Assessment of Cost Variation in Solid and Hollow Floor Construction in Lagos State

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The differences in construction methods between different forms of slabs construction tend to result into variation in the cost of the slabs for any building project. Thus, this study aims at assessing the variation in construction cost among various construction methods available for hollow and solid floors in construction projects within Lagos State. The research design for this study was a survey design approach and the population of the study are active professionals (Architects, Civil Engineers, Builders, Quantity Surveyors, Consultant) and contractors because they are the major participants in the construction activities of the construction industry in Lagos State, Nigeria. The research is based on 46 returned questionnaires out of the 60 that was administered. The data from the questionnaires were analyzed using descriptive tools such as frequencies, percentage and mean values. The hypotheses were tested with paired sample t-test and it was found that the system or method of slab construction well known to the respondents is cast in situ, precast and semi-precast. The study also shows that the cost of in-situ solid slabs are higher than that of hollow slab which is an indication that solid slab construction is more expensive than hollow slab construction provided the hollow slab is a one-way hollow floor and not waffle floor. In pre cast solid slab construction the cost of transportation of units to sites, cost of expertise required in the construction process and the cost of fabrication off site are the three highest and most expensive aspects of precast solid slab while cost of erection and placement and the cost of grouting and topping if required are less expensive. Therefore there is difference in the cost of construction between the solid and hollow slabs but the difference is not appreciable. The study's major recommendation is that, adequate and careful analysis must be done in the choice of floor system being adopted for any project.

Keywords: *Cost variation, Hollow slabs, Lagos state, Reinforced concrete, Solid slab, Waffle floor*

1. BACKGROUND OF THE STUDY

Building designs and construction dates back to the existence of man on earth, and over the years, various design and construction methods have evolved. These evolutions have led to modern designs and construction methods of various elements of a building; such as floors, wall, ceilings and roofs. The design and construction of floor slabs are usually solid, heavily reinforced in two directions and heavily concreted. The construction of these slabs usually require much formwork, high number of reinforcements provided in both ways (top and bottom) and high volume of concrete which results in much time or duration of construction. But over the recent decades, engineering researches have brought forward 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 method of solid slab construction. 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 in order 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 prefabrication. 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 time which cannot be compared to the in-situ construction. Hence, the variations in the duration of construction of these structures cannot be under estimated. 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 cost of production of the two floor systems.

2. TYPES OF CONCRETE FLOOR SYSTEMS

Concrete floor system, in this research, is referred to as any structural system consisting of both the structural floor slab and any beams or columns supporting it. In this study, concrete floor systems will be the focus, as it is the most common floor systems in modern designs and construction. There are mainly two classes of concrete floor systems available in modern construction (Idrus & Newman, 2002). These are Cast in-situ floor systems and pre-cast 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).

2.1 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 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 cost.

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 1:2:4-19mm 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 s 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 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. 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 reduces cost of 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 used, 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 cost 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 propping 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) is between 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

Structural floors according to Adlakha and Puri, (2003), accounted for substantial cost of a building in normal situation. Therefore, any savings achieved in floor considerably reduce the cost of buildings. 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 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 D x 30 to D x 35 where D 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.

3. 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 within Lagos State. This technique was used because of its ease in getting in contact with those who are qualified and experienced to provide information based on the objectives and the direction of the study (transverse). Descriptive and inferential tools were used to analyze the data for the study. Descriptive statistical tools such as frequency, percentage, mean, ranking and paired sample t-test tool (inferential tool) were used in the analysis.

4. DATA ANALYSIS AND FINDINGS

The results of this study are presented below.

Table 1: Awareness of the construction methods used for solid and hollow floors

Construction method	Mean value	Rank
Cast in-situ	3.93	1
Pre cast/pre fabricated	3.43	2
Semi pre cast	2.63	3

Well known = 4, known = 3, fairly known = 2, Not known = 1, no response = 0

Table 1 describes the respondents' perception on the various methods of floor construction. It was observed that cast in-situ method of slab construction was well known to almost all the respondents (mean value of 3.93), while pre cast and semi-pre cast followed with mean values of 3.43 and 2.63 (fairly known). This could be as a result of the technological standard of the Nigerian construction industry. That is, contractors are more knowledgeable of cast in-situ because it is more labour based and less of plant based while the other methods are more technology and plant based.

The analysis of the level of usage of different types of floor system is shown in Table 2 and cast in situ and pre cast floors were considered in this study. From 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 first among other systems. Flat slab followed closely with a mean value of 3.65 and ranked second. Hollow clay pot slab construction was fairly (mean value of 3.24) while waffle, another type of floor was the least used (mean value of 2.39). This shows that most respondents used very often in construction, cast in situ beam and slab, flat slab and hollow slab while hollow block and waffle were rarely used in construction.

