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RESEARCH ARTICLE

Development Of an Optimal Composition of Concrete Materials Management Process for Public Building Project Delivery in Imo State, Nigeria

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ABSTRACT

Optimal composition of concrete materials management process requires that a necessary framework be adopted for sustainable building project delivery. Despite the importance of concrete in building construction, poor management processes often result in material wastage, delays, cost overruns, rework, claims, and stakeholder dissatisfaction. Quality concrete can only be achieved through adequate control and care at every stage of production to ensure uniform strength from batch to batch. This study, as a pilot scheme, developed an optimal composition of labour required for concrete work to enhance project efficiency, quality, and sustainability in the study area. The study aimed to identify the components of concrete materials relevant to labour requirements, explain the concept of optimal labour composition, and develop a framework for determining the optimal labour force required for concrete work. Findings revealed that for 1,800 m³ of concrete, the batching and mixing gang required seven (7) workmen, the transportation gang required eleven (11) workmen, and the placement gang required seven (7) workmen. In addition, one (1) mixer operator was required, giving a total optimal labour force of twenty-six (26) workers for concrete works on the foundation trenches of the proposed Postgraduate Lecture Theatre, Building Department, Imo State University, Owerri. The study demonstrates the importance of analytically determining appropriate labour requirements to ensure timely, efficient, and sustainable project delivery. It recommends strict monitoring through a national or zonal code of practice to ensure quality concrete production at every stage. Stakeholders and construction operatives should also ensure the use of appropriate materials and workmanship while adhering to specified project schedules.

Keywords: *Concrete Materials; Optimal Composition; Labour Force*

1. INTRODUCTION

The focus of this study is on concrete materials; there is a need to examine in detail all the issues relating to types and some basic characteristics of common concrete materials which have some bearing on their selection, procurement, transportation and storage. Concrete is a composite material composed mainly of water, aggregate and cement. Whether the building method adopts the in-situ or precast method, concrete is a major material. Often, additives and reinforcements are included in the mixture to achieve the desired physical properties required in both construction techniques. When these ingredients are mixed, they form a fluid mass that is easily moulded into shapes.

According to Croft (2004), concrete is a strong material which can combine the tensile strength of steel with the compressive strength of stone. It has been used particularly in its reinforced form for most types of engineering and building projects. The strength and the use to which it is put are determined by its constituent parts- cement, water, and aggregates. Concrete is used extremely widely in building and civil engineering structures, due to its low cost, flexibility, durability, and high strength. It also has high resistance to fire. A mixture of sand, aggregate, cement, and water is placed in a mould, or form, as a liquid, and then it sets due to a chemical reaction between the water and cement.

According to Duggal (2012), a good quality of concrete is essentially a homogeneous mixture of cement, coarse and fine aggregates, and water which consolidates into a hard mass due to chemical action between the cement and water. According to Arora and Bindra (2008), building materials account for 50 to 80 percent of the total value of construction. Thus, before construction begins, it is necessary to ensure the availability of all the types of materials needed for building production and their supply at the various sites. Materials management is related to materials purchasing, inventory planning; storage, inventory management; materials supply; transportation, handling, quality control; materials movement from source/depot to project site for mixing, placing, and surplus disposal. This is geared toward providing appropriate materials of the right quality, right quantity, at the right place and at the right time so as to coordinate and schedule the production activity in an integrative way. In order to perform these activities, a functional organisation of materials management should be established to achieve the goal of project delivery within the contract cost and time, ensuring that the specified scope and quality are met without compromising the health and safety of the operators. The correct use of building materials results in materials economy, which is a key issue in materials management in order to accomplish project delivery (Emmitt, 2002).

According to Harris and McCaffer (1985), adequate coordination of material requirements is necessary during the overall planning of a building project execution, before the commencement of the work on site, so that the management may have a thorough appreciation of the work involved. It will also necessitate the involvement of those responsible for production to sort out building material constituents and decide on how, in what order, and at what time to use them. However, it is worthy to note that if materials are purchased too early, capital may be tied down and interest charges incurred on excess inventory of materials. On the other hand, materials not procured and stored promptly may cause delays and extra expenses if not available at the time required. Some materials may even deteriorate during storage in the case of items such as cement, or get stolen unless special care is taken (Austen and Neale 1986). Therefore, there is a need for efficient practice in materials management to accomplish project delivery.

