Reliability Analysis of UTP Water Permeameter for Concrete Samples

by

Azura Ali

Dissertation submitted in partial fulfillment of
the requirement for the
Bachelor of Engineering (Hons)
Civil Engineering

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CERTIFICATION OF APPROVAL

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS
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JULY 2007

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 acknowledgement, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

AZURA ALI

ABSTRACT

The main factor that is indirectly proportional to permeability is durability. Concrete durability depends largely on the ease (or difficulty) with which fluids (water, carbon dioxide, oxygen) in the form of liquid or gas can migrate through the hardened concrete mass since concrete is a porous material. The consistency and accuracy of permeameter in producing results is of utmost important. This research is to determine the reliability of UTP Air Permeameter that has been developed in the concrete technology laboratory of UTP since there is no verification of the reliability of this test method compares other test methods. This project establishes the respond of UTP Permeameter on concrete samples age 3, 7, 28 and 56 days. Besides that, it also established correlations results obtained from UTP Permeameter and other tests method. Concrete samples were cast based on four different grades, which is grade 30, 40, 50 and 60. From this, the samples were moulded into slab and cube. Compressive strength tests was conducted on cube samples while UTP Permeameter test was conducted on slab samples which were cored into cylindrical cube. In conclusion, this project had accomplished its objective. From the correlation of the data obtained, the UTP Air Permeameter is a reliable device. Further laboratory test can be carried out by setting up different values such as different pressure or different grades.

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Praised to ALLAH, The Most Gracious The Most Merciful, without His guidance and permission, I will not be able to perform this task successfully.

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INTRODUCTION

1.0 Background of Study

University of Technology PETRONAS (UTP) has developed a new permeameter device that will be used to determine results such as the permeability or porosity of any samples. Since the device is new and no data on the reliability of the device had been recorded, the task is to analyze the reliability of the device in term of performance and the results generated by the permeameter.

Tests conducted are such as compressive strength and water permeability test. The analysis will be done using the results obtained from the tests. From correlation of the results obtained, the reliability of the UTP Air Permeameter is determined. The tests involve concrete grade 30, 40, 50 and 60 and for the UTP Air Permeameter, the pressure exerted is remained at 3 bars.

1.1 Problem statement

Concrete durability depends largely on the ease (or difficulty) with which fluids (water, carbon dioxide, oxygen) in the form of liquid or gas can migrate through the hardened concrete mass. Concrete is a porous material. Therefore, moisture movement can occur by permeability, diffusion, or sorption.

So, it seems that mass transport in concrete controls the rate at which the aggressive agents penetrate and attack the concrete. It is well known that the coefficient of ability permeability influences the resistance of concrete to sulphate attacks, alkali aggregate reaction and the rate of corrosion of steel reinforcement. The fire and frost resistance concrete is also affected by its permeability [1]

Measuring permeability helps detect durability problems and allows timely and cost effective protection of the concrete structure. In order to measure the permeability of the concrete samples, UTP have show their effort in helping a students in order to find the permeability of concrete by having its own permeameter. The method of penetration depth is used in this investigation to evaluate the water permeability of concrete and mortar samples.

The basic procedure of the test is to allow water to penetrate from the top surface of the sample under a pressure head for a specific time. The depth of penetration of waterfront is determined by splitting the tested specimens.

Water penetration in concrete samples is controlled by many factors, including porosity, pressure head, and testing time. Finally, the coefficient of water permeability (kw) is determined from Valenta equation [2]

There are two main methodologies of measuring permeability. First is statically that is allowing the concrete to dry out and noting the weight loss. Another method is actively that is subjecting the material to a liquid or gas under pressure and measuring the depth of penetration. [3]

Study of UTP Permeameter and find the correlation with the standard permeability test, are very important in order to achieve better result of permeability for concrete and mortar samples in our concrete lab. Since permeability affecting durability, accurate value in permeability test will result in getting the exact durability of the concrete and mortar.

From this study, UTP Permeameter will be identified either it is an ideal device to measure permeability or not. If UTP Permeameter is an ideal device for measuring permeability, it can be widely used and this device can function for both water and air.

1.1 Objective

1. To establish the respond of UTP Permeameter of concrete samples
2. To study the correlation of UTP Permeameter and standard permeability test.
3. To identify whether UTP Permeameter is good or not as the ideal device for permeability test for concrete samples.

1.3 Scope of work:

In order to complete this project, a lot of experiments will be conducted. The scope of work includes:

- The experiments will be carried out for four different proportions; 30 N/mm^2, 40 N/ mm^2, 50 N/ mm^2 and 60 N/ mm^2.
- Each batch of concrete will have same proportions of approximately 1: 1.5: 2.5 (cement: fine: coarse) with w/c = 0.4
- The ingredient for the concrete will be sand, gravel, or crushed stone along with water and Portland cement. No chemical admixture will be added.
- Two types of experiments to be done; first is permeability test and another is strength test.
- Permeability and strength test will involve the age of 3, 7, 28 and 56 days.
- For each test, three samples will be prepared

The result of 96 samples will be obtained to through out the experiment.

CHAPTER 2

LITERATURE REVIEW

2.0 LITERATURE REVIEW

Permeability of concrete is believed to be the most important characteristic of concrete that affects durability [4]. Durable concrete is concrete that in the particular environment of service resist the forces in that environment that tend to cause it to disintegrate without requiring excessive effort for maintenance during its service life [5] . There is an approximately equal inverse relationship between penetrability and compressive strength [6]. This project will be focuses on the reliability of UTP permeameter which will be conducted in the concrete lab, but the literature review will discuss all the mechanism related with permeation.

2.1 Permeation

The most important part of this report is all about permeation. Permeation is the penetration of a substance (permeate) through a solid. The premium mobile is the concentration gradient. The permeate always migrates to the lower concentration in three steps:

1. Absorption (at the interface): Gases, vapour or dissolved chemicals or suspended substances are adsorbed at the surface of the solid.
2. Diffusion (through the solid): The permeate penetrates the solid material through pores or molecular gaps.
3. Desorption: The adsorbate leaves the solid as a gas.

In this report the scope that will be discussing will only focusing in three mechanism, which are permeability (The grade of transmissibility of a solid, meaning how much penetrates in a specific time, dependent on the type of permeate, pressure, temperature, thickness of the solid and the area size), diffusion and absorption.

2.1.1 Permeability

A low permeability concrete generally possesses high strength and is resistant to the ingress of water and salt solutions. The reinforcing steel in concrete structures begins to corrode earlier and corrodes faster when the surrounding concrete is porous because chloride, oxygen, and moisture can more easily reach the steel. Measuring permeability helps detect durability problems and allows timely and cost-effective protection of the concrete structure.

- **Fundamental concept of permeability**

In 1856, Henry Darcy, a French civil engineer, established the fundamental concept of permeability. His concern in the public water supply led him into the design of permeable filter sands for water purification. He investigated the flow of water through sand, and the parameter of his experiment was called the coefficient of permeability or the permeability.

The permeability is the rate of water flow and is proportional to the hydraulic gradient. The permeability in Darcy's law can be written as:

$$Q = k.i.A = k.\frac{\Delta H}{L}.A \tag{1}$$

Where Q is the rate of flow, k is the permeability, **i** is the hydraulic gradient, ΔH is the head loss across specimen, L is the length of specimen, and A is the cross-sectional area of specimen perpendicular to direction of flow. The total head loss is the sum of elevation head loss (He) and pressure head loss (Hp), where the pressure head is related to the water pressure (u).

