An Assessment Of Time Variation In
Solid And Hollow Floor Construction
In Lagos State

Olumide Afolarin Adenuga
Department of Building,
Faculty of Environmental Sciences
University of Lagos, Lagos Nigeria
oaadenuga@yahoo.com

Gboyega Sotunbo
Department of Building,
Faculty of Environmental Sciences
University of Lagos, Lagos Nigeria
oaadenuga@yahoo.com

The choice of construction method employed for constructing suspended slabs in buildings tend to impact significantly on the delivery time of building project. Thus, this study aims at assessing the impact of various construction methods on duration for constructing hollow and solid floor slabs in buildings in Lagos State, Nigeria. The research design for this study was a survey design approach and the populations of the study were professionals involved in construction projects; Architects, Civil Engineers, Builders, Quantity Surveyors, Building Services Consultant and Contractors. These are the major participants in the construction industry in Lagos State, Nigeria. The analysis is based on 46 (forty-six) returned questionnaires out of the 60 (Sixty) questionnaires administered. The data from the questionnaires were analyzed using descriptive statistics tools such as frequency, percentage mean ranking while the hypothesis were tested with a paired sample t-test tool. It was found that the systems or methods of slab construction well known to the respondents are cast in situ, precast and semi-precast. The Cast in-situ beam and slab construction ranked as the most frequently adopted method followed by flat slab, hollow slab clay pot and waffle slab construction. In terms of construction time, placing reinforcement and construction of formwork takes more time than other processes in solid slab construction while in construction of reinforced cast in situ concrete hollow slab; formwork construction, placing hollow bricks or blocks or moulds on formwork and curing concrete takes more time than the other processes involved. The study’s major recommendation is that, adequate and careful analysis should be conducted before taking a decision on the choice of floor system been adopted for any project.

Keywords
Reinforced Concrete, Solid Slabs, Hollow Slab, Time Variation and Project Delivery
Background to the study

Building designs and constructions could be dated back to the existence of man on earth, and over the years, various designs and construction methods have evolved. These evolutions have led to the newest or modern designs and construction methods of various components or elements of a building; such as floors, wall, ceilings and roofs. For instance, the design and construction of floor slabs are usually solid, adequately reinforced in 2-direction and concreted. The construction of these slabs usually requires much formwork, high number of reinforcement provided in both ways (top and bottom) and high volume of concrete which resulted in an ample time or duration of construction. But over the recent decades, engineering researches have brought forth new designs that have led to new construction methods of floor slabs. These modern designs now give birth to entirely new construction methods that totally differ from the traditional way of constructing a solid slab. Hollow floor slabs, a product of modern designs, now require less reinforcement, less formwork and less concrete as a result of the holes, space, foams and balls that are incorporated in the slab. These now require a different method of on-site construction of such slabs to achieve its design which could enhance time savings during construction. Lai (2010) attested to the fact that holes or voids, which are created in the floors replaces the ineffective concrete in the neutral zone of the slab, thereby decreasing the dead weight and increasing the efficiency of the slab. Thus, voids or holes are formed within the slab system. These also give a significant advantage over the conventional solid slabs in terms of reduced material usage (reinforcement and concrete), reduced cost, enhance structural efficiency, decrease construction time and it is a new technology in the construction industry. In either way, floor slabs could be fabricated off-site (as pre-fabricated or pre-cast) and just brought to site for assemblage. The eventual on-site assemblage of these slabs will require newer technology and methods different from the entire on-site cast in-situ construction with construction time variation. Lutz (2002) investigated hollow floors from the aspect of pre-fabrication. In this method, the floor is manufactured or prefabricated from the factory and just brought to site for assemblage through anchorage. One of the advantages of this method is the delivery in time which cannot be compared to the in-situ construction. Hence, the variations in the duration of construction of these structures cannot be under rated. The variance in these two types of floor system could be linked to their method of construction or installation. Therefore, the objectives of the study are to identify the construction methods of hollow and solid floor slabs in construction projects in Lagos State and determine the variation in the time of production of the two floor systems.

Types Of Concrete Floor Systems

Cast In-situ Floor Systems

This class of concrete floor system entails physically constructing the floor slab by mixing, casting in between formwork and hardening of concrete on site. Cast in-situ reinforced concrete structures consist of horizontal elements (beams and floors) and vertical elements (columns and walls) connected by rigid joints. Cast in-situ floor system could be subdivided into monolithic (solid) reinforced in-situ floor slabs and monolithic hollow (ribbed) floor slabs.

Pre-cast Floor System

Pre-casting offers the advantages of off-site manufactured under factory conditions and fast erection on site. When combined with pre-stressing, additional benefits of long span and high load-capacity can be obtained. The precast floor elements are usually simply supported before a topping concrete is placed to complete the system. Pre-cast floor systems are produced to specification and are all in modulus (CCAA, 2010). Pre cast floor system could be subdivided into pre cast solid reinforced slabs and hollow core (Pre cast or Pre stressed).

Construction Methods Of Cast In-Situ Floor System

Generally, the on-site construction method of any cast in-situ floor slabs could be summarized as follows: Construction of formwork, placing of reinforcements, Pouring of concrete or casting and removal of formwork (Rupasinghe & Nolan, 2007); under these four steps, the construction process of monolithic solid slab and hollow clay pot slab will be examined.

Monolithic Solid Slab Construction

Monolithic reinforced solid slabs are slabs which are constructed on-site as a unit with fresh concrete. Below is the construction process of a monolithic reinforced slab.

