Contruss
Engineering Company

ConTruss System Introduction

Contruss Engineering Company

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Contents

Introduction:

Contruss system contains a permanent built-in filler assembled to form voided slabs, an innovative approach developed by the Contruss Engineering Company. The design, patented in 2014, suggests applying filler-equipped slabs cast in a single phase to form mutually perpendicular ribs of I-shaped sections aligned to form the voided slab. The solid and composite fillers of Contruss system introduce more constructional and technical benefits than other permanent ones because of their unique form, material, and components. The commercial name consists of the words concrete+ truss blending and merging into Contruss, denoting a concrete truss, which proves suitable for long spans. In the following, the constructional and technical advantages are enumerated.

1- Introduction of double-sided voided slab

1-1- Two-way voided slab with I-shaped sections:

Bidirectional ribs with I-shaped sections are extremely worthwhile in construction; introducing a high moment of inertia will cause the slab to operate suitably in large spans when subjected to vibration and deflection. In addition, overflowing with many indeterminate degrees, the slab allows for a more efficient arrangement of the openings at various points.

Providing two concrete layers makes I-shaped sections appear in two directions in the double-sided voided slab system, amplifying the rigidity and resistance of the floor. In other words, this system consists of two concrete layers connected by orthogonal shear webs in the floor, forming the so-called concrete truss that will furnish a high rigidity and lower concrete consumption.

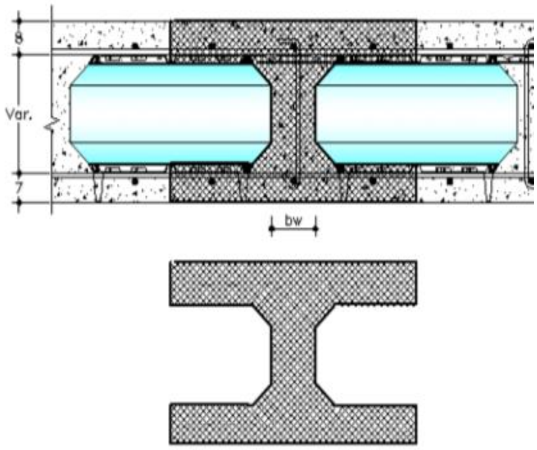


Figure 1.1. Beam sections in Contruss voided slab

1-2- Double-sided voided slab history:

The central concept implies the long-standing idea of eliminating the unloaded parts of the concrete. Based on the structural susceptibility of concrete members to tension, in the past two centuries, engineers attempted to arrive at a solution that enables them to eliminate the unloadable parts of concrete members.

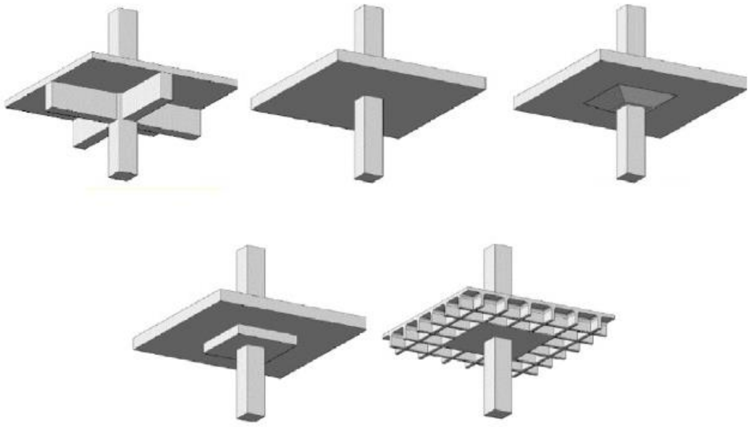


Figure 1.2. Methods of creating voided slabs

The origins of concrete voided slabs applied in constructions can be traced to a long time ago, as some cases belong to the last century. The first voided slab with an I-shaped section, known as a double-sided voided slab with permanent fillers, was developed by using spherical hollow fillers as permanent ones in the concrete slab and was first introduced in 1995 in Europe.