Public building projects in Nigeria often experience delays, cost overruns, and quality issues due to inefficient concrete materials management. Despite the significance of concrete materials in building construction, the lack of effective management processes has hindered project delivery, resulting in wastage, rework, and stakeholder dissatisfaction. This study aims to develop an optimal concrete materials management process for public building projects with a view to enhancing project efficiency, quality, and sustainability in the study area. The problem of unavailability and unreadiness of materials and working implements at the correct time and place can hinder the operations from being carried out on schedule (Okereke, 2003). In such a situation, work cannot be completed until the materials arrive. Sometimes, labour shortages can cause work to be completed more slowly than anticipated. Due to such time delays, the cost of project components may increase in view of the effects of inflation. Owing to inefficient building materials management for optimal public building project delivery in the study area, the building industry is beset with some problems. Some building production participants lack the necessary materials management techniques needed to control materials inventory for effective delivery of public building projects.

The challenges and limitations of current practices to enhance project efficiency, quality, and sustainability in concrete composition include: inability to ensuring uniformity and quality concrete construction requires skilled workers and robust quality control processes at scale is difficult, particularly with new materials or technologies; insufficient knowledge and training on sustainable practices and quality management and shortage of labour force in the construction industry due to aging workforce, lack of interest among youth.

The study aims at developing a framework for optimal concrete materials management in public building projects with a view to enhancing project efficiency, quality, and sustainability in the study area.

To realise the above-stated aim, the following objectives have been set out:

i. identify the components of concrete materials for optimal composition of labour force required;

ii. explain the concept of optimal composition of labour force requirement;

iii. to develop a framework for optimal composition of labour force requirement to carry out concrete work.

2. LITERATURE REVIEW

According to Lyons (2010), concrete is a mixture of cement, aggregates and water together with any other admixtures which may be added to modify the placing and curing processes or the ultimate physical properties. Initially, when mixed, concrete is a plastic material which takes the shape of the mould or formwork. When hardened, it may be a dense, load–bearing material or a lightweight, thermally insulating material, depending largely on the aggregates used. It may be reinforced or prestressed by the incorporation of steel.

Most concrete is crushed and recycled at the end of its useful life, frequently as hardcore for new construction work. However, a growth in the use of recycled aggregates for new concrete can be anticipated, as this will have a significant environmental gain in reducing the demand on new aggregate extraction.

Chudley and Greeno (2010), in strong agreement with Lyon (2010), said that concrete is a mixture of cement, fine aggregate, coarse aggregate and water in controlled proportions and of a suitable quality.

Each of the four constituents has the following specific function. The Fine aggregate (stone): fills up the voids between the paste and coarse aggregate; The coarse aggregate (granites, natural stones): acts as filler; The cement: this, in conjunction with water, acts as a binder. Aggregates form a major component of concrete, typically approximately 80% by weight in cured mass concrete. Aggregate properties, including crushing strength, size, grading and shape, have significant effects on the physical properties of the concrete mixes and hardened concrete. Additionally, the appearance of visual concrete can be influenced by aggregate colour, surface treatments, and shape.

Aggregates for concrete are normally classified as lightweight, dense, or high-density. Standard dense aggregates are classified by size as fine (i.e. sand) or coarse (i.e. gravel). Additionally, steel or polypropylene fibres or gas bubbles may be incorporated into the mix for specialist purposes. About three-quarters (by volume) of concrete consists of a combination of fine and coarse aggregates including sand, gravel and crushed rock. Chudley and Greeno (2010) further opined that aggregate shape, surface texture and grading (distribution of particle sizes) are factors which influence the workability and strength of a concrete mix. Fine aggregates are generally regarded as those materials which pass through a 4 mm sieve, whereas coarse aggregates are retained on a 4 mm sieve. Dense aggregates have a density of more than 1200kg/m for coarse aggregates and more than 1250 kg/m for fine aggregates. These are detailed in BS EN 12620: Aggregates for concrete. Lightweight aggregates include clinker; foamed or expanded blast furnace slag and exfoliated and expanded materials such as vermiculite, perlite, clay and sintered pulverized-fuel ash to BS EN 13055-1.

According to Lyons (2010), cement is the basic building material in concrete. It constitutes a chemical mix of calcium, silica, iron, and gypsum. It is a calcined mixture of clay and limestone (Cement/sand). Cement powder is produced from clay and chalk or limestone. In general, most concrete is made with ordinary or rapid hardening Portland cement, both types being manufactured to the recommendations of BS EN 197-1. Ordinary Portland cement is adequate for most purposes but has a low resistance to attack by acids and sulphates. Rapid hardening Portland cement does not set faster than ordinary Portland cement, but it can develop its working strength at a faster rate.