Formwork construction

Formwork was described as a structure, usually temporary, used to contain poured concrete to mould it to the required dimensions and support until it is able to support itself. It consists primarily of the face contact material (platform) and the bearers that directly support the face (prop) contact material (Rupasinghe & Nolan, 2007). Lightweight horizontal panel formwork systems used for slab construction generally consist of a series of interconnected falsework bays, independent props or system scaffolds and supporting pre-formed decking panels. These can include primary beams spanning between props and supporting a number of panels.
Placing of reinforcement
CCAA (2010) opined that the placement of reinforcement at strategic locations ensures great flexibility during the design and construction stages in situ concrete construction. Bimel and Tipping (1997) stated that deformed bars, bar mats, or welded wire reinforcement usually are required in suspended structural floors as part of the structural design. Reinforcements are used to strengthen concrete for tension forces in structures as concrete is weak in tension but strong in compression (Rwamamara, Simonsson, & Ojanen, 2010). Reinforcements are often delivered to sites in tonnes of standard length in Nigeria and are later cut into pieces of required length. The pieces are then laid or placed on the form work, in required or calculated spaces and then fixed together by an experienced iron fixer (bender) with a binding wire, in its final location or position. Rwamamara et al (2010) agreed with CCAA (2010) that the placement of reinforcement on the formwork on-site gives a great advantage of flexibility on site during placement. Generally, (BS 8110, 1997) the sizes of reinforcement used on sites varies from 12mm – 25mm diameter, depending on the maximum moment to resist, and the spaces between each bars varies from 150mm – 250mm.

After placement of reinforcement, concrete spacers are used to maintain a good space between the formwork and the bars to give a cover of at least 20mm. this is done to prevent the bars against moisture attack and enhance fire resistance. In solid slab construction, reinforcements are provided in both directions as shown above, except for one way solid slab that has its reinforcement in just one direction. The provision of reinforcement in two ways in a solid slab is the aspect that affects delivery time.

Pouring or casting of concrete
Floor concrete requirement differ from those of other concrete used in the structure. Concrete is made up of cement, aggregate (sand, granite-19-25mm) and potable water. In addition to meeting structural requirements, concrete for floors should provide adequate workability, durability and strength necessary to obtain the required finish and floor surface profile (Bimel et al, 1997). Concrete for floors, usually of mix 1:2:4-15mm is used on site. This batch is either mixed by hand or by machine (mixer). A thorough mix is required to attain a required consistency and workability. In a situation where labours are used in placing the concrete, the labours placed the mixed concrete through head pans carefully over the fixed reinforcements and then vibrated to prevent any event void. The concrete is tapped to compact and give an even surface. The placed concrete is allowed to set for at least 28 days with constant curing to attain its workable strength.

In a situation where truck mixer is used to mix and pneumatic concrete pump or crane with bucket is used to discharge in position, the concrete is pumped from the mixed truck through the pneumatic pump or carried through a bucket attached to a crane, up to the point of discharge and then discharged. Skilled masons immediately spread the concrete into position, tapped, compacted and finished to requirement. The floor is then left for 28 days to attain its self-supportive strength before the formwork is removed. The thickness of the slab according to BS8110 (1997) is between 150 – 300mm depending on the design.

Removal of the formwork
After the concrete floor has attained its 28 days strength or more, the formwork can then be struck off carefully by skilled carpenters. BS8110 (1997) suggested that formwork should be removed without shock, as the sudden removal of wedges is equivalent to an impact load on the partially hardened concrete. The code suggested also that formwork should not be removed or struck off the suffix of the slab earlier than 28 days.

Construction of Monolithic Hollow Clay Pot Slab
Hollow (Ribbed) floors are floors economically designed and constructed using hollow blocks, removable foams or permanent voids former such as clay pots. This type of floors have reduced self weight compared to the solid slabs. This is due to the fact that some of the concrete in the neutral zone are removed. Ribbed slab are very adaptable for accommodating a range of service openings. The methods of hollow clay pot construction are as follows: Construction or Laying of formwork, Placing of pots, Placing of reinforcements, Pouring of concrete or casting and Removal of formwork.

Construction of formwork
Formwork as described by Rupasinghe and Nolan (2007) as a structure, usually temporary, used to contain poured concrete to mould it to the required dimensions and support until it is able to support itself. It consists primarily of the face contact material (platform) and the bearers that directly support the face (prop) contact material. Lightweight horizontal panel formwork systems used for slab construction generally consist of a series of interconnected false work bays, independent props or system scaffolds and supporting pre-formed decking panels. These can include primary beams spanning between props and supporting a number of panels. This is similar to the solid concrete slab formwork.

The constructions of the formwork for hollow clay pot slabs are usually done in two ways. These are;

1. Constructing or laying the formwork to cover the whole area of the floor slab and then the pots laid on them.
2. Constructing or laying the formwork just directly under the ribs of the pot. This form is actually the type that affects the time for formwork.
Placing of the clay pots
After the formwork is set, next is the placing of the hollow clay pots. There are various types of pots available for use, depending on the structural design. The product varies from standard classic pots of size 400 x 200 x 250mm and so on. The pots, when delivered to site must be stacked properly before use. In the event of laying the pots, they must be carefully laid, head to head along the shorter direction as shown in the pictures below. The edged pots must be sealed with cement and sand mortar to prevent the concrete filling the hole. Pots laid parallel to one another forms the rib in between them to receive reinforcement and concrete. The rib formed could be between 100mm - 150mm wide, thickness of topping between 50mm – 170mm (BS8110, 1997). In any case where it will require that the pot be cut into two at the side of the beam or where it will go into the beam, the pot is completely removed and the portion of the slab is designed and cast as solid slab. In placing the pots, breakages must be avoided because breakages of these pots will reduces the structural characteristics of the entire slab after casting. Usually, after laying the pots service pipe are laid and fixed in position through the pots or ribs.