Table 2: Level of usage of the types of floor slabs

Types of floor slabs	Mean value	Rank
Cast In situ		
Beam and slab	3.96	1
Flat slab	3.65	2
Hollow clay pot	3.24	3
Hollow block	2.80	4
Waffle floor	2.39	5
Precast		
Beam and slab	3.37	1
Flat slab	3.17	2
Hollow clay pot	2.39	3
Hollow block	2.13	4
Waffle floor	2.11	5

Well known = 4, known = 3, fairly known = 2, Not known = 1, no response = 0

From the pre-cast, pre cast beam and slab construction is used very often in construction (mean value of 3.37) among the pre cast group. Pre cast flat slab (mean value of 3.17) has a low usage level compared to pre cast beam and slab while pre-cast hollow clay pot slab and pre cast waffle slab construction were not frequently used or were not even used at all in the construction industry. It thus shows that most respondents only know about precast beam and slab, flat slab and hollow slab construction but knew next to nothing about precast waffle floor. The table also revealed a trend that cast in-situ method of slab construction has a high level of usage than precast method.

Table 3: Difference in construction cost of hollow and solid slabs

Cost difference	Frequency	Percentage (%)
Rare	4	8.7
Yes	42	91.3
Total	46	100

Table 3 shows the respondents' perception of the difference between the cost of hollow and solid slabs. 91.3% of the respondents affirm that there is a difference in the cost of construction between hollow and solid slabs.

Table 4 shows the outcome of the respondents' perception about the level of cost of construction method of solid and hollow floor slab. Under cast in situ solid slab, cost of reinforcement and fixing on formwork and cost of concrete and placement were the two most expensive aspects of reinforced concrete slab (mean values of 3.85 and 3.76 respectively) while cost of formwork construction and cost of striking off formwork were the least expensive (3.72 and 2.50 respectively). This supports the fact that in cast *in situ* solid slab construction method, reinforcement and concrete are the most expensive followed closely by the cost of formwork construction.

Cast in situ hollow slab construction on the other hand has cost of hollow bricks and mould and placement, the cost of formwork construction and the cost of reinforcement as the three most expensive aspects of reinforced concrete hollow slab construction (mean values of 3.22 and 22.48 respectively). Comparing the mean values of cost in situ solid and hollow slab from the table, one could observe that the mean values for solid slabs are higher than that of hollow slab, which is an indication that solid slab construction is more expensive than hollow slab construction (provided that the hollow slab is a one way hollow floor and not waffle floor). The only addition in hollow slab construction is the cost of hollow bricks which does not exist in solid slab.

Considering precast solid slab construction, the cost of transportation of units to sites, cost of expertise required in the construction process and the cost of fabrication off site are the three most expensive aspects of precast solid slab (mean value of 4.04, 4.02 and 4.00 respectively) while cost of erection and placement and the cost of grouting and topping if required have mean values of 3.83 and 2.98 respectively. In precast hollow slab construction, the cost of transportation of units to site, cost of fabrication of units off site and cost of technical expertise required in construction are the three most expensive aspects of precast hollow floor slab (mean values of 3.85, 3.72 and 3.57 respectively) while cost of erection and placement and cost of grouting and topping if required are the two least expensive aspects of precast hollow slab (mean values of 3.54 and 2.87 respectively).

Table 4: Level of construction cost of hollow and solid floor slabs

Cost of construction method	Mean value	Rank
Cast in situ solid slab		
Cost of reinforcement and fixing of formwork	3.85	1
Cost of concrete and placement	3.76	2
Cost of formwork and construction	3.72	3
Cost of striking off formwork	2.50	4
Cast in situ hollow slab		
Cost of hollow pot or mould and placement	3.50	1
Cost of formwork and construction	3.41	2
Cost of reinforcement and fixing of formwork	3.35	3
Cost of concrete and placement	3.22	4
Cost of striking off formwork	2.48	5
Precast solid slab		
Cost of transportation to site	4.04	1
Cost of technical expertise required	4.02	2
Cost of fabrication off site	4.00	3
Cost of erection and placement on site	3.83	4
Cost of grouting and topping over units	2.98	5
Precast hollow slab		
Cost of transportation to site	3.85	1
Cost of fabrication off site	3.72	2
Cost of technical expertise required	3.57	3
Cost of erection and placement on site	3.54	4
Cost of grouting and topping over units	2.87	5

Very high = 5, Moderately High = 4, High = 3, Low = 2, Very low = 1, No response = 0

Table 5: Difference in construction cost of hollow and solid slabs

Items of cost difference	Mean values	Rank
Quantity of reinforcement in solid to hollow pot slab	3.89	1
Quantity of reinforcement in solid to waffle slab	3.57	2
Labour requirement of hollow to solid slab	3.20	3
Cost effects of concrete in hollow to solid slabs	2.91	4
Volume of concrete used in hollow to solid slabs	2.70	5

