Effects of Used and New Engine Oil on the Properties of Concrete

by

Syamsulzaidi Saifuzzaman

Dissertation

submitted in partial fulfilment of

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CERTIFICATION OF APPROVAL

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Approved by,

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(Dr. Nasir Shafiq)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

DECEMBER 2004

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

SYAMSULZAIDI SAIFUZZAMAN

ABSTRACT

The principal aim of this project was to investigate the effects of the addition of used engine oil on the properties of fresh and hardened concrete. The significance of the experimental program was to confirm the hypothesis that the addition of used engine oil in the fresh concrete mix could be similar to adding an air-entraining chemical admixture, thus enhancing some of the durability properties of concrete while serving as a technique of disposing the oil waste. In this research, a comparative study of the properties of concrete with used engine oil, new engine oil, Sika Aer air entraining agent and control mix was made in order to determine the most significant effect(s) of used engine oil.

Based on the detailed literature review, some of the fundamental engineering properties, such as air content, total porosity and compressive strength were investigated for various concrete mixes.

The compressive strength of control mix at all the ages, 3, 7, 28 and 90 days was obtained higher than the compressive strength of concrete mixes with the addition of used and new engine oil and Sika Aer air entraining agent.

Similarly the total porosity of control mixes was also obtained more than the total porosity of other mixes at all ages. Therefore, addition of used engine oil may enhance the durability of the concrete due to low porosity.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

An increasing trend all over the world is to utilise the processed and unprocessed industrial by-products and domestic wastes as raw materials in cement and concrete. This has a positive environmental impact due to the ever-increasing cost of waste disposal and stricter environmental regulations. Historically, literature on concrete technology and cement chemistry had shown that the leakage of oil into the cement in older grinding units resulted in concrete with greater resistance to freezing and thawing. This effect is similar to adding an air-entraining chemical admixture to the concrete. Such information is not backed by any research study as reported in the literature. Therefore, extensive study on the effects of engine oil on the properties of fresh and hardened concrete has great research potential.

1.2 Problem Statement

Utilization of processed and unprocessed industrial by-products and domestic wastes as raw materials in cement and concrete.

1.3 Objective and Scope of Study

1.3.1 Objective

The main objectives of this study are:

1. To investigate the effects of used engine oil on the properties of fresh concrete, i.e. air content and slump value.
2. To determine the effects of used engine oil on the properties of hardened concrete, i.e. porosity, flexural strength and compressive strength.

3. To compare the properties of concrete with used engine oil with the properties of control mix and concrete mix with new engine oil and with commercial available air entraining agent.

1.3.2 Scope

This research study was conducted into two main stages as:

i. The purpose of this stage was to explore the literature in order to determine the relevant properties investigated by the others and their findings.

ii. Experimental analysis

An extensive experimental program was devised to determine the following properties of fresh and hardened concrete mixes:

a. Air content

b. Total porosity

c. Compressive strength

The experiment results as obtained were analysed using graphical interpretation and statistical trends and correlations.

CHAPTER 2

LITERATURE REVIEW

2.1 Used engine oil as a waste

Wastes can be defined as not readily avoidable by-products for which there is no economical demand and for which disposal is required. Processed or unprocessed industrial by-products or wastes can be used as raw materials in cement manufacturing, as components of concrete binder, as aggregates, a portion of aggregate, or ingredients in manufactured aggregates. Some wastes can be used as chemical admixtures and additives, which can alter and enhance the selected properties of fresh and hardened concrete. The successful use of industrial by-products or wastes in concrete depends on the required properties of the end product. Economical factors would ultimately determine if potentially beneficial waste could be used as an ingredient in concrete. These factors are generally influenced by the cost of waste disposal, the cost of transportation of waste to a manufacturing site, and existing environmental regulations.

Several by-products or wastes have been reported in the literature to be used in concrete [1]:

1. Recycled aggregate concrete is widely used in road construction.
2. Unprocessed wastes have been used as coarse or fine aggregates in concrete with variable success. Such wastes include blast furnace slag aggregate, steel slag aggregate, Ferro-chromium and silica-manganese slags, crushed brick, crushed glass, expanded polystyrene granules, cork granules, sawdust, shredded rubber, cane bagasse, wood ash, china clay waste, slate processing waste, and paper waste.

3. Pozzolans such as fly ash, silica fume, granulated blast furnace slag, rice husks ash, and other industrial or natural mineral by-products are used as extenders of Portland cement.
4. Waste-derived fuels such as coke oven gases, pyrolysis gases, landfill gasses, industrial oils, distillation residues, and halogen-free spend solvents, can be used in manufacturing Portland cement.
5. Many organic fibers, including wastes, are used as concrete reinforcement. These can be classified as natural, which can be either of vegetable or animal origin, or synthetic.

It is estimated that less than 45% of used engine oil is being collected worldwide while the remaining 55% is thrown by the end user in the environment particularly in seas. Used oil affects both marine and human life. Oil in water raises to the top forming a film that blocks sunlight, thus stopping the photosynthesis and preventing oxygen replenishment leading to the death of the underwater life. In addition, used oil contains some toxic materials that can reach humans through the food chain.

The leakage of oil into the cement in older grinding units has been reported to result in concrete with greater resistance to freezing and thawing. This implies that adding used engine oil to the fresh concrete mix could be *similar to adding an air-entraining chemical admixture*, thus enhancing some durability properties of concrete while serving as another technique of disposing the oil waste. However, experimental data from previous study to support this hypothesis appear to be lacking [1].

2.2 Concrete Fundamentals

Concrete is an important construction material. Its basic properties and construction concreting practices has to be taken fully consideration. It may adversely affect its strength and/or durability.

To perform satisfactorily under the severe exposure conditions, the concrete used must have adequate strength and be durable. The structure will be exposed to a combination of wet-dry and freeze-thaw cycles plus the application of deicing chemicals. In order for the concrete components that are exposed to these conditions to be durable, the following is required:

- The concrete must have a low water-cement ratio.
- An air-entraining agent must be used.
- Suitable concrete mix materials must be utilized.
- The concrete must be adequately cured.
- Good construction concreting practices must be followed.

Each of the above requirements is briefly discussed below.

2.2.1 Water-Cement Ratio

The specified concrete water-cement ratio must be the lowest value required to meet the design considerations. In concrete mix design the considerations that are of specific interest are strength, wear resistance, water tightness, and freeze-thaw resistance. All of these properties are influenced by the water-cement ratio. Numerous tests have been performed that show a definite relationship between the water-cement ratio and strength. As the water-cement is lowered the concrete strength increases. This same relationship applies when considering the water-cement ratio and concrete durability. This has pointed out the importance of a low water-cement ratio from both a strength and durability standpoint.

2.2.2 Air Entrainment

Air-entrained concrete must also be used to assure the durability of the concrete elements. Air entrainment is recommended principally to improve the freeze-thaw resistance of concrete but there are other benefits of entraining air into concrete. In addition to improving the resistance of hardened concrete to freezing and thawing, entrained air improves the workability, scaling resistance, water tightness, sulfate resistance, and abrasion resistance of concrete. As can be seen the basic durability properties of concrete are improved by the entraining of air. The introduction of an air-entraining agent into concrete does reduce the strength of the hardened concrete. However, this strength reduction is offset by an improvement in concrete workability which allows the use of a lower water-cement ratio for the mix.

2.2.3 Materials

The durability of the concrete is also affected by the materials used in its production. Concrete is basically composed of two parts: paste and aggregates (both fine and coarse aggregates). The paste is comprised of cement, water, and entrained or entrapped air. It is imperative that the constituents used be of the highest quality. The quality of the hardened concrete can not be better than the constituents used in its production. All constituents must be tested for impurities that would adversely affect the durability and/or strength of the hardened concrete.

2.2.4 Cure

Fresh concrete requires moisture during the **curing** period, which is the transformation of fresh concrete to hardened concrete. Concrete does not harden or cure by drying. Concrete needs moisture to hydrate and harden. The drying of concrete is only indirectly related to hydration and hardening. When concrete dries it is not an indication that it has undergone sufficient hydration to achieve the desired physical properties.

The increase of strength with age continues as long as any unhydrated cement is still present, provided the concrete remains moist or has a relative humidity above 80% and the concrete temperature is favorable. When the relative humidity within the concrete drops below 80% or the temperature of the concrete falls below freezing, hydration and strength gain virtually stop.

If hardened concrete is resaturated after a drying period, hydration is resumed and strength will again increase so long as there is still unhydrated cement within the concrete.

Hardened concrete changes volume slightly due to variations in temperature, moisture, and stress. Concrete that is kept continually moist will expand slightly, but when it is permitted to dry the concrete will shrink. This is referred to as **drying shrinkage,** and it is an inherent and unavoidable property of concrete. It is the primary cause of cracking and the width of cracks is a function of the degree of drying.

The amount of drying shrinkage is directly related to the water content of the freshly mixed concrete. When concrete undergoes drying shrinkage, cracks will occur.

The basic objectives of concrete curing are, therefore:

- To prevent the loss of moisture.
- To control the temperature of the concrete for a definite period.

2.2.5 Construction Practices

Concrete made with high quality materials, a low water-cement ratio, an air-entraining agent, and that is properly cured may not be acceptable from a durability or strength standpoint, if good construction concreting practices are not followed during its placement. It is imperative that the concrete be proportioned, mixed, handled, placed, and consolidated using good concreting practices.

2.3 Water Content: Why Less Is More

The quality of hardened concrete is greatly influenced by the amount of water used in relation to the amount of cement. Higher water contents dilute the cement paste (the glue of concrete). Here are some advantages of reducing water content:

- Increased compressive and flexural strength
- Lower permeability, thus increased watertightness and lower absorption
- Increased resistance to weathering
- Better bond between concrete and reinforcement
- Less volume change from wetting and drying
- Reduced shrinkage and cracking

2.4 Properties of Concrete

2.4.1 Strength

Compressive strength is the most common method to determine concrete quality, since it is inversely related to the water to cement ratio. It is a primary physical property and can be defined as the measured maximum resistance of a concrete to axial loading.

Other types of strength measurements are **flexural strength** or modulus of rupture which is the ability of concrete to bend under load, **tensile strength** which is the ability of concrete to stretch under load, **torsional strength** which is a measure of the elasticity of concrete or the ability to twist under torque, and **shear strength** which is a measure of concrete's rigidity or resistance to horizontal loads.

2.4.2 Durability

Durability of concrete is it's resistance to anticipated exposure conditions. The most destructive condition being the effects of freezing and thawing of concrete while it is wet, particularly when deicing chemicals are used. Deterioration is caused by the freezing of water within the concrete paste, aggregates, or both. Air entrainment of concrete is the most effective method to create concrete which is durable under these conditions.

2.4.3 Permeability and Watertightness

Permeability is the ability of concrete to resist the penetration of water or other substances such as other liquids, gas, ions, etc. Watertightness is the ability of concrete to hold back or retain water or other liquids without visible leakage. The same properties which make concrete less permeable make it more watertight.

2.4.4 Abrasion Resistance

Abrasion resistance in concrete is closely related to its compressive strength. The stronger it is the more resistant it will be. The factors which have a strong influence on abrasion resistance are the water to cement ratio, curing, type of aggregates, and surface finish or treatment.

2.4.5 Admixtures for Concrete

Admixtures are used in concrete to achieve certain properties more effectively and economically, but they are not a substitute for good concrete practice.

Air Entraining Admixtures are used to entrain microscopic bubbles in the concrete, which will improve the concrete's durability. They also improve the workability and reduce or eliminate segregation and excessive bleeding.

The following affects can be expected when using these admixtures;

- *Affects on Freshly Mixed Concrete*

Concrete mixes will require less water for a given slump. The amount of air entraining admixture required to obtain specified air content will be increased. There will be less segregation and bleeding. The amount of heat build up will be reduced due to a lower heat of hydration.

They will retard the setting time. Finishability of the concrete will improve. Their use will improve the pumpability of the concrete.

- *Affects on Hardened Concrete*

The rate of early strength gain will be lower due to the lower rate of hydration.

When used in quantities above 40% by weight of total cementitious material, the concrete may exhibit greater drying shrinkage. With adequate curing they will improve the permeability of the concrete. They may affect the color of the concrete.

2.4.6 Slump of Fresh Concrete

Concrete must be produced with a workability, consistency, and plasticity suitable for the job conditions. **Workability** is a measure of how easy or difficult it is to place, consolidate, and finish concrete. **Consistency** is the ability of fresh concrete to flow. **Plasticity** determines concrete's ease of molding.

The **Slump Test** is a measure of concrete consistency. It is indicative of workability when assessing similar mixes. However, it should not be used to compare mixes of totally different proportions. When used with different batches of the same mix design, a change in slump indicates a change in consistency, and in the characteristics of materials, mix proportions, or water content. **It is not a measure of how much water is in the mix, how wet the concrete is, or the 'water to cement ratio'.**

Several factors that influence the water content in concrete are aggregate size and shape, slump, water to cement ratio, air content, cement content, admixtures, and environmental conditions.

2.5 Air Content of Concrete

Air entrained concrete is produced by using either an air entraining cement or an air entraining admixture that stabilizes bubbles formed during the mixing process. The air entraining agent enhances the incorporation of bubbles of various sizes by lowering the surface tension of the mixing water.

Entrapped air, the natural air content in all concrete, creates voids within the concrete, which are normally larger than 1 mm. in diameter. **Entrained air,** air content in concrete that in artificially produced, creates voids within the concrete, which are between 0.001 mm and 1.0 mm in diameter. It will be discussed more detail in next section.

Non air entrained concrete is susceptible to damage from the **Freeze-Thaw Effect.** This occurs as the water in moist concrete freezes and produces hydraulic and osmotic pressures in the capillaries and pores of the cement paste and aggregate. This is caused by the expansion of water upon freezing, in which growing ice crystals displace unfrozen water. If the pressure exceeds the tensile strength of the paste or aggregate, the cavity will dilate and rupture. Over time the effect of successive freeze-thaw cycles will cause significant deterioration of the concrete. The deterioration is visible in the form of cracking, scaling, and/or crumbling of the concrete surface.

When concrete is air entrained, the air voids act as empty chambers in the paste for the freezing and migrating water to enter, thus relieving the pressure and preventing damage to the concrete. Upon thawing, most of the water returns to the capillaries due to the capillary action and pressure from the compressed air in the voids.

An increase in the amount of mixing water will increase the air content since more water will be available for the generation of **bubbles.** Prolonged vibration of concrete will decrease the air content considerably. As concrete temperature increases the air content will decrease, particularly in concrete with a higher initial slump. The use of hot mixing water in clod weather will reduce the effectiveness of the air entraining admixture.

Mixing action is one of the most important factors in the production of entrained air in concrete. Generally more air is entrained as the speed of mixing is increased up to about 20 rpm, but it decreases above that point. When concrete slump is above 6 inches air content will increase during prolonged agitation, but when the slump drops below 6 inches, **air content** will decrease.

2.6 Air-Entrainment

Air entrainment introduces thousands of microscopic air bubbles into concrete, which allows the material to withstand the effects of freeze/thaw cycles. Air entrainment is the process whereby many small air bubbles are incorporated into concrete and become part of the matrix that binds the aggregate together in the hardened concrete. These air bubbles are dispersed throughout the hardened cement paste but are not, by definition, part of the paste (Dolch 1984). Air entrainment has now been an accepted fact in concrete technology for more than 45 years.

Extensive laboratory testing and field investigation concluded that the formation of minute air bubbles dispersed uniformly through the cement paste increased the freeze-thaw durability of concrete. This formation can be achieved through the use of organic additives, which enable the bubbles to be stabilized or entrained within the fresh concrete (Whiting 1983, ACI Comm. 212 1963). These additives are called air-entraining agents.

Besides the increase in freeze-thaw and scaling resistances, air-entrained concrete is more workable than non-entrained concrete. The use of air-entraining agents also reduces bleeding and segregation of fresh concrete (Whiting 1983; ACI Comm. 212 1963; Rixom and Mailvaganam 1986).

2.6.1 Air-Entraining Materials

The most commonly used chemical surfactants can be categorized into four groups: 1) salts of wood resins, 2) synthetic detergents, 3) salts of petroleum acids, and 4) fatty and resinous acids and their salts (Dolch 1984; Whiting 1983).

Until the early 1980s, the majority of concrete air entrainers were based solely on salts of wood resins or neutralized Vinsol resin (Edmeades and Hewlett 1986), and most concrete highway structures and pavements were air entrained by Vinsol resin. Today, a wider variety of air-entraining agents is available and competes with Vinsol resins.

Each admixture to be used as an air-entraining agent should cause a substantial improvement in durability and none of the essential properties of the concrete should be seriously impaired. This provides a means to evaluate air entraining admixtures on a performance basis.

Variations in air content can be expected with variations in aggregate proportions and gradation, mixing time, temperature, and slump. The order of batching and mixing concrete ingredients when using an air-entraining admixture has a significant influence on the amount of air entrained; therefore, consistency in batching is needed to maintain adequate control. [4]

2.6.2 SIKA® AER 50/50

SIKA® AER 50/50 is a high air entraining admixture for pumpable lightweight concrete or grout.

Description

SIKA® AER 50/50 is a foaming agent for lightweight pumped or poured concrete or grout used in structures characterized by very high noise and thermal isolation and for low strength concrete or grout fillings.

Properties

- Sika AER 50/50 is a high concentrated liquid foaming admixture for concrete made with lightweight aggregates (expanded clays and polystyrene) or foe all other kinds of concrete or grout where high air content is required.
- Due to its stabilizing components Sika AER 50/50 allows one to produce very high stable air content during the work and pumping time. The volume of concrete or grout after pumping or pouring is extremely stable.

- Depending on the quality of sands, lightweight aggregate, cement and water content, Sika AER 50/50 allows the production of concrete with specific weight of 800 to 1000 kg per cubic meter.

Uses

Concrete or grout where high air content is desired (not for freeze-thaw resistant concrete), for example:

- Isolations for roofs (lightweight aggregate-foamed concrete)
- Cavity filling
- Back filling-roadways, sewer trenches, etc.
- Embedding pipes
- Infilling of old works

Advantages

Sika AER 50/50 is user-friendly product. Lightweight concrete or grout can be made using conventional mixers and truck mixers.

Density (25^0 C)

~ 1.00 kg/liter

Dosage

Sika AER 50/50 can be used at the rate of 1.6 – 2.0 liters per cubic meter of lightweight concrete.

