FLEXURAL BEHAVIOR OF REINFORCEMENT BEAM USING SLAB DECK PERMANENT FORMWORK

MUHAMMAD AMIR SUFI BIN SHUKRI

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Faculty of Civil Engineering and Earth Resources
UNIVERSITI MALAYSIA PAHANG

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ABSTRACT

The use of slab deck permanent formwork method in reinforcement beam construction will give an effect on thier strength referring to the bonding of interfacial between cast in situ concrete and permanent formwork. In addition this method will minimized the construction handling, transportation and the number of workers. This paper presents the experimental result of the static loading effect on the reinforcement beam slab deck permanent formwork. Two different thickness (50mm and 75mm) with different material such as SikaGrout and normal plain concrete were incorporated as slab deck permanent formwork in reinforcement beam and a solid reinforcement beam without slab deck permanent formwork as the control specimen. Five number of sample, with dimension 150mm x 200mm x 3000mm, were tested, two of different thickness Sikagrout and normal concrete slab deck permanent formwork and one solid beam as control beam. The beams were subjected to four point loading test until failure. The findings of the experiment been shown that the beam with 75mm of SikaGrout slab deck permanent formwork were improved the performance of the structure. The observation made suggested that reinforcement beam with 75mm thickness of SikaGrout slab deck permanent formwork gave the optimum performance of the reinforced beam structure.

ABSTRAK

Penggunaan kaedah papak dek acuan kekal dalam pembinaan rasuk bertetulang akan memberi kesan terhadap kekuatan struktur tersebut dengan merujuk terhadap ikatan antara muka acuan kekal dan konkrit tuang di tapak. Selain itu, kaedah ini dapat mengurangkan dalam pengendalian, pengangkutan dan bilangan pekerja dalam pembinaan. Laporan ini membentangkan keputusan ujikaji kesan beban yang dikenakan pada papak dek acuan kekal rasuk bertetulang. Dua ketebalan yang berbeza (50mm dan 75mm) dengan bahan yang berbeza seperti SikaGrout dan konkrit biasa telah digunakan sebagai papak dek acuan kekal dalam rasuk bertetulang dan rasuk bertetulang tanpa papak dek acuan kekal dijadikan sampel kawalan. Lima sampel, bersaiz 150mm lebar, 200mm dalam dan 3000mm panjang, diuji, setiap dua papak dek acuan kekal *SikaGrout* dan konkrit biasa dengan ketebalan yang berbeza dan satu rasuk sebagai sampel rasuk. Rasuk dikenakan empat ujian titik beben sehingga gagal. Hasil ujikaji menunjukkan rasuk dengan 75mm tebal papak dek acuan kekal *SikaGrout* telah menunjukan peningkatan dalam prestasi struktur. Pemerhatian yang dibuat menunjukkan bahawa rasuk bertetulang dengan ketebalan 75mm papak dek acuan tetap *SikaGrout* memberikan keupayaan yang optimum kepada struktur rasuk bertetulang.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

A beam is a structural member which spans horizontally between supports and to carry transverse loads such as a joist, girder, rafter, or purlin. In current construction, beams are usually made of steel, reinforced concrete, wood or composite, but most of the construction in Malaysia, reinforced concrete beams is the preferred choice struture. Nowadays, there are various methods use in construction of reinforced concrete beams in term of their weight, flextural strength, transverse load distribution, crack control and durabillity. One of the method is composite construction where using permanent formwork or slab deck method.

Permanent formwork is used to speed construction by removing the need for extensive formwork and falsework. Economies can be achieved by the use of composite construction where the formwork becomes an integral part of the completed structure. Sometimes permanent formwork is used in localities where it is difficult or impossible to remove the formwork. Beside, permanent formworks sometimes can contribution to the strength of the structure where permanent formwork is employed, the interfacial bonding between the cast concrete and the formwork are bond and act together as a single unit. Furthermore, as the formwork, damage during construction handling and transportation can be minimized.

This particular project focuses on behaviour of reinforcement concrete beam using flat slab dack as permanent formwork. To make the formwork, two different material such as sikagrout and normal plain concrete are employed. Besides, these permanent formworks

will specifically being designed for joist beam structure (150x200x3000) for the upper floor of the residential project.

