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Assessment of Steel Framed Buildings in Nigeria A Case Study of Osun School Infrastructure Revamp (O-Schools)

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***Abstract*—This paper deals with an aspect of the development of the technology of the steel framed buildings in Nigeria which was introduced in Osun State south-western Nigeria in the late 2011s. It is specifically concerned with its progress in the context of the Osun school infrastructure revamp (O-Schools). Two school buildings were used for the analysis. The results conclusively demonstrate that steel-based options are, in all cases, the most cost effective and quickest forms of construction for buildings. The paper also discusses the relationship between building construction professionals and current approaches to the integration of mechanical, structural and architectural design for steel framing buildings. The paper also highlighted the many other advantages of steel frames. These include speed of construction, adaptability and ease of service integration.**

Keywords—Steel-framed; building; infrastructure-revamp; constructional prrofessional

I. INTRODUCTION

The advent of steel framed buildings in Nigeria is one of the most exciting developments in recent times in the building industries. While this method of building has been used in advanced countries such as the US, Europe and Japan for decades, it has only recently been introduced and accepted in Nigeria. The steel-framing concept has proven itself over a century and is currently the fastest growing building technique in the world. The steel structural system has recently been rediscovered by designers and construction contractors seeking innovative technologies [1]. Over the past few years, metal construction has become a standard technological alternative for Nigerian civil construction projects. The use of metallic structures has been increasingly used in industrial buildings, because of a number of advantages including more accurate and more rapid project completion [1].

Steel is one of the most sustainable building materials in the world. Steel is durable, safe, strong and not susceptible to rot, termites, or mold [2]. Steel used for framing will last from hundreds to over a thousand years due to its zinc coating, a natural element. Steel structures require less material (both reduced weight and reduced volume) to carry the same loads as concrete or masonry or wood structures. Steel is dimensionally stable: it will not warp, split, or creep - making it durable and built to last [2]. Whether to use steel or concrete for the structural frame is one of the most significant early decisions of any project. This choice has a wide-ranging effect on many subsequent aspects of the building design and performance. These, in turn, all have an impact on the cost and value of the project and are fundamental to its overall success [3].

The steel framing building technology was introduced in Osun State south-western Nigeria in the late 2011s for the Osun school infrastructure revamp (O-Schools). The design system was imported from developed countries and is optimized to work well in Nigeria climate with little or no modifications. The intent of this paper is to assess the steel framed buildings in Nigeria in the context of the O-Schools. This involved both the development of new relationships between architects and engineers and the adoption of new technologies. This research is of great importance to the expansion of educational building in Nigeria particularly Osun State. The results will show whether it is well acceptable to use steel frame or not in building construction.

II. THE RELATIONSHIP OF PROFESSION AMONG THE PROFESSIONALS

Building construction involving structural steel has four main stages which are design, fabrication, transport and erection. Structural engineers are principally concerned with the structural form of a building, whereas architects are concerned with the harmonious integration of the building functions, forms, mechanical systems, as well as the building itself [4]. The mechanical engineers create their system design with input from other specialty professionals on the steel frame building design team. The mechanical engineer is usually responsible for the plumbing system design; heating, ventilation, and air-conditioning (HVAC) design, sequence of operation for the control system design; and, in most cases, the energy calculations, which show compliance with the Building Energy Efficiency Standards [5]. The mechanical engineers coordinate the mechanical equipment requirements with the electrical engineer to make sure that the electric service to the building is of the proper size. The dividing line between the civil engineer and the mechanical engineer relative to the plumbing design is usually drawn at a five-foot perimeter around the house [6]. The mechanical engineer determines the sewer, water, and gas (if applicable) requirements of the building and coordinates this with the civil engineer to ensure that the proper size and capacity of the utilities are brought on site and the proper connections are provided for the building.

