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Sip-technology as solution in low-rise multi-family residential buildings

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Abstract. The article is devoted to the study of the possibility of using SIP-technology in solving the problem of housing shortages in Bujumbura. The author analyzed the design features of houses, foreign experience in the development of low-rise construction, the advantages of using SIP-panels compared to other building materials. Organizational and technological solutions for the construction of low-rise apartment buildings using SIP-panels will help to provide the population with comfortable housing at an affordable price. The SIP-technology enables the construction in places with difficult terrain due to their difficult engineering and geological conditions.

1. Introduction

The Republic of Burundi is located in the central-eastern part of Africa. The total area of Burundi is 27,834 km2, and the population in 2017 was 11,742,319. According to the United Nations Department of Economic and Social Affairs, the Population Division, Burundi is the second most densely populated country in Africa, with 401.7 inhabitants/ km² [1, 2, 3]. A large population is observed in the city of Bujumbura, the capital of Burundi. Geographically, Bujumbura is adjacent to Lake Tanganyika on the northeast side. Its relief varies from west to east - from flatland to highland with an average height of about 900 m above sea level.

The location of Bujumbura on the shores of the longest lake in the world makes the capital of Burundi a major African inland port. The port is the economic center of the city. There is a migration of people from rural areas and small towns to the capital, for a number of reasons such as: the opportunity to find work, higher wages, career prospects and self-realization, education, a variety of entertainment, the availability of services.

This overcrowding in the capital has led to a housing shortage. Increased material well-being and changes in the demographic composition of the population entail an increase in the demand for quality and comfort of housing. There are two possible options to expand the city: either in the direction of the plain, or in the direction of the plateau. Since 2005, the city is expanding more in the plain, into places where rice cultivation is practiced. Building in such places is very difficult and expensive, because the fields are constantly flooded. Construction in plateaus is not yet practiced because of the complexity of the relief. [4]

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This housing issue of the Burundian population can be solved by the construction of multi-apartment houses (up to 5 floors) using Canadian technology (a vulture panel) in places with difficult terrain.

2. The history of low-rise construction

In America and in Europe, low-rise construction was developed to solve the housing problem. In Canada, after the Second World War, the flow of migrants increased significantly and the need to provide them with housing appeared. A huge number of individual houses were erected according to standard designs and construction technology, which met the following necessary requirements: construction deadlines, all-season work, continuous production of components, and housing comfort. [5, 6]

In the late 40s and 50s of the 20th century, the population's demand for housing in America increased excessively. The main reasons were a dramatic improvement in the demographic situation (increase in the number of registered marriages, an increase in the birth rate), due to the economic growth (growth of the gross national product by 15 post-war years by more than 2.4 times) and an increase in the purchasing power of the population (by 22%) housing shortages caused by prolonged stagnation in the US construction industry from 1928 to 1933 and obsolete housing stock. [7]

In Europe, the process of suburbanization of cities and the development of low-rise construction has its own specifics. In France, in order to decentralize Paris in 1965, it was decided to build 5 new satellite cities at a distance of 25 km from the center (Sergy-Pontoise, Mantes-la-Vallee, Saint-Captain-en-Yvelines, Évry, Malen-Sinard) . In London, the process of suburbanization intensified after the Second World War. New towns were built with the aim of unloading London from the population and industry, which grew spontaneously and redevelopment of the city and surrounding suburbs to restore the consequences of the Second World War. It was built 23 such cities around London.

3. The advantages of using SIP-panels

Given the small purchasing power of the Burundian population, and the acute issue of providing the population with affordable housing, an alternative to building technology is needed, which would make it possible to quickly build entire settlements at the optimum speed of construction and a relatively low price. This alternative is seen in the construction of multi-apartment residential buildings with 5 floors, allowing investors to get the maximum possible profit from $1m^2$ of the territory, and the consumer to get a high level of comfort with minimal cost.

The use of Canadian technology is due to a number of advantages [8]. Canadian technology is based on the use of Structural Insulated Panels.

SIPs are produced by sandwiching a layer of insulating foam between two wood-based panels such as oriented strand board (OSB). The panels provide the primary structural role, while the foam provides shear and insulating properties.