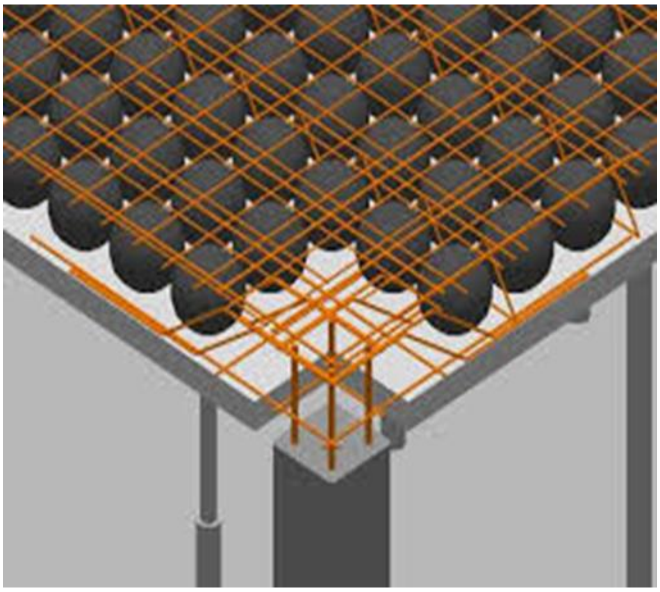


Figure 1.3. Schematic image of spherical voided slab

In 2002, some companies made significant modifications to the manner of manufacturing permanent fillers, reshaping them to rectangular cuboid ones. In comparison to spherical fillers, the new ones made a marked reduction in self-weight and concrete consumption.

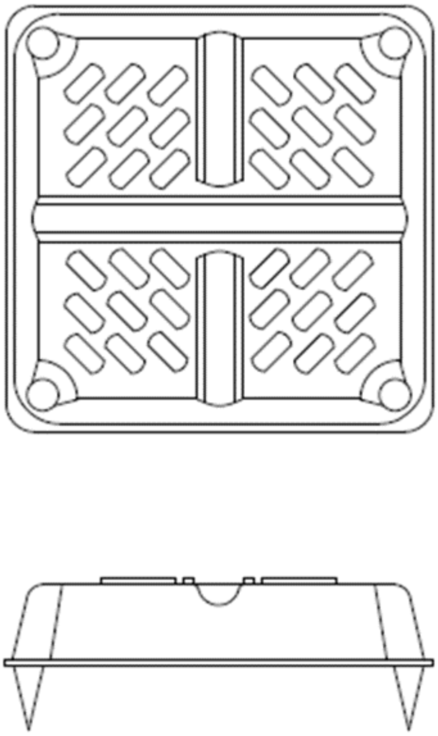


Figure 1.4. Schematic image of rectangular cuboid formwork

The filler itself offers no structural benefits and is aimed to eliminate unloadable concrete and impose a concrete-free hollow zone inside the slab, thus assuming the name of permanent filler.

Besides the advantages issued for the permanent cuboid fillers, there are some potential defects in the system. As noticed in some projects, some of the major deficiencies are the formation of stress concentration in the sharp corners at connecting points of the shear web and flange of the ribs, fracture of the fillers during construction, the difficulty of concrete in proceeding to flow to the bottom surface of fillers, and inadequate cover clearance for rebar.

Contruss engineering group, a major company in pioneering and practicing state-of-the-art technology for construction purposes, initiated the development of voided slabs with constituent permanent fillers in 2008 in the Middle East, as the first one to extend this innovative system locally and internationally.

Based on conceptual knowledge of voided slab systems, the research and development department of the company innovated the design and production of permanent fillers in order to overcome the shortcomings of the previous permanent ones. Subsequently, the company started the manufacture of its invented permanent fillers, commercially named “Contruss”, with trademark registration in 2014. Once the patent product was marketed in the construction industry, the voided slab system with permanent fillers achieved unique distinction among clients and contractors.

