Research Proposal

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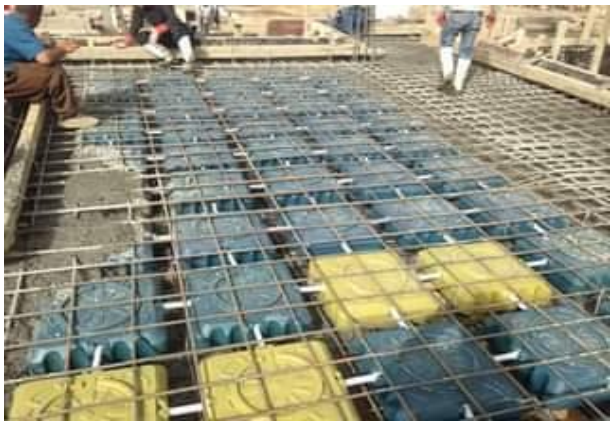
Comparative Study of Waffle Slabs with Flat Slabs and Conventional RC Slabs: From Economics and safety view



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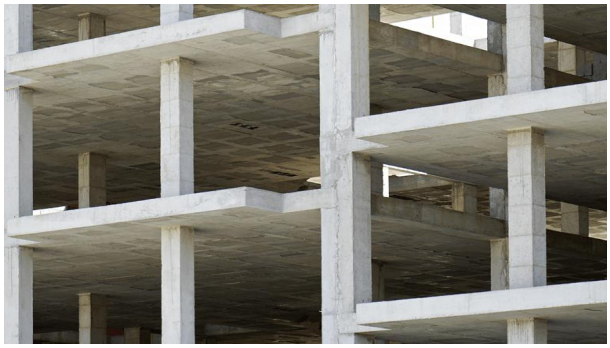


Introduction

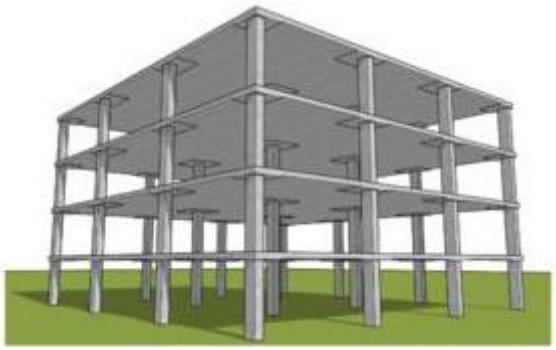
An important part of the total responsibility of the structural engineer is to select, from many alternatives, the best structural system for the given conditions. The wise choice of structural system is far more important, in its effect on overall economy and serviceability, than refinements in proportioning the individual members. Close cooperation with the architect in the early stages of a project is essential in developing a structure that not only meets functional and esthetic requirements but exploits to the fullest the special advantages of reinforced concrete, which include; versatility of form, durability, fire resistance, speed of construction, cost and availability of labor and material. Slab is a structural system consisting of a deck supported on columns which is used to transfer dead and live loads to the supporting vertical members through bending, shearing and torsion.

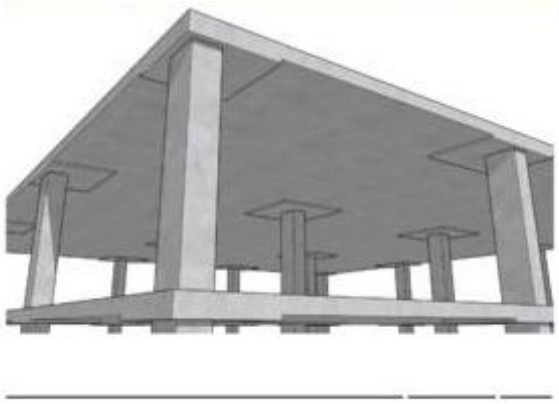
They are used in various places like buildings, bridges, and parking areas. As these places require large column free area with conventional flat slabs it is a major challenge. Since concreting larger area means increased dead weight of the slab thereby resulting to simultaneous heavy structures which in-turn leads to a costly construction practice. Development in this field and in Kurdistan can be observed with the usage of waffle slabs which meets the requirement of reduction in dead weight. As the weight of slab decreases, slab moments get reduced and simultaneously material gets reduced, they also exhibit relatively less deformation and possess higher stiffness under heavy load.