According to Canadian Construction Materials Centre (NRC-CCMC), both academic studies and demonstration houses have shown that houses built using SIPs have higher insulating values than standard wood-frame construction. Industry studies suggest that SIPs may also be better at controlling air leakage. Other potential advantages include a faster rate of construction and a reduction in construction waste since SIPs are pre-manufactured to architectural and engineering designs. [9]

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Fig. 1. General view of the SIP-panel

Fig. 2. Multi-familial residential house made of SIP-panels

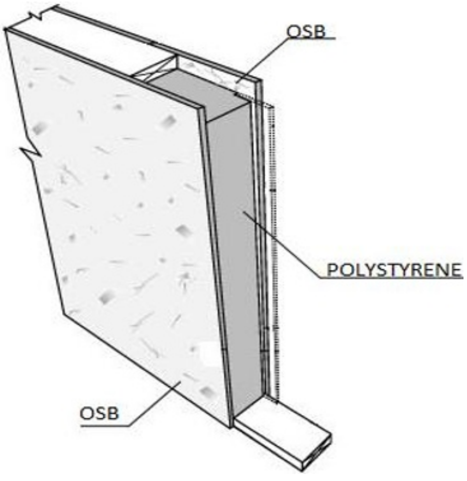

Fig. 3. SIP-panel and his components

Fig. 4. SIP-panel under load

Fig. 5. Horizontal load

Fig. 6. Horizontal load

The strength of the panel depends on the oriented strand board's strength:

– The flat long-sized chips orientation provides anisotropic constructional properties material – increased bending strength and increased elastic strength along the major axis slabs.

– The thickness of the panels ranges from 120 mm to 224 mm. The panel has exceptional properties for energy saving, strength (for a horizontal load - 2500 kg, and for a vertical load - 19000 kg), for sound insulation. (Tab. 1,2,3)

Table 1. The load bearing capacity of a slab panel [kg/m^2]

Deflection	Span				
	3050	3660	4270	4880	5490
L/360	340	236	172	122	95
L/240	454	358	259	186	141

Table 2. Sound insulation characteristics of SIP-panels

Overall thickness, m	Sound absorbing layer		Insulation value, dB	Application area
	density,kg /cm^3	thickness, mm		
124	25	100	44	external and internal walls and partitions
164	25	140	56	external and internal walls and partitions
214	25	200	74	slab, roofing

Table 3. Comparative thermotechnical parameters of SIP-panels and other building materials for the Moscow region

	Материал	**Ro, m^2*^{o}C /W**
1	SIP-panel, 164мм	3,93
2	ceramic building bricks, 510мм	1,40
3	Wood beam 150mm + clapboard trim	1,04
4	Wood beam 150мм+ brick cladding	1,28
5	Foam concrete 400 mm	2,06
6	Brick 380 mm + mineral wool 75 mm + clapboard cladding	2,03

This comparative analysis show that SIP-panel has thermotechnical properties for superior than other traditional building materials used for the erection of external walls. RDH building science investigated the energy consumption in low-rise multi-family residential buildings in British Columbia. They review and assess the actual energy consumption of low-rise residential buildings, as well as the impacts of building enclosure retrofit- or rehabilitation-related improvements on the overall energy consumption of these buildings. These findings are used to assess the benefits of better building enclosure design strategies to reduce energy consumption and associated GHG emissions for both new and existing buildings. [10, 11, 12, 13]. Consequently, the cost of heating will be significantly less in the cold season, and in the hot season houses will be kept comfortable and reduce the cost on mechanical cooling systems such as air conditioners and electric fans. AndrewAcred, Sara Omrani, V. Garcia-Hansen, B. Capra and R. Drogemuller, in [14, 15] studied the natural ventilation in multi-storey buildings. He compares the qualitative insights, and their implications for design, with numerical solutions for building operation scenarios. At the very early stages of design, this approach can be used to make decisions such as the choice of building form, and the suitability of a given ventilation scheme. The iteration of the method allows an initial design to be rapidly refined. Once a workable ventilation scheme has been chosen, then it will be used design tools such as building energy simulation software.

4. Construction phase of houses with SIP-panels

The technological process of house's construction from SIP panels consists of following steps: construction of the foundation, fixing the structural beam under the slab panel; installation of slab panels; creation of a support contour for placing further wall panels; installation of wall SIP-panels; processing connection between wall panels; strengthening the windows and doors openings with a structural board; laying of the strapping bar and slab panel, which is done after the installation of wall panels;- installation of the roof; external finishing work; internal work.