Very high = 5, Moderately High = 4, High = 3, Low = 2, Very low = 1, No response = 0

Table 5 displays the result of the respondents' opinion on cost difference in the construction of solid and hollow slabs. The respondents attested that the quantity of reinforcement required in solid to hollow slab is moderately high (3.89). Thus, the cost of reinforcement in solid floor is higher than that required in hollow clay pot construction. This is due to the fact that hollow pot slabs have their reinforcement sin one-way why solid slabs have theirs in two-way. The volume of concrete used was said to be lower in ribbed floor than in solid. The labour required in hollow slab to that of solid slab is low (3.20).

Testing Hypothesis

Null Hypothesis (H_o): There is no significant difference in the construction cost of solid and hollow floor slabs in construction projects.

Alternative Hypothesis (H_1): There is significant difference in the construction cost of solid and hollow floor slabs in construction projects.
To test this hypothesis, a paired sample t-test analysis was used.

Table 6 shows a paired sample t-test on difference in construction cost between cast in situ solid and hollow slabs in construction projects. The value of t (df = 45) is – 3.463, P < 0.05 with a two tailed P value, sig. (2-tailed) of .001, t is significant at 5% level. Therefore the null hypothesis 'there is no significant difference in the construction cost of cast in situ solid and cast in situ hollow floor slabs in construction projects' is rejected and the alternative 'there is significant difference in the construction cost of solid and hollow slabs construction in construction projects is accepted. Thus, there is difference in the construction cost of cast in situ solid and hollow floor slabs.

Table 6: Paired sample t-test on difference in construction cost of cast in situ solid and cast in situ hollow slab

Variables (Time comparison)	Cast in situ solid slab & Cast in situ Hollow slab
Mean	-2.130
Std. Deviation	4.172
Std. Error Mean	0.615
T	- 3.463
df	45
Sig. (2-tailed)	0.001
Decision	**Significant (Accept H_1)**

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

The same test was also done on precast method and the result is tabulated in Table 7.

Table 7: Paired sample t-test on difference in construction cost of precast solid and precast hollow slab

Variables (Time comparison)	Precast solid slab & Precast Hollow slab
Mean	1.326
Std. Deviation	4.022
Std. Error Mean	0.593
T	2.236
df	45
Sig. (2-tailed)	0.030
Decision	**Not Significant (Accept H_1)**

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

Table 7 above shows a paired sample t-test on difference in construction cost of precast solid and precast hollow slabs in construction projects. The value of t (df = 45) is 2.236, P < 0.05 with a two tailed P value, sig. (2-tailed) of 0.030, t is significant at 5% level. Therefore, the null hypothesis 'there is no significant difference in the construction cost of precast solid and precast hollow floor slabs in construction projects' is rejected and the alternative 'there is significant difference in the construction cost of precast solid and precast hollow floor slabs in construction projects' is accepted. Therefore, the difference in the cost of construction is founded on the reduced volume of concrete and quantity of reinforcement.

5. 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 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 into 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 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. From 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.

Considering the cost implication, under cast in situ solid slab, cost of reinforcement and fixing of formwork and cost of concrete and placement are the two highest or most expensive aspect of reinforced concrete solid slab and are ranked first and second respectively while cost of formwork construction, and cost of striking off of formwork are the two least expensive aspect of reinforced concrete slab. Cast in situ hollow slab construction on the other hand, has the cost of hollow bricks or moulds and placement, the cost of formwork construction and the cost of reinforcement are the three most expensive aspect of reinforced concrete hollow slab construction and are ranked first, second and third respectively while cost of concrete and cost of striking off formwork are the two least expensive aspects and are ranked fourth and fifth respectively.

Comparing the mean values of cost in situ solid and hollow slab from the table below, one could observe that the mean values for solid slabs are higher than that of hollow slab, which is an indication that solid slab construction is more expensive than hollow slab construction (provided that the hollow slab is a one-way hollow floor and not a waffle floor). But the only addition we have in hollow slab construction is the cost of hollow bricks that may lead to additional cost of materials which does not exist in solid slab. This result correspond with Lai, (2010) that the voids or holes formed within the slab system gives a significant advantage over the conventional solid slabs in terms of reduced material usage (reinforcement and concrete) which in turn, reduced the construction cost of the slabs. Thus, there exists difference in cost among these systems of construction. The difference is evident in the cost of reinforcement and cost of concrete required in solid and hollow slabs. This is due to the fact that hollow pot slabs have their reinforcement in one-way (except for waffle) why solid slabs have theirs in two-ways. In terms of the volume of concrete used, ribbed floor requires lesser volume of concrete than in solid, thus the cost will be lower since the volume is lesser. But care must be taken if the thickness of the ribs and beams are deeper than that of the solid; so that the concrete saved in the voids within the span, will not be required in the depth of the beam and ribs.