WHAT ARE FLAT SLABS (FS)?

Flat slabs system of construction is one in which the beams used in the conventional methods of constructions are done away with. The slab directly rests on the column and load from the slab is directly transferred to the columns and then to the foundation.

To support heavy loads the thickness of slab near the support with the column is increased and these are called drops, or columns are generally provided with enlarged heads called column heads or capitals. Absence of beam gives a plain ceiling, thus giving better architectural appearance and also less vulnerability in case of fire than in usual cases where beams are used. Plain ceiling diffuses light better, easier to construct and requires cheaper form work.





Advantages of Flat slabs :

The construction depth for each floor is held to the absolute minimum, with resultant savings in the overall height of the building. The smooth underside of the slab can be painted directly and left exposed for ceiling, or plaster can be applied to the concrete. Minimum construction time and low labor costs result from the very simple formwork.

Disadvantages of Flat slabs :

Shear stresses near the columns may be very high, requiring the use of special types of slab reinforcement there. The transfer of moments from slab to columns may further increase shear stresses and requires concentration of negative flexural steel in the region close to the columns. At the exterior columns, where such shear and moment transfer may cause particular difficulty, the design is much improved by extending the slab past the column in a short cantilever.

reinforced concrete slab :

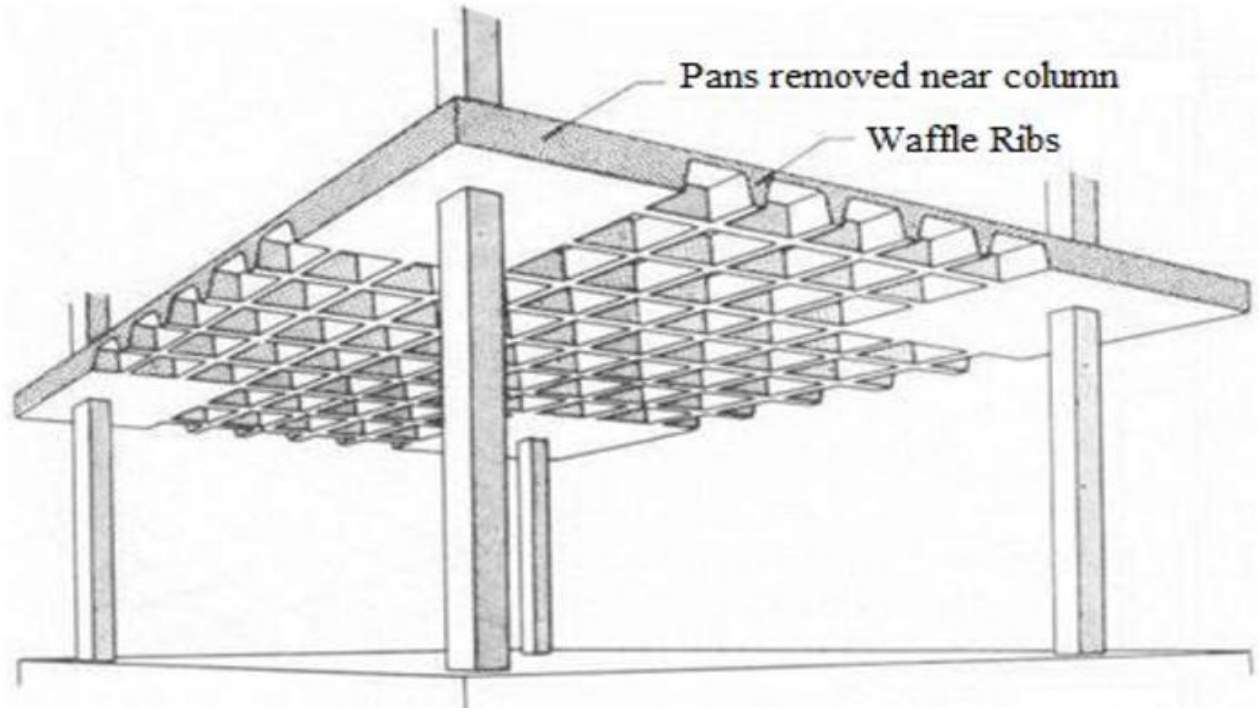
is a crucial structural element and is used to provide flat surfaces(floors and ceilings) in buildings. On the basis of reinforcement provided, beam support, and the ratio of the spans, slabs are generally classified into one-way slab and two-way slab. The former is supported on two sides and the ratio of long to short span is greater than two. However, the latter is supported on four sides and the ratio of long to short span is smaller than two. It's usually used in house construction and frame structure

WHAT IS WAFFLE SLAB (WS)?