1.2 PROBLEM STATEMENT

Construction of the structure for example beam, slab and column at the top level is not as easy as in thought, many of which it greatly contributed to the waste material usage and manpower. The problem occurs because worker need to allocate lots of cost for the pre casting the structure and using a heavy mechine to bring up the heavy structure to the upper level. This will spent a bulk of money on that. Besides, this kind of problem is not really significant with a big project.

One of the ways to overcome this kind of problem is through the application of permanent formwork. This will contribute lots of benefits towards the contractors and the environment itself. Generally, the application of the permanent formwork will minimized the construction handling, transportation and the number of workers needed for a upper construction project. But referring to the bonding of interfacial between cast in situ concrete and permanent formwork, it will give an effect on their strength of the beam. Therefore, an experimental test should be taken in order to identify the material use and the accurate thickness of the formwork that need to be consider and design.

The use of Sikagrout permanent formwork is hoped the units can act solely as permanent formwork. They may be designed for minimized the construction handling besides can maintain or gain the strength of reinforcement concrete beam.

1.3 OBJECTIVE OF STUDY

The objectives of the proposed Slab deck permanent formwork are listed as follows:

i. To determine the flexural strength of permanent formwork beam with different slab deck thickness and material used.
ii. To determine the deflection and crack pattern of permanent formwork concrete beam.

1.4 SCOPE OF STUDY

In this experimental study, the effect of sikagrout and normal plain conrete permanent formwork thickness of the beam where the flexural strentgh will be focused. Four beams with dimension of 200mm height, 150mm width and 3 meter span will be prepared. Solid beam without permanent formwork will be designated as a control parameter and beam with sikagrout permanent formwork (25% and 38% thickness) and normal plain concrete permanent formwork (25% and 28% thickness) will be designated as Beam 1, Beam 2, Beam 3 and Beam 4 respectively. The thickness permanent formwork for Beam 1, Beam 2, Beam 3 and Beam 4 is (150x50)mm (sikagrout), (150x75)mm (sikagrout), (150x50)mm (normal concrete) and (150x75)mm (normal concrete) respectively. Table 1.0 shows the details of the slab deck permanent formwork properties.

Material used for permanent formwork such as Sikagrout-215, Ordinary Portland Cement (OPC), sand, coarse aggregates, concrete reinforced bar and links bar will be used. A concrete of grade 30 and uncrushed coarse aggregate with maximum size of 20mm will be used. As for the reinforcement, reinforcement bar of size 12mm and shear link bar of size 8mm will be used. The reinforcement design used for the beam is 2T12 and for shear link reinforcement of H8-250

The beam samples will be tested for the flexural strength test to determine which beam will have the more flexural strength. Then, all of this sample beam also will be compare in term of deflection and crack pattern. The method chosen for this experiment is 4 point test for flexural test and Linear variable displacement transducer, LVDT will be fixed to observe the deflection of the beam. Figure 1.1 shows the details of 4 point test that needs to be done, referring to BS 1881-Part 118-83.