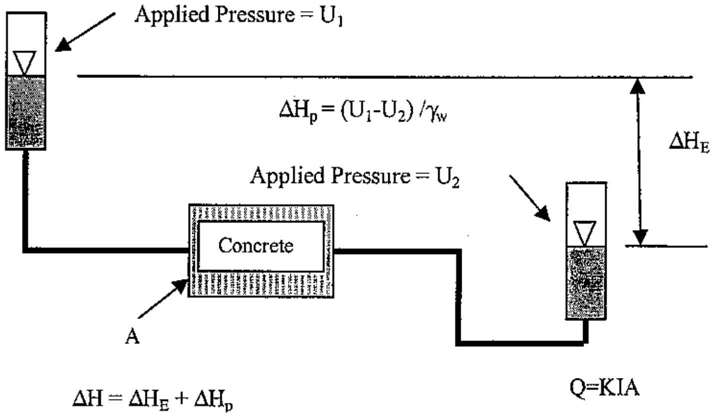


Figure 1: Fundamental Concept of Permeability Testing

Darcy's law is valid for the flow through most granular materials. As long as the flow is laminar, a linear relationship between specific discharge and hydraulic gradient is found. Under the turbulent flow, the water flow paths are more tortuous; therefore, the relationship becomes nonlinear. According to Darcy's law, there are two testing methods used to measure the permeability, a constant head method and a falling head method (falling head or falling headwater-rising tail water).

The system for constant head method can maintain a constant hydraulic pressure or head to within ±5%, and the head loss across the specimen is held constant. As shown in Figure 1.2(a), the water is allowed to flow through specimen. After an adequate amount of water is collected over the time of test, the flow rate Q is determined.

The permeability is then calculated by:

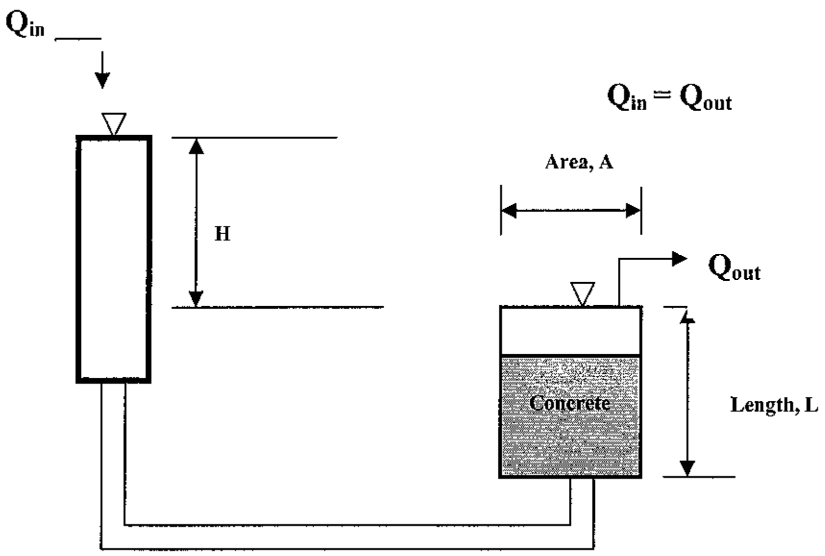
$$K = \frac{QL}{Ah} \tag{2}$$

Where Q is the flow rate, L is the length of specimen, A is the cross sectional area of specimen, and h is the constant head shown in Figure1.2 (a). In the falling head method, the head in the standpipe and the time are measured.
The permeability is then calculated by:

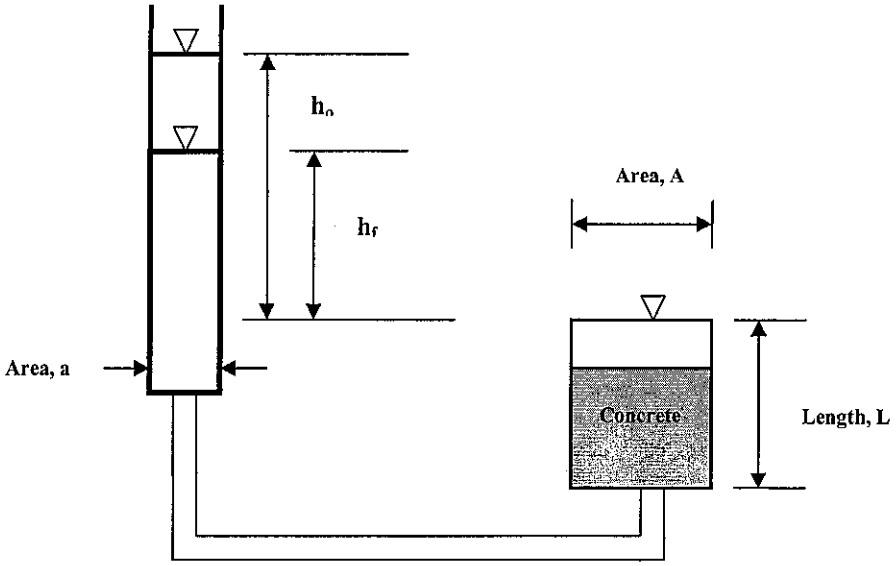
$$K = \frac{aL}{At} \ln \frac{h_o}{h_1} \tag{3}$$

where a is the cross-sectional area of the stand pipe, L is the length of specimen, A is the cross-sectional area of specimen, t is the time required for the head to fall from h_o to h_r, h_l is the water head at beginning of test, and h_2 is the water head at end of test (Figure 1.2(b)).

The literature review indicates that the constant head method is more appropriate for measuring high permeable materials (K > 10-3 cm/s), and the falling head method is more appropriate for measuring less permeable materials (K < 10-3 cm/s). The falling head method is, therefore, a better alternative for measuring the permeability of asphalt mixtures, for which the typical values of permeability are in the range of 10-3- 10-5 cm/s.



a) Constant Head Method



b) Falling Head Method

Figure 2: Two common methods for measuring permeability

Air permeability testing has also been utilized to quantify the permeability of dry, porous media. Early applications were based on the falling head water permeability tests, with a pressurized air vessel substituting for the imposed water head and the quantity of air flow through the porous media related to the pressure drop in the air supply. To calculate values of permeability using air flow, the form of Darcy's law commonly used in falling head techniques must be manipulated. The following equation provides the intrinsic or absolute permeability [7], [8], [9] of the porous media being tested:

$$K = \frac{VL\mu}{ATP_a} \cdot \ln \frac{p_1}{p_2}$$

where K is the intrinsic (absolute) permeability, V is the volume of the pressure chamber, ~ is the dynamic viscosity of air, A is the cross-sectional area of sample, T is change in time (seconds) over pressure loss, Pa is the atmospheric pressure, p_1 is the air pressure at the beginning of time measurement, and p_2 is the air pressure at the end of time measurement.

The intrinsic permeability can be equated to a measurement of the average diameter of the effective void pathways [7],[8]. This value of permeability is considered absolute because it is independent of the fluid flowing through the porous medium.

The intrinsic permeability can be expressed as an equivalent hydraulic conductivity commonly referred to as permeability) through the following relation[7],[8],[9] :

$$K = k_w \frac{\mu_w}{g\rho_w} \tag{5}$$

where K is the intrinsic (absolute) permeability, k_w is the hydraulic conductivity (permeability), w ~ is the dynamic viscosity of water, ρ_w is the mass density of water, and g is the acceleration due to gravity. Equations 4 and 5 may be combined to yield a direct equation for calculating the hydraulic conductivity for air permeameter measurements as:

$$k_w = \frac{VL\mu\rho_w g}{ATP_o\mu_w} \cdot \ln\frac{p_1}{p_2}$$

(6)

2.1.2 Diffusion

Diffusion in chemistry, the spontaneous migration of substances from regions where their concentration is high to regions where their concentration is low. Diffusion is important in many life processes especially in concrete mechanism. [10].

For this mechanism to occur concrete must have a continuous liquid phase (i.e., continuous pores filled with pore solution), and there must be a concentration gradient that drives chlorides toward the zones of lower concentrations.

In1851, Adolph Eugene Fick, a German physiologist, developed a mathematical solution for flow of species under concentration gradient. Fick's second law, as shown in Equation below governs non-steady state systems in which concentration of the species at a point changes with time.