2.6.3 Factors Affecting Air Entrainment

The air-void system created by using air-entraining agents in concrete is also influenced by concrete materials and construction practice. Concrete materials such as cement, sand, aggregates and other admixtures play an important role in maintaining the air-void system in concrete. It has been found that air content will increase as cement alkali levels increase (Pomeroy 1989; Whiting 1983) and decrease as cement fineness increases significantly (ACI Comm. 212 1963).

Aggregates

- Fine aggregate serves as a three-dimensional screen and traps the air; the more median sand there is in the total aggregate, the greater the air content of the concrete will be (Dolch 1984).
- Sands and gravels with higher clay contents or higher percentages passing the No. 200 sieve will make it more difficult to entrain air in the concrete mix.
- Some organic impurities found in sand can entrain air or de-entrain air.
- It has been reported by researchers that increases in the particles retained on the No. 30 and No. 50 sieves will increase the amount of entrained air, all else being equal.
- Excessive fines, minus No. 100 material, cause a reduction in air entrainment.

Batch Water

- It is more difficult to entrain air when using hard water. For example, recycled wash water is very hard and therefore hinders air entrainment.

Cement

- Air entrainment dosage rates are determined by cement content.
- A change in cement Blaine fineness can affect the ability of the concrete to entrain air. The finer the cement, the harder it may be to entrain air. Be careful when switching to Type III cement, which is normally finer than Type I or Type II cements.
- The higher the alkali content of a cement, the easier it will be to entrain air. Low alkali cements may require as much as 40% more air entraining admixture than higher alkali cement. Be careful to check air contents when switching cement brands.

Concrete Slump

- The addition of mix water to concrete with slumps below 6" will increase the entrained air content with further mixing. The addition of water to concrete with slumps above 6" will generally decrease the entrained air content with further mixing.

- With extremely low slump concrete, for example slip-form mixes; there may not be enough water present to form air bubbles. The dosage of air entraining admixture may have to be increased considerably to get normal results.

Mixing

- The amount of air that is entrained in a given concrete mix will decrease as the mixer blades become worn or if hardened concrete is allowed to accumulate in the drum or on the blades.

- The air content may increase or decrease depending on the size of the batch and the rated capacity of the mixer. For example, less air is entrained when very small batches are produced in a large mixer.

Mineral Admixtures

- Concretes containing fly ash produced relatively stable air-void systems. However, the volume of air retained is affected by fly ash types. In mixtures containing fly ashes, the amount of air-entraining agent required to produce a given percentage of entrained air is higher, and sometimes much higher, than it is in comparable mixtures without fly ash (Gebler and Klieger 1983).

- Silica fume has no significant influence on the production and stability of the air-void system during mixing and agitation. Silica fume has no detrimental effects on the air-void system. (Pigeon, Aitcin, and LaPlante 1987; Pigeon and Plante 1989).

Temperature

- Air entrainment varies inversely with temperature.

- The same mix will entrain more air at 50° F (10°C) than at 100°F (38°C).

2.7 Advantages and disadvantages of air entrainment

Firstly, admixture refers to addition of a substance which is added at the cement manufacturing stage at the mixing stage. Functions of *admixtures* are "to modify the properties of the concrete so as to make it more suitable for the work at hand, or for economy, or for other purposes such as saving energy".

Major purpose of air entraining agents is to protect concrete from the deleterious effects of freezing and thawing. It is due to intentionally entraining air bubbles in the concrete by means of a suitable admixture. This air should be clearly distinguished from accidentally entrapped air, which is in the form of larger bubbles left behind during the compaction of fresh concrete.

When mixed with water, air-entraining admixtures produce discrete bubbles cavities which become incorporated in the cement paste. The essential constituent of the air-entraining admixture is a surface-active agent which lowers the surface tension of water to facilitate the formation of the bubbles, and subsequently ensures that they are stabilized. The surface-active agents concentrate at the air/water interfaces and have hydrophobic and hydrophilic properties which are responsible for the dispersion and stabilization of the air bubbles. The bubbles are separated from the capillary pore system in the cement paste and they never become filled with the products of hydration of cement as gel can form only in water [2].

Air-entrained concrete made with a low water/cement ratio and an adequate cement factor with low tricalcium aluminate cement will be resistant to attack from sulfate soils and waters. Also, the expansive disruption caused by alkali-silica reactivity is reduced through the use of air entrainment. Results of some carbonation tests reported on plain and air-entrained concrete indicate that air entrainment lowers the carbonation, and therefore provides better protection to reinforcing bars against corrosion due to carbonation. *Entrained air improves the workability of concrete, reduces segregation and bleeding in freshly mixed and placed concrete, and increases pump-ability of fresh concrete* if introduced in low percentages up to 6%.

At constant water/cement ratios, increases in air will proportionally reduce strength. For moderate-strength concrete, each percentile of entrained air reduces the compressive strength approximately 2–6%. Air entrainment also reduces the flexural strength, the splitting tensile strength, and the modulus of elasticity of hardened concrete.

2.8 Does Cement Brand Affect Air Content? [5]

In a Minnesota study, researchers prepared mortar samples using six different brands of ASTM C 150 Type I cements, Ottawa sand (20 to 30 mesh), and neutralized vinsol resin air-entraining agent at a dosage of 1 ounce per 100 pounds of cement. The mix-by-weight was 0.5:1:3 for water, cement and aggregate, respectively. Technicians measured the air content using a volumetric meter at a lab temperature of about 70° F. Air contents varied from 5.4% to 10.2% among the six cement brands. Why the variation? Most of it is probably due to differences in alkali content or cement fineness. Cement alkali contents can range from 0.2% to 1.0% (expressed as equivalent Na_2O). And at a fixed dosage of air-entraining agent, air content will increase with alkali content. As cement fineness increases, air content decreases at a fixed dosage of air-entraining agent. If there is changes from a Type I to finer-ground Type III cement, it might have to double the dosage rate to maintain the same air content.

CHAPTER 3

METHODOLOGY / PROJECT WORK

3.1 Procedure Identification

Seven concrete mixes were prepared in one (1) group. The water/cement ratio was 0.55 for the 7 mixes of Group 1.

The variables in Group 1 were the type of the air-entraining agent: commercial air-entraining chemical admixture, used engine oil, and new engine oil; the dosage of the air-entraining agent measured as percentage by weight of cement: 0.15%and 0.30%; and the mixing time as measured after all ingredients including the air-entraining agent were in the mixer: 2 min.

The all mixes (7 mixes) of Group 1 were designed to achieve a nominal 28 days concrete compressive strength of 30 MPa. In all 7 mixes of Groups 1, ASTM Type 1 Portland cement was used. The fine aggregate was natural sand. The coarse aggregate used had a maximum size of 20 mm. The coarse aggregate was crushed limestone. The mix composition is 1: 2.33: 4, which are cement, sand and coarse aggregate respectively. Assuming oven-dry conditions for the aggregates, the mix proportion for Groups 1 is summarized in Table 3.1. The commercial air-entraining admixture used was Sika-Aer. It will be referred to as Sika throughout the paper.

Table 3.1: Mix proportions for Group 1

Material	Group 1 (kg/m3)
Cement	350
Sand	819
Coarse Aggregate	1230
Water	158

The aggregates were at room temperature before preparation of the concrete mixes took place. Mixing was conducted in the laboratory using a 5-foot^3 capacity concrete mixer. The casting procedure was the same for all the mixes. The (150mm)x(150mm)x(150mm) cubes; cores of size 50mm diameter, 50mm thick; and the (100mm)x(100mm)x(500mm) beams used to test the properties of hardened concrete, were moist cured all the time until the day of testing.

The tested properties of fresh concrete are slump and air content. The tested properties of hardened concrete were the compression strength measured at 3, 7, 28 and 90 days; porosity measured at 3, 7, 28 and 90 days; and the modulus of rupture or the flexural strength measured at 28 days.

Project flow is shown in Gantt chart in Appendix I.

3.2 Tools Required

The tools required for this research are concrete mixer, slump test equipment, air entrainment test equipment, Universal Testing Machine, cube and cylinder moulds, desiccator and vacuum pump, curing tank, coring machine.

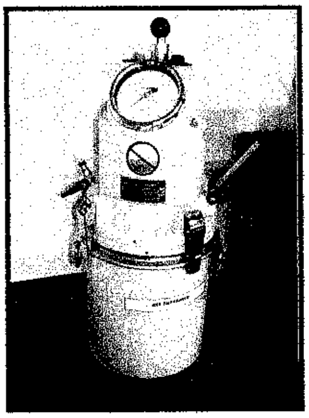


Figure 3.1: Air Entrainment Test

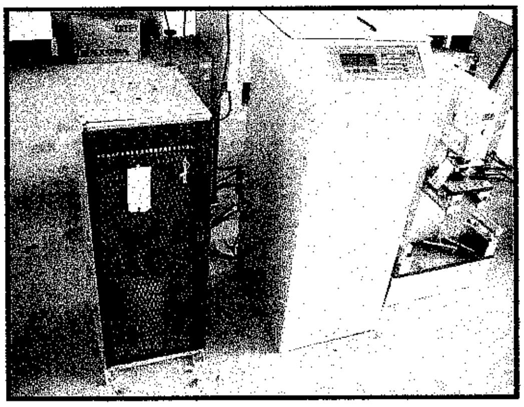


Figure 3.2: Flexural and Compression Test

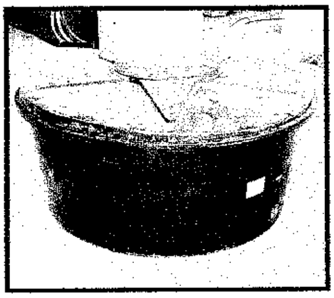


Figure 3.3: Curing Tank

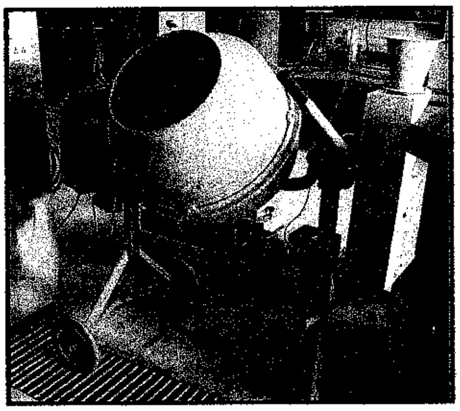


Figure 3.4: Concrete Mixer

Figure 3.5: Slump Test

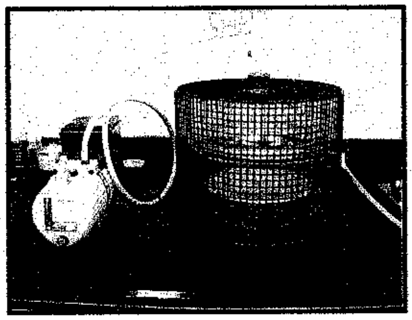


Figure 3.6: Desiccator and Vacuum Pump

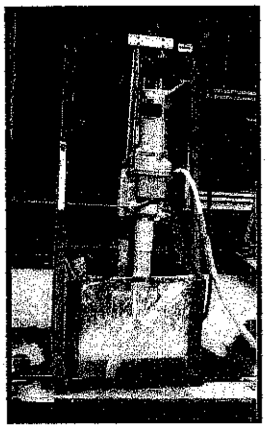


Figure 3.7: Coring Machine

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Sample Calculation for Preparing Concrete Mix

Below are the sample calculations for concrete mix for preparing 3 cubes. The calculations for proportion of cement, water, sand, and coarse aggregate for each part are shown as below.

For 3 cubes

Volume $= (0.15m \times 0.15m \times 0.15m \times 3)$

$= 0.010125m^3$

Weight $= 0.010125m^3 \times \left(2400\frac{kg}{m^3}\right)$

$= 24.3kg$

Divided into composition;

Cement $= \left(\frac{14.64}{100}\right)(24.3kg)$

$= 3.558kg$

Sand $= \left(\frac{34.12}{100}\right)(24.3kg)$

$= 8.291kg$

Coarse aggregate $= \left(\frac{51.24}{100}\right)(24.3kg)$

$= 12.451kg$

Water $= (3.558kg \times 0.45)$

$= 1.601kg$

Engine Oil $= (3.558kg \times 0.0015)$

$= 5.337g @ mL$

For 2 beams

Volume $= (0.1m \times 0.1m \times 0.5m \times 2)$

$= 0.01m^3$

Weight $= 0.01m^3 \times \left(2400\frac{kg}{m^3}\right)$

$= 24kg$

Divided into composition;

Cement $= \left(14.64/_{100}\right)(24kg)$

$= 3.514kg$

Sand $= \left(34.12/_{100}\right)(24kg)$

$= 8.189kg$

Coarse aggregate $= \left(51.24/_{100}\right)(24kg)$

$= 12.298kg$

Water $= (3.514kg \times 0.45)$

$= 1.581kg$

Engine Oil $= (3.514kg \times 0.0015)$

$= 5.271g\ @\ mL$

4.2 Results from Laboratory Works

From the laboratory works, the author had done several testing on the samples in order to compare in later analysis. Below are the results gained from the testing using compressive strength machine, porosity, slump, and air entrainment test.

Table 4.1: Test Results for Various Mix with Water/Cement (w/c) Ratio 0.55

Group	Mix No	Mix Properties			Fresh Concrete Properties		Hardened Concrete Properties								
		Air Entraining Agent	Dosage (%)	W/C ratio	Slump (cm)	Air Content (%)	f_r @ 28 days (MPa)	Compression Strength				Porosity (%)			
								3 days (MPa)	7 days (MPa)	28 days (MPa)	90 days (MPa)	3 days	7 days	28 days	90 days
Group 1	1	None		0.55	13.0	4.0	3.271	14.70	21.87	33.97	41.50	16.81	11.61	10.25	11.53
	2	Used Engine Oil	0.15%	0.55	15.0	5.3	2.944	11.33	17.19	26.91	35.97	9.74	9.16	8.94	8.48
	3	Used Engine Oil	0.30%	0.55	18.0	6.6	2.845	7.82	14.05	24.37	41.79	11.12	10.89	9.91	9.69
	4	New Engine Oil	0.15%	0.55	15.5	6.9	2.781	13.82	20.93	31.42	43.45	9.55	9.10	9.08	9.04
	5	New Engine Oil	0.30%	0.55	19.0	8.0	2.777	12.36	18.45	28.40	39.63	10.21	9.75	9.71	8.95
	6	Sika	0.15%	0.55	17.0	7.3	2.727	10.75	15.82	21.42	41.50	9.96	8.60	8.52	7.97
	7	Sika	0.30%	0.55	20.0	8.4	2.748	3.72	7.07	14.03	26.34	12.85	12.36	11.77	11.04

4.3 Laboratory Works Problems

During the laboratory works, there are some few things that need to be considered when analyzing the data in future. There are:

i. Sand used was in moist condition at the bottom of the pan, therefore it might be affecting the water/cement (w/c) ratio. The water/cement (w/c) ratio might be higher than 0.45 or 0.55 as required.

ii. Mixer was a little bit dirty to use as previous student did not wash the mixer properly. It will affect the proportion.

iii. The amount required for used engine oil is too little. Therefore, it is hard to get accurate amount.

4.4 Properties on fresh concrete

From Table 4.1, slump increases in concrete mixes with addition of used engine oil, new engine oil and Sika compared to control mix. A result obtained from slump test of concrete mix with addition of used engine oil is similar to concrete mix with addition of new engine oil with same dosage; both 0.15% and 0.30% by weight of cement. The increment of 15% and 42% compared to control mix from concrete mix with dosage of 0.15% and 0.30% by weight of cement respectively. The increment of 31% and 54% compared to control mix from concrete mix with addition of Sika of 0.15% and 0.30% by weight of cement respectively.

For air content comparison in concrete mix with addition of Sika with dosage of 0.15% by weight of cement, there is increment 83%, 33% and 73% compared to control mix from concrete mix with addition of used engine oil, new engine oil and Sika respectively. As for comparison between mixes with dosage of 0.30% by weight of cement, the increment is 110%, 65% and 100% respectively.

4.5 Properties on hardened concrete

From the results obtained as shown in Table 4.1, it can be summarized into graphs as shown below.

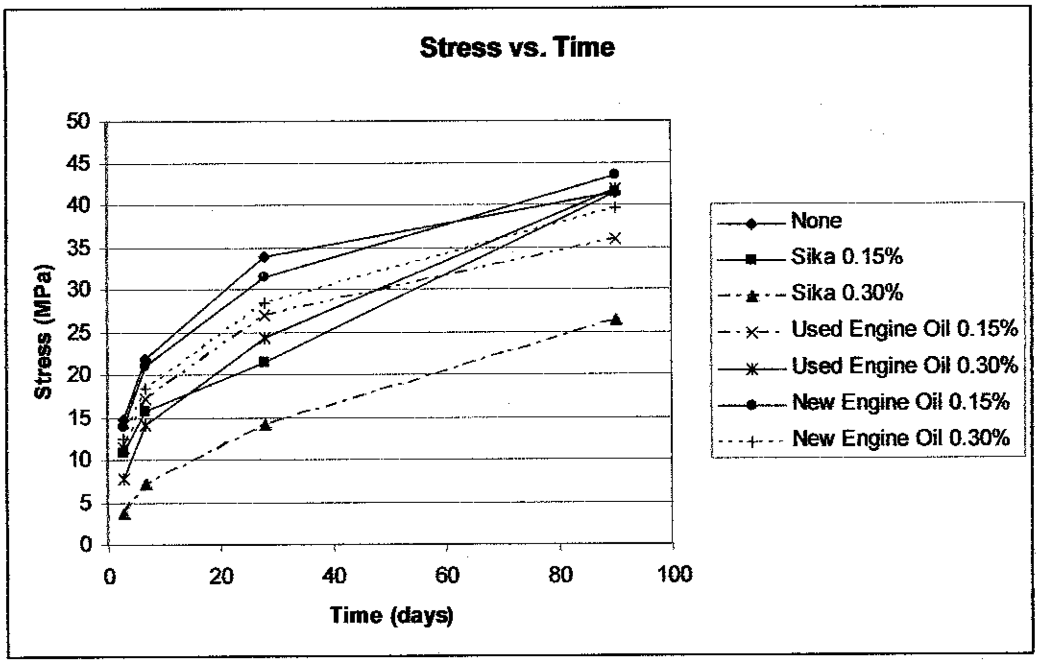


Figure 4.1: Graph Stress vs. Time

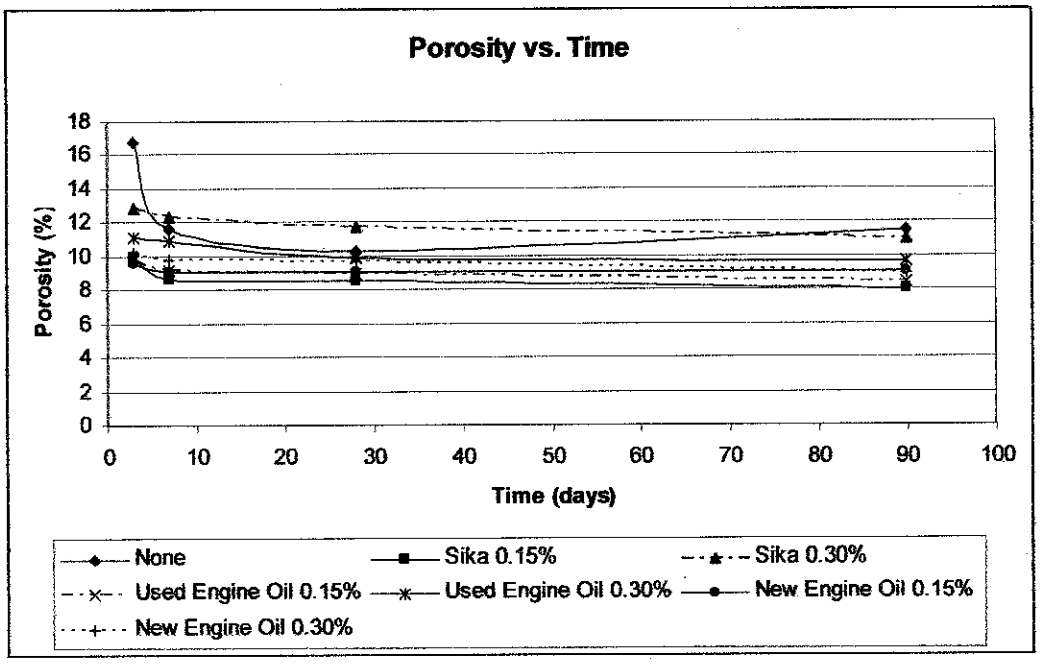


Figure 4.2: Graph Porosity vs. Time

4.5.1 Strength

Referring to Table 4.1 and Figure 4.1, all the concrete mixes will be discussed below. For control mix, there are 43% of 28-days strength was achieved during first 3 days. Then, 64% of 28-days strength was achieved during next 7 days. Subsequently, only 22% of 28-days strength gained later after 90 days of curing.