The other professionals in the steel frame building are builders, erection engineers, fabricators, shop detailers, transporters and erectors. The builder has overall management and control of the building site and ensures that the building construction is in accordance with project schedule. The erection engineer approves the sequential erection procedure which includes how the structure is stabilized at each stage and signs any modification, and is required to provide guidance to the builder and erection crew. Fabricator is the person responsible for making the steel work. Shop detailer is the party engaged to produce the shop drawings. Transporter is the person who transports the steel member from the fabricator to the building site. Erector is the person responsible for erecting the structure. Each party is responsible for the matters that are under its management and control. Managing risks arising from these matters is more effective when parties regularly consult one another and review how the next part of the process will proceed [7]. It is through their collaboration that complex buildings can be designed to the highest aesthetic and structural standards. Hence, it is the responsibility of these professionals to exercise all reasonable skill, care and diligence and display their expertise according to the professional standards in the steel frame building [8].

III. METHODOLOGY

This study started in 2013, we interviewed 43 building construction professionals including 8 architects, 6 builders, 21 structural, mechanical and electrical engineers, 2 residential contractor, 2 HVAC contractors, 1 plumbing contractor, 1 electrical contractor, 2 roofing and sheet metal contractor across Osun State Nigeria to ensure the study drew on the most up to date knowledge and expertise. Their expertise and independence ensures the credibility and accuracy of the study results. The study looks at the costs and benefit of buildings built by steel framing. The buildings were fully examined, taking into account the entire major variable of steel fabrication include design, connections, transport and erection, costs and other related benefits of the construction materials. We analyzed over 160 pages of interview transcripts and 64 pages of field notes to determine how steel frame is being used by professionals for building construction. We also looked for evidence of how the roles of the subcontractor organizations as well as those of individuals are changing because of the adoption and integration of steel frame into the building design and construction process.

Osun school infrastructure revamp (O-Schools) was used as a case study to understand the use and benefit of steel frame building in detail. The two buildings in the study represent typical modern school structures, for which a number of steel and concrete systems were examined. Building 'A' is typical of a speculative middle school building of modest specification in St James Grammar School, Ayetoro, Osogbo. It is storey building, of a width that permits good natural ventilation and lets in plenty of natural light. The building consists 25 classrooms dining hall, portable water supply system with 16 standard toilets facilities, library, and recreation centre and computer laboratory. Building B is typical of a prestige high school building in Osogbo Grammar School, Osogbo. It is more complex structure than Building A. It is two storeys high and is natural ventilation and lets in plenty of natural light. The structure feature an ICT studio, laboratories, library, food court, examination hall for minimum of 1,000 students, auditorium. The study contains rates for steel fabrication which include design, connections, transport and erection while the itemized rates for the various concrete components, including foundations, ground floor, basement, upper floors and roof, as well as the associated work such as excavation, reinforcement and formwork.

Fig. 1. St James Grammar School, Ayetoro, Osogbo

Fig. 2. Osogbo Grammar School, Osogbo

IV. FINDINGS AND DISCUSSION

A. Respondent

The study showed that steel offers considerable advantages over concrete, making it the first choice material for large building construction in any location. Steel construction can dramatically reduce the impact of building activities on the surrounding area. Steel construction minimizes noise and dust, shortens the construction period and reduces the amount of waste generated. Steel frames are easier to alter than the concrete alternative. Off-site fabrication improves the quality of the building frame, since the majority of work is carried out under closely controlled factory conditions. Steel offers a clean, efficient and rapid construction method, which reduces the impact of building activities on the environment. The small amount of waste produced is generally recycled, and all steel is potentially reusable.

B. *Case Study*

The two case studies focus on the construction of school buildings in which the engineers, architect and builder took the management role in their developmental methodology. The concrete components, including foundations, ground floor, basement, upper floors and roof, as well as the associated work such as excavation, reinforcement and formwork. The steel fabrication include design, connections, transport and erection, but assume that the steel is not to be painted. Other steel-related components, shear studs and steel decking, have also captured. The pricing of all options was supplied by respondents and average was determined.

TABLE I.