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2}$$

This equation can be used for modeling ionic diffusion from surface into a semi-infinite homogenous environment where C is the ionic (e.g., chloride) concentration at a point as a function of its distance from the exposed surface *(x)* and the time of exposure *(t),* and *D* is a material property called "diffusion coefficient". By solving this partial differential equation, one can obtain the concentration of species at a function of location and time; C(x,t) [1],[7].

2.1.3 Absorption

When water (possibly containing chlorides) encounters a dry concrete surface, it gets drawn into the porous microstructure due to capillary suction. This mechanism is known as absorption. Capillary absorption is dominant among the three mentioned transport mechanisms, because it causes the fastest transport of water.

The dominant mechanism of ingress at short periods of exposure (a few hours), especially near partially saturated or unsaturated surfaces, is sorption, defined as the absorption of water by capillary pores and transport [11], [12] by capillary action. Long term moisture movement is controlled by transport through the gel pores and moisture diffusion, which is driven by a concentration gradient [13], [14].

2.2 Calculation for both absorption and diffusion

Absorption and diffusion mechanisms are non-linear functions of moisture content in the material [15], and can be expressed as follows [16],[17],[18],[19]:

$S(\theta) = S_o \sqrt{(1-\lambda\theta_n)}$ (7)

$D(\theta) = D_o \exp(m\theta_n)$ (8)

Where $S(\theta)$ and $D(\theta)$ are the sorptivity and moisture diffusion coefficient at any moisture content A, such that the normalized moisture content

$$\theta_n = \frac{\theta - \theta_o}{\theta_s - \theta_o}$$

$S(\theta)$ and $D(\theta)$ ate the respective values at an initial moisture content of θo, and θ_s is the moisture content at saturation. m and λ are constants depending on the initial and saturation moisture contents.

Moisture transport through concretes and mortars for short durations is typically described using the sorption equation based on parallel tube model of porous media as [11],[14],[20],[21]:

$$\frac{M}{A} = St^{\frac{1}{2}} + S \qquad (9)$$

M is the mass of water absorbed through a surface of area A, S is the sorptivity coefficient (or simply, sorptivity), t is the time from the start of the test, and S is a correction term to account for the rapid uptake of water when the specimen comes into initial contact with water. Sorptivity has been found to be particularly useful in service life estimation of concrete structures [20],[23],[24] minimizing sorptivity being critical to the reduction of deleterious ion ingress into concrete. A generalized form of Equation 9 could be written as:

$$\frac{M}{A} = B\left[1 - \exp\left(\frac{-St^{\frac{1}{2}}}{B}\right)\right]$$

(10)

Where B is a constant related to the distance from the absorbing surface over which the capillary pores dominate the initial sorption. At smaller times (in the limit $t^{1/2} < B/S$), the right hand side of Equation 10 approximates to $S\ t^{1/2}$, which is the same as Equation 9, when S is set to zero.

The unsaturated flow theory made use of in the development of Equations 9 and 10 [11], [25] is applicable only for short periods of exposure since there is a clear deviation from the $t^{1/2}$ behavior at longer durations of exposure.

It is therefore evident that Equation 10 can at best account for surface or near-surface effects, and cannot provide information on moisture movement through the bulk of concrete that is crucial to predicting long term durability.

Even at short durations, it has been observed that a $t^{1/2}$behavior need not be followed always and a t^{α} behavior has been proposed, with $\alpha<1/2$ [26]. Some authors attribute this to continued hydration, or leaching because of the deionized water used for sorptivity tests [20]. In some cases, a negative intercept in the fit of Equation 9 has been observed [19], [26].

A modified equation comprising of two sorptivity coefficients - short term and long term - to account for the two slopes observed for results obtained from a wide variety of mortars and concretes has been proposed [28] The long term coefficient was attributed to microstructural features other than capillary pores. Based on experimental studies on mortars and high performance concretes, a stretched exponential function has been found to describe moisture uptake in porous materials over an extended period of time [14], which is given as:

$$\frac{M}{A} = B\left[1 - \exp\left(\frac{-St^{\frac{1}{2}}}{B}\right)\right] + S_g t^{\frac{1}{2}}$$

(11)

The coefficients Band S in Equation 11 are the same as explained earlier, and Sg is the sorptivity of smaller pores, or in other words, a representation of the combined effects of moisture intake by gel pores, and diffusion. A $t^{1/2}$ dependence even for longer durations is obvious in this equation as well.

For both permeability and diffusivity, the amount of water added to the mix at the site was directly and positively related and identified as a possible major factor. The data indicated that the total amount of sand and stone in the mix was possibly correlated to the permeability.

2.3 Effect of permeability on concrete

2.3.1 Durability

The main factor that is indirectly proportional to permeability is durability. Concrete durability depends largely on the ease (or difficulty) with which fluids (water, carbon dioxide, oxygen) in the form of liquid or gas can migrate through the hardened concrete mass since concrete is a porous material [28], [29]. Corrosion of reinforcement is one of the main durability problems of concrete structures [31].

For an example, result of the intrusion of chloride (i.e. salt-water) into concrete is the corrosion of the reinforcing steel. Once this occurs, the structure will no longer maintain its structural integrity; the lifespan is reduced, and the general safety of the public is severely degraded. It is increasingly apparent that for many concrete members, the ability of the concrete to resist chloride penetration is an essential factor in determining its successful performance over an extended period.

There is a research done by conducted by Abdol R. Chini, Ph.D., P.E., of the University of Florida in order to test concrete samples from The Florida Department of Transportation (FDOT) projects around the state of Florida using a procedure designed to indicate a particular concrete permeability to the chloride ion.

Almost more than 500 sets of samples were collected from concrete being placed on FDOT projects in all eight FDOT geographic districts. Each set consisted of three 4-inch by 8-inch cylinders, which were trucked to the State Materials Office (SMO) in Gainesville for testing. AASHTO T 277 (ASTM Cl202), "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration," was used to determine the relative permeability of the concrete samples.

At the end of the six-hour rapid permeability test, coulomb values representing the total current passed through the concrete slices over the testing period were obtained. The total charge passed in coulombs correlates with the resistance of the specimen to chloride ion penetration. These values have been shown to be representative of the chloride ion permeability, which is an indirect indication of the permeability of concrete [30].

2.4 Compaction and Workability

Air voids reduce the proportion of solid matter in concrete and thus lend to impair its mechanical properties, 1% of air by volume will, for example, reduce the compressive strength of a concrete by 5 to 6%. If the voids form a connected system, as may be the case if the concrete is poorly compacted, water may more readily be able to penetrate the body of the concrete; if it freezes there, its resultant expansion may cause damage; if the water contains aggressive compounds, their attack will take place within the concrete instead of being confined relatively harmlessly to the surface; moisture and air may penetrate to the reinforcing steel and eventually rust it away.

Through compaction is vital, therefore, and can be achieved only if the workability of the concrete is appropriate to the location in which it is being placed and to the method being used to compact it. A construction containing congested reinforcement, for example, is likely to demand more workable concrete than once containing little or no steel. Again, compaction by hand will require the concrete to be more workable than when mechanical vibration is used.

An ideal concrete is one which is workable enough to be thoroughly compacted by whatever means is available, but which does not require an excessive water content to achieve that workability.

2.5 Water/Cement Ratio

Water is necessary to make cement into a paste and thus to render a concrete workable, only a proportion actually combines chemically with the cement during the hydration process. The excess remains distributed within the paste, and there are three main reasons for keeping this excess to the minimum compatible with adequate workability for the job in hand.

A cement paste which is too greatly diluted may be excessively fluid, tending to drain away from the surface of the aggregate particles. Depending on other factors, this may cause defects in the fresh concrete such as harshness in working, loss of cohesiveness, or a tendency for the mix components to segregate.

The greater the amount of excess water present the greater will be its tendency to rise to the surface of the freshly placed concrete. This phenomenon, known as 'bleeding' forms fine open channels which remain after the concrete has hardened and may detract from its durability if it should be exposed to frost or to aggressive solutions.