Placing of reinforcements
Bimel, et al (1997) stated that deformed bars, bar mats, or welded wire reinforcement usually are required in suspended structural floors as part of the structural design. Reinforcements are used to strengthen concrete for tension forces in structures as concrete is weak in tension but strong in compression (Rwamamara et al, 2010). Reinforcements are often delivered to sites in tonnes of standard length in Nigeria and are later cut into pieces of required length. The ribs usually require two pieces of reinforcement (bottom) and may be one at the top to complete a triangular stirrups section.

In design, the top reinforcements are usually eliminated and the stirrups shaped in U-form to be hanged on the pots. This is due to the fact that the top bars serve no purpose so it is eliminated. Unlike the solid slabs which are reinforced in both directions, ribbed slabs of hollow clay pot are reinforced just in one direction of the rib. This, apart from the less form work, reduces construction period due to the reduction in reinforcement. Generally, (BS 8110, 1997) the size of reinforcement used on sites varies from 10mm – 16mm diameter, depending on the maximum moment to resist.

After placement of reinforcement, concrete spacers are used to maintain a good space between the formwork and the bars in the ribs to give a cover of at least 20mm. This is done to prevent the bars against moisture attack and enhance fire resistance. In topping, no serious reinforcement is required according to BS8110 (1997), but wire mesh is usually provided to prevent cracks. Considering the cost of a standard wire mesh, 6mm mild steel bar are provided over the pots as mesh to resist cracks in the thin 50 -75mm topping. If 6mm diameter bars are used, the centre to centre space must not be greater than 300mm (usually, 150-200mm spacing are used on site). This is to ensure that it lies within the top of the pots and not protrude through the spacing.

Casting of Concrete
Before casting, the deck must be kept clean of any materials on the pots and ribs, and the surface must be wet to prevent sudden drying of the topping which could lead to cracking. Concrete for this type of floors are usually of mix 1:2:4-19mm. This batch is machine mixed. A thorough mix is required to attain a required consistency and workability. In a situation where labours are used in placing the concrete, the labours placed the mixed concrete through head pans carefully in the ribs and over the pots. The rib must be vibrated to prevent any event void in it. The concrete is tapped to compact and give an even surface.

In another situation where truck mixer is used to mix and pneumatic concrete pump or crane with bucket is used to discharge in position. The concrete is pumped from the mixed truck through the pneumatic pump or carried through a bucket attached to a crane, up to the point of discharge and then discharged. Skilled masons immediately spread the concrete into position, vibrated, tapped, compacted and finished to requirement. The supervisor must ensure that the mesh is well embedded in the concrete to avoid exposure. During casting, continual check must be carried out on the prop to ensure that nothing has moved or sagged, as problems can only be rectified within half an hour of placing the concrete over the affected area. This is to ensure adequate prevention against deflection during casting. The floor is then left and cured for 28 days to attain its self-supportive strength before the formwork is removed. The total depth of the slab according to BS8110 (1997) depends on the design which is a factor of the height of pot used and of topping.

Removal of formwork
After the concrete floor has attained its 28 days strength or more, the formwork can then be struck off carefully by skilled carpenters. BS8110 (1997) suggested that formwork should be removed without shock, as the sudden removal of wedges is equivalent to an impact load on the partially hardened concrete. The code suggested also that formwork should not be removed or struck off the suffix of the slab earlier than 28 days.

Pre-cast or Prefabricated Floor Slabs
Traditional cast-in-situ concrete floor systems involve the use of temporary shuttering which adds to the cost of
construction and time. Use of standardized and optimized precast floor components where shuttering is avoided can prove to be economical, fast and better in quality. Some of the prefabricated flooring components available but not limited to, are: precast Reinforced Concrete slabs/ planks and precast hollow concrete panels.

Pre-cast Hollow Concrete Slab
Hollow core floor planks (slabs) are precast, prestressed units produced on long-line casting beds using slide forming or extrusion methods. During manufacturing, cores are formed throughout the length of the unit, reducing its self-weight. Planks or slabs are usually 1200-mm-wide, though it could be produce 2400-mm-wide units. These wider units may require increased crane capacity but offer greater speed of placement, less joints, grouting and sealing. Thicknesses of slabs vary from 150–400 mm in 50-mm increments. The thickness is determined by span, loading, fire rating and cover to reinforcement to satisfy exposure conditions. The economical typical span for a precast hollow core unit is approximately 0 x 30 to 0 x 35 where 0 is the depth of the precast unit plus topping. Where slenderness ratios fall between 35:1 and 45:1, panels should be checked for vibration-resonance effects. Spans exceeding 45:1 should not be used. Planks may be used as plain sections or topped to give a composite unit. The topping increases plank capacity and fire rating. It provides a level surface or drainage falls and is recommended for most building work. For economy, the structure should be dimensioned to accommodate the 1200- or 2400-mm modular plank width (CCAA, 2003).

Lai (2010) attested to the fact that holes or voids which are created in the floors replace the ineffective concrete in the neutral zone of the slab, thereby decreasing the dead weight and increasing the efficiency of the slab. For instance, in the clay pot slab construction, the neutral zone of the concrete is replaced with the hollow clay pots while in the case of hollow slabs, the concrete in the neutral zone are removed without replacing it with any other materials. Thus, voids or holes are formed within the slab system. These also give a significant advantage over the conventional solid slabs in terms of reduced material usage (reinforcement and concrete), reduced cost, enhance structural efficiency, decrease construction time and it is a new technology in the construction industry. Lutz (2002) investigated hollow floors from the aspect of prefabrication. In this method, the floor is manufactured or prefabricated from the factory and just brought to site for assemblage through anchorage. The advantage of this method in material saving, good quality control, and delivery in time and within cost, can not be compared to the in-situ construction.