With the development of engineering in the whole world, Kurdistan has not been deprived of this latest type of slab.

A waffle slab is a platform with a reinforced concrete roof or floor has a square grid with deep sides. This is also known as a grid slab. It has two-directional reinforcement on the outside of the material, giving it the shape of the pockets on a waffle. Waffle slabs at the entrances of hotels, shopping malls and restaurants are mainly used to install good lighting and artificial lighting.

Its main function is to withstand higher loads and longer distances than flat floors because these systems are lighter and therefore can be used for roofing and floor. They are also used where there is a restriction on the depth of the beams to obtain a clear height.



The top of a waffle slab is generally smooth, like a traditional building surface, but underneath has a shape reminiscent of a waffle. Straight lines run the entire width & length of the slab, generally raised several inches from the surface.

These ridges form the namesake square pockets of the entire length and width of slab. It helps insulate the floor since hot air gets trapped in the pockets. Waffle slabs have a thick solid-slab floor from which the bottom layer concrete in tension is partially replaced by their ribs along orthogonal directions. The ribs are reinforced with steel. This type of reinforcement is common on concrete, wood and metal construction. A waffle slab gives a substance significantly more structural stability without using a lot of additional material. This makes a waffle slab perfect for large flat areas like foundations or floors. Reinforced concrete floors and roof construction employing a square grid of deep ribs with coffers in the interstices.

Classification of Waffle Slab

Waffle slab are classified into the following types based on the shape of the slabs (PVC sheets):

١. Triangular - pod structure
٢. Square - pod structure

Design of Waffle Slab

- The design of the waffle slap depends on the total area required for the waffle slab is the main point to design a waffle slab.
- The thickness is usually ٨٠ mm to ١٠٠ mm
- Waffle slab overall depth is limited to ٣٠٠ mm to ٦٠٠ mm.
- Width of waffle slab is usually ١٠٠ mm to ٢٠٠ mm.
- The distance between two ribs in a row is ٦٠٠ mm to ١٥٠٠ mm.
- Using re-bars to reinforcement for extra strength.
- The waffle slab has reinforcement in the form of a mesh or individual bars.
- Reinforcement in the waffle slab is two-way.
- Small beams are connected with main horizontal beams that form a grid-like shape.

Characteristic & Details of Waffle Slab

- A waffle slab construction is generally suitable for flat areas.
- The amount of concrete used in the waffle slab is less compared to other types.
- Waffle layers have good shrinkage resistance.
- Waffle slab is a structural component that is hollow from the top and has a grid-like structure at the bottom.
- Waffle slab can be used for floor construction and ceiling.
- A flat slab cannot be built for a longer span and also cracks can occur.
- Waffle slab is a special type of slab that is mainly built for a long time and is resistant to cracking and sagging.

Waffle Slab Construction

- The waffle slab construction is done in three ways:
- In situ construction,
- Precast Construction
- Prefabricated construction.
- As per the design and the size required waffle slab is cast in site
- In the construction of the precast waffle slab, the slab panels are casted elsewhere and joined to the reinforcement.
- In prefabrication of waffle slab, reinforcement is provided on the slab panels during casting.
- Compared to the other two slab types, the construction cost of the slab made of prefabricated is higher.
- Waffle slab construction is generally preferred for gaps of more than ١٢ meters.
- Waffle slab construction requires approximately ٣٠٪ less concrete and ٢٠٪ less reinforcement.

Advantages of Waffle slabs

١. Because these systems are lighter in weight, waffle slabs can carry heavier loads and longer distances than flat slabs.

٢. Suitable for intervals of ٧ m - ١٦ m, longer breaks are possible with post-tensioning.

٣. Waffle slab can be used as both ceiling and floor slab.

٤. These systems are lightweight, so significant savings on the structure are ensured as the light framework is required.