The labour required in hollow slab to what is required in solid slab higher though the increase in labour required is due to additional labour required to place pots of mould on formwork in hollow slab construction. This will eventually lead to increase in the cost of labour, thereby, causing difference in the cost of construction between hollow and solid slab construction. Considering precast solid slab construction, the cost of transportation of units to sites, cost of expertise required in the construction process and the cost of fabrication off site are the three highest and most expensive aspects of precast solid slab and are ranked first, second and third respectively while cost of erection and placement, and the cost of grouting and topping (if required) are the least expensive of the log and are ranked fourth and fifth respectively. On precast hollow slab construction, the cost of transportation of units to site, cost of fabrication of units off site and cost of technical expertise required in construction are the three highest and most expensive aspects of precast hollow floor slab and are ranked first, second and third respectively. While cost of erection and placement, and cost of grouting and topping if required, are the two least expensive aspect of precast hollow slab and are ranked fourth and fifth respectively. As the mean values for precast is higher than those for the cast in situ, it implies that precast system is more expensive than cast in situ system. Though this finding opposes Yin, Samuel and Hong (2007) findings that precast is cheaper than cast in situ, as precast components are produced in precast plant almost totally but the site is only left with hoisting operations which significantly reduces massive formwork and scaffolds, but the cost of expertise and the cost of plant required in hoisting and placing a precast unit could pool a significant change in the cost.

The null was rejected and the alternative was accepted. Thus, there is difference in the cost of construction method of cast in situ solid and hollow slabs. While for precast, the null hypothesis was rejected and the alternative was accepted. Thus the difference in the cost of construction is in the reduced volume of concrete and reduced quantity of reinforcement. 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 engineering 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.

Under cast in situ solid slab, reinforcement and fixing on formwork, and concrete and placement are the two most expensive aspect of reinforced concrete solid slab while formwork construction and striking off of formwork are the two least expensive aspect of reinforced concrete slab. Cast in situ hollow slab construction on the other hand has the cost of hollow bricks or moulds and placement, the cost of formwork construction and the cost of reinforcement has the three most expensive aspect of reinforced concrete hollow slab construction. While the cost of concrete and the cost of striking-off formworks are the two least expensive aspects. Therefore, solid slab construction is more expensive than hollow slab construction (provided that the hollow slab is a one-way hollow floor and not waffle floor) but lesser than waffle.

The only addition we have in hollow slab construction is the cost of hollow bricks which does not exist in solid slab. In precast solid slab construction, the cost of transportation of units to sites, cost of expertise required in the construction process and the cost of fabrication off site are the three most expensive aspects of precast solid slab while cost of erection and placement, and the cost of grouting and topping if required is minimal. On precast hollow slab construction, the cost of transportation of units to site, cost of fabrication of units off site and cost of technical expertise required in construction are the three most expensive aspects of precast hollow floor slab. While cost of erection and placement, and cost of grouting and topping if required, are the two least expensive aspect of precast hollow slab. As the mean values for precast is higher than those for the cast in situ, it implies that precast system is more expensive than cast in situ system. Thus, there exists difference in cost among these systems of construction. The difference is evident in the cost of reinforcement and cost of concrete required in solid and hollow slabs. This is due to the fact that hollow pot slabs have there reinforcement in one-way (except for waffle) why solid slabs has theirs in two-ways. The volume of concrete used is lesser in ribbed floor than in solid, thus the cost will be lesser since the volume is lesser. But care must be taken, should the thickness of the ribs and beams are deeper than that of the solid the concrete saved in the voids within the span, will be required in the depth of the beam and ribs. The labour required in hollow slab to what is required in solid slab more. And the increase in labour required are due to additional labour required to place pots or moulds on formwork in hollow slab construction. This will eventually lead to increase in the cost of labour, thereby, causing difference in the cost of construction between hollow and solid slab construction. Therefore, there is significant difference in the cost of construction between solid and hollow slabs; precast solid and precast hollow slabs construction in construction projects. The difference in the cost of construction is in the reduced volume of concrete and reduced quantity of reinforcement.

6. CONCLUSIONS

The construction cost of many alternative choices of slabs system and their respective construction methods should be thoroughly broken down at the design stage to determine the cost implications or differences of the choices to be able to arrive at the slab system best for the project in terms of cost. The aspects of cost of slab to be examined are cost of materials, cost of labour and cost of the required construction technology and expatriates. But in some extreme engineering conditions or special cases that would inform the choice of slab such as load bearing capacity of the foundation soil and other functions that the slab is to serve to the overall purpose of the building, the implication of the cost of construction may not be an issue.

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 engineering 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.

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