For concrete mix with addition of used engine oil with dosage of 0.15% by weight of cement, there are 42% of 28-days strength was achieved during first 3 days. Then, 64% of 28-days strength was achieved during next 7 days. Subsequently, only 34% of 28-days strength gained later after 90 days of curing.

For concrete mix with addition of used engine oil with dosage of 0.30% by weight of cement, there are 32% of 28-days strength was achieved during first 3 days. Then, 58% of 28-days strength was achieved during next 7 days. Subsequently, only 71% of 28-days strength gained later after 90 days of curing.

For concrete mix with addition of new engine oil with dosage of 0.15% by weight of cement, there are 44% of 28-days strength was achieved during first 3 days. Then, 67% of 28-days strength was achieved during next 7 days. Subsequently, only 38% of 28-days strength gained later after 90 days of curing.

For concrete mix with addition of new engine oil with dosage of 0.30% by weight of cement, there are 44% of 28-days strength was achieved during first 3 days. Then, 65% of 28-days strength was achieved during next 7 days. Subsequently, only 40% of 28-days strength gained later after 90 days of curing.

For concrete mix with addition of Sika with dosage of 0.15% by weight of cement, there are 50% of 28-days strength was achieved during first 3 days. Then, 74% of 28-days strength was achieved during next 7 days. Subsequently, only 94% of 28-days strength gained later after 90 days of curing.

For concrete mix with addition of Sika with dosage of 0.30% by weight of cement, there are 27% of 28-days strength was achieved during first 3 days. Then, 50% of 28-days strength was achieved during next 7 days. Subsequently, only 88% of 28-days strength gained later after 90 days of curing.

From Table 4.1 and Figure 4.1, compressive strengths between mixes are compared to control mix. For age of 3 days, concrete mix with addition of used engine oil only gained 77% and 53% of 3-day control mix compressive strength for dosages of 0.15% and 0.30% by weight of cement respectively. While for concrete mix with addition of new engine oil gained 94% and 84% of 3-day control mix compressive strength for dosages of 0.15% and 0.30% by weight of cement respectively. For concrete mix with addition of Sika gained 73% and 25% of 3-day control mix compressive strength for dosages of 0.15% and 0.30% by weight of cement respectively.

For age of 7 days, concrete mix with addition of used engine oil only gained 79% and 64% of 7-day control mix compressive strength for dosages of 0.15% and 0.30% by weight of cement respectively. While for concrete mix with addition of new engine oil gained 96% and 84% of 7-day control mix compressive strength for dosages of 0.15% and 0.30% by weight of cement respectively. For concrete mix with addition of Sika gained 72% and 32% of 7-day control mix compressive strength for dosages of 0.15% and 0.30% by weight of cement respectively.

For age of 28 days, concrete mix with addition of used engine oil only gained 79% and 72% of 28-day control mix compressive strength for dosages of 0.15% and 0.30% by weight of cement respectively. While for concrete mix with addition of new engine oil gained 92% and 84% of 28-day control mix compressive strength for dosages of 0.15% and 0.30% by weight of cement respectively. For concrete mix with addition of Sika gained 63% and 41% of 28-day control mix compressive strength for dosages of 0.15% and 0.30% by weight of cement respectively.

For age of 90 days, concrete mix with addition of used engine oil only gained 87% and 101% of 90-day control mix compressive strength for dosages of 0.15% and 0.30% by weight of cement respectively. While for concrete mix with addition of new engine oil gained 105% and 95% of 90-day control mix compressive strength for dosages of 0.15% and 0.30% by weight of cement respectively. For concrete mix with addition of Sika gained 100% and 63% of 90-day control mix compressive strength for dosages of 0.15% and 0.30% by weight of cement respectively.

Comparison of flexural strength was made with taking control mix result as reference data. There is 12% and 15% loss of strength from control mix for concrete mix with addition of used engine oil for dosage of 0.15% and 0.30% by weight of cement respectively.

There is 15% loss of strength from control mix for concrete mix with addition of new engine oil for dosage of 0.15% and 0.30% by weight of cement.

There is 18% loss of strength from control mix for concrete mix with addition of Sika for dosage of 0.15% and 0.30% by weight of cement.

4.5.2 Porosity

From Table 4.1 and Figure 4.2, porosity of all mixes was analysed. For control mix, there is 64% extra of 28-day air content during first 3 days. Then, air content decreased to 13% extra of 28-day air content during the next 7 days. Subsequently, air content had risen again for 12% extra of 28-day air content at the age of 90 days of control mix.

For concrete mix with addition of used engine oil with dosage of 0.15% by weight of cement, there is 9% extra of 28-day air content during first 3 days. Then, air content decreased to 2% extra of 28-day air content during the next 7 days. Subsequently, air content had loss 5% of 28-day air content at the age of 90 days of control mix.

For concrete mix with addition of used engine oil with dosage of 0.30% by weight of cement, there is 12% extra of 28-day air content during first 3 days. Then, air content decreased to 10% extra of 28-day air content during the next 7 days. Subsequently, air content had loss 2% of 28-day air content at the age of 90 days of control mix.

For concrete mix with addition of new engine oil with dosage of 0.15% by weight of cement, there is 5% extra of 28-day air content during first 3 days. Then, air content decreased to 0.2% extra of 28-day air content during the next 7 days. Subsequently, air content had loss 0.4% of 28-day air content at the age of 90 days of control mix.

For concrete mix with addition of new engine oil with dosage of 0.30% by weight of cement, there is 5% extra of 28-day air content during first 3 days. Then, air content decreased to 0.4% extra of 28-day air content during the next 7 days. Subsequently, air content had loss 8% of 28-day air content at the age of 90 days of control mix.

For concrete mix with addition of Sika engine oil with dosage of 0.15% by weight of cement, there is 17% extra of 28-day air content during first 3 days. Then, air content decreased to 1% extra of 28-day air content during the next 7 days. Subsequently, air content had loss 6% of 28-day air content at the age of 90 days of control mix.

For concrete mix with addition of Sika engine oil with dosage of 0.30% by weight of cement, there is 9% extra of 28-day air content during first 3 days. Then, air content decreased to 5% extra of 28-day air content during the next 7 days. Subsequently, air content had loss 6% of 28-day air content at the age of 90 days of control mix.

From Table 4.1 and Figure 4.2, comparison of porosity between each mixes was analyzed at each different age of mixes. All comparisons are percentage of reduced air content as referred to control mix. For age 3 days, concrete mix with addition of used engine oil has reduction of 42% and 34% for dosages of 0.15% and 0.30% by weight of cement respectively. While for concrete mix with addition of new engine oil has reduction of 43% and 39% for dosages of 0.15% and 0.30% by weight of cement respectively. Concrete mix with addition of Sika has reduction of 41% and 24% for dosages of 0.15% and 0.30% by weight of cement respectively.

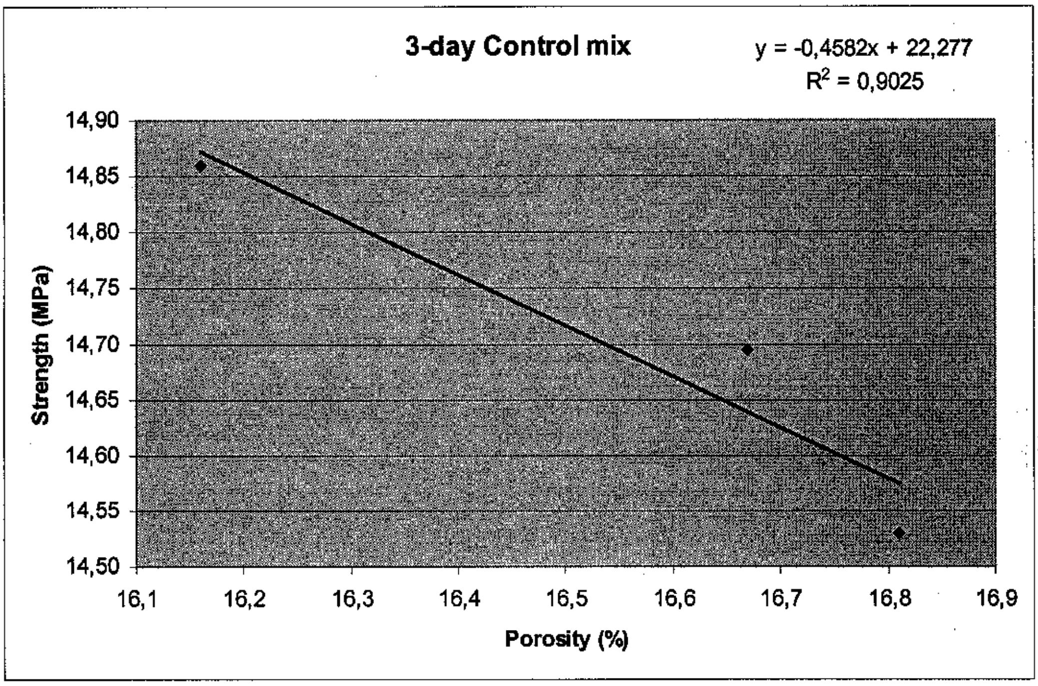
For age 7 days, concrete mix with addition of used engine oil has reduction of 21% and 6% for dosages of 0.15% and 0.30% by weight of cement respectively. While for concrete mix with addition of new engine oil has reduction of 22% and 16% for dosages of 0.15% and 0.30% by weight of cement respectively. Concrete mix with addition of Sika has reduction of 26% and 6% for dosages of 0.15% and 0.30% by weight of cement respectively.

For age 28 days, concrete mix with addition of used engine oil has reduction of 13% and 3% for dosages of 0.15% and 0.30% by weight of cement respectively. While for concrete mix with addition of new engine oil has reduction of 11% and 5% for dosages of 0.15% and 0.30% by weight of cement respectively. Concrete mix with addition of Sika has reduction of 17% and 15% for dosages of 0.15% and 0.30% by weight of cement respectively.

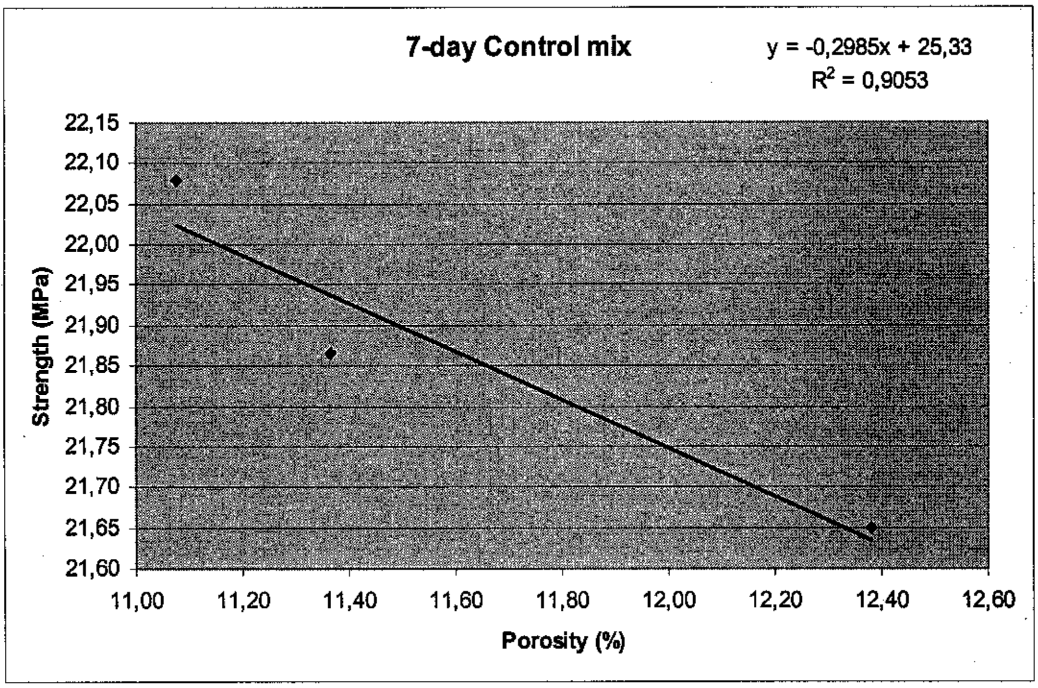
For age 90 days, concrete mix with addition of used engine oil has reduction of 26% and 16% for dosages of 0.15% and 0.30% by weight of cement respectively. While for concrete mix with addition of new engine oil has reduction of 22% and 22% for dosages of 0.15% and 0.30% by weight of cement respectively. Concrete mix with addition of Sika has reduction of 31% and 4% for dosages of 0.15% and 0.30% by weight of cement respectively.

4.5.3 Strength vs. Porosity

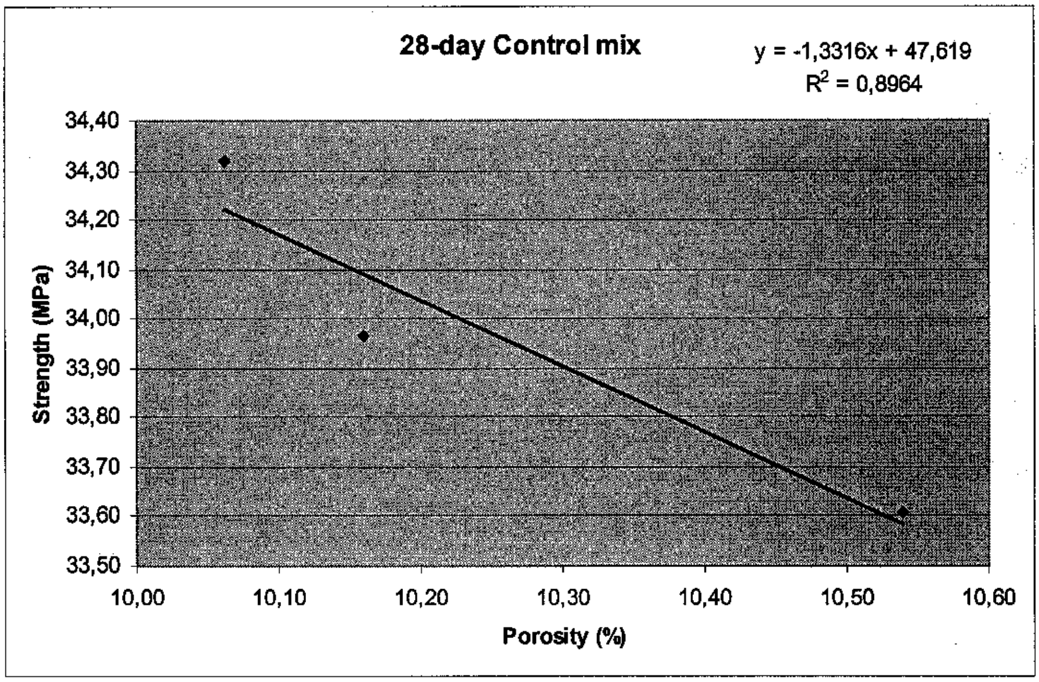
From the results obtained as shown in Table 4.1, it can be summarized into graphs as shown below.