Figure 1.5. Contruss permanent formwork

1-3- Advantages of double-sided voided slabs applied for spans beyond 7 meters

a) Two-way load-bearing function:

In many types of concrete slabs, the transfer of loads occurs in the floor plane with a straight trajectory along one direction of the slab, making the load path longer and increasing the beam and column dimension values and the floor weight. On the contrary, the two-way voided slab distributes the loads equally in two directions towards the supports and ensures all the benefits derived from two-way solid slabs.

b) Elimination of beams:

The high moment of inertia and rigidity and the low weight of voided slabs make it possible to transfer dead and live loads directly on the supports; there is no need to add beams. Although this feature also characterizes mushroom slabs, the lower weight of the voided slabs reaches up to 30 to 40 percent compared to the filled ones of equal rigidity. Therefore, voided slabs prove excellent for engineering long spans as they open up the possibility of omitting beams and forming a flat soffit (an even bottom surface for the floor). This omission brings the following advantages:

- Constructing long spans without beams

- Decreasing the height of the structure and increasing the number of floors

- Offering flat intrados floors without drop panels and drop beams

Note that deciding to remove the beams depends largely on the structural system. For the structures enjoying shear walls and the structures less-than-10-meter high, the elimination is advantageous unless the presence of beams is essential.

c) low weight, fewer columns, and high earthquake resistance:

- Necessity for fewer columns due to the reduction in floor dead load, which causes the foundation to bear a lighter load and decreases the excavation height.

- Weaker lateral force and ultimate shear due to the reduction in floor dead load, which implies a higher structural seismic strength.

- Lesser deflection and greater slab rigidity

d) Flexibility in architectural design:

Voided slabs with permanent fillers are efficient means for actualizing the creation of long spans. From the architectural point of view, providing long spans introduces suitable flexibility in the design and makes a larger usable space; additionally, it facilitates the possibility of occupancy change.

e) Suitable acoustic, thermal, and vibrational insulation properties:

The bidirectional ribs form two solid concrete layers, introducing an appropriate rigidity that hinders vibrations.

As the polystyrene filler covers a large area, by up to 80 percent of the slab surface, the Contruss system proves more efficient in insulating against airborne noise and heat compared to conventionally filled slabs. The 15-cm thickness and much lower heat and sound transmission coefficients compared to concrete, polystyrene insulates the floor suitably against the transmission of noise and heat.

Note: Classical floors are not capable of providing appropriate insulation for the transmission of airborne noise, but double-sided voided slabs are capable of acting as an acoustic insulation due to the presence of hollow spaces inside the slab.

f) Allowing for large openings in the slab:

The prime function of slabs is their structural function as a rigid diaphragm for distributing seismic loads among supports. From the structural point of view, openings are likely to disturb the load distribution patterns on floors. The double-sided voided slab enjoys a high moment of inertia and many indeterminate degrees, enabling it to perform as a rigid diaphragm, even in the presence of large openings.

2- Introduction to Contruss filler

Contruss filler is a stay-in-place composite combination with the central core made of Expanded Polystyrene (EPS) material along with plastic plates, supports, and piles made of Polypropylene (PP) material. Compared to other floors with permanent fillers, Contruss floor provides enormous constructional and technical benefits, received from the application of lightweight permanent fillers.

Figure 2.1. Positioning of Contruss fillers

3- Contruss system installation

3-1- Floor shuttering:

The floor's entire bottom surface is covered continuously with steel or timber shuttering (or other formworks such as precast concrete or fiberglass), with the scaffolds, props, and braces positioned below.

Figure 3.1. Floor formwork

3-2- Placing the lower rebar:

The lower rebar runs in two perpendicular directions together with the additional rebar, middle beam rebar, and dowel rebar. Floor deflection must be controlled with a survey camera in this phase.

figure 3.2. Placement of lower rebar

3-3- Positioning the Contruss fillers:

The Contruss fillers are placed on the floor in accordance with the design details and tied together with belts that prevent horizontal and vertical movements.

Figure 3.3. Placing the permanent fillers

3-4- Positioning the upper rebar:

The upper rebar is placed according to the design details, preparing the slab for concrete pouring.

figure 3.4. Positioning the upper rebar

3-5- Concrete pouring, vibration and levelling:

The concrete is poured in a single stage, and the concrete consistency must be adequate to fill up the lower layer. Supplementing the mixture with super-plasticizers brings the benefit of higher flowability without strength loss. While the concrete is poured, it completely buries the Contruss filler. Afterwards, the fresh concrete is leveled and smoothed in a traditional manner.

Figure 3.5. Concrete pouring, vibration and levelling

3-6- Stripping the formwork:

Once the concrete hardens, the formwork can be removed, and a smooth surface with a flat soffit appears.