Hollow floors, which could also be called hollow core slabs can be used for most applications requiring a floor system in Office buildings, auditoriums, hotels, commercial buildings, residential dwellings, houses of worship, nursing homes and educational facilities, are all ideal applications. This is because of the advantage it gives in large span and of course its aesthetics cannot be compared to that of the solid slabs. In either way, floor slabs could be fabricated off-site (as pre-fabricated or pre-cast) and just brought to site for assemblage. The eventual on-site assemblage of these slabs will require newer technology and methods different from the entire on-site construction. Floors, which is a component part of a building was major course of the study.

Construction Period Comparison Between Hollow Slabs And Solid Slabs System
Kadir, (2006) discovered that significant difference occur between in-situ slab construction and precast system up to about 76 per cent, with respect to delivery time. From these results, it could be concluded that the difference in actual labour productivity between conventional and precast system mainly contributed by the cycle time (difference of 76 per cent) rather than the crew size (difference of 18 per cent). Shorter cycle time implies that total project construction time would also be reduced, hence minimizing management overhead and meaning that owners can occupy their house earlier. Visser, (2009) discovered that waffle moulds or precast brick result into additional time of construction for in situ hollow slabs due to the placement of forms on slab formwork, erection time amounts to the time it takes to construct a flat slab, with the additional time of moulds placement. Fixing of reinforcement between forms can also prove to be a more time consuming task. The fixing of steel reinforcement in between and on top of the moulds or bricks is also more strenuous than that of the flat surface and proves to be more labour intensive. Thus, the construction period for in-situ hollow slabs may be higher than that of solid slabs due to the placement of moulds or bricks to form the hole on site. Basri, (2008) Captured in the study of construction period as one of the critical factor in the choice of a slab system that, 83% of the respondents agreed that precast construction would result to faster completion of projects. In this survey, 100% of the projects were either completed in the same period of time as conventional construction; or even faster. 26% of the projects cut the 83% construction time while 52% recorded an astonishing savings in time. Of cause, it is logical to note that the off-site production of the floor system has reduced greatly the on-site time required for construction. Because on-site activities are only left with hoisting, placing and finishes which takes less time and less work force. It then clearly showed that the reduction in construction time is the most obvious benefit of precast system of slab constructions.
**Research Method**

The study was carried out in Lagos State, Nigeria. Lagos State is situated in the South Western part of Nigeria. Lagos state was chosen as a result of the large number of construction works going on in the state. The populations for this study are Architects, Civil Engineers, Builders, Quantity Surveyors, Consultant and Contractors who are major participant in the construction activities in the construction industry in Lagos State. The research design for this study is a survey design approach (quantitative) through which data were collected. Survey design approach was adopted because this will give varying opinions on the subject by different professional respondents which would be of great influence on the analysis. The primary data were collected through the administration of structured questionnaire and site visitation while the secondary data were gathered from the review of past projects, journals, conference proceedings articles and the internet.

A total number of 60 (sixty) questionnaires were distributed which represent 100% for the study. In all, a total of 46 questionnaires were returned which represent 76.7% and 14 questionnaires were not returned which represent 23.3% of the total 100%. Since the 46 returned questionnaires represent over 75% (i.e. 76.7%) of the total distributed, the sample size for the research was set at 46 (forty-six) based on the returned questionnaire. The sample frame for the study therefore contain 27 (twenty-seven) Civil Engineers, 14 (fourteen) Quantity Surveyors and 4 (four) Builders to make a total of 46 respondents. The sampling technique for this study was non-probabilistic, specifically convenience sampling technique. This was adopted to source for the required information for the study of the Nigeria construction industry. It was observed that beam and slab construction is used very often by all the respondents as it pulled a mean value of 3.96 and ranked 1st among other systems. Flat slab followed closely with a mean value of 3.65 and ranked 2nd. Hollow clay pot slab construction was fairly used as it ranked 3rd with a mean value of 3.24 while waffle, another type of floor was only said to be least used as it ranked 4th with a mean value of 2.39. This shows vividly that most respondents used very often in construction, cast in situ beam and slab, flat slab and hollow slab while hollow block and waffle are rarely used in construction.

Of the pre-cast, the table above shows that precast beam and slab construction is used very often in construction as it is ranked 1st with a mean value of 3.37 among the precast group. Precast flat slab which ranked 2nd with a mean value of 3.17 has a low usage level compared to precast beam and slab while pre-cast hollow clay pot slab and precast waffle slab construction are not frequently used or are not even used at all in the construction industry. It thus shows obviously that most respondents only know about precast beam and slab, flat slab and hollow slab construction but knows next to nothing about pre-cast waffle. The table also revealed a trend that cast in-situ method of slab construction has a high level of usage than precast method.

**Level of usage of floor systems**

The analysis of the level of usage of different types of floor system are shown in Table 2 above. Cast in situ and pre cast were considered. Of the cast in situ, it was observed that beam and slab construction is used very often by all the respondents as it pulled a mean value of 3.96 and ranked 1st among other systems. Flat slab followed closely with a mean value of 3.65 and ranked 2nd. Hollow clay pot slab construction was fairly used as it ranked 3rd with a mean value of 3.24 while waffle, another type of floor was only said to be least used as it ranked 4th with a mean value of 2.39. This shows vividly that most respondents used very often in construction, cast in situ beam and slab, flat slab and hollow slab while hollow block and waffle are rarely used in construction.