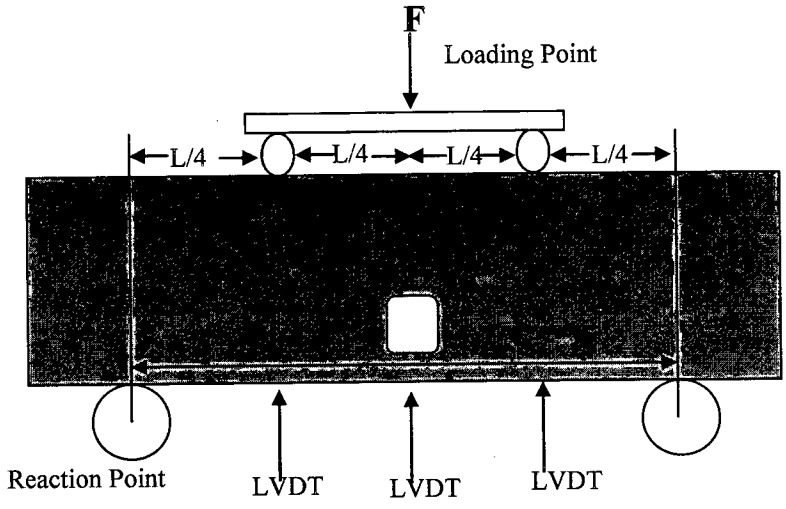

Figure 1.0: 4 point test

Table 1.0 : Slab deck permanent formwork properties

Beam	Deck Slab Material	Thickness (mm)	Bar Reinforcement	Link Reinforcement
Beam 1	-	-	2T12	H8-250
Beam 2	Normal Plain Concrete	150x50	2T12	H8-250
Beam 3	Normal Plain Concrete	150x75	2T12	H8-250
Beam 4	SikaGrout	150x50	2T12	H8-250
Beam 5	SikaGrout	150x75	2T12	H8-250

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

Beam are structural elements carrying external loads that cause bending moments, shear forces and torsional moments along their length. The beams can be singly or doubly reinforced and can be simply supported, fixed or continuous. The structural details of such beams must resist bending, diagonal tension, shear and torsion to transmit forces through a bond without causing internal cracking. The detailer must be able to optimize the behaviour of the beams under load.

Reinforced permanent formwork panels usually incorporate 55-75 mm thick precast concrete slabs with embedded reinforcement. An in-situ concrete topping acts compositely with the precast panels, resulting in a significant reduction in the weight of the slab and reducing the amount of in-situ concrete required. The system is frequently used in cantilevered balcony applications and imposes few restrictions on designers due to the flexibility in panel size.

2.1 COMPOSITE ACTION

In structural engineering, composite construction exists when two different materials are bond together so strongly that they act together as a single unit For permanent formwork method, "Adding in-situ concrete to precast formwork is one of terminology. Where the design makes specific allowance for interaction of the two

materials in order to increase the structural capacity of either concrete, this is composite action." (FIP, 1998)

In mixed construction in situ concrete is active with precast, but in structure performance of the precast is not necessarily increased. There is a fine dividing line between the two line. This is the same situation as the projects to be carried out in the concrete mix is mixed with slab deck permanent formwork where the materials used are SikaGrout. Permanent formwork that has reached its strength will be brought up to the top and the concrete will be poured into the mold. From there we can study the reaction between the two materials bond.

In the mixed of precast-in situ construction precast concrete is used supposedly as a "permanent horizontal formwork", either for beams or slabs. Spandrel, L or U-shape troughs cast in thickness of 30 to 100 mm may provide for the formwork.

2.2 DEFLECTION

There are important relation between applied load and stress there is flexural and shear and the amount of deformation or deflection that a beam can display. In design of beam, it is important to limit the deflection for specific load. So, in these situation, it is not enough only to design for the flexural strength and shearing stresses, but also for redundant deflection of beams.

The formwork should be able to resist the effects of concentrated loading due to reinforcement. For satisfactory performance of non-participating formwork at the ultimate limit state the following conditions should hold:- $R^* > 2S^*$, where R^* is the design resistance based on the characteristic strength of the formwork, fk and S^* is the design load effect due to the above nominal loads. In the case of participating permanent formwork the design requirements for precast concrete units with appropriate shear connection to the composite insitu concrete

Load testing should be carried out on site by the contractor to demonstrate the ability of the proposed permanent formwork to support the designed loading withouth above the deflection limit. Deflection of permanent formwork 4 hours after completion of concreting should not exceed 1/300 of the span of the formwork unit. In assessing deflection, allowance should be made where necessary for creep (BA 36/90 The Use of Permanent Formwork ,1991)

Al-Rifaie and Hassan (1911) presented the results of an experimental and theoretical study of the behavior of permanent formwork one-way bending elements. The results showed that this type of method can undergo large deflections before failure and is suitable for construction of horizontally spanning unit for one-way bending.

2.3 CRACK BEHAVIOUR

In general, cracking will occur in design reinforced concrete member even under service load. Tensile cracking develops when concrete with a limited capacity for elongation tends to deform with the tensile reinforcement through the bonding action. Mechanism of cracking is based on redistribution of concrete stress at crack formation that is compatible with observed internal and surface cracking.