For a concrete which must have an acceptable degree of resistance to sulphate attack, sulphate resisting Portland cement made to the recommendations of BS 4027 could be specified. Duggal (2012) opined that Portland cement should be kept in sacks of 0.035 m3 (50 kg) capacity for local use. These are stored for a short period of time in an airtight room, avoiding moisture & dampness, at some distance from walls and at some height from floors. The stack should be covered with suitable coverings to avoid circulation of air through the stack, and not more than ten bags should be stacked one over another.

Water is an important ingredient for making concrete. It is the sole ingredient/agent responsible for the hydration (the chemical process) of cement. Almost any natural potable water that has no pronounced taste or odour is acceptable for the concrete mix. The general rule is that if water is of a quality suitable for drinking, then it is satisfactory for making concrete. The proportion of water added to the mix establishes its permeability, resistance to weather, wear, and its use in construction. Water must be clean and free from impurities, which are likely to affect the setting time, durability, the quality or strength of the resultant concrete, and may cause efflorescence, surface discolouration, and corrosion of steel Chudley and Greeno, 2010).

The proportion of water added to the mix establishes its permeability, weather resistance, and wear, and it is used in construction. Precaution must be taken because if more water than required is added, it may cause bleeding in concrete, which reduces the strength of concrete in a bad manner. Conversely, the use of a limited amount of water for concrete will decrease the workability of concrete, and so it will cause honeycomb in concrete and pores (voids) present in the hardened concrete (ACI 318). This results in weaker concrete in the long run (cvilconcept.com).

Having quality concrete can only be achieved by ensuring adequate care at every stage of the concrete production. This ensures concrete of uniform strength from batch to batch. The various stages required in concrete production are batching or measurement of materials; mixing; transporting; and placement. The rules required to be followed in these various stages of concrete production include the following processes:

Quality concrete is achievable through the use of proper and accurate quantities of all the ingredients. The aggregates, cement, and water should be measured with an accuracy of ± 3 percent of batch quantity, and the admixtures by 5 percent of the batch quantity. There are two major methods of batching concrete materials. These are volume batching and weigh batching. Whichever method is chosen, the following factors affect the choice of batching method. Such factors include: The size of the job; The required production rate; The required standards of batching. For most important works, weigh batching is recommended.

Mixing- The object of mixing is to make the concrete mass homogeneous, uniform in colour and consistency. All the aggregate particles should have a coat of cement paste, and all the ingredients of the concrete should blend into a uniform mass. The mixing should be done either by hand or by a machine mixer. Hand mixing is used for small jobs. It is done over an impervious floor. Measured quantities of coarse and fine aggregate are spread over the floor in alternate layers. The cement is poured over it, and the ingredients are mixed dry with a shovel until colour uniformity is achieved. This mix is spread out in a thickness of 200mm and water is sprinkled.

Machine mixing- A machine mixer gives quality work. The mixers can be broadly classified as batch mixers and continuous mixers.

Batch mixer: - this produces concrete batch by batch with a time interval.

Continuous mixer: - this produces concrete continuously till plant is working. Batch mixers are used for small and medium-sized work.

Batch mixer may be of head pan type or drum type. The Drum type may be further classified as tilting (T), non- titling (NT), or reversing (R) type.

Transporting of concrete- Concrete should be transported to the place of deposition at the earliest time without the loss of homogeneity obtained at the time of mixing. A maximum of 2 hours from the time of mixing is permitted if trucks with agitators and 1 hour if trucks without agitators are used for transporting concrete. It should be ensured that segregation does not take place during transportation and placement. The methods adopted for transporting concrete depend upon the following factors: The size of the job; the importance of the job; the distance of the deposition place from the mixing place; and the nature of the terrain.

Some of the methods of transporting concrete are listed as follows: Mortar Pan, Wheelbarrow, Chutes, Dumper, Belt Conveyor, Skip, Hoist and Pumping.

Placement: - Duggal (2012) maintains that to achieve good quality concrete, it should be placed with utmost care, securing the homogeneity achieved during mixing and the avoidance of segregation in transporting. The various situations in which concrete is placed are as follows: Foundations, Beams, columns, and Slabs. Table 1 shows the major sources of Concrete Materials (Cement, Sand, Granite /Chipping) in the Study Area.