S/N	Elemental building cost for concrete based option			
	Description	*Composite beam and slab* ₦/m²	*Reinforced concrete flat slab* ₦/m²	*Initu concrete frame with precast concrete floors* ₦/m²
1	Substructure	11,029	12,912	12,146
2	Frame & upper floors	22,327	38,736	38,736
3	Pitched roof	9,146	9,146	9,146
4	Stairs	6,725	6,725	6,725
5	External walls	83,390	83,390	83,659
6	Windows & external doors	1,076	1,076	26,631
7	Internal walls & doors	25,555	24,748	22,865
8	Wall finishes	4,304	4,304	4,304
9	Floor finishes	22,865	22,865	22,865
10	Ceiling finishes	12,912	12,912	12,912
11	Sanitary fittings &disposal	12,912	12,374	12,374
12	Mechanical services	62,139	63,215	62,139
13	Electrical services	26,093	26,093	26,093
14	Builders work	28,783	28,783	28,783
	Subtotal	329,256	334,367	343,473
	Contingency (5%)	16,462	16,718	17,174
	Total building cost/ m²	345,718	351,085	360,647
	Construction period (weeks)	24	26	26
	Saving @ 21 % p.a.	-2	0	0
	Net building cost/ m²	345,716	351,085	360,673

Source: Modified from Corus Construction & Industrial (2004)

TABLE II.

S/N	Elemental building cost for steel based option			
	Description	*Slimdek* ₦/m²	*Long span cellular beams* ₦/m²	*Post tension ribbed slab floors* ₦/m²
1	Substructure	10,760	9,953	12,912
2	Frame & upper floors	26,900	28,245	45,730
3	Pitched roof	9,146	9,146	9,146
4	Stairs	6,456	6,725	6,456
5	External walls	79,355	81,507	77,472
6	Windows & external doors	1,076	1,076	1,076
7	Internal walls & doors	24,748	25,555	23,672
8	Wall finishes	4,304	4,304	4,304
9	Floor finishes	22,865	22,865	22,865
10	Ceiling finishes	12,912	12,912	12,912
11	Sanitary fittings &disposal	12,912	12,912	12,912
12	Mechanical services	61,601	62,677	63,215
13	Electrical services	26,093	26,631	26,900
14	Builders work	20,982	20,982	20,982
	Subtotal	320,110	325,490	340,554
	Contingency (5%)	16,005	16,275	17,028
	Total building cost/ m²	336,115	341,765	357,582
	Construction period (weeks)	25	24	28
	Saving @ 21 % p.a.	-8	-9	0
	Net building cost/ m²	336,133	341,780	357,610

Source: Modified from Corus Construction & Industrial (2004)

The results in table 1 and 2 shows that steel-based options are, in all cases, the most cost effective. The composite beam and slab system was the lowest cost concrete option, while slimdek was cheapest structural system, with long spans not far behind. All concrete frame structures need to begin later than the steel alternatives, since a ground-bearing slab must be constructed first. The long span steel option is the fastest construction system, since there are few pieces to assemble. It reduces the cost of finance, since a shorter construction period reduces the time during which interest has to be paid. The rapid completion of a building also brings an earlier return on investment. In general, reinforced concrete systems are three to eight per cent more expensive than the steel options.

V. CONLUSSION

The steel-based buildings can be easily extended either vertically or laterally, unbolted and re-bolted, strengthened and reshaped because of the nature of the connection of one piece of steel to another. The minimal disruption caused during construction, its limited impact on the environment. Furthermore good design at inception will allow the steel elements of the structure to be unbolted and reused elsewhere. Considering these numerous advantages, steel will be the dominant form of construction material of choice for school buildings in Nigeria. The collaborative process of engineers, architect and other building professionals, the school infrastructure revamp in Osun State Nigeria has gained an insight into the possibilities offered by advanced building methods, which are almost entirely absent, while the developed part of the world have benefited from the innovations of the steel-framed buildings. The study observed that the technical innovations displayed in the building could not have been achieved either by architects or engineers working separately, their partnership were the crucial factor. Therefore, steel-framed buildings are better than concrete based because of the cost-effective, inherent ease with which they can be modified or adapted.

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