There are several parameters for a permanent formwork, to ensure the constructed structure to be long life and durable. Firstly, it must be strong enough to carry the pressure that the fluid concrete can exert. Then, the strength of the permanent formwork must endure until the concrete is self-supporting. Solid rectangle beam can resist the cracking when the beam is design with applying the bar and link based on the load acted on the beam.

Without rebar, the concrete would be exceptionally susceptible to cracking. But in using a permanent formwork can reduce the amount of rebar that is necessary in a structure and in the same time it give the set concrete a high tensile strength. (Cavallari, 2003)

In the design of deck slabs incorporating non-participating permanent formwork, cover, cracks width must be calculated on the basis that the formwork is no present. Where corrugated or profilled sheeting is used which provieds a downward projection of the insitu concrete the calculated crack width at the lowest surface shall not exceed 0.5mm. (BS 5400: Part 5)

On the other hand according to Changli & Qian, (2010), all members made with permanent formwork showed significant debonding between the cast in situ concrete and formwork. When a flexural or shear crack is arrested by the formwork layer, the discrete crack becomes bridged at the bottom by the layer. When the shear stress overcomes the interfacial shear resistance, debonding occur as a shear crack propagating along the interface.

For the other context Sr. Lect., Dept. of Civ. Engrg., The Univ. of Adelaide, Australia they did the research inorder to determine the behavior of steel profiled sheets as permanent formwork to the sides of reinforced concrete beams. Based on the result, addition of profiled steel sheets to the sides of reinforced concrete beams can substantially increase both their flexural and shear strengths without loss of ductility and that this system is not prone to shear bond failure at the profiled-sheet and concrete beam interface.

2.4 THE ADVANTAGE OF PERMANENT FORMWORK

"Permanent formwork" is a term that refers to braces or molds that are put in place to contain concrete as it sets. Unlike other types of formwork that is removed after the concrete sets completely, permanent formwork is left in place as an additional support or stabilizer.

BS 5400: Part 5: 1979 classifies permanent formwork into two groups, there are participating and non-participating :

i. Participating formwork

Precast concrete units incorporating a welded lattice projecting into and providing shear connection with the overlying insitu concrete deck to form a composite deck slab.

ii. Non-participating formwork

Glass fibre reinforced cement (GRC) consisting of hydraulic mortars reinforced with alkali resistant glass is manufactured to give a range of sections designed to support various deck slab thicknesses and spans and manufacturers' catalogues show the commonly used sections.

The concrete and the formwork can bond more solidly through the corrugations, though the ridges will also provide enough flexibility that the likelihood of cracking is reduced. Cavallari (2003), state that one of the advantages to using permanent formwork becomes apparent when pouring concrete into the ground. Without a form, the concrete will seep into the soil, leading to excess waste of concrete.

Forms are used to prevent such waste, temporary formwork can be used to create the mold, but if permanent formwork is used instead, two distinct advantages become apparent. First, less digging will be involved if the forms are permanent, since extra space within the hole will be necessary to remove the temporary forms once the concrete sets. Second, leaving the formwork in the hole once the concrete is set creates an extra barrier between the moisture in the soil and the concrete that can be damaged by moisture freezing and thawing.

Furthemore, the permanent formwork is used in addition to rebar rather than in place of it, though using a permanent form can reduce the amount of rebar that is necessary in a structure. Rebar consists of steel bars that are placed within the void where the concrete will be poured to give the set concrete higher tensile strength. Without such rebar, the concrete would be exceptionally susceptible to cracking.

2.5 CURING REGIME

Concrete is the most used as a material in construction. The mix ingredient obtained by mixing cement, aggregate, sand and water in required proportions. The strength, durability and other characteristic of the concrete depend to the ingredients, proportion of mix, compaction and control during curing and placing.

Take a long time curing process can delay the advent of shrinkage but the effect of curing on magnitude of shrinkage is small. The greater the quantity of hydrated cement the smaller is the volume of unhydrated cement particles which restrain the shrinkage thus, take a long time curing could be expected to lead to greater shrinkage but hydrated cement paste contain less water becomes stronger with age and is able to attain a larger friction of its shringkage tendency without cracking. (Neville, 1995)

2.6 SIKAGROUT PROPERTIES

SikaGrout is a pumpable dual-shrinkage compensated, self-levelling, prebagged cementitious grout with extended working time to suit local ambient temperatures. SikaGrout, founded by Kaspar Winkler in 1910, is a globally active specialty chemical company headquartered in Baar, Switzerland manufacturing and supplying products.