Let us consider in more detail the steps that affect the speed and cost of installation work.

The main element that guarantees the solidity and quality of the building, traditionally is the foundation. While choosing a foundation many factors should be taken into account such as the nature of the soil in the area of building, the frost depth, the level of groundwater occurrence, features of the constructed structure, etc. The cost of foundations are usually about 15-20% of the total construction costs.

Houses from SIP-panels have a relatively small weight, which allows the use of following types of foundations:

- shallow foundation (fig. 7);
- screw pile foundation (fig. 8);
- isolated column footing foundation.

In the construction of light buildings from SIP panels, it is most advisable to use shallow foundations, which, along with reliability, allow significant reduce material consumption and reduce labor costs. [16, 17]

During the construction of light buildings from SIP panels, it is most advisable to use shallow foundations [fig. 7], which, along with reliability, can significantly reduce the consumption of materials and reduce labor costs.

In contrast to the traditional reinforced concrete foundation, foundations on screw piles [fig. 8] can reduce costs by 30-40% and allow installation on complex soils in 3-4 days.

Fig. 7. Shallow foundation

Fig. 8. Screw pile foundation

Shallow foundations are often made of monolithic reinforced concrete. He is almost universal for different types of soil, as it refers to the type of "floating plate".

Isolated column footing foundation is a separate support, which are laid under the most important parts of the building (angles, intersection of the bearing walls, under the bearing walls with a given spacing) and are connected by horizontal elements (metal beam, wooden beam, concrete grillage) under load-bearing structures. This type of foundation is more economical in terms of cost, works and materials, but less reliable. It can only be used on stable soils and generally for independent construction.

Currently, screw pile foundations are used in construction of SIP panel houses by many developers. A screw pile is a steel pipe with a blade welded to it. Screw piles were developed by the military in the 1960s. for supporting bridges, high-voltage lines in the weak and frozen soils. This type of foundation has a high bearing capacity and reliability. During the screwing process, the soil between two adjacent piles are compacted by a screw pile blade. Foundation laying is possible at any time of the year and on almost all types of soil. Screw pile foundations are generally 30-40% cheaper than shallow foundations. [18, 19]

5. Conclusion

The Burundian issue of house shortage can be solved by using new constructive solutions, using new materials, application of new equipment and engineering solutions, application of new organizational and technological solutions.

Sip-PANEL technology is a solution due to his advantages.

– high speed construction of the building. It is mounted on a ready-made foundation without the use of heavy machinery at any time of the year by a brigade of 3-4 people in just 2-3 weeks, that is, 10–20 times faster than brick construction.

– due to the smaller wall thickness, we get up to 20% of additional usable area. The panels themselves can be a supporting structural member. The inner and outer surfaces of the building are smooth and ready for any traditional finish. The solid foam core of a SIP delivers continuous insulation and is available in a variety of thicknesses to help builders increase their building envelope performance.

– limited financial capacity: SIP panels and their installation are cheaper than building with the usual materials. For the same amount, we get a more spacious and comfortable home built using SIP technology than one of the traditional houses. Moreover, SIPs use OSB structural panels that meet indoor air quality requirements. There is no need of additional measures for the insulation of the house. SIP panels have a high thermo-technical capacity: they retain heat in winter, while in summer they retain the effect of night cooling. Another advantage is that, from the beginning of the project, you can be sure of the amount of your new home. Risks and additional monthly expenses are absent.

– SIP panels are the most appropriate solution in the case of the capital of Burundi where the building land is located on mountain slopes (south-east of the capital), and in flood-prone areas (north-west of the capital: These types of terrain can only support light foundations and constructions. With Canadian technology houses are built without using heavy machinery. The construction itself, as well as the foundation, are lightweight, airtight and withstand environmental conditions.

– Houses made of SIP panels have unique properties: are not subject to absorption of moisture and rotting; withstand hurricane winds with a speed of up to 250 km per hour and earthquakes of up to 8 points. The estimated lifetime of homes from SIP-panels is more than 100 years.

– SIP panel is an ecological material: meets the modern requirements of healthy housing. Houses are built from the most advanced modern environmental materials.

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