Figure 3.6. Removing the formwork

4- Contruss system advantages

4-1- Economic advantages:

a) Reduced construction expenditure for long spans:

Most floor slabs in the construction industry function as one-way slabs. For over-7-meter spans in one-way slabs, the high deflection and vibration in the floor and the necessity of laying secondary beams indicate that one-way slabs are not practical choices, both economically and constructionally. The two concrete layers and the orthogonal webs are arranged in a way that they form a highly rigid and two-way slab, enabling the architects to design spans that are up to 20 meters long.

In general, one of the main drawbacks of concrete structures is the large dimensions of columns, overcome by omitting the middle columns in Contruss system. Furthermore, due to the inclusion of two concrete layers along with orthogonal webs, the Contruss floor system forms a highly rigid and resistant slab that adequately withstands the lateral loads. Additionally, providing long spans offers better aesthetic benefits from an architectural point of view.

Figure 4.1. Increased effective span

b) Variability in filler dimensions:

Contruss fillers are the only permanent ones that enable the designers to measure the precise dimensions that are to be cut in the factory by means of commonly-used CNC machines to fit the required spaces. As a result, there is no need to waste time measuring, reshaping, and resizing them on-site, thus simplifying the slab construction. With regard to economic and constructional improvements, Contruss fillers offer the possibility of being manufactured with dimensions ranging from 45 to 60 cm and 12 to 65 cm in height.

Figure 4.2. Varying dimensions of Contruss filler

c) Increased number of parking spots:

Removing the middle columns in the Contruss system enables the designer to provide more parking spots. Beyond the financial aspect, this increase facilitates the movement and steering of cars.

In some cases, the increased number of parking spots makes it possible to eliminate a parking floor, thus offering substantial savings.

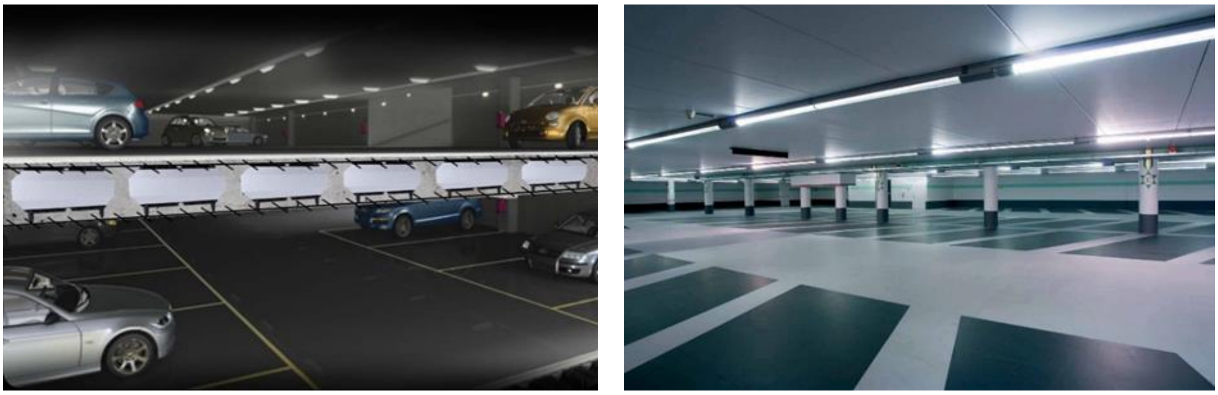


Figure 4.3. Increased number of parking spots

4-2- Architectural advantages:

a) Increased column-to-column span length:

The greater span length offered by Contruss floor is considered its most considerable advantage over other floor types. Achieving long spans in structural design is accompanied by many benefits such as larger spaces, more parking spots, facilitated occupancy change, the possibility of displacing the retaining walls, and architectural freedom.

figure 4.4. Increased effective span

b) Creating a flat soffit by eliminating drop beams and drop panels:

Using Contruss system reduces the floor thickness. For example, the floor will be 35-cm-thick in a span of 12 meters. Nevertheless, a flat surface is obtained under the floor, which can be more conveniently used for electrical and mechanical services, dropped ceiling support installation, or lathe-plaster work. In contrast, other floor systems with or without fillers require beams of, for instance, 80 cm height, drop panels, and uneven intrados surface, which complicate the passage of electrical and mechanical services.