The excess water causes void in the paste structure which are unlikely to become filled with solid hydrates. The lower the proportion of these voids, the better will develop the useful properties of the concrete such as strength, abrasion resistance impermeability and durability. Drying shrinkage will minimized because it is primarily loss of water from voids which causes porous bodies to contract on drying.

The proportion of water to cement by weight, called the water/cement ratio, is thus of prime importance in most aspects of concrete technology.

2.6 Maximum Aggregate Size

Using the largest size of coarse aggregates will reduce the amount of jointing material needed, it consequently reduces the over-all effect if any shrinkage which may take place as the jointing material dries after having hardened.

In accordance with the approximate rule that the largest aggregate particle should not normally exceed about one-fifth to one-quarter of the minimum dimension of the work. In much reinforced concrete work, on the other hand, the limiting dimension if found to be the distance between the reinforcing bars, or between the bars and the forms into which the concrete is to be placed. It is this last dimension, of course, which determines the thickness of the concrete cover to the steel. If the steel is too prevented from rusting, it is vital that this cover should not suffer from under compaction, as might occur if the maximum aggregate size were too great to pass between formwork and reinforcement.

2.7 Mix Design

There is no single concrete which is ideal for all applications: the purpose for which the concrete is required will dictate the properties needed, while the nature of the available materials will determine the mix proportions necessary to achieve them.

Each of the mix design has its merit, depending on the materials to be used and the intended purpose of the concrete. It must be stressed too that all mix design procedures are no more than means of estimating proportions for the initial mix. This estimate needs to be checked by making at least one trial mix. It will frequently be found that the proportions have to be adjusted according to experience gained from the trial.

Provided concrete can be fully compacted, its strength will be inversely related to its water/cement ratio; typical curves, showing how strength rises as water/cement ratio is reduced, may be found in many references.

When designing a mix it is also necessary to allow for the fact that the measured strength of concrete will vary as the result of such factors as fluctuations in the properties of the materials, inconsistencies in batching, differences in compaction, and variations in sampling and testing.

CHAPTER 3

METHODOLOGY

3.1 Methodology

Different grade of concrete are prepared. The concrete that been used in this experiment are Grade 30, 40, 50 and 60. The differences of grade in concrete are used to analyze the permeability. The pressure of UTP Air Permeameter is remained 3 bars for all samples and there are three samples for each grade. The samples are prepared for 3, 7, 28 and 56 days.

Table 1: Experimental detail

Concrete Grade	**No. of samples for each test**	**Test**	
		Compressive strength (N/mm^2)	**UTP Water Permeameter (m^3/min)**
30	3	150mm x 150mm	Cylindrical Cube
40	3		
50	3		
60	3		

Table 2: Mix proportion of concrete

W/C ratio	Concrete grade	Cement (kg/m^3)	Fine Aggregate Sand (kg/m^3)	Coarse Aggregate 20mm (kg/m^3)	Water (kg/m^3)
0.49	30	22.05	31.92	61.90	10.76
0.47	40	22.84	31.50	61.43	10.76
0.42	50	25.73	29.93	60.38	10.76
0.35	60	30.71	26.25	58.80	10.76

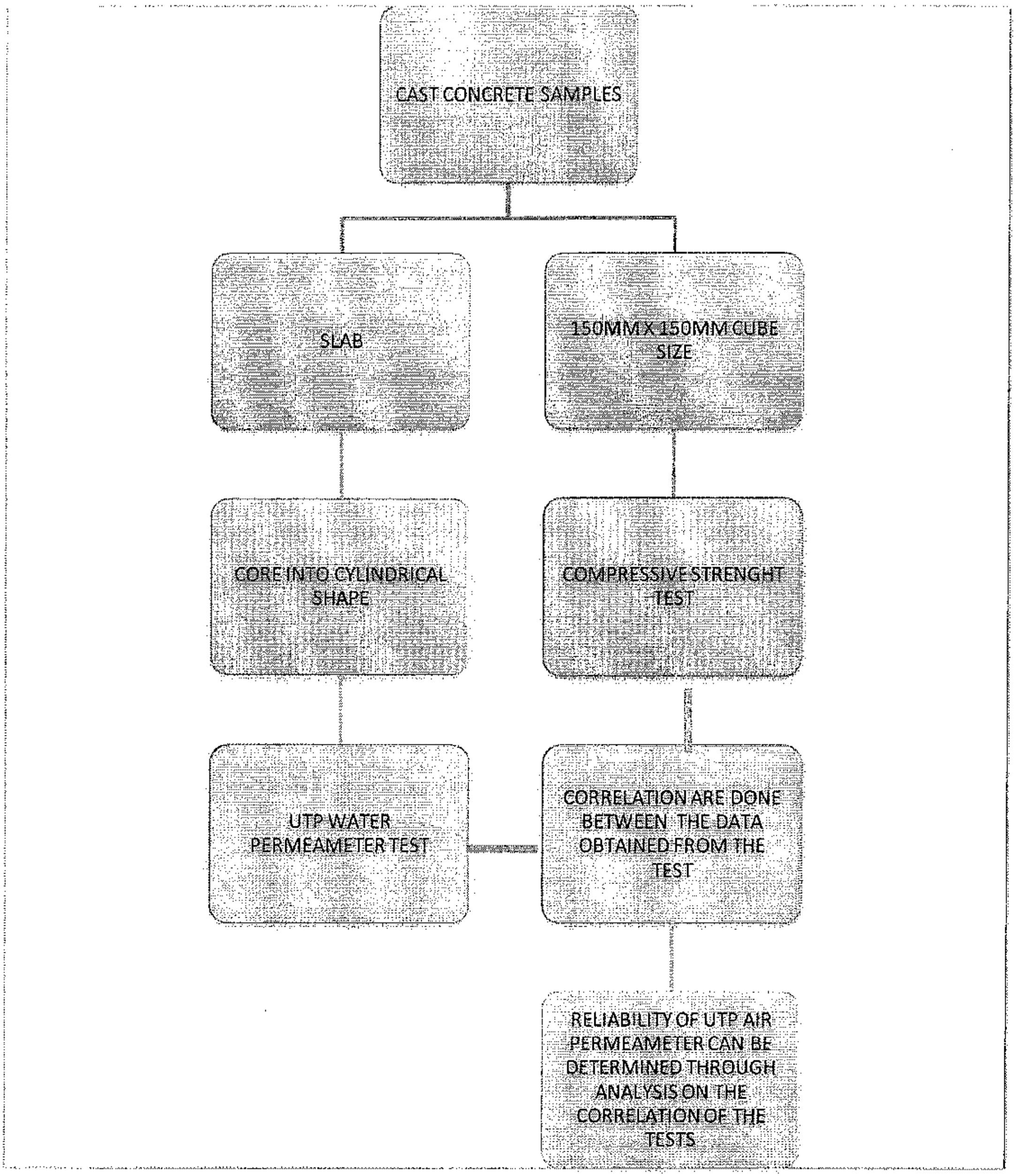


Figure 3: Flow Diagram of Determining the Reliability of UTP Permeameter

3.2 Testing Methodology

3.2.1 Compressive Strength Test Cubes

Figure 4: Compressive Strength Test Equipment

1. The specimen is removed from curing tank: and the surface water is wiped and the specimen is grit off.
2. Each specimen is weight to the nearest kg.
3. The top and lower platens of the testing machine are cleaned. The cube is carefully centered on the lower platen and it is ensured that the load will be applied to two opposite cast faces of the cube.
4. Without shock, the load is applied and increased continuously at a nominal rate within the range of 0.2 N/mm^2 to 0.4 N/mm^2 until greater load can be sustained. The maximum load applied to the cube is recorded.
5. The type of failure and appearance of cracks is noted.
6. The compressive strength of each cube is calculated by dividing the maximum load by the cross sectional area. The results are expressed to the nearest 0.5 N/mm^2.