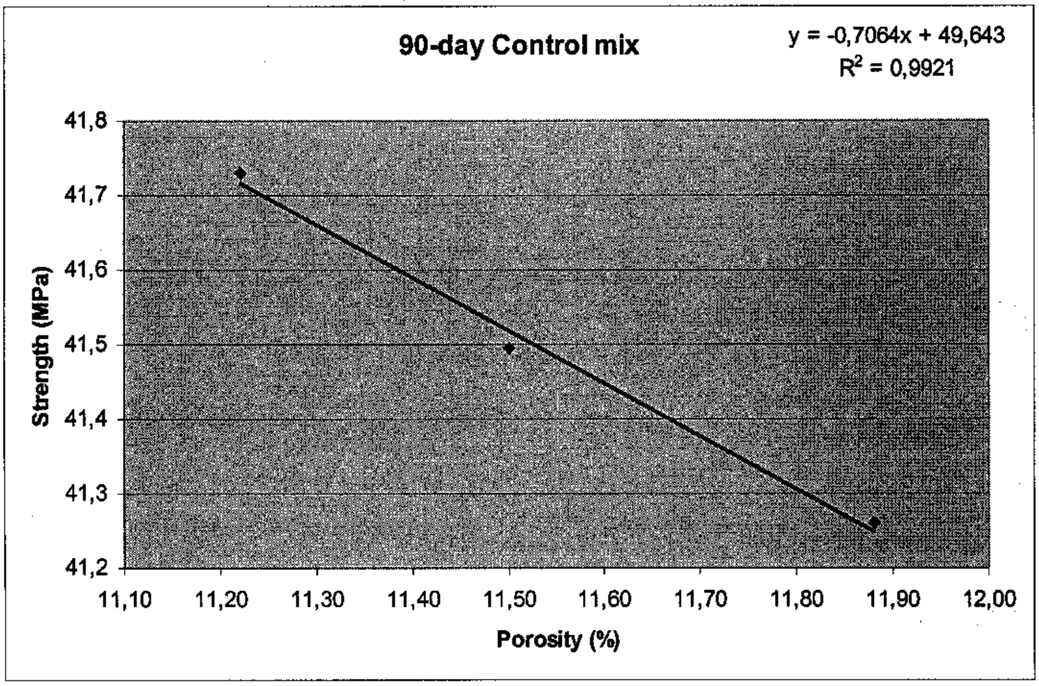
(a)


7-day Control mix
y = -0,2985x + 25,33
R2 = 0,9053
22,15
22,10
22,05
22,00
21,95
21,90
21,85
21,80
21,75
21,70
21,65
21,60
Strength (MPa)
11,00
11,20
11,40
11,60
11,80
12,00
12,20
12,40
12,60
Porosity (%)

(b)


28-day Control mix
y = -1,3316x + 47,619
R2 = 0,8964
34,40
34,30
34,20
34,10
34,00
33,90
33,80
33,70
33,60
33,50
Strength (MPa)
10,00
10,10
10,20
10,30
10,40
10,50
10,60
Porosity (%)

(c)



(d)

Figure 4.3: Strength vs. porosity for all ages of control mix

For control mix, the correlations between strength and porosity are essentially good. For aged 3, 7, 28 and 90 days, the R^2 values are 90.3%, 90.5%, 89.6% and 99.2% respectively. It ranges between 90%-99%.

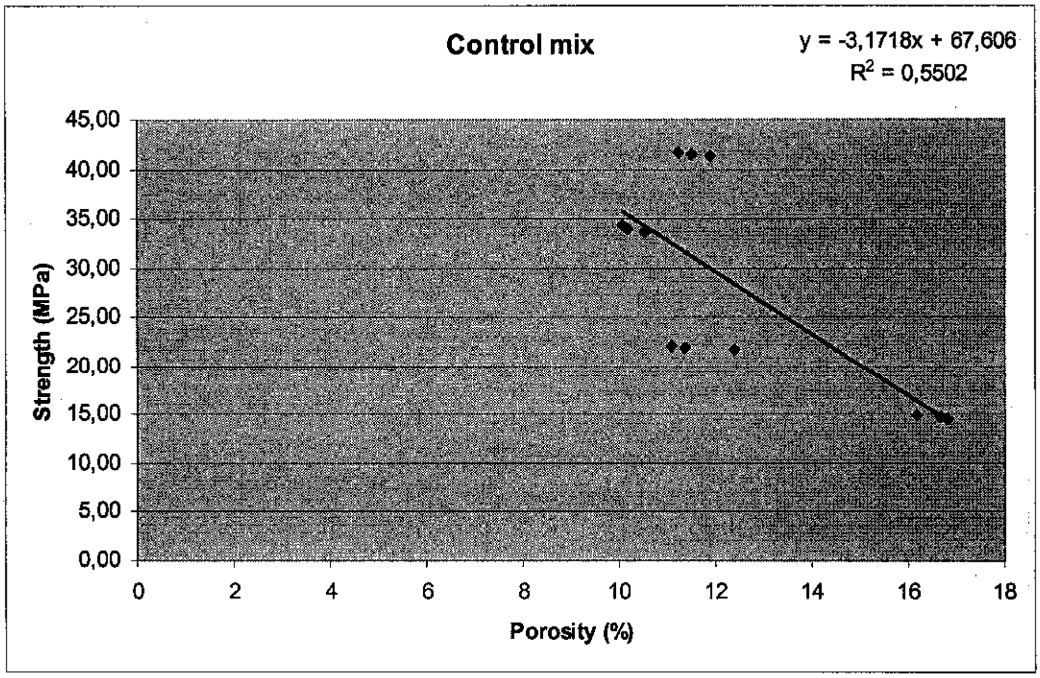
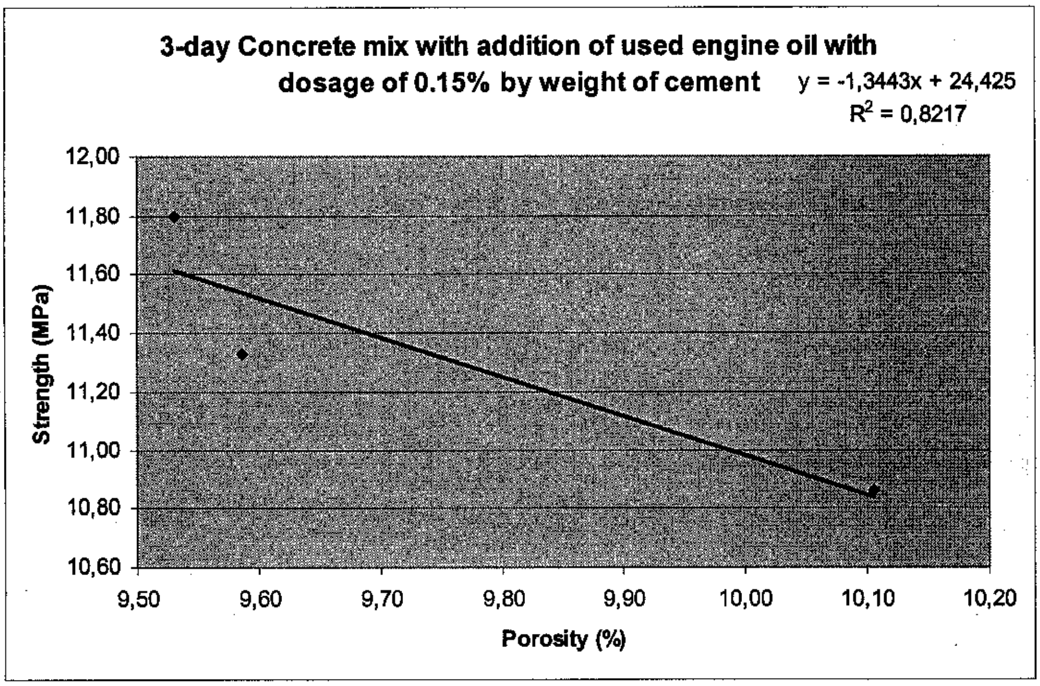
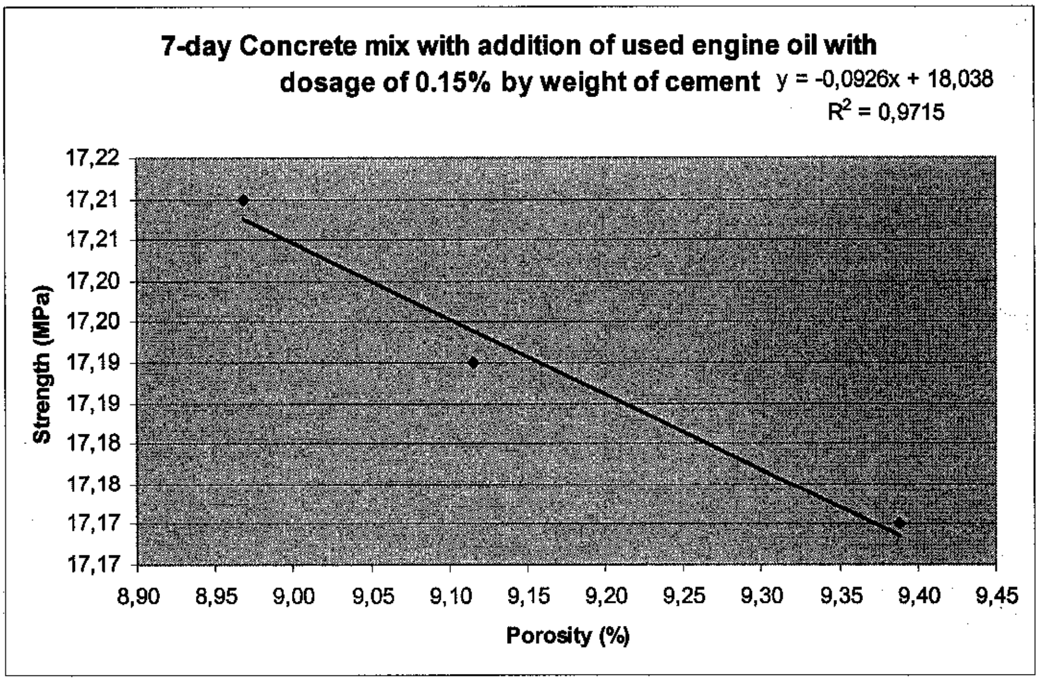


Figure 4.4: Strength vs. porosity for control mix

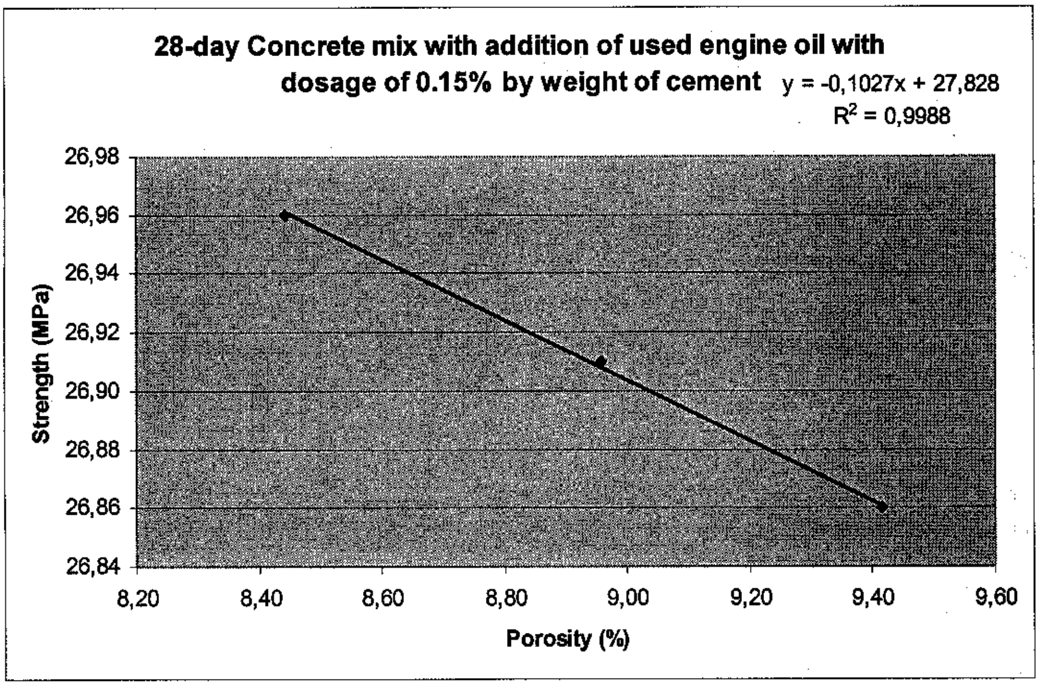
From Figure 4.4, R^2 value is 55%. Therefore, this correlation is moderately average. It has to conduct more tests to get more accurate correlation.



(a)



(b)



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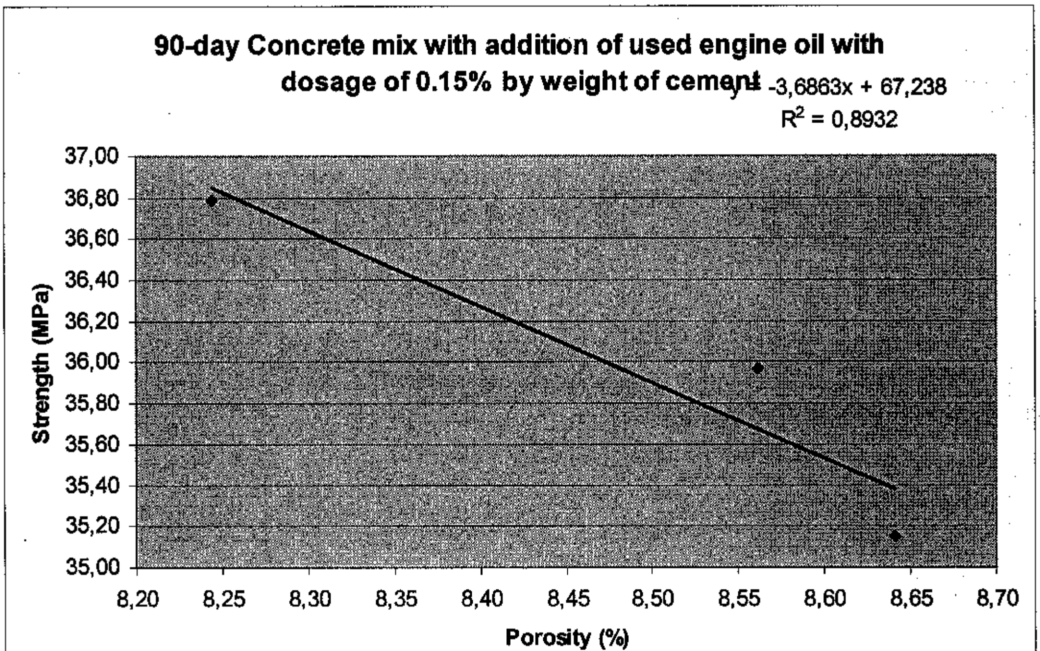
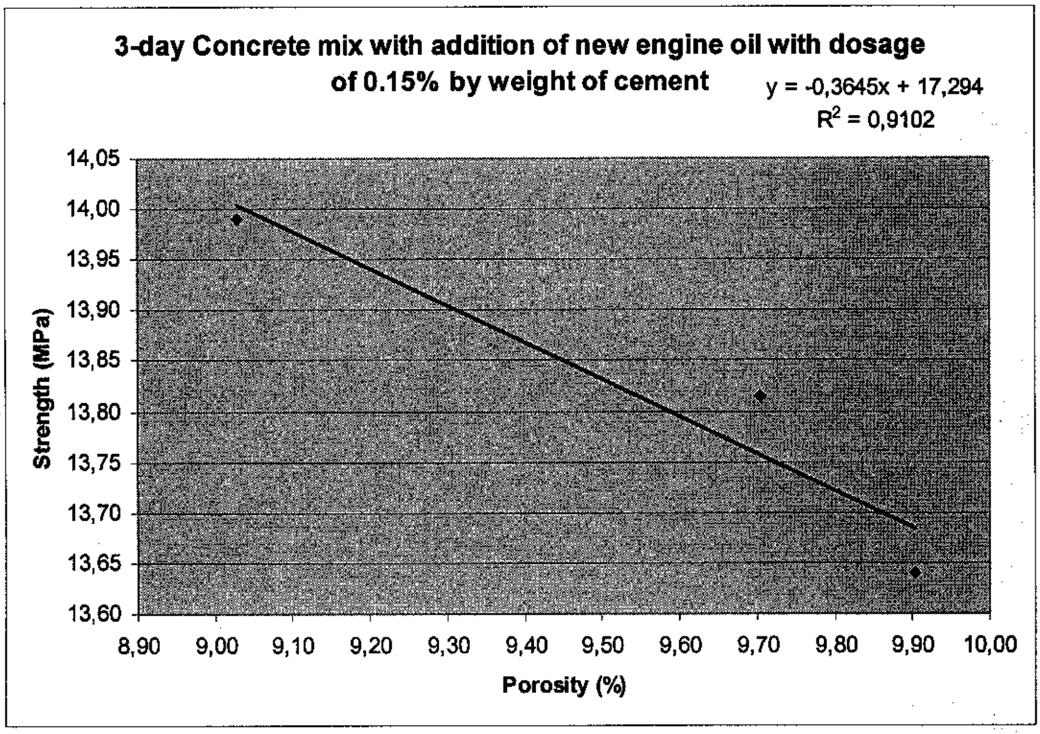


(d)

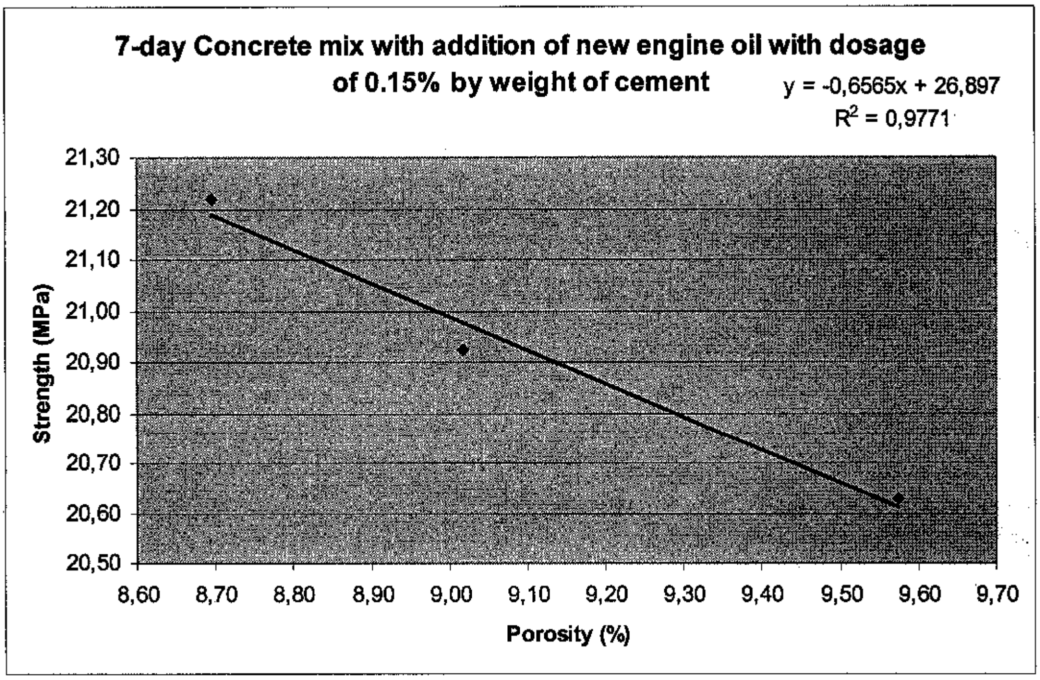
Figure 4.5: Strength vs. porosity for all ages of concrete mix with addition of used engine oil with dosage of 0.15% by weight of cement