Of the pre-cast, the table above shows that precast beam and slab construction is used very often in construction as it is ranked 1st with a mean value of 3.37 among the precast group. Precast flat slab which ranked 2nd with a mean value of 3.17 has a low usage level compared to precast beam and slab while pre-cast hollow clay pot slab and precast waffle slab construction are not frequently used or are not even used at all in the construction industry. It thus shows obviously that most respondents only know about precast beam and slab, flat slab and hollow slab construction but knows next to nothing about pre-cast waffle. The table also revealed a trend that cast in-situ method of slab construction has a high level of usage than precast method.

**Data analysis and findings**

Table 1 above described the responses of the respondents on the various methods of floor construction known to the respondents. It was observed from the study that cast in-situ method of slab construction is well known to almost all the respondents with a mean value of 3.93 and ranked 1st, while precast and semi-precast followed with mean value of 3.43 and 2.63 and are ranked 2nd and 3rd respectively among the known methods of slab construction in Nigeria construction industry. This could be as a result of the technological development of the Nigeria construction industry. Contractors are more knowledgeable on cast in-situ because it is more of labour based and less of plant based, but other methods like pre cast are more of technology and plant based that cast in situ.

**Construction methods used for solid and hollow floors**

<table>
<thead>
<tr>
<th>Construction method</th>
<th>Mean Value</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast in-situ</td>
<td>3.93</td>
<td>1</td>
</tr>
<tr>
<td>Precast/ prefabricated</td>
<td>3.43</td>
<td>2</td>
</tr>
<tr>
<td>Semi precast</td>
<td>2.63</td>
<td>3</td>
</tr>
</tbody>
</table>

Note: Well Known = 4, Known = 3, Fairly Known = 2, Not Known = 1, No Response = 0, Percentage = % and Total Number of Respondents = N

Table 1. Construction methods used for solid and hollow floors

**Difference in construction period**

The result of the level of time required in construction process of reinforced hollow concrete slab and reinforced solid concrete slab are tabulated in...
Table 2. Level of Usage of types of floor slab by the respondents

Table 3 below. The table has four sections which are cast in situ solid slab, cast in situ hollow slab, precast solid slab and precast hollow slab. On the process of construction of reinforced cast in situ concrete solid slab, time required to place reinforcements, time required for formwork construction and the time required for the concrete to cure with mean value of 3.93, 3.72 and 3.22 are the three highest mean values and ranked 1st, 2nd and 3rd respectively. While the required time to place concrete and the time required to strike-off formwork with mean value of 3.15 and 2.78 are the two least mean values and are ranked 4th and 5th respectively. It thus, means that placing reinforcement and construction of formwork takes more time than other process in solid slab construction process or method. On the process of construction of reinforced cast in situ concrete hollow slab, time required for formwork construction, time required to place hollow bricks or blocks or moulds on formwork and time required to cure concrete with mean value of 3.70, 3.46 and 3.24 are the three highest mean values and ranked 1st, 2nd and 3rd respectively. While time required in lay reinforcement in ribs, required time to place concrete and the time required strike-off formwork with mean value of 3.15, 2.97 and 2.74 are the three least mean values and are ranked 4th, 5th and 6th respectively. It then implies that formwork construction, placing hollow bricks or mould on formwork and curing takes more time than other process in hollow slab construction process or method.

Precast concrete slab have a different construction method or process from what is obtained in cast in situ. Here, the units are manufacturer off site and brought to site for erection. Table 3 below also shows various time required for various process of precast slab construction. On precast solid slab, time required for off-site fabrication of units and transportation of units to site with mean value of 3.52 and 3.33 are the two highest mean and are ranked 1st and 2nd respectively while the time required in erecting and placing units in position, and time required in grouting and casting toppings with mean value of 3.28 and 3.09 are least as they are ranked 3rd and 4th respectively. On precast hollow core/hollow slab, time required for off-site fabrication of units and transportation of units to site with mean value of 3.48 and 3.26 are the two highest mean and are ranked 1st and 2nd respectively while the time required in erecting and placing units in position, and time required in grouting and casting toppings with mean value of 2.98 and 2.76 are least as they are ranked 3rd and 4th respectively.

Duration of construction process of slabs

Table 4 shows the result of response of the respondents on duration of cast in situ hollow slab to solid slab and cast in situ to precast slabs. Majority of the respondent affirms that duration or time of construction of cast in situ hollow slab is higher than that of solid slab (36 respondents) while just only 10 respondents affirm that the construction duration is lower. In the same vein, majority of the respondents (35 respondents) affirms also that the duration of construction of cast in situ slabs system is higher than that of precast system, while 10 and 1 respondent did not obliged as they settled for low and very low respectively. These shows that cast in situ hollow slab takes more time than cast in situ solid slabs as cast in situ construction system takes more time to construct than precast slab.

Testing of Hypothesis

Null Hypothesis (Ho): There is no significant difference in the construction time between solid and hollow floor slabs construction in construction projects.

Alternative Hypothesis (Ha): There is significant difference in the construction time between solid and hollow floor slabs construction in construction projects.

To test this hypothesis, a paired sample t-test analysis was used.