3.2.2 UTP Air Permeameter

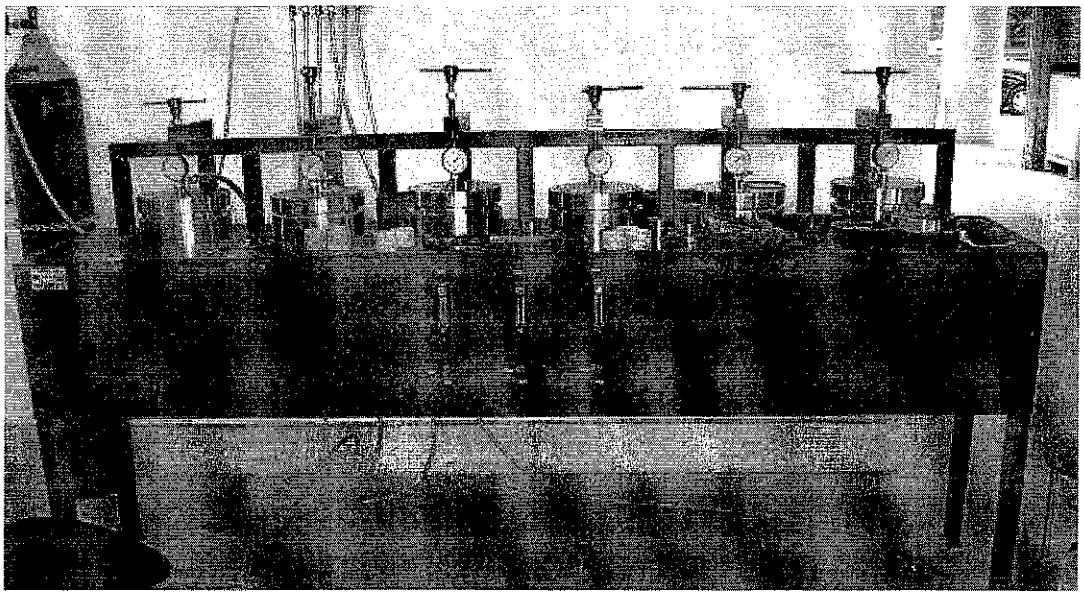


Figure 5: UTP Water Permeameter

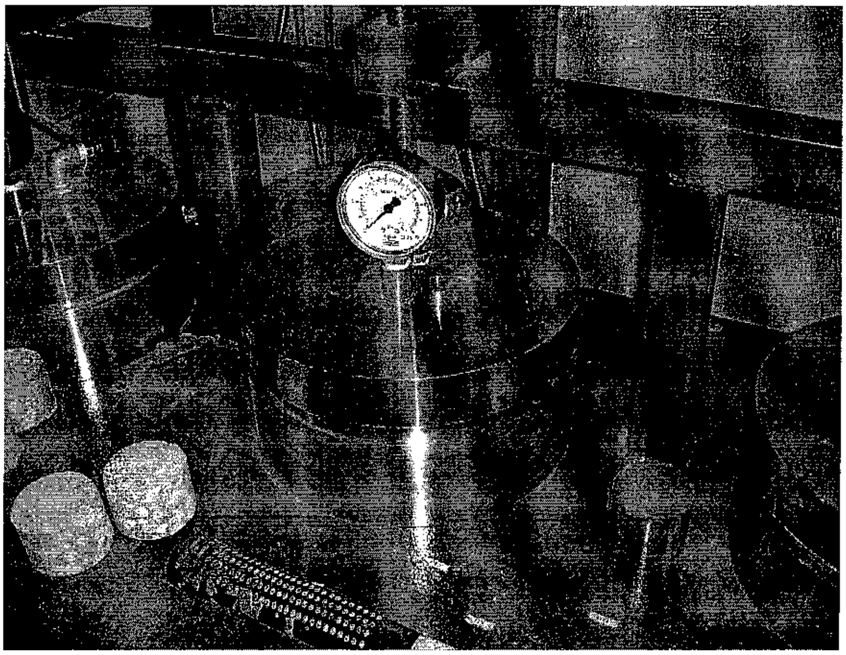


Figure 6: Panel to Place Cored Sample

1. The apparatus is supplied complete with six dummy test samples, which are manufactured from mild steel for preliminary test run use.
2. The dummy test samples are fit.
3. The cell cap is tightened by turning the clamping onto the cell cap.

4. The inlet tubing is connected to the cell. Quick coupling connector is supplied for this purpose.
5. The gas regulator and all other inlets control valves on the wall mounting panel are turned on simultaneously. Ensure the release valve is off and it is only turned on when release gas is needed.
6. The pressure is increased gradually and no leakage occurs. The optimum working pressure is 8 bars and it is to maintain to the maximum.
7. The preliminary test run is completed
8. Make a mark on the mechanical clamping rod for future application testing force is needed.
9. Step 3 to 6 is referred for testing specimen preparation and start the testing.
10. With all the outlets and flow meter control valves remain closed, determine the cell to be tested and turn on the direct supply line in accordance to the numerical number.
11. The flow meter to be used is turned on and the specimen's flow rate range is estimated.
12. Flow rates are recorded once a steady state of flow has been reached (approximately 10 minutes)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Data Gathering and Analysis

Several tests had been conducted throughout the research period such as compressive strength test and water permeability test. From the data obtained from the tests, comparison had been done to observe the correlation between the data and determine the reliability of the results. The data had been summarized into tables and graph to observe the correlation.

4.1.1 Compressive Strength Test

Table 3: Compressive strength of concrete

Concrete grade	3 days		7 days		28 days		56 days	
	Strength (N/mm^2)	Fail Load (kN)	Strength (N/mm^2)	Fail Load (kN)	Strength (N/mm^2)	Fail Load (kN)	Strength (N/mm^2)	Fail Load (kN)
30	27.0	607.9	36.0	812.4	37.5	841.7	38.0	855.3
40	38.0	849.1	44.5	1000.4	49.0	1100.2	51.0	1153.7
50	48.0	1100.2	54.0	1215.3	56.0	1256.8	56.5	1271.1
60	57.5	1290.9	58.0	1310.2	61.5	1380.6	63.0	1420.4

The grade and the days studied for the compressive strength of concrete are shown in Table 3.The are correlation between the grade and the two parameter studied which are fail load (kN) and strength (N/mm^2).The fail load and the strength of concrete is higher as the grade of the concrete is increases. For the grade of 30, the fail load is 607.9 KN and the strength is 27.0 N/mm^2 on day 3 of curing. While on the 7 days, the failed load is 812.4KN and the strength measured is 36N/mm^2. As day goes by, the strength and failed load for 28 and 56 days increases to 37.5N/mm^2, 38N/mm^2 and 841.7KN, 855.3KN respectively.

For concrete Grade 40, the initial strength is 38N/mm^2 with failure load of 607.9KN. The failure load and the strength increase on the 7 days 1000.4KN and 44.5N/mm^2 respectively. Their strength continues to obviously increase on the 28 and 56 days to 49 N/mm^2 and 51 N/mm^2 respectively. It's the same goes to the failure load which are 1100.2KN and 1153.7KN for 28 and 56 day respectively.

For series of concrete Grade 50, the 3,7,28 and 56 day compressive strength are 48 N/mm^2, 54N/mm^2, 56N/mm^2 and 56.5N/mm^2 respectively. It was observed that the strength and the failure load are directly proportional for all grade of concrete. It is because, as the strength getting higher, so, the ability of concrete to sustain load also will increases. That's why the result for load failure for grade 50 on 3,7,28 and 56 days are 1100.2 KN, 1215.3KN, 1256.8KN and 1271.1KN respectively.

Compared to grade of 60, the fail load also increases from 1290.9 KN and 57.5 N/mm^2 strength on the 3 day and become 1420.4KN and 56.5N/mm^2 for the strength. In term of days studied, there are significant difference between day 3, 7, 28 and 56. The result indicates the increase of day studied will increase the fail load and strength for the same sample.

From the result, it is shown that the grade of the concrete adversely affect the value of the failure load and the strength. The load and the failure load increases as the grade increases. Result of grade 60 is higher compare to the result of lower grade of concrete. This indicated that the w/c affect and made the concrete stronger as the value are increases.