For concrete mix with addition of used engine oil with dosage of 0.15% by weight of cement, the correlations between strength and porosity are essentially good. For aged

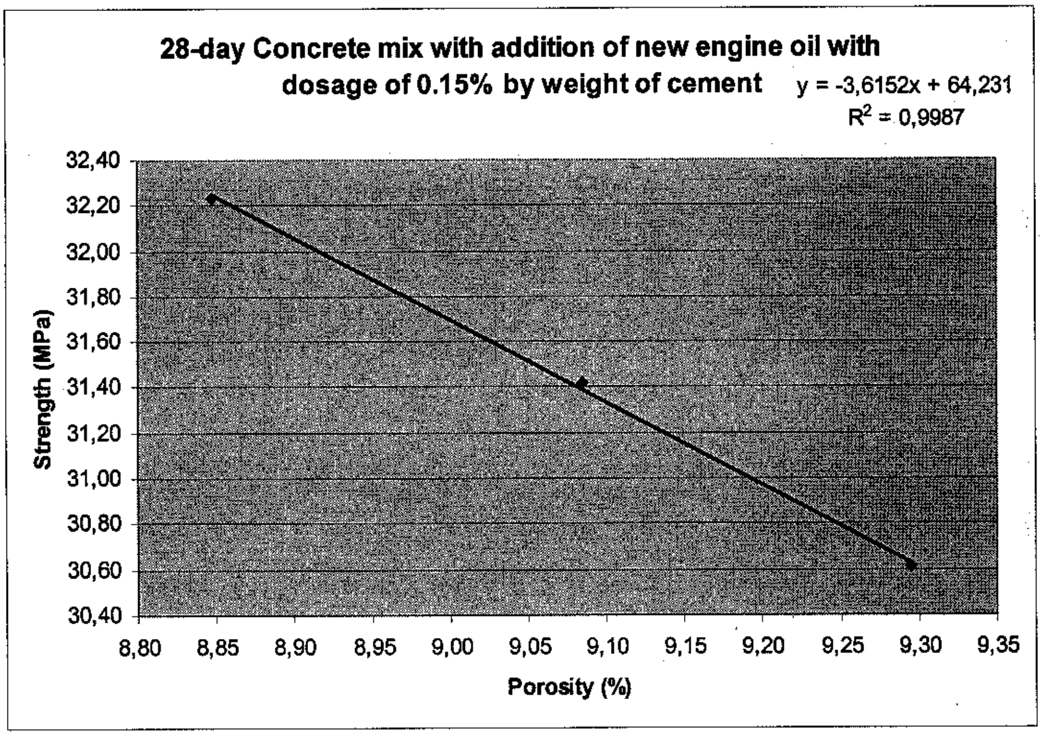
3, 7, 28 and 90 days, the R^2 values are 82.2%, 97.2%, 99.9% and 89.3% respectively. It ranges between 82%-100%.



(a)



(b)



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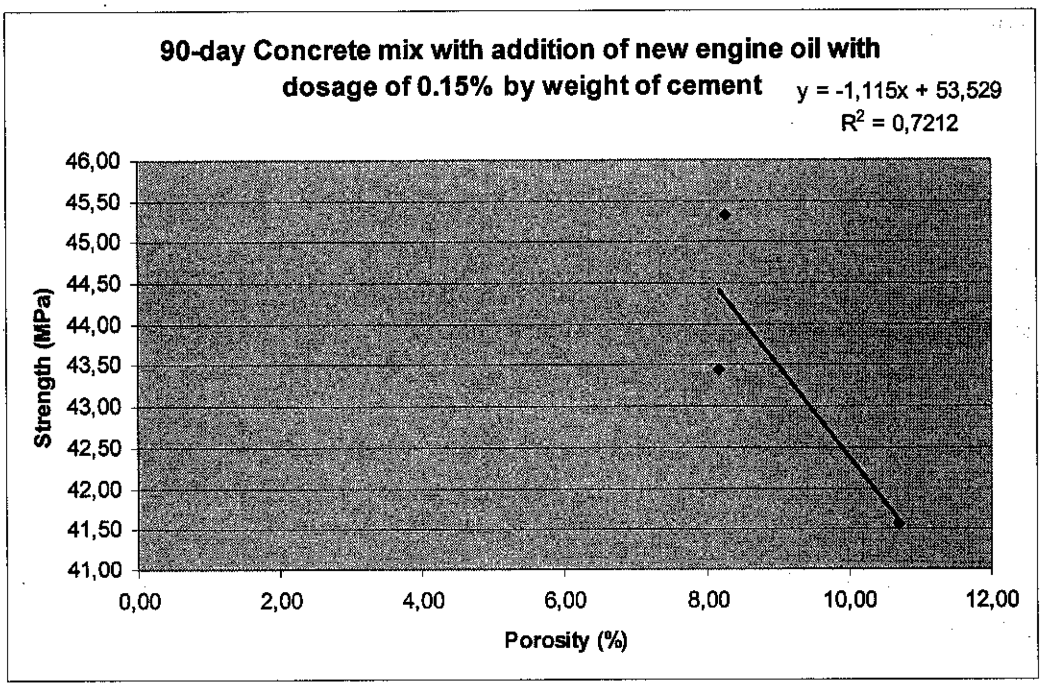
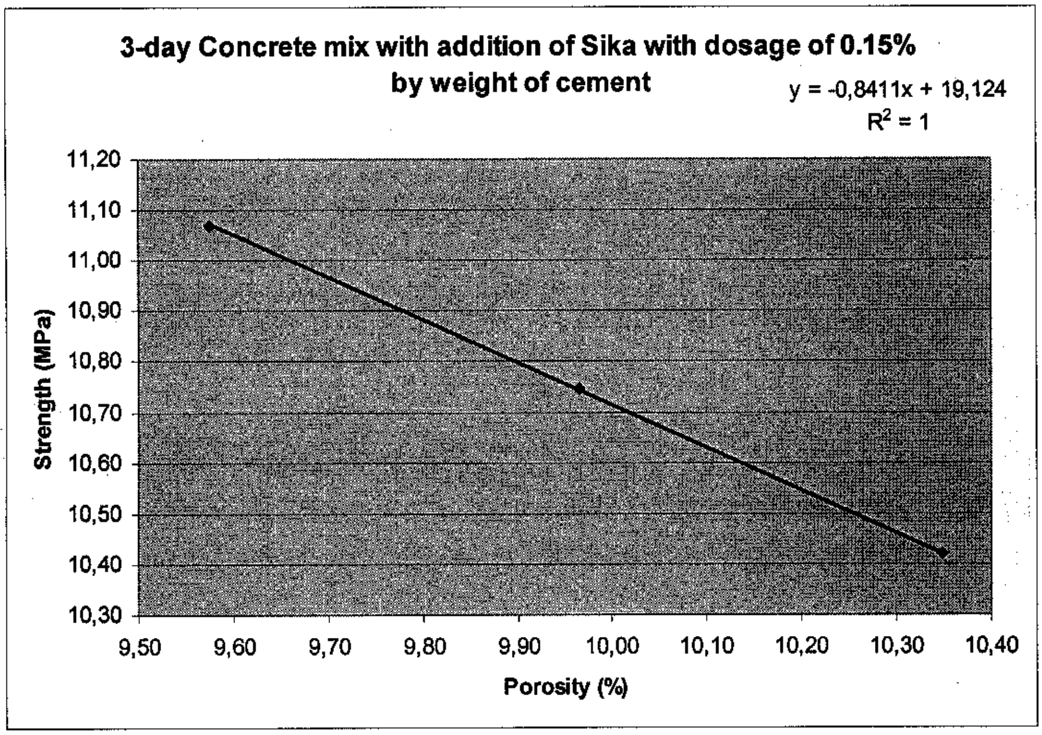


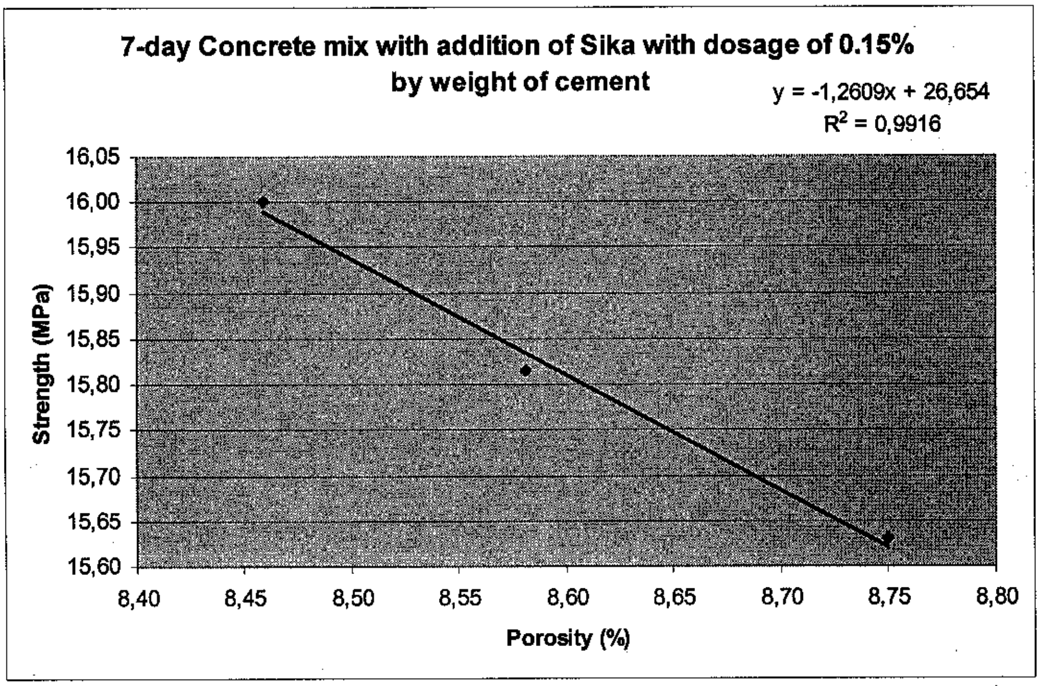
(d)

Figure 4.6: Strength vs. porosity for all ages of concrete mix with addition of new engine oil with dosage of 0.15% by weight of cement

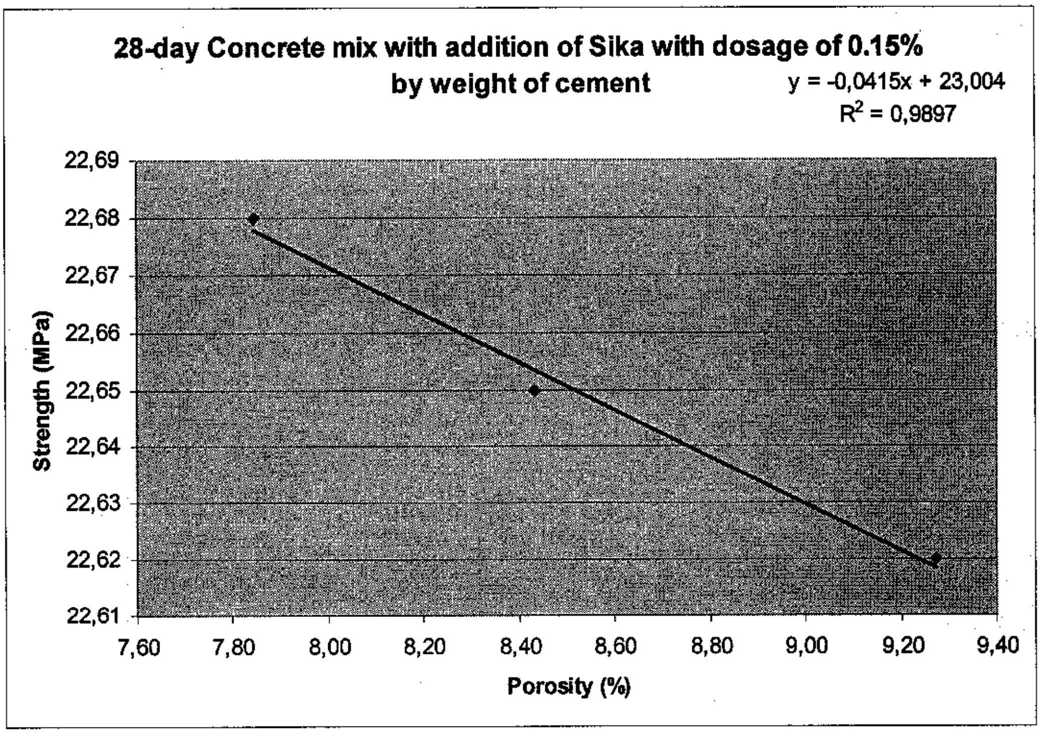
For concrete mix with addition of new engine oil with dosage of 0.15% by weight of cement, the correlations between strength and porosity are essentially good. For aged 3, 7, 28 and 90 days, the R^2 values are 91%, 97.7%, 99.9% and 72.1% respectively. It ranges between 72%-100%.



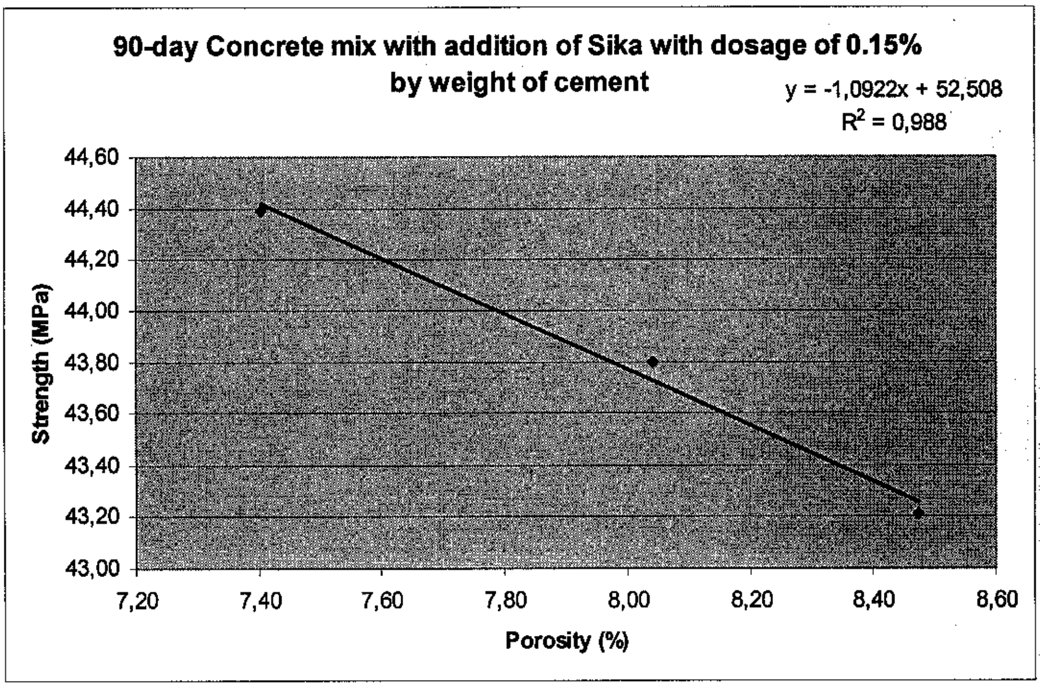
(a)


7-day Concrete mix with addition of Sika with dosage of 0.15%
by weight of cement
y = -1,2609x + 26,654
R2 = 0,9916
Strength (MPa)
16,05
16,00
15,95
15,90
15,85
15,80
15,75
15,70
15,65
15,60
8,40
8,45
8,50
8,55
8,60
8,65
8,70
8,75
8,80
Porosity (%)

(b)


28-day Concrete mix with addition of Sika with dosage of 0.15%
by weight of cement
y = -0,0415x + 23,004
R2 = 0,9897
Strength (MPa)
22,69
22,68
22,67
22,66
22,65
22,64
22,63
22,62
22,61
7,60
7,80
8,00
8,20
8,40
8,60
8,80
9,00
9,20
9,40
Porosity (%)

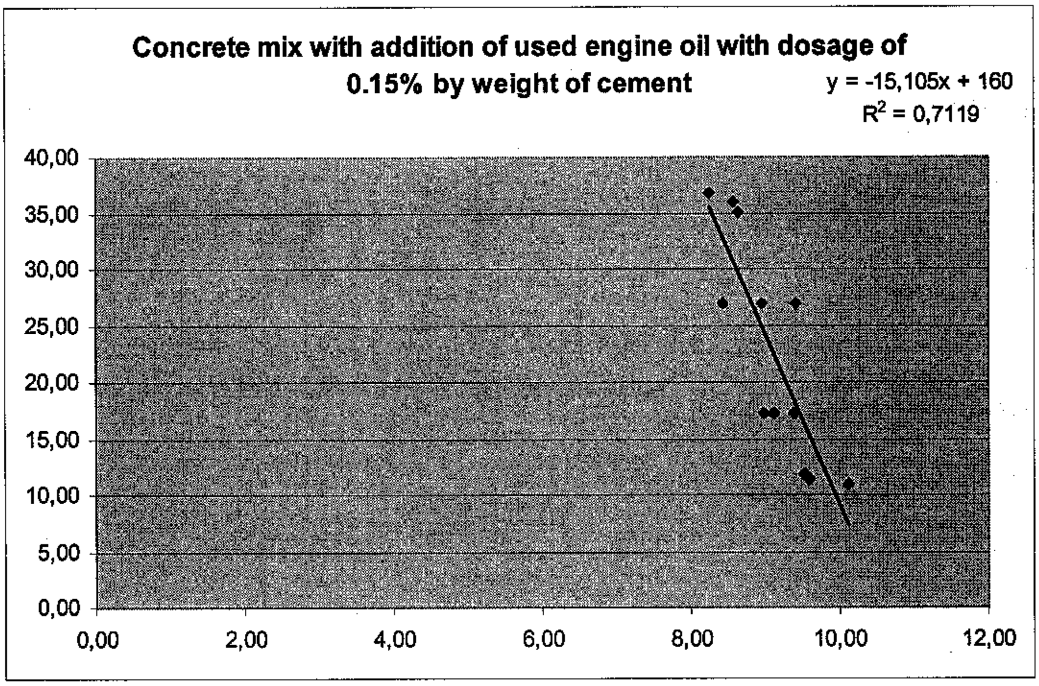
(c)