Disadvantages of Waffle slabs

- Waffle slab is not used in typical construction projects.
- The casting forms or molds required for precast units are very costly and hence only economical when large scale production of similar units are desired.
- Construction requires strict supervision and skilled labor.
-

Type and usage of Waffle Slab

١. Concrete waffle slab is used to make industrial and commercial construction.

٢. Wood waffle slab and metal waffle slab is used to make other construction.

٣. This type of material is generally used to make airport, parking garage.

٤. Flat Grid is good for large working area like foundation or floors.

٥. Flat grid is used in particular project like clean rooms and places required low frequency vibration.

٦. This type of slab is used in wood, metal and concrete construction.

Objective of study

- The basic aim of this report is to exhibit the design and show the comparative benefits of Waffle slabs, flat slabs and RC slabs.
- To find the mechanism for determining which of the slabs are proper to be chosed in structure.

The aims are:

i. Savings on weights and material
ii. Vertical penetration between ribs is easy.
iii. Attractive soffit appearance if exposed.
iv. Can be used for long span also.
v. Economical when reusable formwork used.
vi. Reduction in dead load of slab.
vii. Economical for structure having repeated works.

Practical cases

Example 1**:**

In a comparative study done by Zekirija Idrizi [٤] and his colleague on the ١٤-story building with two different slab systems, in terms of economy and seismic performance of a typical ١٤-Story RC building.

After completion of all structural analysis, they found that by replacing the solid slab system of a ١٤-story building with a waffle slab system, there are ٢٠٪ of savings in concrete volume and ٢٧٪ of savings in steel reinforcement as shown in (Fig. ١).

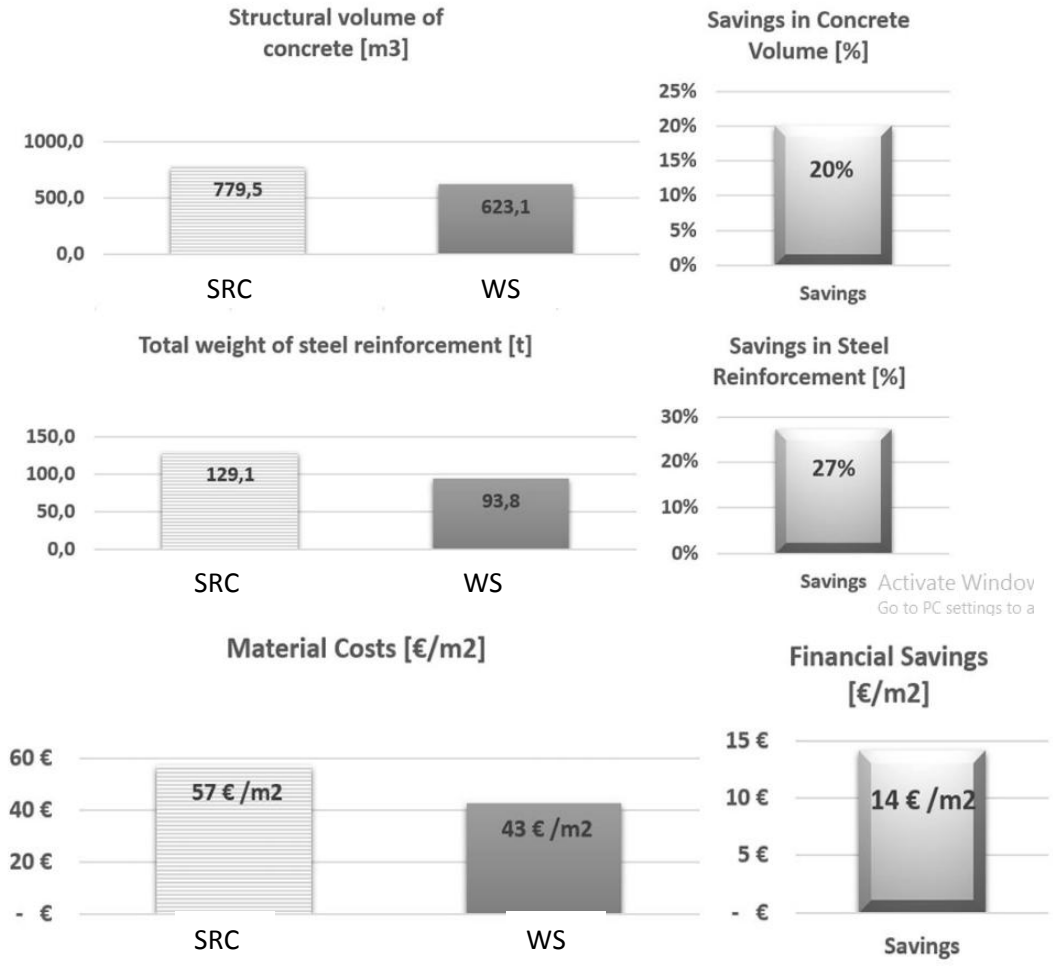


Figure 1: ***Solid vs. waffle slab comparative results in term of material and financial saving***