SikaGrout has high ultimate strength and it is good bonding with concrete., SikaGrout is grouting material with excellent bond to concrete and high in compressive and tension strength gain in which one day curing sikagrout can gain their strength from 30-50 N/mm^2. (Concrete Product,2006). Table 2.7.1 has shows the relationship between strength and curing period (Sika Group,2010)

Table 2.7. : Relationship between strength and curing period

(Unfilled SikaGrout 215 Property)	**Age (days)**	**Consistency**		
		Flowable	Plastic	Dry Pack
Compressive Strength (N/mm^2)	1	34	46	54
	7	57	62	67
	28	66	71	76
Flexural Sterngth (N/mm^2)	1	5.8	6.8	8.4
	7	8.3	9.6	10.3
	28	10.2	11.9	12.4
Tensile Strength (N/mm^2)	1	2.6	3.4	3.6
	7	4.7	5.3	6.0
	28	5.4	6.2	6.9

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this chapter will elaborate on the detail in design the reinforcement beam using slab deck permanent formwork. This design mostly conducted at Concrete Laboratory in UMP. Details of the test set up and the procedure of testing are explained. Figure 3.1 shown the work progress for this experiment.

3.2 FLOW CHART

Figure 3.1 shows the work progress for this study:

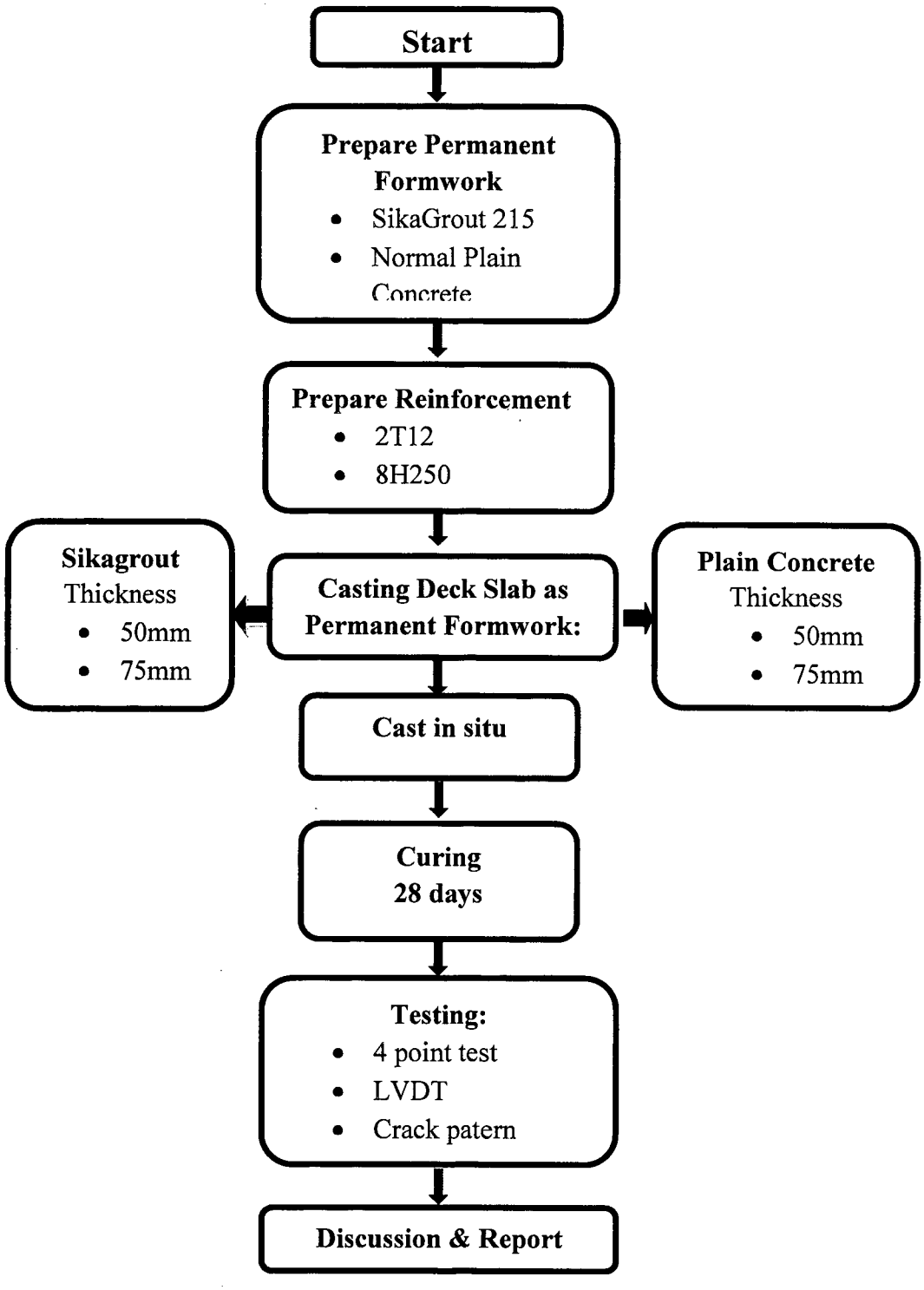

Figure 3.1 : Work progress

3.3 RAW MATERIAL

Raw materials listed below were used for preparation of the sample:

i. SikaGrout 215
ii. Ordinary Portland Cement (OPC)
iii. Crushed Coarse Aggregate with 20mm maximum size
iv. Crushed Sand
v. Steel Reinforcement:
   - High Yield main bar
   - Mid steel shear reinforcement
vi. Plywood and timber for prepare formwork

In this experiment, five numbers of sample were cast. As a control beam, the sample was cast without slab deck premanent formwork. Another four sample was with different thickness and meterial of slab deck permanent formwork Size beam are 150mm in with by 200 in depth and 3000mm length.

3.3.1 Preparation of Formwork For Slab Deck Permanent Formwork

In this experiment, 4 formwork of slab deck was prepared as a permanent formwork. There two different thickness which is 50mm and 75mm. Using two different thickness for the permanent fomrwork is to identidy which thickness is suitable for act as permanent foormwork. Figure 3.2 (a-d), shows the preparation of formwork.