Advantages gained by removing drop panels and drop beams and creating a flat intrados floor:

- Reduced construction costs because of the decreased floor height
- Simplified formwork, concrete pouring, and rebar placement
- Lower cost of dropped ceiling installation
- Flexibility in architecture
- Facilitated passage of mechanical services

Figure 4.5. Creating a flat intrados floor

c) Creating large irregular openings:

The high rigidity and the two-way function of the Contruss system ensure that large irregular openings are no longer a burning issue concerning the structural performance of the rigid diaphragm, especially for the construction of reception halls, villas, and commercial and educational centers. Moreover, creating additional openings for the passage of mechanical services is possible even after the realization of the slab.

Figure 4.6. Creating large irregular openings

4-3- Technical advantages:

a) Possibility of creating openings after slab construction:

There are various reasons for creating openings after the completion of the slab, but it is not approved in one-way floors due to the disruption occurred to the arrangement of beams. The incorporation of two concrete layers and bidirectional webs into the Contruss system offers a highly rigid and two-way slab that is capable of creating openings after slab construction.

b) Fire-resistance:

Since the polystyrene is flame retardant, the Contruss floor performs efficiently in the transmission of heat and functions more properly in burning compared to other floors, as certified that it is a non-flammable material.

The polystyrene used in the Contruss floor is a fire-retardant material, which is expanded and manufactured through hot steam at 100 degrees C, with no volumetric change after one week. Exposed to fire, it contracts and is not burnt.

c) Insulation of noise and vibration:

Material resistance to the transmission of sound is investigated in two fields: 1) airborne noise and 2) stomping noise.

With respect to airborne noise, concrete enjoys satisfactory sound-proofing properties; as such, the Contruss slab operates suitably against airborne noise because of having two concrete layers.

The trapped air bubbles inside the polystyrene decrease the sound power level and boosts the insulation capacity against the passage of percussion noise through the slab. The use of polystyrene in the Contruss filler results in improved acoustic behavior.

The high rigidity of the Contruss voided slab decreases the floor vibrational amplitudes in comparison with common concrete slabs, thus protecting the residents from being filled with panic.

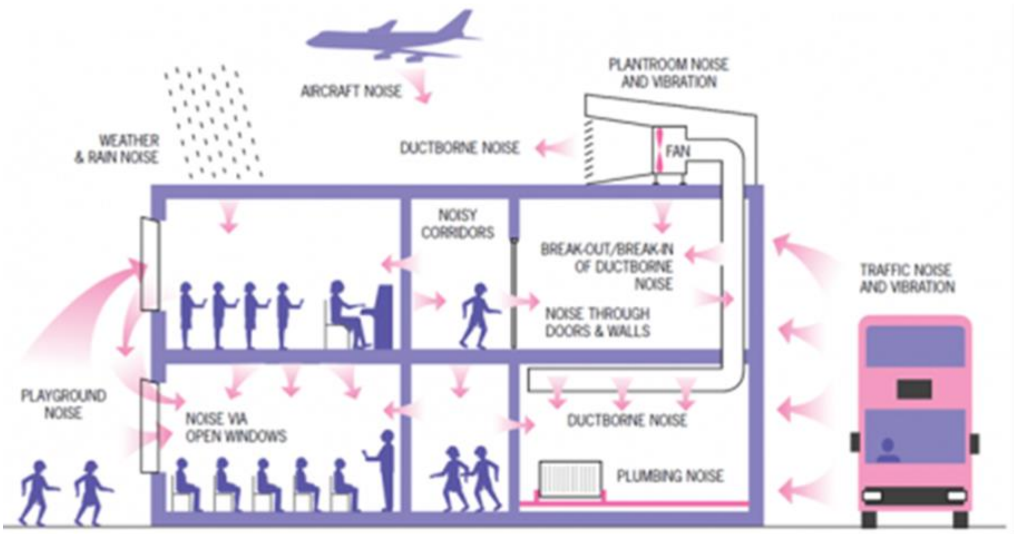


Figure 4.9. Schematic view of sound wave transmission in a building

d) Offering a light-weight floor:

The variability of Contruss filler dimensions causes a larger reduction in weight and cost of the floor compared to other voided slab systems. CNC machining enables the manufacture of fillers in varying sizes, meeting the structural design requirements. A prismatic Contruss filler can be 45 to 60 cm wide and 12 to 65 cm high, providing optimum slab dimensions, technically and economically.