Table 5 above shows a paired sample t-test on difference in construction time between cast in situ solid and hollow slabs in construction projects. The value
of \( t (df = 45) \) is \(-4.263, P < 0.05\) with a two tailed \( P \) value, \( \text{sig.(2-tailed)} = .000\), \( t \) is significant at 5% level. Therefore the null hypothesis \( H_0 \): there is no significant difference in the construction time between cast in situ solid and cast in situ hollow floor slabs construction in construction projects is rejected and the alternative hypothesis \( H_1 \): there is significant difference in the construction time between solid and hollow slabs construction in construction projects is accepted. Thus, there is difference in the construction time of the method of construction of solid and hollow slabs.

The same test was also done on precast method and the result is tabulated in Table 6.

### Discussion of Findings

It was revealed that, the system or method of slab construction well known to the respondents is cast in situ with a mean value of 3.93, precast and semi-precast with mean value of 3.43 and 2.63.

### Table 3. Process of reinforced concrete slab construction

<table>
<thead>
<tr>
<th>Process of Reinforced Concrete Slab Construction</th>
<th>Mean Value</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Cast in-situ solid slab)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time required for formwork construction</td>
<td>3.93</td>
<td>1</td>
</tr>
<tr>
<td>Time required to place reinforcement</td>
<td>3.72</td>
<td>2</td>
</tr>
<tr>
<td>Time required to place concrete</td>
<td>3.22</td>
<td>3</td>
</tr>
<tr>
<td>Time required to cure</td>
<td>3.15</td>
<td>4</td>
</tr>
<tr>
<td>Time required to strike off formwork</td>
<td>2.78</td>
<td>5</td>
</tr>
<tr>
<td>(In-situ hollow slab)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time required for formwork construction</td>
<td>3.70</td>
<td>1</td>
</tr>
<tr>
<td>Time required to place hollow bricks or mould on formwork</td>
<td>3.46</td>
<td>2</td>
</tr>
<tr>
<td>Time required to place reinforcement in ribs</td>
<td>3.42</td>
<td>3</td>
</tr>
<tr>
<td>Time required to place concrete</td>
<td>2.15</td>
<td>4</td>
</tr>
<tr>
<td>Time required to cure</td>
<td>3.94</td>
<td>5</td>
</tr>
<tr>
<td>Time required to strike off formwork</td>
<td>2.74</td>
<td>6</td>
</tr>
<tr>
<td>(Precast solid slab)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time required for off-site fabrication.</td>
<td>3.52</td>
<td>1</td>
</tr>
<tr>
<td>Time required for transportation of units to site.</td>
<td>3.33</td>
<td>2</td>
</tr>
<tr>
<td>Time required for erection and placement of units on site.</td>
<td>3.28</td>
<td>3</td>
</tr>
<tr>
<td>Time required for grouting and casting topping</td>
<td>3.09</td>
<td>4</td>
</tr>
<tr>
<td>(Precast hollow slab)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time required for off-site fabrication.</td>
<td>3.48</td>
<td>1</td>
</tr>
<tr>
<td>Time required for transportation of units to site.</td>
<td>3.26</td>
<td>2</td>
</tr>
<tr>
<td>Time required for erection and placement of units on site.</td>
<td>2.98</td>
<td>3</td>
</tr>
<tr>
<td>Time required for grouting and casting topping</td>
<td>2.76</td>
<td>4</td>
</tr>
</tbody>
</table>

Note: Very High = 5, Moderately High = 4, High = 3, Low = 2, Very Low = 1, No Response = 0 and Number of Respondents = \( N \)

### Table 4. Duration of construction process of solid and hollow slabs

<table>
<thead>
<tr>
<th>Duration of construction</th>
<th>Mean Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast in situ hollow slabs to solid slab</td>
<td>3.00</td>
</tr>
<tr>
<td>Cast in situ floors to precast floors system</td>
<td>2.98</td>
</tr>
</tbody>
</table>

Table 6 above shows a paired sample \( t \)-test on difference in construction time between precast solid and precast hollow slabs in construction projects. The value of \( t (df = 45) = 1.594, P < 0.05\) with a two tailed \( P \) value, \( \text{sig.(2-tailed)} = .118\), \( t \) is significant at 5% level. Since 0.118 is greater than 0.05 therefore the null hypothesis \( H_0 \): there is no significant difference in the construction time between solid and hollow slabs construction in construction projects is accepted for precast system. This is expected because precast solid and hollow slabs are all manufactured in the factory and all brought to site for erection and placement. The same process of construction applies to all precast units unlike cast in situ.

### Table 3. Process of reinforced concrete slab construction

<table>
<thead>
<tr>
<th>Duration of construction</th>
<th>Mean Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast in situ hollow slabs to solid slab</td>
<td>3.00</td>
</tr>
<tr>
<td>Cast in situ floors to precast floors system</td>
<td>2.98</td>
</tr>
</tbody>
</table>

Table 4. Duration of construction process of solid and hollow slabs

Note: Very High = 5, Moderately High = 4, High = 3, Low = 2, Very Low = 1, No Response = 0 and Number of Respondents = \( N \)

of \( t (df = 45) \) is \(-4.263, P < 0.05\) with a two tailed \( P \) value, \( \text{sig.(2-tailed)} = .000\), \( t \) is significant at 5% level. Therefore the null hypothesis \( H_0 \): there is no significant difference in the construction time between cast in situ solid and cast in situ hollow floor slabs construction in construction projects is rejected and the alternative hypothesis \( H_1 \): there is significant difference in the construction time between solid and hollow slabs construction in construction projects is accepted. Thus, there is difference in the construction time of the method of construction of solid and hollow slabs.

The same test was also done on precast method and the result is tabulated in Table 6.