3.3.2 High Yield Main Bar and Mild Steel Bar

For each sample, two numbers of high yield bars of 12mm diameter are used as tension bars and 8mm mild steel bars as compression bars. In order to control shear stresses in the concrete beam, mild steel stirrups with size 8mm diameter have provided. The preparation of reinforcement bar and reinforcement detail are shown in Figure 3.3 and Figure 3.4 .

3.3.3 Preparation of SikaGrout 215 as Permanent Formwork

SikaGrout 215 has prepared with adding water by determination of the water requirement per 25 kg bag. The mixing was mix for at least 3 minutes until a uniform, lump-free consistency is obtained. Figure 3.5 (a-b) shows the Sikagrout 215 and Figure 3.6 (a-d) shows the preparation of SikaGraout slab deck permanent formwork

3.3.4 Preparation of Normal Plain Concrete as Permanent Formwork

Materials used in this concrete mix design is cement, fine aggregate and coarse aggregates with maximum size of 20mm. In this project, Ordinary Portland cement (OPC) was used in the concrete mix. It is selected for this research is based on extensive use in the field the construction. This is because this type of cement is very suitable for concrete work during hardening process.

Fine aggregate used is based on the specification of sand grading process. Fine aggregate used consisted of non-ground types. UMP concrete laboratory was already provided the sand which is sieved to selecting size and category of the fine aggregate.

In this experiment, the maximum size of coarse aggregate size needed is 20 mm Then, the aggregate will weighed and placed at dry place for drying process in laboratory. This is important to ensure that the aggregates that are free from free water content that will affect the strength of concrete. Therefore, the aggregates also must be free from any impurities that may affect the strength and workability of concrete.

Water used for mixing concrete is tap water because tap water is not polluted or contains any substance than can affect the chemical reaction between water and cement in order to achieve a cementing property. Figure 3.7 (a-b) show the preparation of NPC slab deck permanent formwork