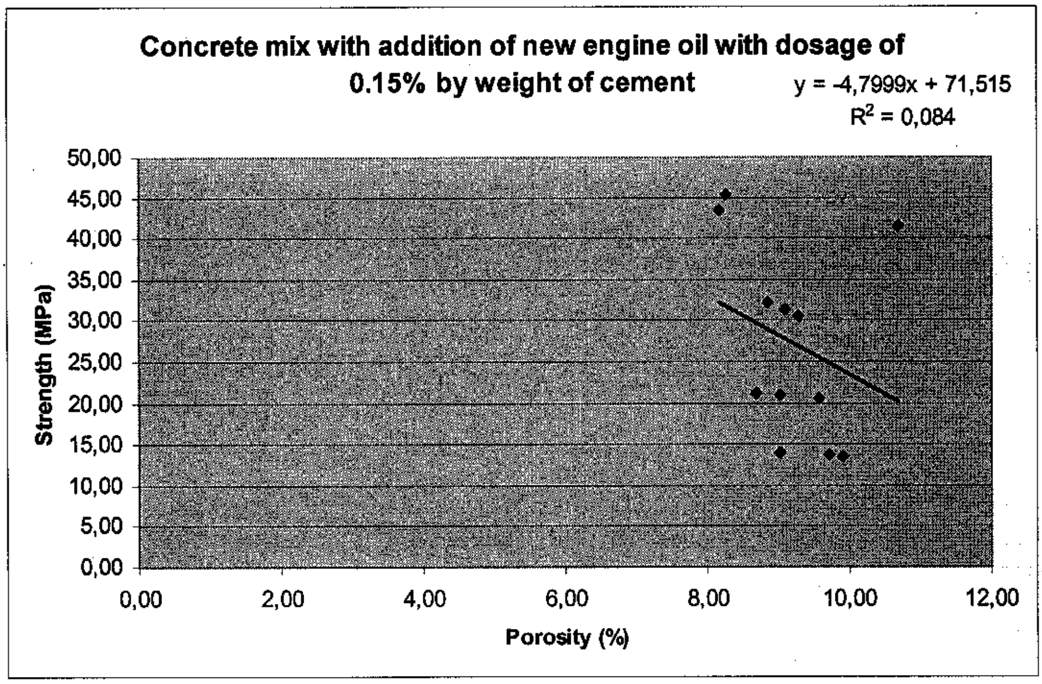
(d)

Figure 4.7: Strength vs. porosity for all ages of concrete mix with addition of Sika with dosage of 0.15% by weight of cement

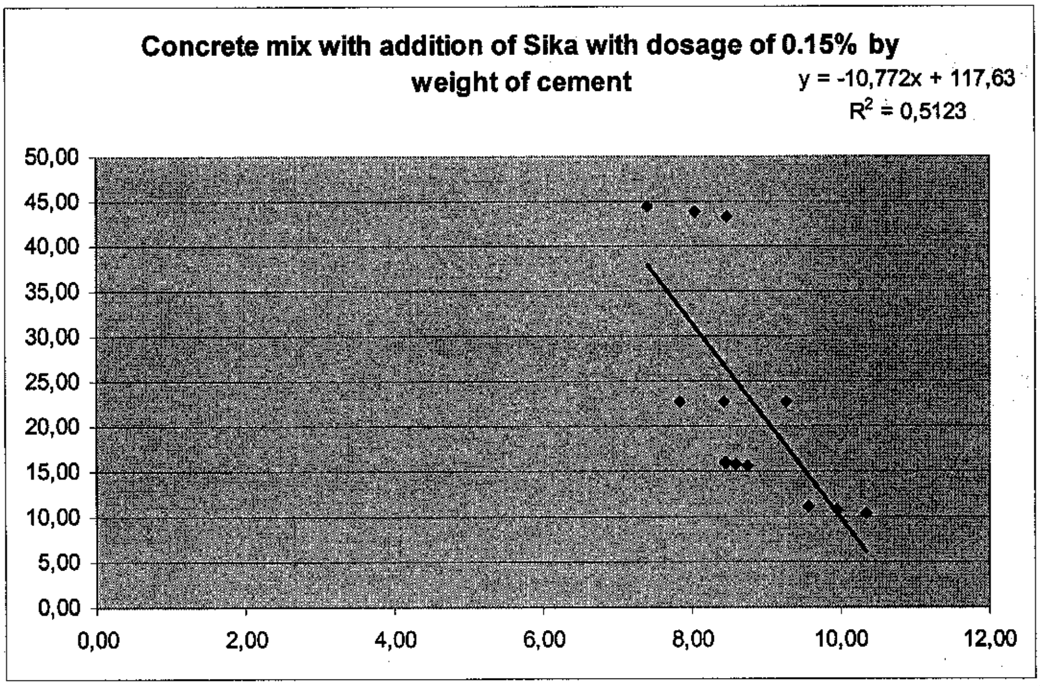
For concrete mix with addition of Sika with dosage of 0.15% by weight of cement, the correlations between strength and porosity are essentially very good. For aged 3, 7, 28 and 90 days, the R^2 values are 100%, 99.2%, 99% and 98.8% respectively. It ranges between 99%-100%.


Concrete mix with addition of used engine oil with dosage of 0.15% by weight of cement
y = -15,105x + 160
R² = 0,7119
40,00
35,00
30,00
25,00
20,00
15,00
10,00
5,00
0,00
0,00
2,00
4,00
6,00
8,00
10,00
12,00

(a)


Concrete mix with addition of new engine oil with dosage of 0.15% by weight of cement
y = -4,7999x + 71,515
R² = 0,084
Strength (MPa)
50,00
45,00
40,00
35,00
30,00
25,00
20,00
15,00
10,00
5,00
0,00
0,00
2,00
4,00
6,00
8,00
10,00
12,00
Porosity (%)

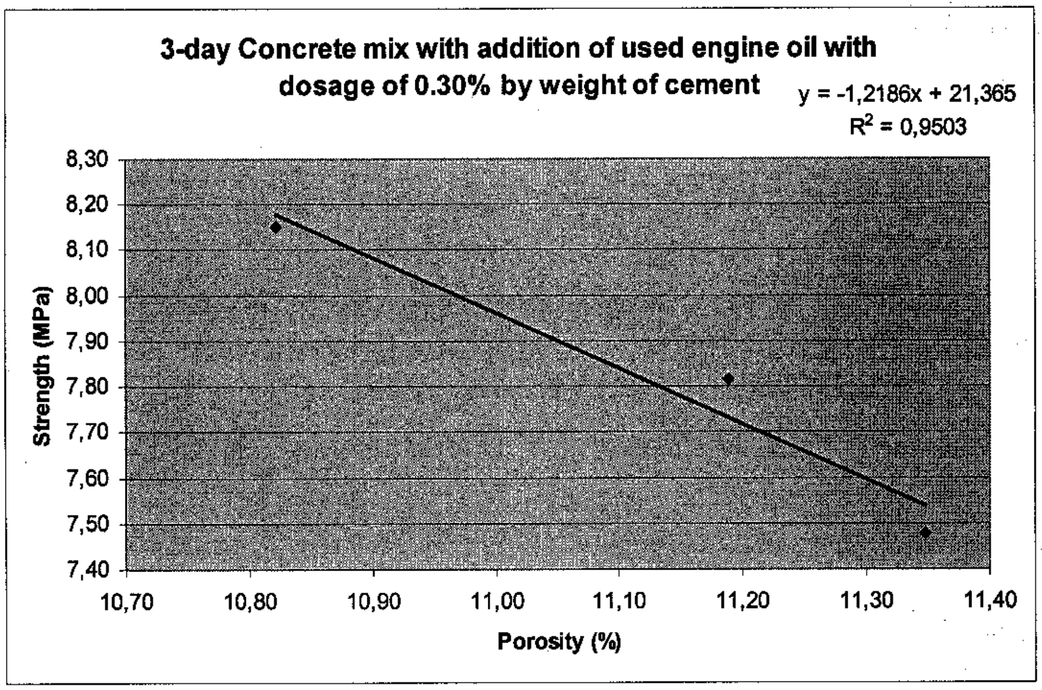
(b)



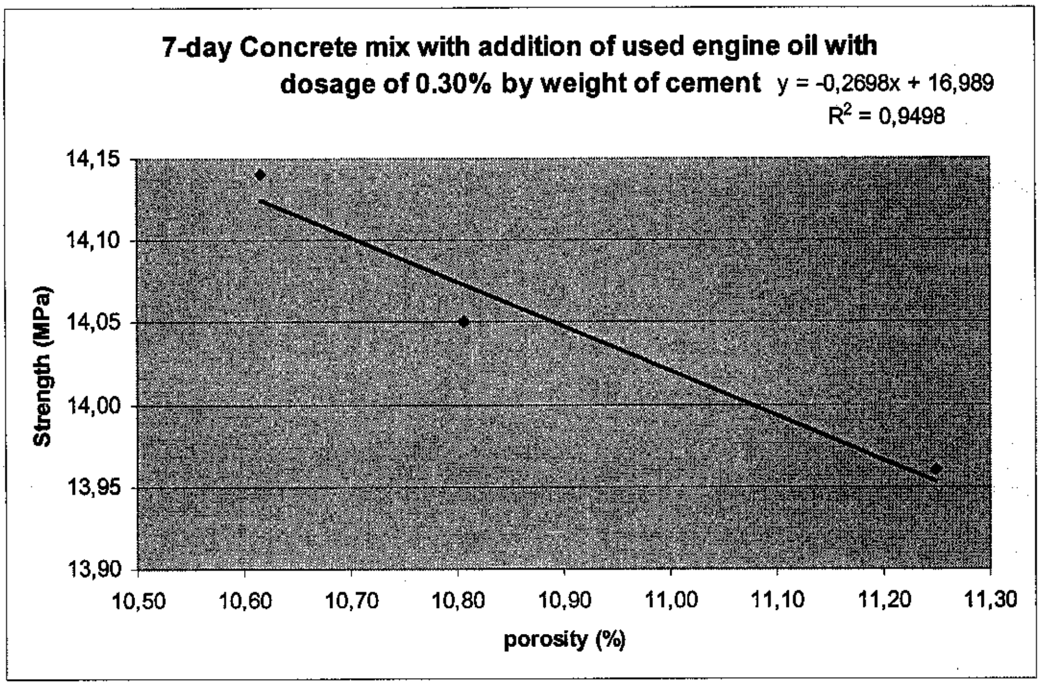
(c)

Figure 4.8: Strength vs. porosity for all concrete mixes with addition of air entraining agents with dosage of 0.15% by weight of cement

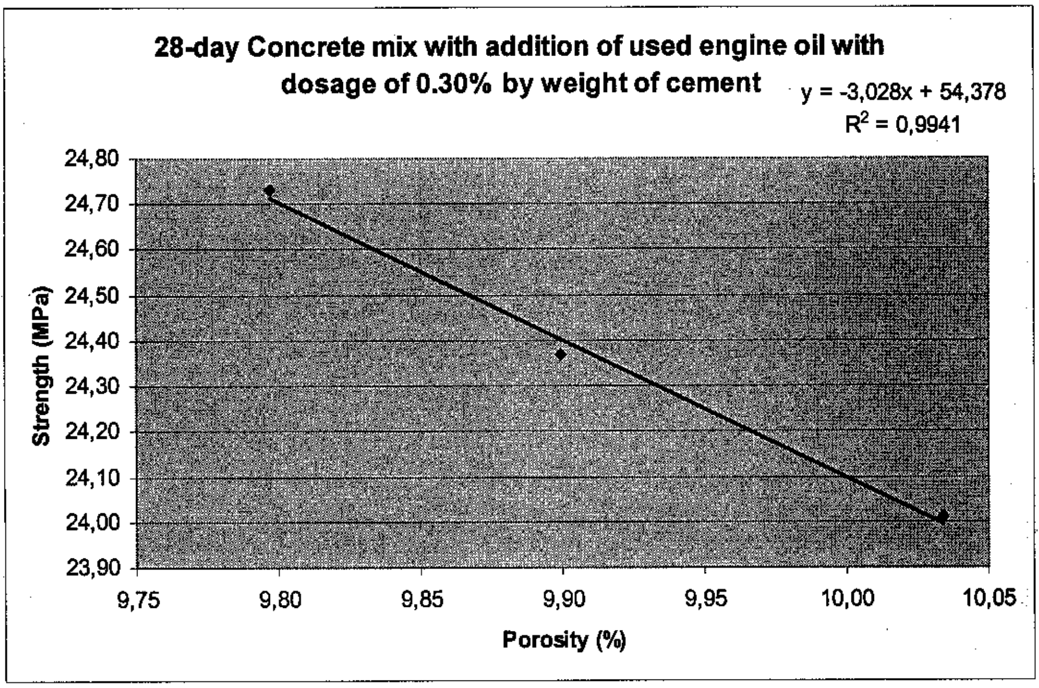
For concrete mix with addition of used engine oil with dosage of 0.15% by weight of cement, the correlations between strength and porosity are essentially good, which is 71.2%. For concrete mix with addition of new engine oil with dosage of 0.15% by weight of cement, the correlations between strength and porosity are essentially not accurate, which is 8.4%. Therefore, this correlation can not be used. For concrete mix with addition of Sika with dosage of 0.15% by weight of cement, the correlations between strength and porosity are essentially average, which is 51.2%.


3-day Concrete mix with addition of used engine oil with dosage of 0.30% by weight of cement
y = -1,2186x + 21,365
R² = 0,9503
Strength (MPa)
8,30
8,20
8,10
8,00
7,90
7,80
7,70
7,60
7,50
7,40
10,70
10,80
10,90
11,00
11,10
11,20
11,30
11,40
Porosity (%)

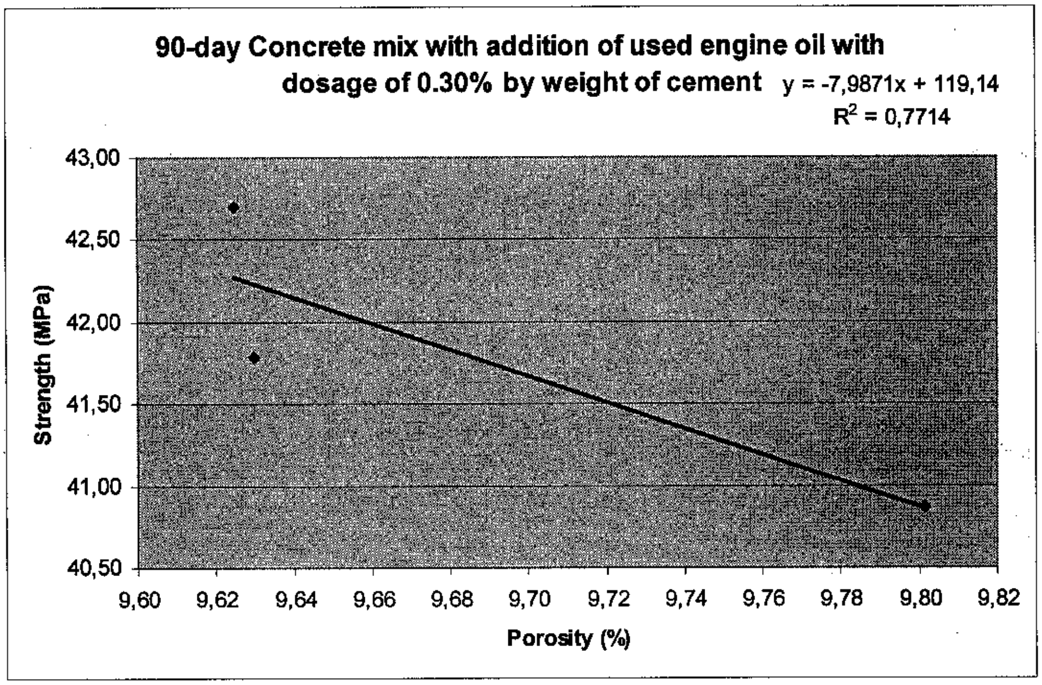
(a)


7-day Concrete mix with addition of used engine oil with dosage of 0.30% by weight of cement
y = -0,2698x + 16,989
R² = 0,9498
Strength (MPa)
14,15
14,10
14,05
14,00
13,95
13,90
10,50
10,60
10,70
10,80
10,90
11,00
11,10
11,20
11,30
porosity (%)

(b)



(c)

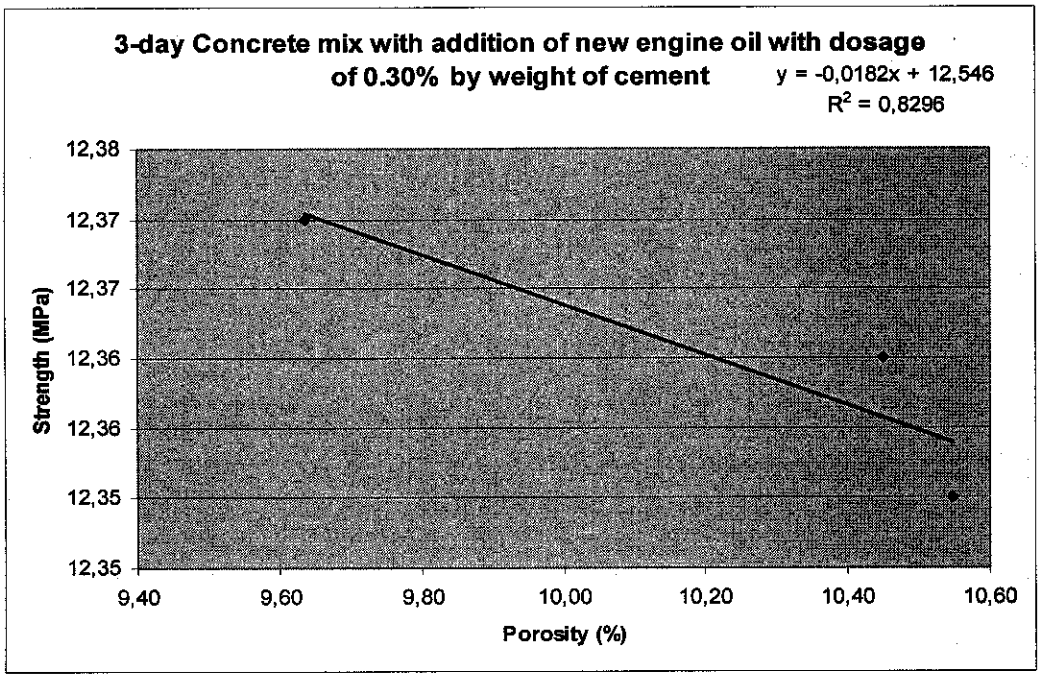


(d)

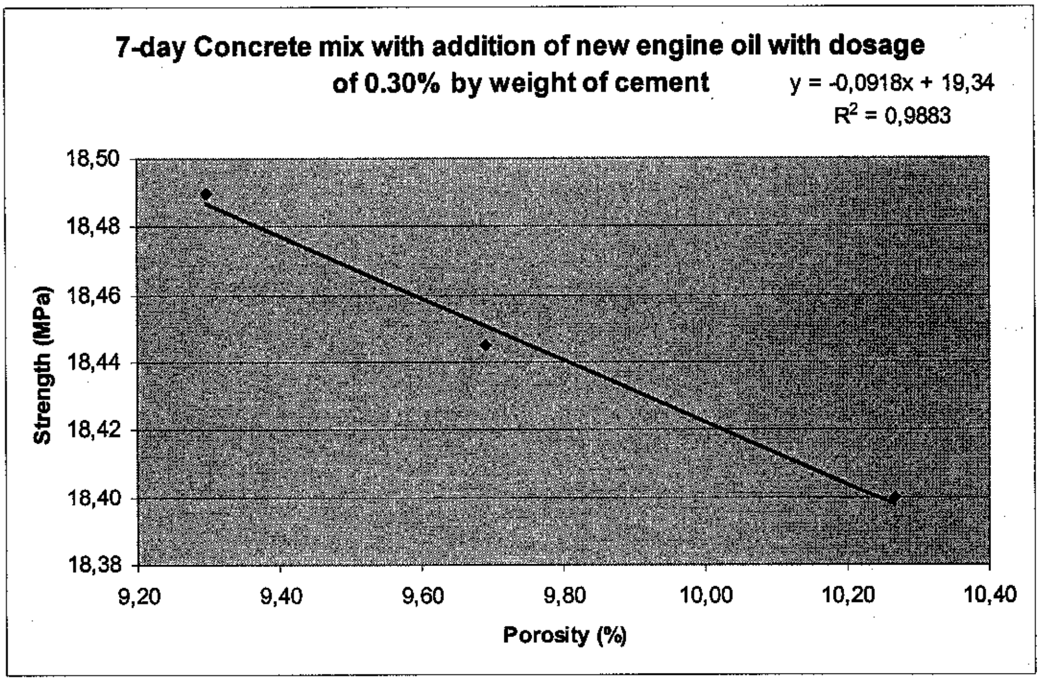
Figure 4.9: Strength vs. porosity for all ages of concrete mix with addition of used engine oil with dosage of 0.30% by weight of cement

For concrete mix with addition of used engine oil with dosage of 0.30% by weight of cement, the correlations between strength and porosity are moderately good. For aged

3, 7, 28 and 90 days, the R^2 values are 95%, 94.9%, 99.4% and 77.1% respectively. It ranges between 77%-99.4%.