They concluded that the benefits of using a waffle slab system over the solid slab system are significant not only in the sense of achieving a lighter and economical structure but also in the sense of providing a safer structure with improved level of seismic performance in seismic design situations.

Example 2**:**

Sarita and her colleagues[٣] has taken a typical plan of shopping center into consideration. The design of various slabs in the entire building is done by standard design steps The comparison of various slabs (Waffle Slabs; Flat Slabs; Conventional RC Slabs) are done with respect to its design and construction aspects.

They concluded from their paper that From the following paper with the help of the case study, we conclude that waffle slabs are more advantageous as compared to other slabs such as flat slabs and RC slabs, in terms of loading, large spans, aesthetic appearance, etc. the design of their comparison is shown in the following (table ١)

Table ١. DESIGN SUMMARY

	Size (m)	Slab Thickness (mm)	Deflection (mm)	Total Ast mm^2)	Max. Moment (KN-m)	Max. Shear (KN)	Factored Load ($KN\,m^2$)	Economy & Construction	Uses
Waffle Slab	٧,٥ × ٧,٥	١٠٠	٧,٦٥	١١١٨, ٥٨	٥٦	٢٥	١٥,١٥	Economical for repetitive works, requires more time for construction as compared to RCC slabs.	Suitable for large loads, large spans, repetitive works, aesthetic appearance, etc.
Waffle Slab	١٥ × ٧,٥	١٠٠	٨,٧٢	١١٦٠	١٢٨	٥٤	١٧,٠٥	Economical for large spans and repetitive works, skilled labors required, aesthetically more useful structures, no need of finishing in various cases	Suitable for large loads, large spans, repetitive works, aesthetic appearance, etc.
Flat Slab	٧,٥ × ٧,٥	٣١٥	٢٢,٩	٩٠١٠, ٥	٢٨٤,١١	١١٧٠, ٨٤	٢٣,٨١	Suitable for medium spans, beam-less construction, difficulty while construction pods and post-tensioning, complicated designs	Beam-less construction, aesthetics, less complication while construction
Flat Slab	١٥ × ٧,٥	٦٠٠	-	-	-	-	-	Not for large spans, Suitable for medium spans, beam-less construction, difficulty while construction pods and post-tensioning, complicated designs	Beam-less construction, aesthetics, less complication while construction & suitable for medium spans
Conventional RCC Slab	٧,٥ × ٧,٥	٢٦٠	٣١,٢٥	١٨٩٤	٤٣,٦٢	٦١,٢٦	١٦,٥	Suitable for short spans, most easiest way of construction, skilled labors not required, can be constructed in rural areas very easily.	Easiest way of construction, less complicated designs, residential buildings, etc.

Example 3

We obtain another example that done by students in Sudan University, In this study a square slab of ٦×٦ m panels is modeled for both waffle and flat slab under the same loading conditions and using the same construction material. The models are used to study parameters like maximum deflection, maximum bending moment and punching shear resistance. The amount of concrete and reinforcement required in slab signify the superiority of waffle slab over flat slab and consequently can be employed in various applications as an economical alternative for flat slab in their analysis they obtaining this result shown below

***Concrete quantities**
concrete quantities comparison:

Slab	**flat**	**waffle**	**Difference**
Concrete quantity	٧٤,٥ m٣	٥٩,٣ m٣	% ٢٠

C*Reinforcing steel quantities:

Reinforcing steel quantities comparison:

Slab	**flat**	**waffle**	**Difference**
Reinforcing Steel quantity	٦,٢	٥,١	% ١٨

Conclusions

From the aforementioned examples, we found that using waffle slabs is more economical safe in compare to other types of slabs, but waffle slab is recent in our region and not very commonly used in Kurdistanal region, for this reason RC slab is better in structuring houses.

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