### Std. Deviation = Standard Deviation, Std Error = Standard Error, Df = Degree of Freedom, Sig. = Significance and \( N = 46 \)

### Table 6.

The same test was also done on precast method and the result is tabulated in Table 6.

### Std. Deviation = Standard Deviation, Std Error = Standard Error, Df = Degree of Freedom, Sig. = Significance and \( N = 46 \)

Table 6 above shows a paired sample \( t \)-test on difference in construction time between precast solid and precast hollow slabs in construction projects. The value of \( t (df = 45) = 1.594, P < 0.05\) with a two tailed \( P \) value, \( \text{sig.(2-tailed)} = .118\), \( t \) is significant at 5% level. Since 0.118 is greater than 0.05 therefore the null hypothesis \( H_0 \): there is no significant difference in the construction time between solid and hollow slabs construction in construction projects is accepted for precast system. This is expected because precast solid and hollow slabs are all manufactured in the factory and all brought to site for erection and placement. The same process of construction applies to all precast units unlike cast in situ.

### Table 3. Process of reinforced concrete slab construction

<table>
<thead>
<tr>
<th>Process of Reinforced Concrete Slab Construction</th>
<th>Mean Value</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Cast in-situ solid slab)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time required for formwork construction</td>
<td>3.93</td>
<td>1</td>
</tr>
<tr>
<td>Time required to place reinforcement</td>
<td>3.72</td>
<td>2</td>
</tr>
<tr>
<td>Time required to place concrete</td>
<td>3.22</td>
<td>3</td>
</tr>
<tr>
<td>Time required to cure</td>
<td>3.15</td>
<td>4</td>
</tr>
<tr>
<td>Time required to strike off formwork</td>
<td>2.78</td>
<td>5</td>
</tr>
<tr>
<td>(In-situ hollow slab)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time required for formwork construction</td>
<td>3.70</td>
<td>1</td>
</tr>
<tr>
<td>Time required to place hollow bricks or mould on formwork</td>
<td>3.46</td>
<td>2</td>
</tr>
<tr>
<td>Time required to place reinforcement in ribs</td>
<td>3.42</td>
<td>3</td>
</tr>
<tr>
<td>Time required to place concrete</td>
<td>2.15</td>
<td>4</td>
</tr>
<tr>
<td>Time required to cure</td>
<td>3.94</td>
<td>5</td>
</tr>
<tr>
<td>Time required to strike off formwork</td>
<td>2.74</td>
<td>6</td>
</tr>
<tr>
<td>(Precast solid slab)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time required for off-site fabrication.</td>
<td>3.52</td>
<td>1</td>
</tr>
<tr>
<td>Time required for transportation of units to site.</td>
<td>3.33</td>
<td>2</td>
</tr>
<tr>
<td>Time required for erection and placement of units on site.</td>
<td>3.28</td>
<td>3</td>
</tr>
<tr>
<td>Time required for grouting and casting topping</td>
<td>3.09</td>
<td>4</td>
</tr>
<tr>
<td>(Precast hollow slab)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time required for off-site fabrication.</td>
<td>3.48</td>
<td>1</td>
</tr>
<tr>
<td>Time required for transportation of units to site.</td>
<td>3.26</td>
<td>2</td>
</tr>
<tr>
<td>Time required for erection and placement of units on site.</td>
<td>2.98</td>
<td>3</td>
</tr>
<tr>
<td>Time required for grouting and casting topping</td>
<td>2.76</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 3. Process of reinforced concrete slab construction

<table>
<thead>
<tr>
<th>Duration of construction</th>
<th>Mean Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast in situ hollow slabs to solid slab</td>
<td>3.00</td>
</tr>
<tr>
<td>Cast in situ floors to precast floors system</td>
<td>2.98</td>
</tr>
</tbody>
</table>
and are ranked 2nd and 3rd respectively. This means that the respondents are familiar with cast in situ and pre cast/prefabrication method while in the case of semi precast method, they are not familiar with the method. The findings correspond with Idrus and Newman, (2002) and Seeley, (1995) in terms of their classification of solid slab construction. They classified solid slab construction in majorly cast in situ and precast while semi precast was out of their classifications. Therefore, the major classification of slabs construction methods are cast in-situ and precast. 

Beam and slab construction of slab was discovered to be well known to the respondents followed by flat slab and hollow clay pot slab while the respondents do not have a good knowledge of waffle slab construction under cast in situ method. Under precast method of construction, beam and slabs construction is well known in the construction industry followed by precast flat slab while the least known on the table is precast waffle slab construction. It then shows vividly that most respondents only know about precast beam and slab, flat slab and hollow slab construction but knows less to nothing about precast waffle.

In terms of the level of usage, the study revealed that cast in situ beam and slab construction is the most used, followed by flat slab while hollow block slab and waffle slab construction are less used. This implies that most respondents use very often in construction, cast in situ beam and slab, flat slab and hollow slab while hollow block and waffle are rarely used in construction. Of the pre-cast, precast beam and slab construction, precast flat slab construction, pre-cast hollow clay pot slab construction are mostly used while waffle construction is the least used. One can then say, that cast in situ construction method is most used in Nigeria construction industry while precast is still breeding or used mostly for special construction that requires it.

