used in mixing concrete. They are cement, water, sand, and aggregate. When the concrete formula was designed, cement and sand were utilized as constants. Water and aggregate were used as variables. After the variations of the basic formula were mixed, placed in cylinder molds, and allowed to cure according to A.S.T.M. specifications, each of the cylinders was placed in a compression testing machine to determine total compressive strength. The results of these tests provided a sufficient amount of information on which to arrive at definite conclusions.

Conclusions

A great percentage of the people in the United States come in contact with concrete everyday of their lives, yet few people understand this material and its origin. The writer has achieved tremendous satisfaction in obtaining new knowledge concerning an area of study of which almost nothing was known. When this research was begun, the writer became apprehensive about the success of the research since such a small amount of information was available which was useful. Due to information offered by people involved in the cement and concrete industries, the research was completed. Each passing day brought forth more useful information. Not all of the information was utilized in this research. Rather, it will be saved, and it will be very useful when applied to further research of this topic. It is felt that the purposes of this study have been adequately achieved. A thorough understanding of the topic has been accumulated and there is now understanding concerning both segments of the research.

Any industrial education teacher who reads this research should realize that concrete is a material that should be added to the list of other materials that are studied in industrial education laboratories. Cement and concrete are fantastic materials, and students should have the opportunity to use them and to explore them.

Recommendations

As a result of conducting this study, there are a few recommendations that can be made. The first three recommendations deal with additional research studies that could be made. The final recommendation involves the classroom and related activities.

First, another study of cement could be made, but this study should be made on a national scale. However, an extensive amount of time would be needed to complete the research.

Secondly, a study could be composed of information concerning the extensive testing that is made of cement in laboratories at cement processing facilities. It is impossible to imagine the broad range of tests performed in these laboratories.

Third, any of a number of additional design formulas could be determined for concrete and each of these formulas could be tested just as the formula in this research was tested. This would provide a comparative base for concrete formulas.

Lastly, it is recommended that the use of concrete be utilized as a construction material in the classroom. This could be accomplished on a limited basis in a classroom, or more extensively at a construction site. Concrete is a versatile material and students should be exposed to its uses.

BIBLIOGRAPHY

Abdun-nur, Edward A. Recommended Practice for Evaluation of Compression Test Results of Field Concrete, First Edition. Detroit: American Concrete Institute, 1965.

Annual Book of ASTM Standards, 1973, First Edition. Easton: American Society for Testing and Materials, 1973.

Dunham, Clarence W. The Theory and Practice of Reinforced Concrete, Fourth Edition. New York: McGraw-Hill Book Company, 1966.

Hadley, Earl J. The Magic Powder, First Edition. New York: G. P. Putnam's and Sons, 1945.

Murdock, L. J. Concrete Materials and Practice, Third Edition. London: Edward Arnold (Publisher) Ltd., 1960.

Neville, Adam M. Hardened Concrete: Physical and Mechanical Aspects, First Edition. Detroit: American Concrete Institute, 1971.

________. Properties of Concrete, Second Edition. New York: John Wiley & Sons, 1973.

Orchard, D. F. Concrete Technology, Third Edition. New York: John Wiley & Sons, 1973.

Portland Cement Association. Design and Control of Concrete Mixes, Eleventh Edition. Skokie: Portland Cement Association, 1968.

Taylor, W. H. Concrete Technology and Practice, Second Edition. New York: Elsevier Publishing Company, 1967.

Troxell, George Earl. Composition and Properties of Concrete, Second Edition. New York: McGraw-Hill Book Company, 1956.

APPENDIXES

Appendix C

a
June 26, 1976

Mr. Jim Jensen
Director of Personnel
Martin-Marietta Cement, Northern Division
P. O. Box
Davenport, Iowa 52808

Dear Mr. Jensen:

I am a graduate student in industrial art education at the University of Northern Iowa in Cedar Falls, Iowa. At the present time, I am enrolled in a research projects course. I am developing a research paper, the topic of which is cement processing.

I am interested in available information concerning the history of the cement industry, industrial-geographical information, and any occupational information which is available.

I will look forward to your response.

Thank you.

Sincerely,

James Gephart

Appendix D

a

July 7, 1976

Mr. Peter Fauerby
Technical Service Engineer
Northwestern States Portland Cement Co.
12 2nd Street N.E.
Mason City, Iowa 50401

Dear Mr. Fauerby:

Please accept a sincere thank you from me for the personal tour of the Northwestern States Portland Cement Company on July 6, 1976. I was able to accumulate a great deal of information from the tour.

I will look forward to our conversation during your visit to Cedar Falls next week.

Sincerely,

James Gephart

VITA

Name	James E. Gephart
Date of Birth	
Place of Birth	Iowa
Wife	Nancy Lynn
Children	Amy Lynn,
Education	Thomas Jefferson High School Cedar Rapids, Iowa Graduated, 1963 University of Northern Iowa Cedar Falls, Iowa B. A., 1968 University of Northern Iowa Cedar Falls, Iowa M. A., 1977
Past Positions	Iowa Teachers Conservation Camp University of Northern Iowa Summers 1968, 1969, 1970, 1971
Present Position	Hoover Junior High School Ninth Grade Industrial Arts Waterloo, Iowa 1968-1977