Table 1. Sources of Concrete Materials in the South-East States of Nigeria

BUILDING MATERIALS	ABIA	ANAMBRA	EBONYI	ENUGU	IMO
Cement	Nkalagu, Ebonyi State. Ewokoro, Ogun State; Ekpella, Edo State; Gboko, Benue State.	Nkalagu, Ebonyi State Ewokoro, Ogun State; Ekpella, Edo State; Gboko, Benue State.	Nkalagu, Ebonyi State; Ewokoro, Ogun State; Gboko, Benue State.	Nkalagu, Ebonyi State; Ewokoro, Ogun State; Ekpella, Edo State; Gboko, Benue State.	Nkalagu, Ebonyi State; Ewokoro, Ogun State; Ekpella, Edo State; Gboko, Benue State.
Sand (River) Sand (Dung)	Ihie Road Ukwa West L.G.A; Ogbor Hill Aba; Ohuhu River Umuahia; Nsirimo River Umuahia;	River Niger Onitsha; Ukpor River Nnewi South L.G.A; Amamputu Uli Ihiala L.G.A ;	Abakaliki Enugu Road b/4 Ezzamgbo; Ofirikpo Sand Beach; Idibe Sand Beach.	Ugwuaji Stream, Ugwuaji, Enugu. Trans-ekwulu Akwuke off Agbani Road, Nike Lake, Nike.	Njaba River, Awo-omama, Orlu L.G.A Nworie River, Nekede, Owerri South L.G.A Tipper Park/stone Market, Owerri.
Gravel(Natural)	Isukwuata Quarry Industry; Umunneochi L.G.A	Umunya Oyi L.G.A; Amamputu Uli Ihiala L.G.A;	Ishiagu, Abakaliki Enugu Road b/4 Ezzamgbo;	Ugwuaji Nike Ugwuonyeama Nike. Cable Point Emene.Enugu Ezike. Igbo-etiti	Stone /Tipper Market, Nekede. Quarry Okigwe; Njaba river; Atamri river; Nwaori river
Granites Chipping	Quarry Industry Umunneochi L.G.A Isuakuata, Lakpanta,Lokpaukwu, Uturu	Umunya Oyi L.G.A; Asaba, Okigwe	Abakaliki, mgbo, Ishiagu, Okigwe, Uturu	Abakaliki, mgbo, Ishiagu, Okigwe, Uturu	Abakaliki, mgbo, Ishiagu, Okigwe, Uturu

4. RESULTS AND DISCUSSION

Building materials management is a process that coordinates planning, assessing the requirements, sourcing, purchasing, transporting, storing, and controlling of materials, minimizing wastage and optimizing profitability by reducing the cost of materials. Mantri (2011) affirms that materials control is the system that ensures the provision of the required quantity and quality of materials of the required quality at the required time with the minimum capital investment. It covers the following functions: Stock control; Scheduling of requirements; Purchasing; Receiving and inspecting; Storing and issuing.

Ordering and procurement (Purchasing) of Materials

Sadiwala (2007) asserts that the need for an efficient and economical procurement of various supplies of materials is necessary for the efficiency of firms' profitability. The materials management department has to perform this function of purchasing and procurement of materials very efficiently. Timely delivery of any building project depends on the efficiency with which this particular function of purchasing and procuring the requisite materials at the appropriate time is done and its availability is assured. Walton (1995) states that the procurement/purchasing officer must have a sound knowledge of building materials and their prices. He should be able to place orders for materials well in advance.

The functions of purchasing can be stated as follows:

i. The requisition of materials is necessary by proper authority to initiate its purchase;

ii. To select a proper supplier for the materials requisition, before placing an order;

iii. To negotiate the price of the materials from the suppliers, and it will be purchased at the lowest price;

iv. The quality of materials should be assured and should not be compromised for the cost of the materials;

v. The materials should be purchased of the right quality, at the proper time and at the cheapest cost; and

vi. To set the proper purchase policy and procedure.