The result of the level of time required in construction process of reinforced hollow concrete slab and reinforced solid concrete slab revealed that time required to place reinforcements, time required for formwork construction and the time required for the concrete to cure are the three highest activities and are ranked 1st, 2nd and 3rd respectively. While the required time to place concrete and the time required strike-off formwork are the two least activities and are ranked 4th and 5th respectively for cast in situ system of construction. Critically, this means that placing reinforcement and construction of formwork takes more time than other process in solid slab construction process or method. On the process of construction of reinforced cast in situ concrete hollow slab, time required for formwork construction, time required to place hollow bricks or blocks or moulds on formwork and time required to cure concrete are the three highest activities and ranked 1st, 2nd and 3rd respectively. While time required in laying reinforcement in ribs, required time to place concrete and the

<table>
<thead>
<tr>
<th>Variables (Time comparison)</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast in situ solid slab &amp; Cast in situ Hollow slab</td>
<td>-2.457</td>
<td>3.908</td>
<td>.576</td>
<td>- 4.263</td>
<td>45</td>
<td>.000</td>
<td>Significant (Accept H1)</td>
</tr>
</tbody>
</table>

Std. Deviation = Standard Deviation, Std Error = Standard Error, Df = Degree of Freedom, Sig. = Significance and N = 46

Table 5. Paired sample t-test on Difference in construction time between cast in situ solid and cast in situ hollow slab

<table>
<thead>
<tr>
<th>Variables (time comparison)</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precast solid slab &amp; Precast Hollow slab</td>
<td>-.739</td>
<td>3.144</td>
<td>.464</td>
<td>1.594</td>
<td>45</td>
<td>.118</td>
<td>Not Significant (Accept H0)</td>
</tr>
</tbody>
</table>

Std. Deviation = Standard Deviation, Std Error = Standard Error, Df = Degree of Freedom, Sig. = Significance and N = 46

Table 6. Paired sample t-test on Difference in construction time between precast solid and precast hollow slab
time required to strike-off formwork are
the three least and are ranked 4th, 5th
and 6th respectively. It then implies that
formwork construction, placing hollow
bricks or mould on formwork and curing
takes more time than other process in
hollow slab construction process or
method. Precast concrete slab have a
different construction method or pro-
cess from what is obtained in cast in
situ. Here, the units are manufacturer
off site and brought to site for erection.
Time required for off-site fabrication of
units and transportation of units to
site are the two highest and are ranked
1st and 2nd respectively while the time
required in erecting and placing units in
position, and time required in grouting
and casting toppings are least as they
are ranked 3rd and 4th respectively for
precast solid slab. On precast hollow
core/hollow slab, time required for
off-site fabrication of units and trans-
portation of units to site are the two
highest and are ranked 1st and 2nd
respectively while the time required
in erecting and placing units in
position, and time required in grouting
and casting toppings are least as they
are ranked 3rd and 4th respectively. The
study therefore affirms that the duration
or time of construction of cast in situ
hollow slab is higher than that of solid
slab. In the same vain, the duration of
construction of cast in situ slabs system
is higher than that of precast system.
These shows that cast in situ hollow
slab takes more time than cast in situ
solid slabs as cast in situ construction
system takes more time to construct
than precast slab. This findings supports,
that, a significant time difference exists
between the construction of solid and
hollow cast in situ slabs, and that
there is also a significant time savings
between precast and cast in situ.

Conclusions
At the design stage, the choice of slab
and its construction time or period
for any project should be critically
examined and analyzed to determine
its implication on the total duration of
the project so as to avoid prolonged
construction period or unanticipated
delay in the project delivery time which
could be unpleasant to clients’ cash
flow and anticipations

Under the cast in-situ system, beam
and slab construction is mostly used
among the identified list, followed by
flat slab, hollow clay pot and waffle
slab construction respectively. This is
evident as most upper floor slabs of
residential and some office buildings
in Nigeria are constructed of beam
and slab while newer office buildings,
commercial and other heavy engineer-
ning buildings are now constructed of
hollow slabs, flat slabs and waffle
slabs. While under pre-cast system,
precast beam and slab construction,
pre-cast hollow core or hollow slab and
other forms of precast slabs are not
often used, thus, one can then say that
based on the result of the study, cast in
situ construction method is most used
in Nigeria construction industry while
precast is still under-used or are most
for special construction that requires it.

References
slab construction. Reported by American
Concrete Institute (ACI) committee 302.1R.
USA.
BS 8110, (1997): Structural Use of Concrete:
Part 1. Code of Practice for Design and
Construction.Publication of British Standard
Institution, London.
floors. Cement and Concrete Aggregates
Concrete Manufacturer Association, (2008):
Hollow core slab system; Information
Construction related factors influencing the
choice of concrete floor system. Journal of
Construction Management and Economic.,
0144 – 6193.
Kadir, M. R. Abdul, Lee, W.P., Jaafar, M.S.,
Construction performance comparison
between conventional and industrialised
building systems in Malaysia. Structural
Lai Tina, (2010): Structural behaviours of
bubble deck slabs and their applications to
light weight bridge deck. A Master’s Thesis
Submitted to the Department of Civil and
Environmental Engineering, Massachusetts
Institutes of Technology. Massachusetts,
USA.
Lutz Clemens, (2002): Prestressed hollow core
concrete slabs – Problems and possibilities
for modern, efficient concrete construction.
Rwamamara, R., Simonsson, P., and Ojanen, J.
(2010): Advantages of industrialized methods
used in small bridge construction.Poster
session of the Proceedings at IGLC-18, (July),
Technion, Haifa, Israel.
Ed). Hampshire, UK: PALGRAVE.
Concrete Floor Systems In Residential
Construction; Proliferation of homes built
with insulating concrete forms inspires wider
Scotland.
Visser, W. D. (2009): Which type of slab is
the most effective solution to concrete
structures?. A Bachelor Degree Research
Submitted the Department of Quantity
Surveying, Faculty of Engineering, Built
Environment and Information Technology.
University of Pretoria. SA