(a)



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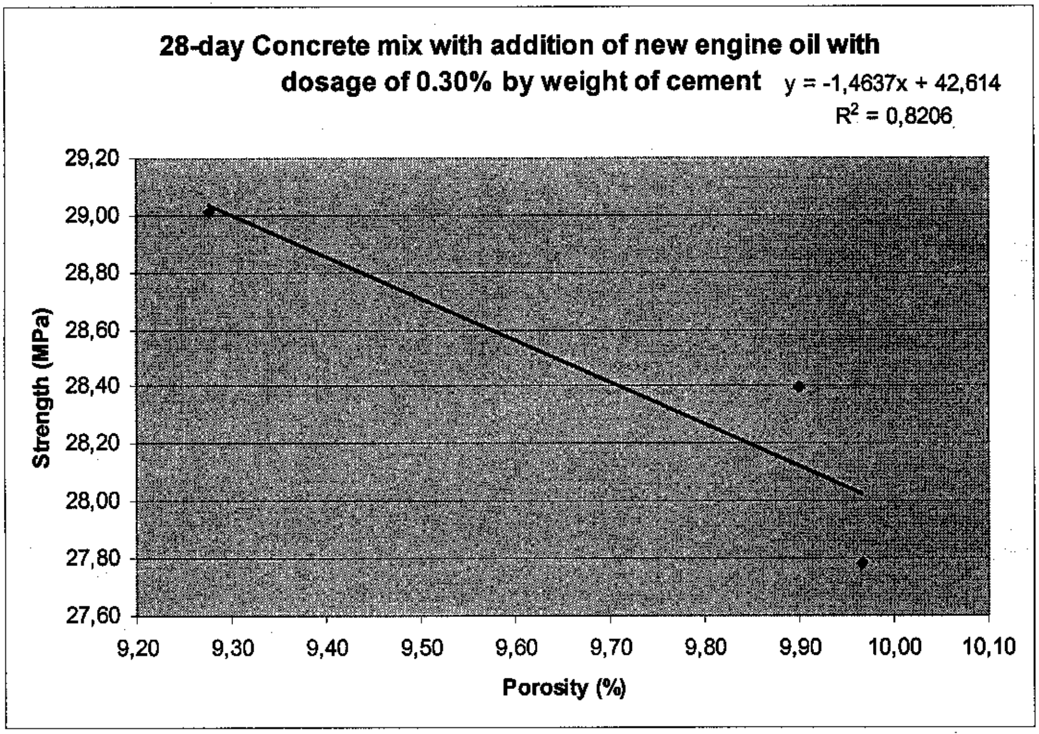

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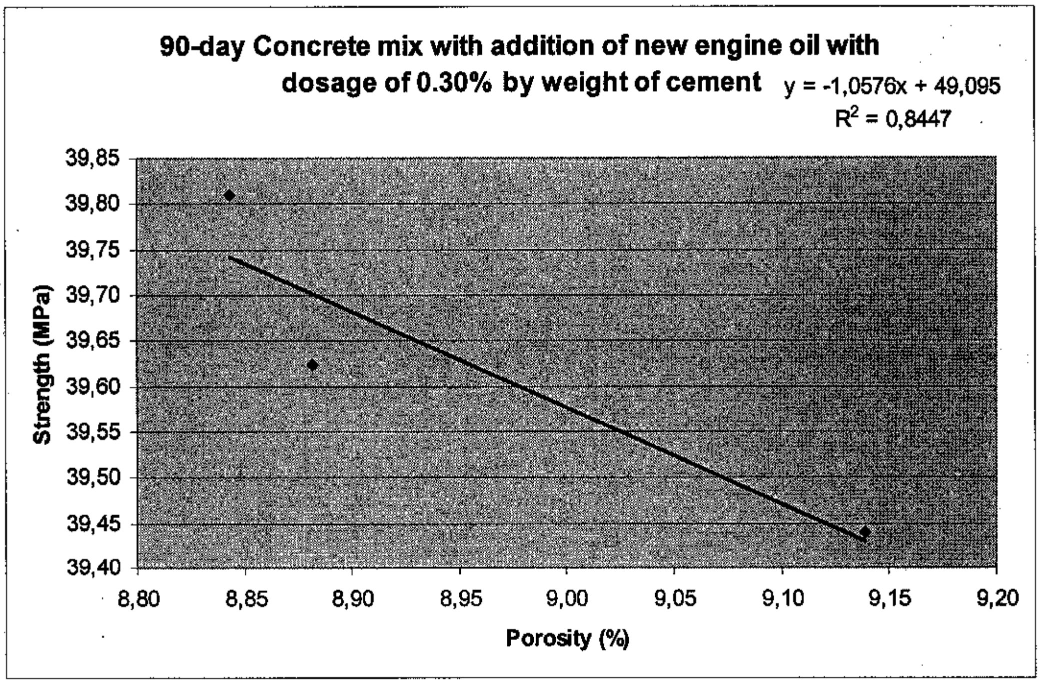
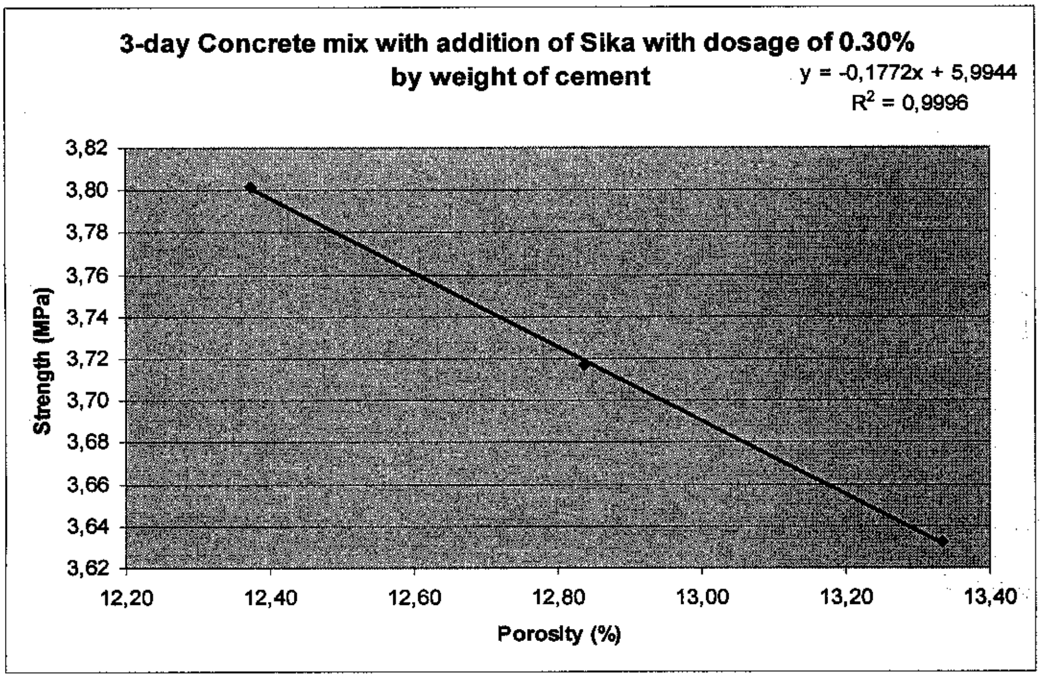


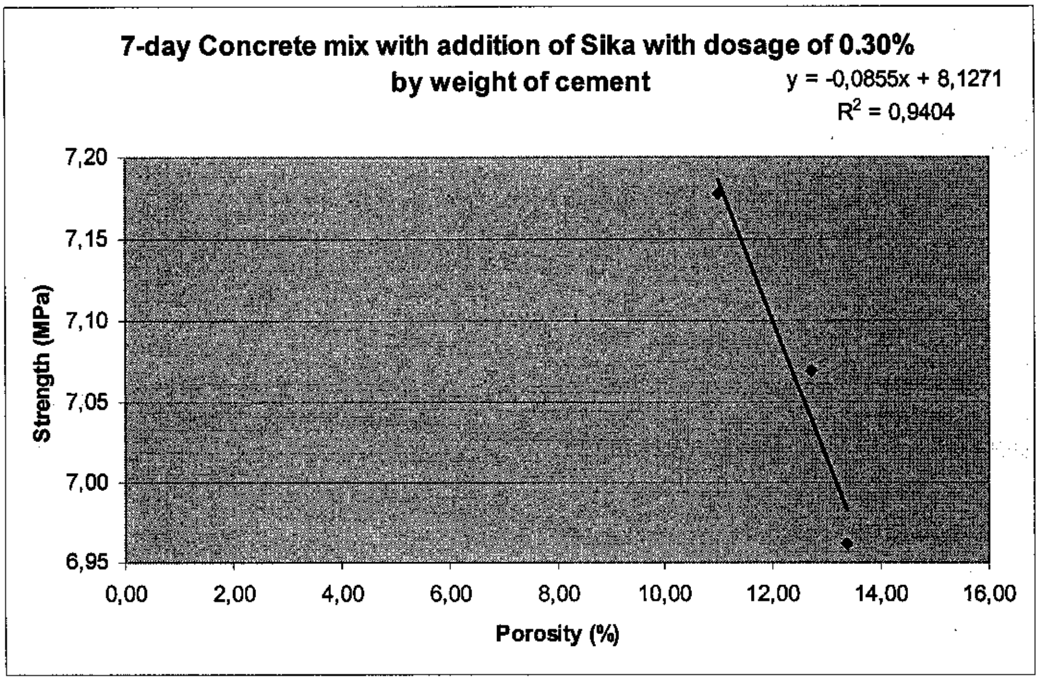
(d)

Figure 4.10: Strength vs. porosity for all ages of concrete mix with addition of new engine oil with dosage of 0.30% by weight of cement

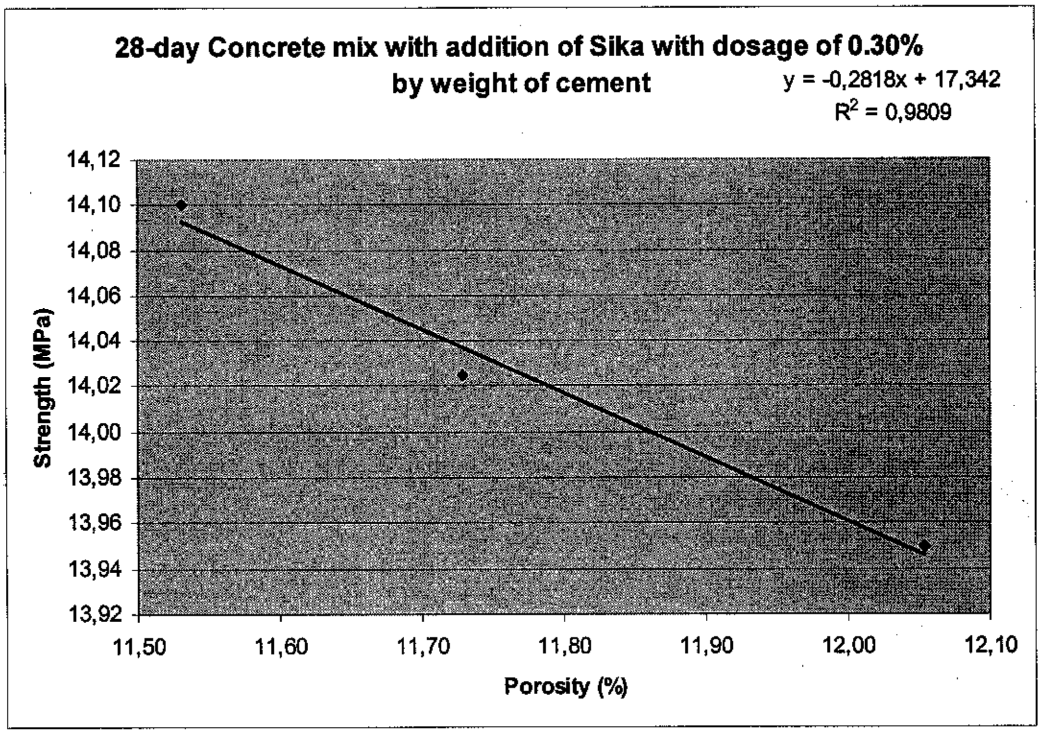
For concrete mix with addition of new engine oil with dosage of 0.30% by weight of cement, the correlations between strength and porosity are essentially good. For aged 3, 7, 28 and 90 days, the R^2 values are 83%, 98.8%, 82% and 84.5% respectively. It ranges between 82%-98.8%.



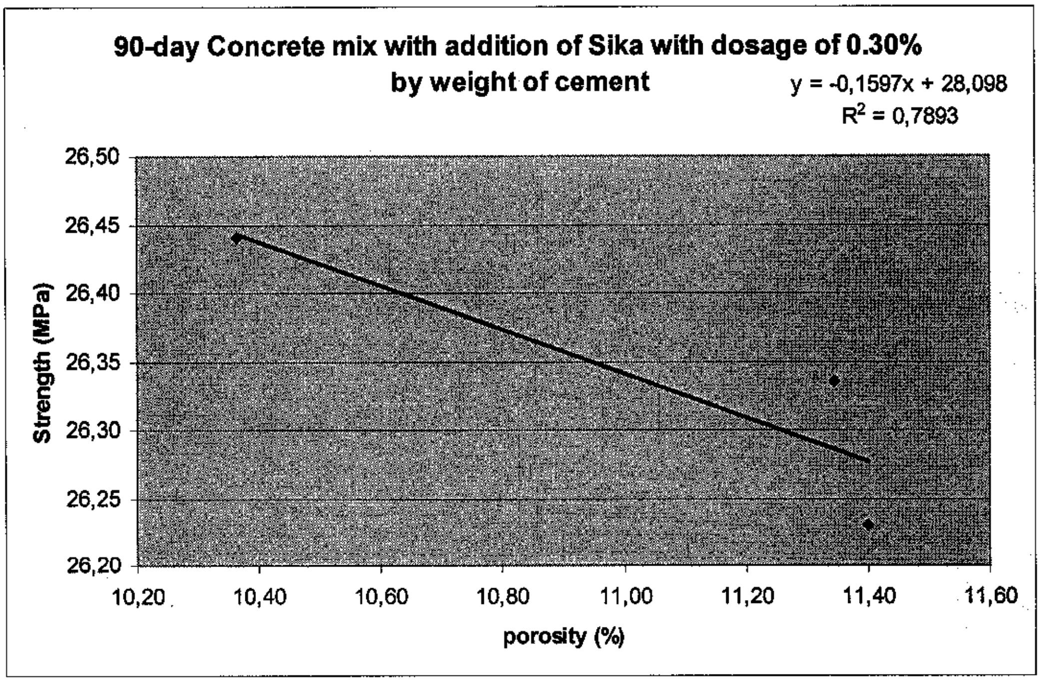
(a)



(b)