4.1.2 UTP Water Permeameter

Table 4: Permeability Result for All Samples

Grade/days	3 days	7 days	28 days	56 days
	Permeability (ml/min)	**Permeability (ml/min)**	**Permeability (ml/min)**	**Permeability (ml/min)**
30	117.8	100.9	98.1	79
40	78.6	55.1	40.6	31.9
50	63.4	39.2	33.7	27.3
60	57.8	32.5	30	22.4

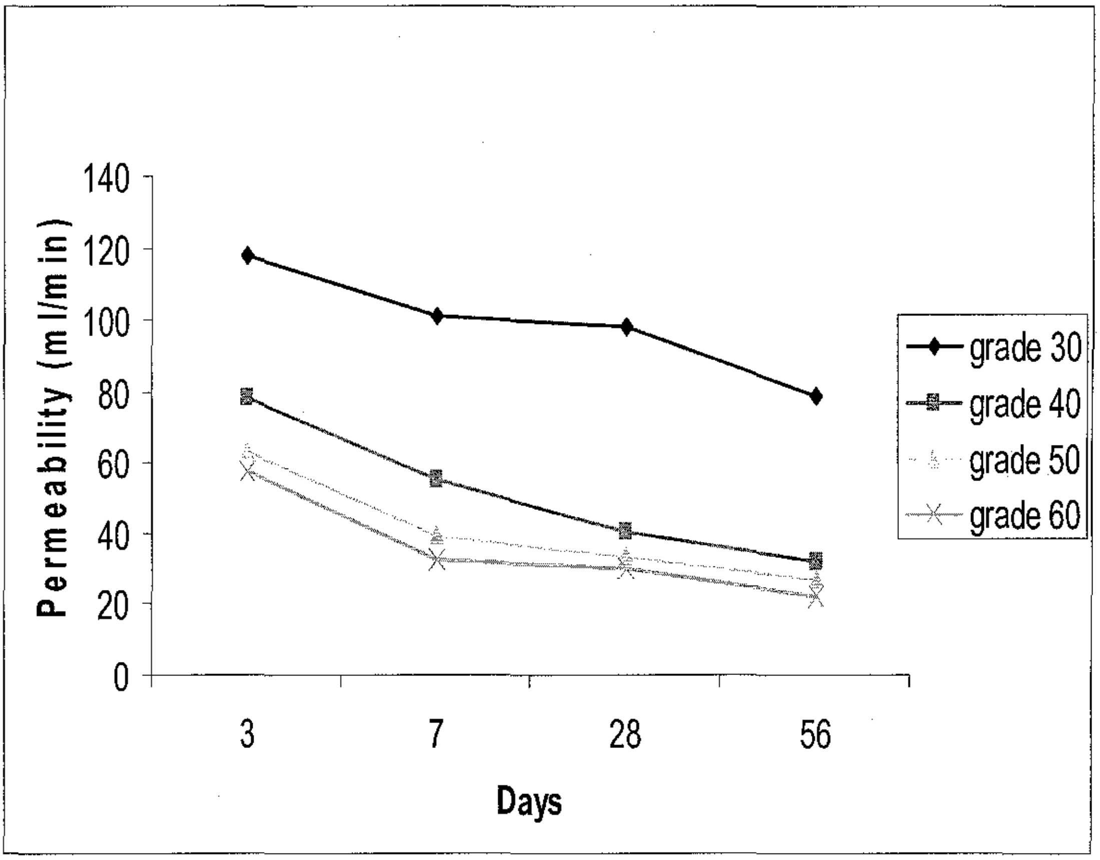


Figure 7: Relationship between permeability and concrete ages

Based on the Table 4, the permeability for the concrete grade 30 have the highest permeability compared to grade 40, grade 50, and grade 60. Permeability for concrete grade 30 for 3 days, 7 days, 28 days and 56 days are 117.8ml/min, 100.9ml/min, 98.1ml/min, and 79ml/min respectively. The permeability for the concrete is decrease as the duration is increase.

The permeability for concrete grade 40 is decrease until 56 days that is for 3 days the permeability is 78.6ml/min, 7 days the permeability is 55.1ml/min, and for 28 days the permeability is 40.6ml/min. After 28 days until 56 days the permeability is decrease slowly that is at 28 days the result is 40.6ml/min and for 56 days is 31.9ml/min.

For grade 50, the permeability slope between day 3 and day 7 are higher. Its change from 63.4ml/min to 39.2ml/min. The slope then continue decreases to 33.7ml/min and 27.3ml/min for 28 and 56 day respectively.

Grade 60 has very low permeability compared to others. At third days the permeability is 57.8ml/min and then increase until 32.5ml/min for seventh days. After 7 days the permeability decrease until 28 days becomes 30ml/min and for 56 days the permeability is 22.4ml/min.

From the graph the permeability is decrease as the duration is increase. This is because permeability is durability of the concrete for the fluids to migrate through the hardened of the concrete mass. So, as the duration is higher more fluids are migrated through the concrete.

4.2 Correlation of Experimental Data Obtained

From the experimental results obtained from compressive strength test and UTP permeameter test, correlation among the data is performed to determine the reliability of the UTP air permeameter equipment.