The following factors should be considered while purchasing the materials are as follows:

i. *The Quality***:** The quality of the product is measured in terms of its specification. The specifications include design, materials used, physical/chemical composition, and properties of materials, etc.

ii. *Quantity:* The quantity of materials at any time during the execution of the project shall be optimum. Buying in small quantities shall be avoided as it will delay implementation of the project. On the other extreme, buying in quantities larger than what is required is also not advisable.

iii. *Price:* Since the price almost depends on the quality, the price is determined by the quality standards expected of materials.

iv. *Time:* The materials required shall be made available at the time they are required. Delay in arrival of the materials will delay the implementation of the project.

v. *Sources***:** Right quality of materials at the right prices can be purchased only from the right sources. Materials can be purchased either directly from the manufacturers or from the dealers or from retailers in the open market. Purchasing is one of the major functions of materials management. This function contains the following activities:

i. Identification and selection of possible suppliers;
ii. Finalizing the terms and references of purchases that are to be made.
iii. Placing the purchase orders;
iv. Managing the purchase orders till delivery of materials and
v. Giving clearance for payment of received goods.

Materials Reception and Recording

Materials Reception - Materials reception involves receiving purchased materials on arrival and confirming their quality and quantity with the purchase order. For example, that the cement or reinforcement ordered is of the specified trade mark nd type. The procedures for receiving incoming materials include: receiving the incoming materials in stores; checking and inspecting these incoming materials; recording the incoming materials in the goods received book; Informing the purchase manager/department about damaged and defective goods, surplus or deficit supplies, and returning damaged or defective goods to the suppliers. According to Bikinmi (2007), the flow of materials at the project site begins with materials receipt, particularly in relation to deciding where to locate a payload, checking for quantity and quality, and administering paperwork.

Technology and Collaboration

Digital Solutions

According to Kumar & Singh 2019), utilising software to manage and track materials, projects, and stakeholders in real-time. Tracking materials, projects, and stakeholders in real-time; Automating routine tasks and workflows to improve efficiency; Providing insights and analytics to inform decision-making; Integrating with other systems and tools to ensure seamless data exchange. Including project management tools like Procore, PlanGrid, or Autodesk Construction Cloud; Inventory management software like Trade Gecko or Zoho Inventory; and Building Information Modelling (BIM) software like Autodesk Revit or Graphisoft ArchiCAD are key success factors, highly beneficial in the following ways: Improved efficiency and productivity; Enhanced visibility and transparency; Better decision-making through data analysis; Reduced errors and delays.

Collaboration

i. Fostering collaboration among stakeholders, including suppliers, contractors, project managers, and clients (Aziz & Hafez, 2013). This could be in the form of regular meetings and progress updates; establishing clear communication channels and protocols; clearly defining roles and responsibilities among stakeholders; and providing regular progress updates and feedback. Collaborative software like Slack, Microsoft Teams, or Asana; shared document management platforms like Google Drive or Dropbox. Adopting these practices also has the following benefits:
ii. Improved communication and coordination; increased trust and transparency
iii. Better risk management and issue resolution
iv. Enhanced project outcomes

By leveraging digital solutions and fostering collaboration, construction projects can improve efficiency, reduce costs, and ensure high-quality outcomes.

Determination of Optimal Composition of Labour Force required to carry out Concrete Work

In determining the optimal composition of the labour force gang for concreting foundation, column bases, and over-site concrete. Expected completion time (Duration) is not expected to exceed 12 months. The concrete mixes of 1:2:4 and 1:4:8 are to be mixed using a filling-type drum concrete mixer with a capacity of $0.3m^3$

Solution: Concrete works involve three simple construction processes, namely: preparation (mixing) of concrete, transporting and placing of concrete into position. The key process is the mixing of the concrete, while the rest of the operations depend on it. For organisational reasons, the whole concreting work will be undertaken by three different gangs of workmen: the mixing gang; the transportation gang; and the placement gang.

Determination of the Mixing Gang

The standard time (S_t) for the process of concrete mixing, i.e., concrete mixer of drum capacity = V_{ol} =0.3

To determine the mixer productivity (Pm)

$$P_m = \frac{t \times 3600 \times v_{0l} \times y \times K_t}{t_c} \text{……………………………………..Equation1}$$

Where,

t =8hr/day

V_{ol} = volume capacity of mixing drum in m^3

Y= yield coefficient (y=0.63 to 0.75)

t_c = time of mixing cycle (in seconds) (170 seconds)

K^t =time utilization of concrete. Its value depends on the efficiency of the machine operator (K_t=0.85 – 1.75)