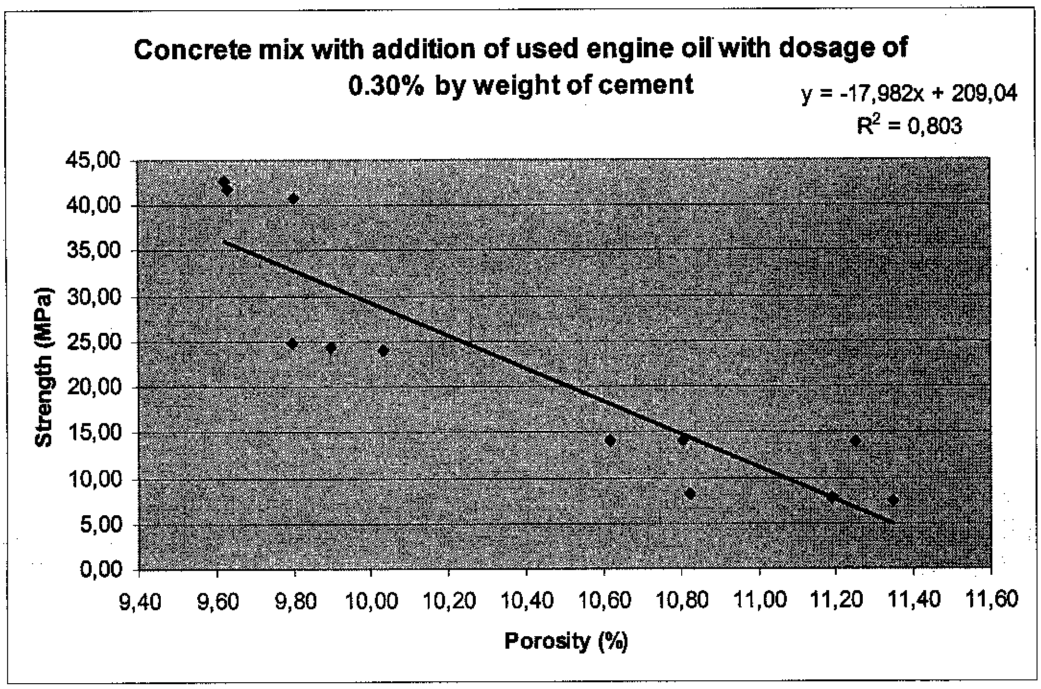
(c)



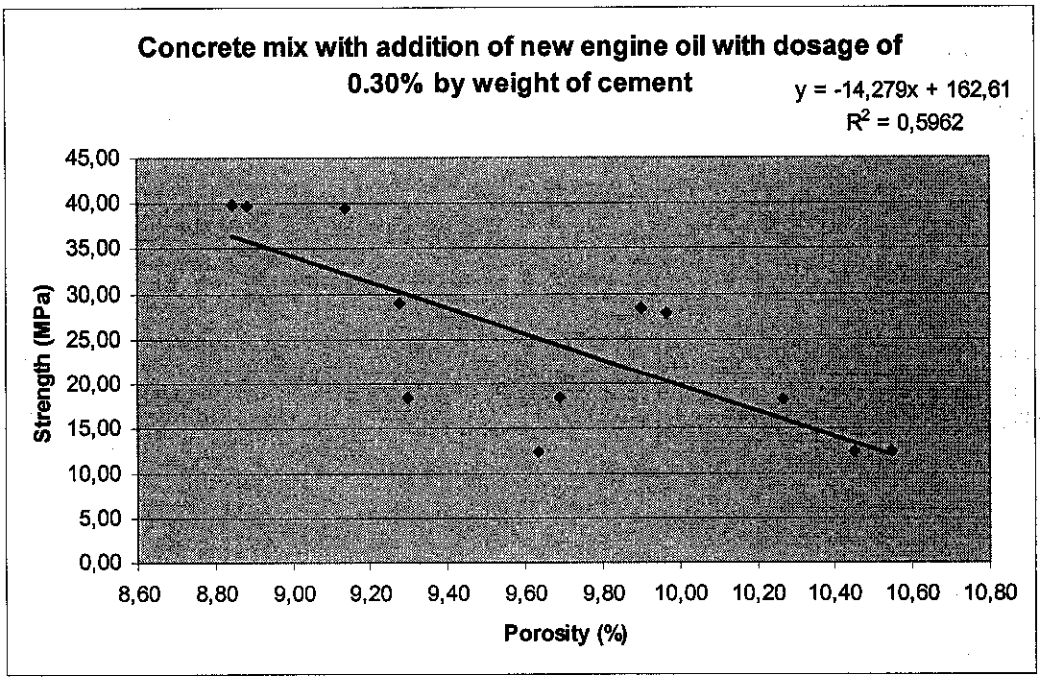
(d)

Figure 4.11: Strength vs. porosity for all ages of concrete mix with addition of Sika with dosage of 0.30% by weight of cement

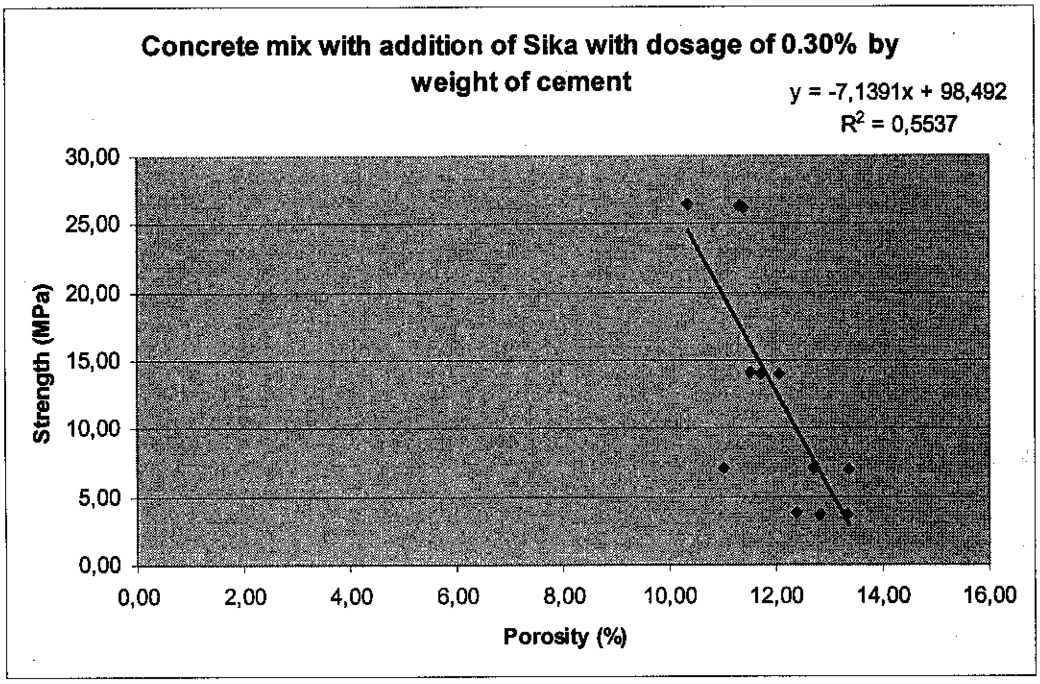
For concrete mix with addition of Sika with dosage of 0.30% by weight of cement, the correlations between strength and porosity are moderately good. For aged 3, 7, 28 and 90 days, the R^2 values are 100%, 94%, 98.1% and 78.9% respectively. It ranges between 79%-100%.



(a)



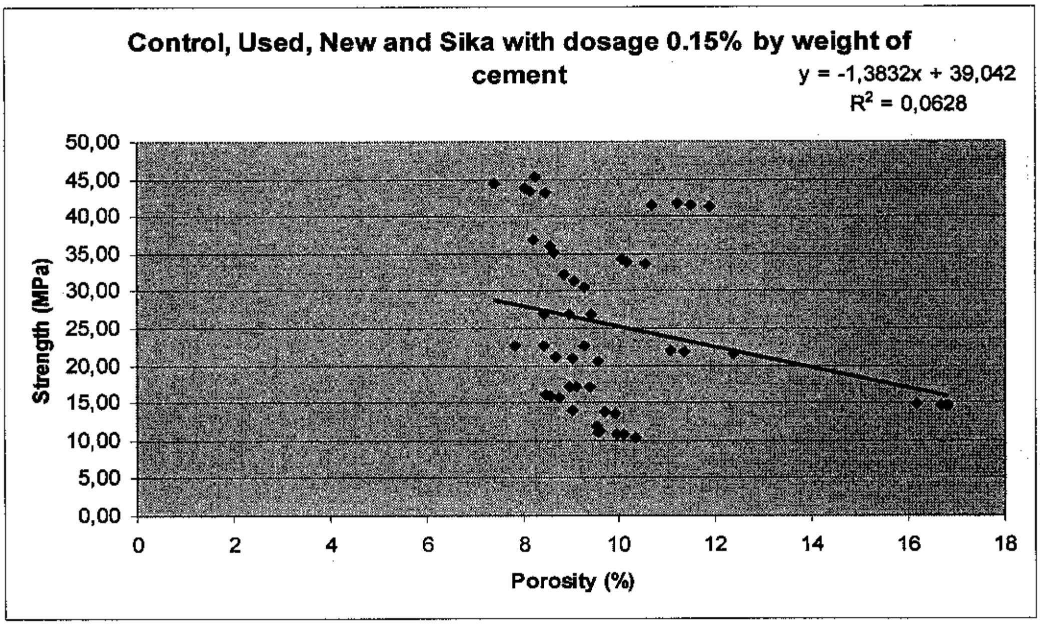
(b)



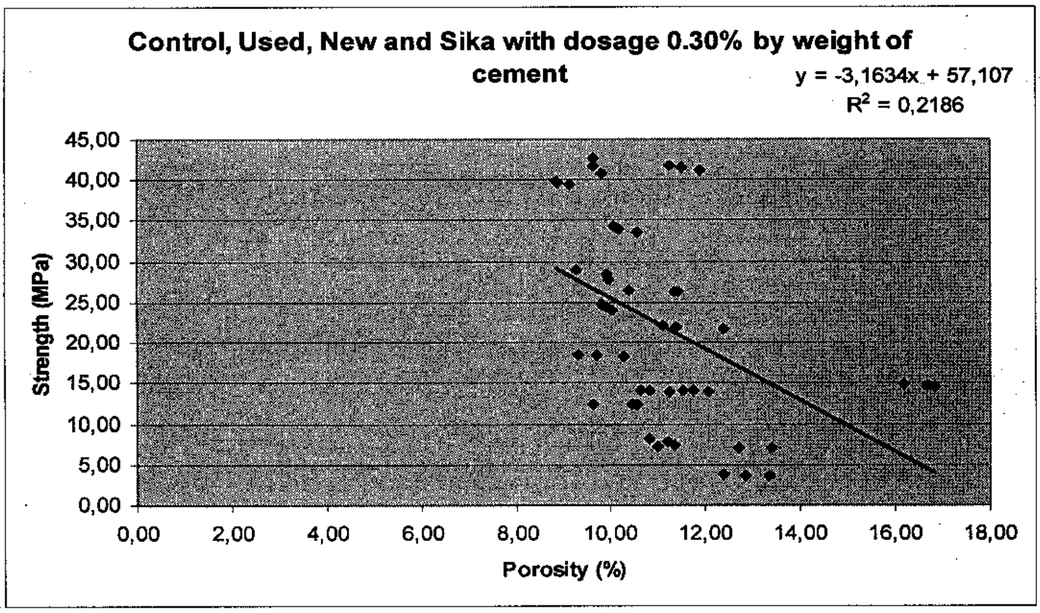
(c)

Figure 4.12: Strength vs. porosity for all concrete mixes with addition of air entraining agents with dosage of 0.30% by weight of cement

For concrete mix with addition of used engine oil with dosage of 0.30% by weight of cement, the correlations between strength and porosity are essentially good, which is 80.3%. For concrete mix with addition of new engine oil with dosage of 0.30% by weight of cement, the correlations between strength and porosity are essentially not accurate, which is 59.6%. Therefore, this correlation can not be used. For concrete mix with addition of Sika with dosage of 0.30% by weight of cement, the correlations between strength and porosity are essentially average, which is 55.4%.



(a)



(b)

Figure 4.13: Strength vs. Porosity for all concrete mixes with different dosages

From Figure 4.13, it shown that correlation between strength vs. porosity of dosage 0.30% is more accurate compared to strength vs. porosity of dosage 0.15%. The difference of accuracy is about 16%.

Table 4.2: Summarized correlations and R^2 for various mixes

Mix No.	Additives	Dosage	Correlation	R^2
1	None	-	Y= -3.172x + 67.6	0.5502
2	Used engine oil	0.15%	Y= -15.11x + 160	0.7119
3	New engine oil	0.15%	Y = -4.800x + 71.5	0.0840
4	Sika	0.15%	Y = -10.77x + 117.6	0.5123
5	Used engine oil	0.30%	Y= -17.98x + 209	0.8030
6	New engine oil	0.30%	Y = -14.28x + 162.6	0.5962
7	Sika	0.30%	Y = -7.139x + 98.5	0.5537

For Table 4.2, it shown that concrete mixes with addition of used engine oil with both dosages of 0.15% and 0.30% by weight of cement has the highest value of R^2 for each concrete mix with same dosage, which is 0.7119 and 0.8030 respectively.

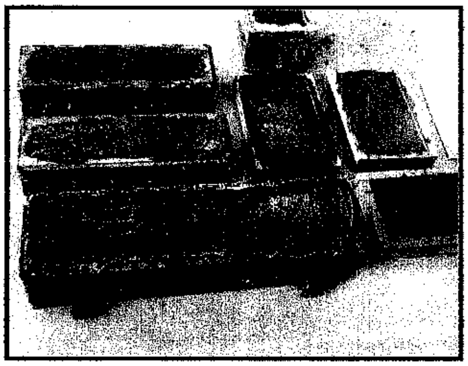


Figure 4.14: Concrete Casting/Moulding

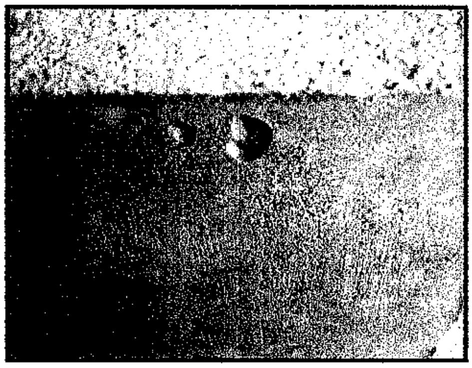


Figure 4.15: Honeycomb in Concrete

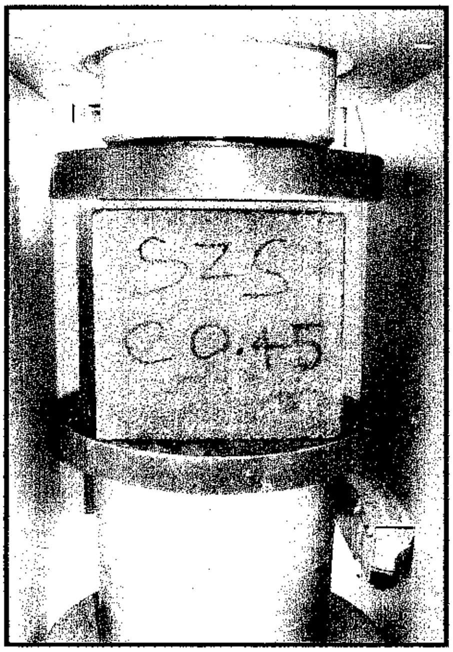


Figure 4.16: Compressive Test Sample (Before)

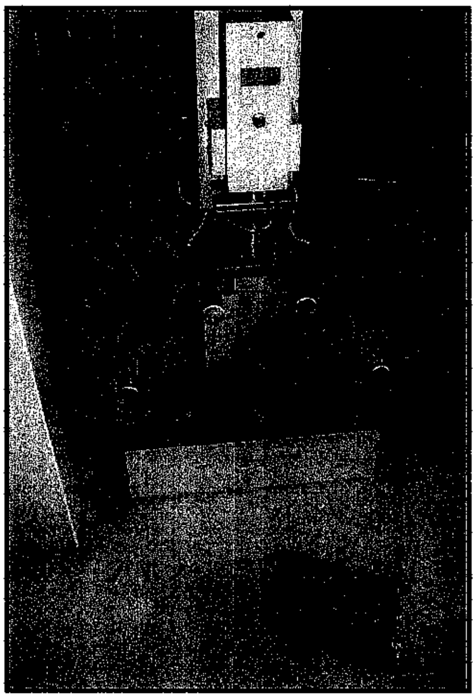


Figure 4.17: Flexural Strength Test (After)

Figure 4.18: Compressive Test Sample (After)

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

To assess the effect of used engine oil on concrete properties, 7 mixes were prepared. Tests were conducted on fresh and hardened concrete properties according to British Standard procedures.

When the water cement ratio was 0.55 for all companion mixes, for the use of an air-entraining agent (none, used engine oil, or new engine oil), the following conclusions were made:

1. The performance of the used engine oil and the new engine oil mixes were almost identical.
2. Used engine oil acted as a chemical plasticizer improving the fluidity and increases the slump of the concrete mix.
3. The air content of the fresh concrete mix with engine oil (both used and new) was higher than the air content of the fresh concrete control mix.
4. The compressive strength using used engine oil and new engine oil were identical, but less than control mix.
5. For porosity, air content in mixes with engine oil is less compared to control mix.
6. Compressive strength for concrete mix with addition of engine oil with dosage of 0.15% 28 days is 21% less than control, but the porosity is 13% less which will enhance the durability. Less porosity, less permeability.
7. Since the addition of engine oil (used and new) did not increase the compressive strength as compared with control mix, however, it give the lower porosity as compare to the porosity of control mix. Therefore

concrete with used or new engine oil will enhance the durability properties of concrete.

As this Final Year Project has been completed, there are needs to address recommendations for future steps. The recommendations may include:

1. More detailed research on microstructure of concrete mixes with addition of used and new engine oil in order to determine the properties of concrete in depth.
2. Conduct tests for both used and new engine oil to investigate their composition and chemical reactions with cementitous material in more detail.
3. More tests can be done to further study these effects on concrete properties, such as modulus of elasticity, splitting tensile strength, etc.
4. Tests on gas and water permeability to be performed in order to assess the degree of durability enhancement.

As the conclusion, the project undertaken requires the author to work independently with minimal supervision in order to ensure that the task given is completed within the allocated time frame.

The project is concluded to be a success with the accomplishment of all the objectives. Although some recommendations can be made, it did not contradict with the objectives since all of them have been fulfilled.

Overall, tremendous experience has been gained from this project. The experience is in both technical hands on work and project management. Therefore, this project is really good for the author.

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[12] http://www.concreteconstruction.net/ThisMonth/ProbClinic.asp?ProbClinicID=J99A069&PubID=5

APPENDIX I

GANTT CHART

		FIRST SEMESTER																SECOND SEMESTER															
No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	SW	EW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	SW	EW
1	Selection of Project Topic																																
	-Propose Topic																																
	-Topic assigned to students																																
2	Preliminary Research Work																																
3	Submission of Preliminary Report					20FEB																											
4	Project Work																																
	Mixing for 12 required mixes																																
5	Project Work																																
	Testing for compressive strength and porosity																																
	Testing for flexural strength																																
6	Submission of Progress Report								19MAC																	13SEPT							
7	Project Work																																
	Data analysis from lab testing																																
8	Submission of First Draft Dissertation																																3DEC
9	Submission of Final Draft Dissertation																																8DEC
10	Oral Presentation																																

SW Study
EW Exam Week