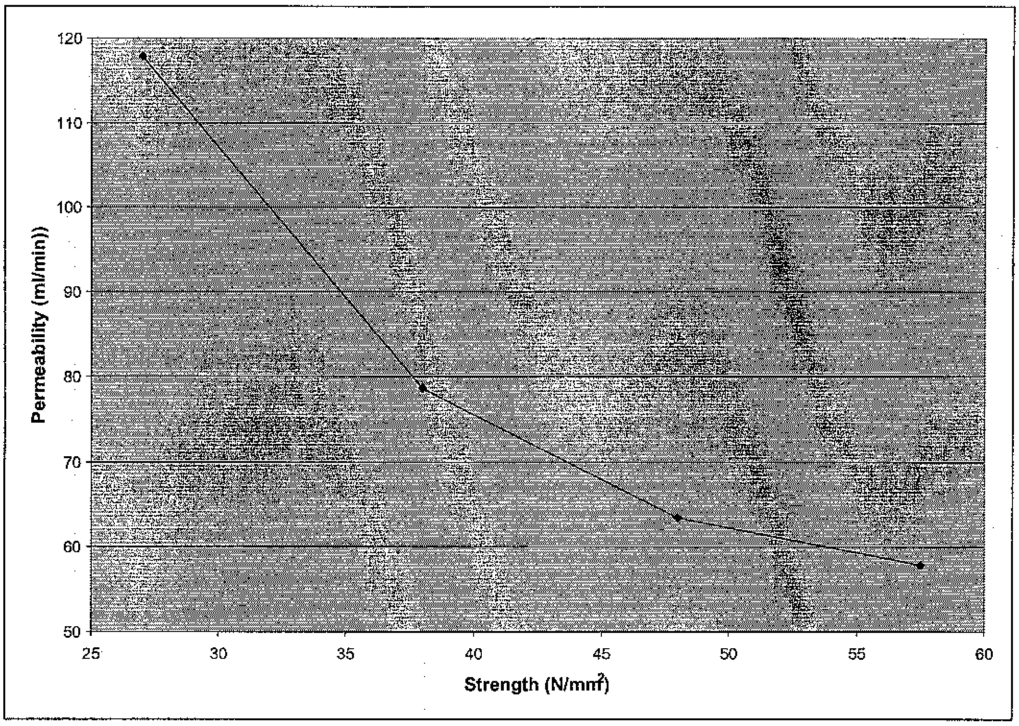


Figure 8: Graph of Permeability Vs Strength for Day 3

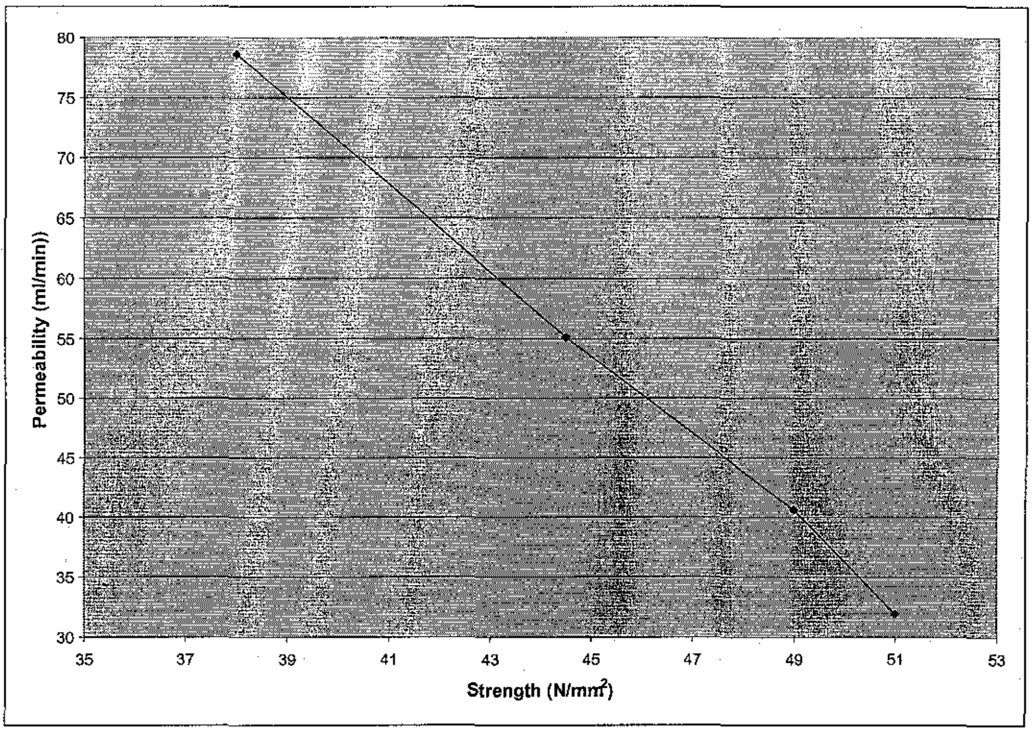


Figure 9: Graph of Permeability Vs Strength for Day 7

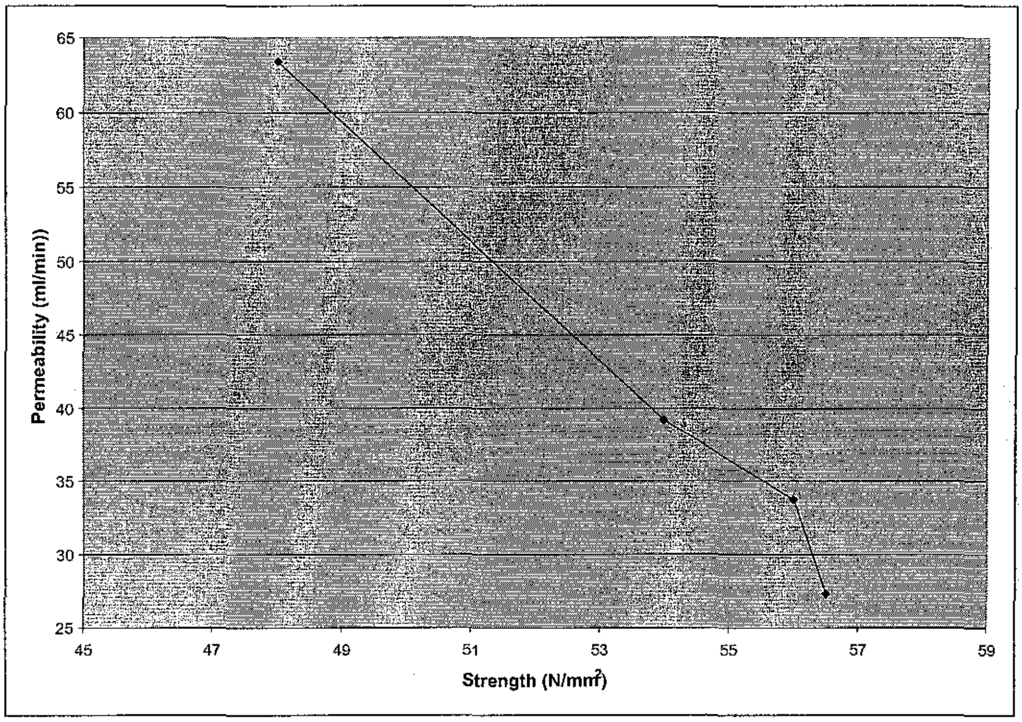


Figure 10: Graph of Permeability Vs Strength for Day 28

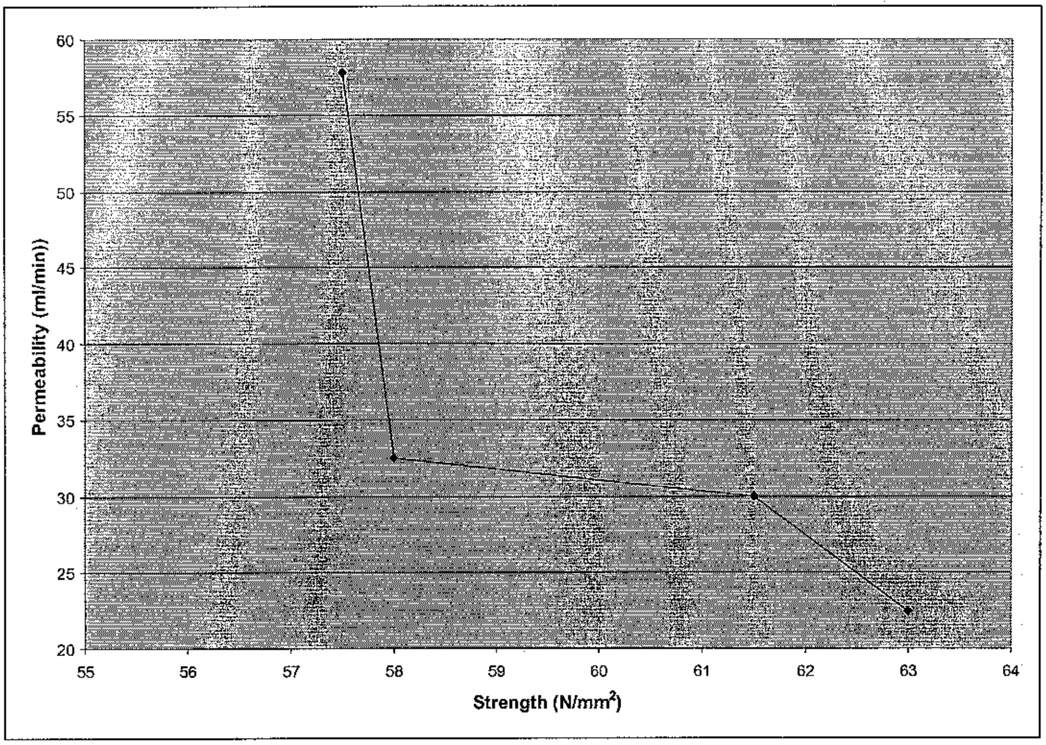


Figure 11: Graph of Permeability Vs Strength for Day 56

In Figure 9-11, the graph shows the permeability results versus strength for concrete sample. As mention earlier, the permeability will be inversely proportional with the strength. It shows that the data obtained are reliable. From the graph it can be observed that the permeability is inversely proportional with the strength of the concrete. As the permeability decreases, the strength increases.

The concrete samples are placed in curing tank to prevent the loss of water to achieve higher strengths at the end of the day. As a result, compressive strength of the concrete samples increases as the age of sample increases. However, the permeability decreases when compressive strength increases is because the pores in the concrete samples have been filled.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusions

From this exciting experiment of using the UTP Permeameter to indicate the reliability analysis of UTP Permeameter for concrete samples, the mixtures of the concrete are the same. The only different them is the water cement ratio.