Substituting the above values:

$$P_m = \frac{t \times 3600 \times v_{0l} \times y \times K_t}{t_c} \text{ ………………………………..Equation 2}$$

$$P_m = \frac{8 \times 3600 \times 0.3 \times 0.75 \times 0.85}{170} \quad = \frac{5508}{170} \quad = 32.4m3/md$$

Volume of concrete work is established to be 1800m^3 (Proposed Lecture Theatre)

Mixer productivity =32.4m^3/m^d

a. Determination of Mixing Gang

Standard output $\frac{T}{S_t} = \frac{\text{time utilization of concrete}}{\text{standard time of mixing concrete}}$ ………………..Equation 3

Standard time of mixing concrete = 1.59hr/m^3

Standard Output, $So = \frac{T}{S_t} = \frac{8}{1.59} = 5.03m^3/m^{-d}$

P$_l$ = No. of workmen $\frac{P_m}{S_o} = \frac{32.4}{5.03} = 6.44 \cong 7$ No. of labourers

Accept 7 labourers

Labour required, Lr = $\frac{Quantity\ of\ concrete}{Standard\ Output}$…………………………..Equation 4

Lr = $\frac{Q}{S_o} = \frac{1800}{50.03}$ = 357.85 $\cong 358\, m^{-d}$

Time = $\frac{L_r}{P_l} = \frac{358}{6.44} = 55.59 \cong 56\ days$

Determination of Transportation Gang

S$_t$ = 2.61 m hr/m^3

Standard Output, $So = \frac{T}{S_t} = \frac{8}{2.61} = 3.07m^3/m^{-d}$

Labour required, Lr = $\frac{Quantity\ of\ concrete}{Standard\ Output}$…………………..…………Equation 5

Lr = $\frac{Q}{S_o} = \frac{1800}{3.07} = 586.319 \cong 586\ days$

P$_l$ = No. of workmen $\frac{L_r}{T} = \frac{586}{56} = 10.46 \quad \cong 11$

Accept 11 no. labourers for transportation gang

Determination of Placement of Gang

S$_t$ = $\frac{\boldsymbol{q}}{z} =$ 1.8 hr/m^3

$So = \frac{\boldsymbol{T}}{\boldsymbol{S_t}} = \frac{8}{2.61} = 3.07m^3/m^{-d}$

Standard Output, $So = \frac{\boldsymbol{T}}{\boldsymbol{S_t}} = \frac{8}{1.8} = 4.44m^3/m^{-d}$

Lr = $\frac{\boldsymbol{Q}}{\boldsymbol{S_o}} = \frac{1800}{3.07} = 586.319 \cong 586\ days$

Lr = $\frac{\boldsymbol{Q}}{\boldsymbol{S_o}} = \frac{1800}{4.44} =$ 405.405 ≅ 406 days

P$_l$ = No. of workmen $\frac{L_r}{T} = \frac{406}{56} = 7.25$

Accept 7 no. labourers for placement gang

Summary

Batching and mixing: 7

Transporting: 11

Placement: 7

The whole concreting gang is therefore made up of twenty-five (25) plus one (1) mixer operator, making up to twenty-six (26) workers. This number should be accepted as the optimal composition of labour force required to carry out 1800m^3 of concrete on foundation trenches for the Proposed Post Graduate Lecture Theatre for the Building Department, Imo State University Owerri.

5. CONCLUSION

The study has significantly shown the need to analytically formulate an appropriate framework for optimal composition of labour force requirements to carry out concrete work to deliver projects on schedule. Quality concrete could only be achieved by ensuring adequate care at every stage of the concrete production. This ensures concrete of uniform strength from batch to batch. The incidence of instability, poor standard of work, and abandoned projects could be avoided or reduced to the barest minimum by establishing optimal compositions of labour force requirements. Judiciously embarking on these processes will ensure that the whole concreting work will be undertaken by the following three different gangs of workmen: Batching and mixing; Transportation; and Placement.

Based on the findings of the study, the following recommendations are made:

i. There should be strict monitoring by national or zonal codes of practice for appropriate quality concrete at every stage of the concrete production, ensuring that the whole concreting work is undertaken by the aforementioned three different gangs of workmen for optimal composition of labour force requirements.

ii. Building projects should have a regulatory body monitoring and moderating compliance.

iii. Stakeholders and operatives in the building industry should take responsibility to deliver the project within the specified schedule with quality materials and workmanship.

iv. To reduce or eliminate the incidence of failed building projects, proper evaluation of the quantity and quality of materials is necessary.

6. COMPETING INTERESTS

None to declare

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