Based on the results, following conclusions are drawn:

1. The strength of the concrete is increases as the concrete age's increases.
2. The strength inversely proportional to the water cement ratio. The lower the water cement ratio, the higher the strength will be.
3. The permeability decrease as the grade of the concrete increases.
4. Permeability also affected by the age of concrete. Its decrease as the days go by.
5. Although the result can't be compare with the result from the permeability standard test, we can see that the results are significant since the permeability is decreases as the age of the concrete increases.
6. UTP Permeameter can be used as a device to find a permeability of concrete samples.

5.2 Recommendation

Trough out the experiment, there are something that need to be improved in order to get a better result in a more affective way. Recommendations that should be considered are:

1. The technician has to make sure that all the devices and the basic things that were provided by the university in the concrete lab are enough. It is because; it will delay the work if suddenly the devices are not enough.

2. The design of the UTP Permeameter will be more effective if the entire six cells can be used at one time instead of using only one cell. It is because, there are lots of student wanted to do the experiment and each of the experiment will take more than couples of hour.

3. The testing devices provided in the concrete lab should be checked at all time. During the experiment, there are some test couldn't be done due to damaged apparatus. This will obviously effect the research operation.

4. Make sure that the student; throw away all the used concrete instead of leave it in the curing tank and there will be no space for the other student to curing their concrete. Hence, affect the result.

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Appendices

1. Compressive Strength Test

Table 1: Result for Compressive Strength Test (Concrete Grade 30)

Sample	3 days		7 days		28 days		56 days	
	stress	Max load	Stress	Max load	Stress	Max load	Stress	Max load
1	20.85	600.3	39.43	810.2	35.04	842.0	37.73	840.9
2	28.40	599.7	33.64	815.6	36.71	837.8	47.13	855.0
3	31.75	623.7	34.93	811.4	40.75	845.3	29.14	870
Average	27.0	607.9	36.0	812.4	37.5	841.7	38.0	855.3

Table 2: Result for Compressive Strength Test (Concrete Grade 40)

Sample	3 days		7 days		28 days		56 days	
	stress	Max load	Stress	Max load	Stress	Max load	Stress	Max load
1	38.07	840.0	44.19	998.9	47.58	1097.3	50.24	1149.0
2	36.33	855.8	43.37	1005.9	50.00	1104.1	49.72	1187.5
3	39.6	851.5	45.94	996.4	49.42	1099.2	53.04	1124.6
Average	38.0	849.1	44.5	1000.4	49.0	1100.2	51.0	1153.7

Table 3: Result for Compressive Strength Test (Concrete Grade 50)

Sample	3 days		7 days		28 days		56 days	
	stress	Max load	Stress	Max load	Stress	Max load	Stress	Max load
1	47.54	1097.3	54.03	1200.8	55.54	1268.5	56.5	1289.5
2	48.53	1104.1	53.95	1220.0	56.98	1300.6	57.78	1265.3
3	47.93	1099.2	54.02	1225.1	55.48	1201.3	55.22	1258.5
Average	48.0	1100.2	54.0	1215.3	56.0	1256.8	56.5	1271.1

Table 4: Result for Compressive Strength Test (Concrete Grade 60)

Sample	3 days		7 days		28 days		56 days	
	stress	Max load	Stress	Max load	Stress	Max load	Stress	Max load
1	57.19	1285.6	57.98	1304.3	61.0	1375.1	62.98	1400.8
2	56.86	1300.0	57.52	1313.7	62.11	1401.0	63.76	1457.0
3	58.46	1287.1	58.5	1312.6	61.39	1365.7	62.26	1403.4
Average	57.5	1290.9	58.0	1310.2	61.5	1380.6	63.0	1420.4

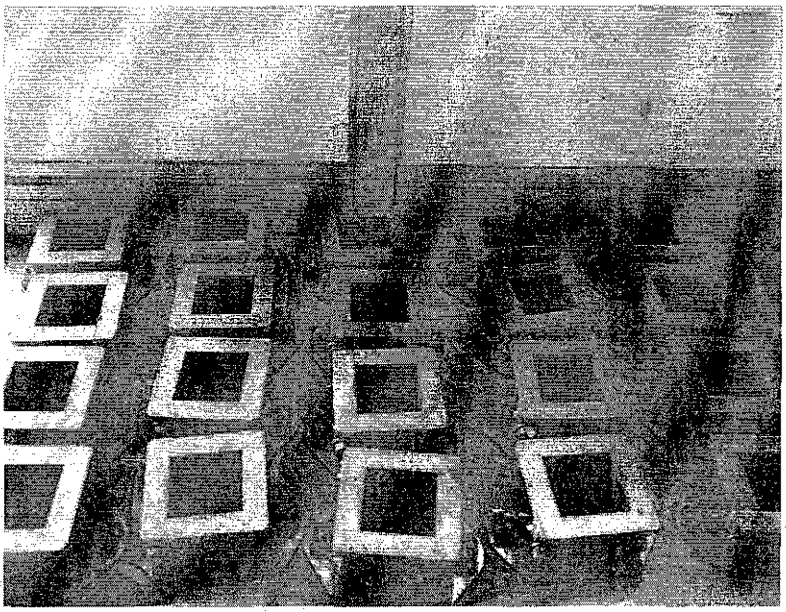

Figure 1: Mould for Concrete Casting (150mm x 150mm)

Figure 2: Concrete Mixer

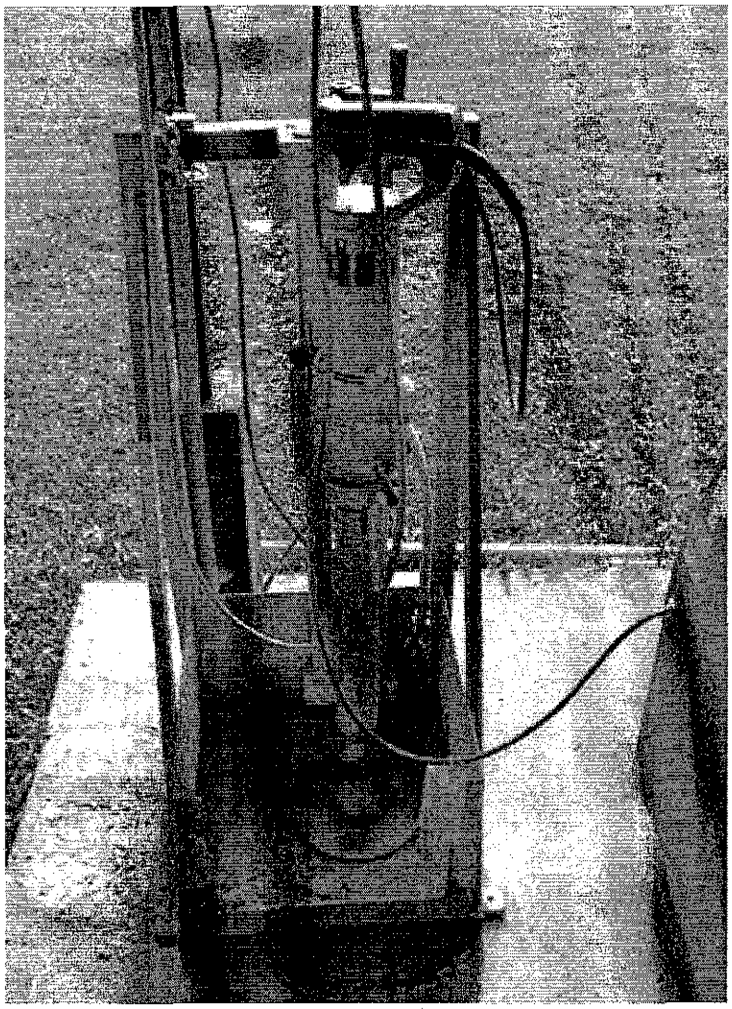

Figure 3: Coring Equipment