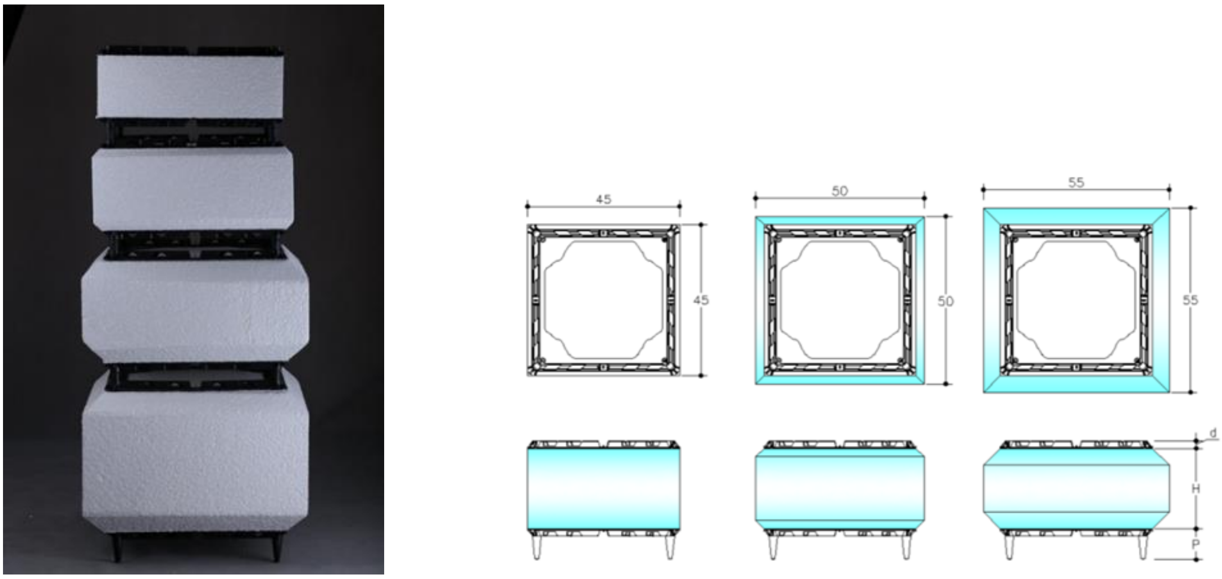


Figure 4.10. Variability of Contruss filler dimensions

Re-structuring a slab by emptying some parts of concrete fulfills the aim of freeing the slab from unloadable concrete in the middle of the floor height. The amount of the concrete-free space created is highly influenced by the filler measurements, determined according to the loading and span length values. The Contruss filler is also noted for the distinctive design and production in preferable sizes and proportions according to the client's immediate priorities to keep the weight and cost as low as possible.

Table 4.1. Filler size and height

Filler height	Floor thickness(cm)	Effective span(m)
Size 15	30	9
Size 20	35	11.5
Size 25	40	13
Size 30	45	14
Size 35	50	15.5
Size 40	55	17.5
Size 45	60	19
Size 50	65	20.5
Size 55	70	22
Size 60	75	25

e) Providing adequate clearance for rebar:

Tailoring the trays placed over the fillers to secure them brings the rebar to a standstill at the desired distance, leaving enough clearance over Contruss fillers without resort to spacers and affording a manageable design for the steel mesh.

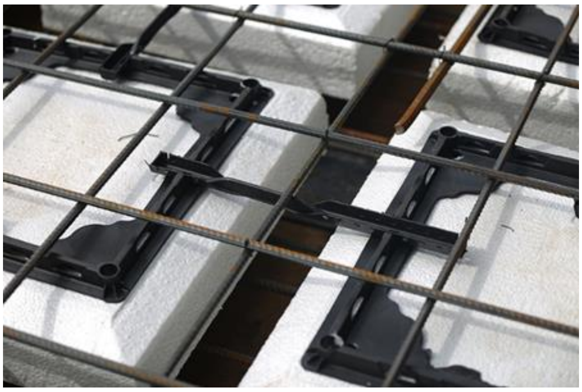


Figure 4.11. Providing clearance for rebar

f) Floor vibration and deflection control:

The bidirectional I-shaped ribs supply the Contruss voided slab with a high moment of inertia compared with flat, waffle, and prestressed slabs. Contruss floors can be roughly thought of as a hollow-web concrete truss. Therefore, the rigidity of the floor is so high that its vibration and deflection are kept well below desirable limits, and it behaves like a rigid diaphragm as the lateral forces are transmitted.

g) Opposition to stress concentration in the shear web:

The characteristic benefit of two-way voided slabs is the resultant I-shaped ribs. The unique contours of Contruss filler, depicted in figure 4.12, lend a curved outline at the web-flange connection of the rib. As a result, sheer force transfers appropriately, countering stress concentration. Stress concentration, the major deficiency of plastic-filler slabs, is overcome thanks to the innovative design offered by Contruss filler.

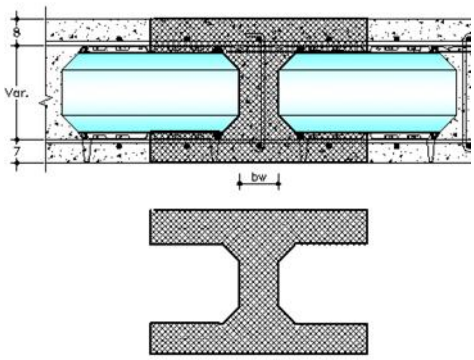


Figure 4.12. Opposition to stress concentration in I-shaped ribs

h) Easy to cut:

The Contruss polystyrene filler can be slashed down easily with a saw to fit the plans of irregular and unsymmetrical schemes with potentially various span lengths. This unique characteristic furthers the placement of fillers on the corners of the plan.

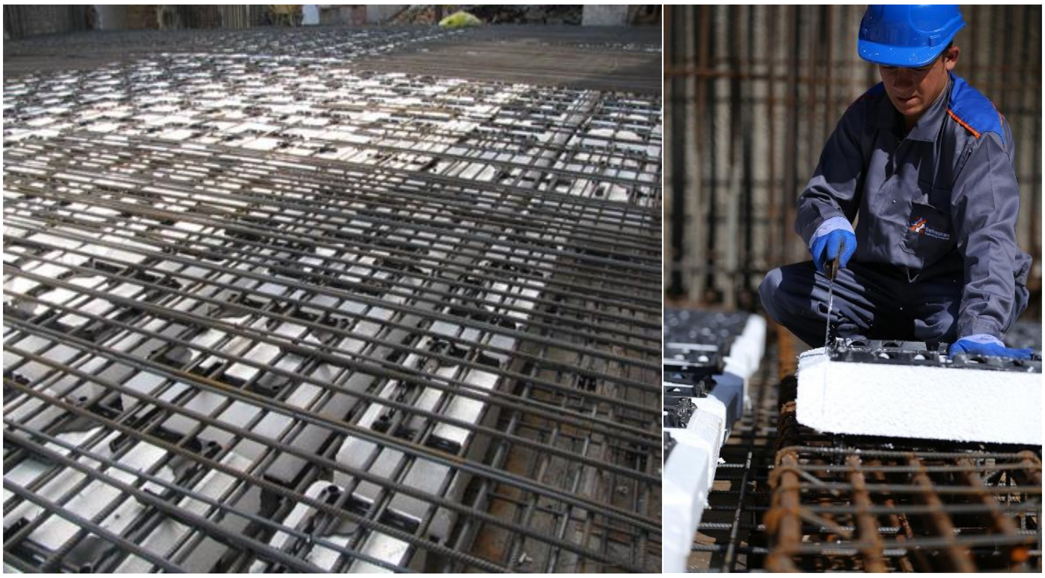


Figure 4.13. Slashed filler

4-4- Constructional advantages:

a) Simplified implementation:

Due to the elimination of drop beams, and drop panels, the floor formwork will be installed readily by conventional reinforcement workers. In addition, the omission of beams reduces the volume of stirrups and rebar practiced for the floor and allows for quick installation.

b) Construction speed:

Positioning the fillers, placing the lower and upper rebar, and pouring the concrete constitute the major steps to follow for the realization of Contruss floors. Contrary to beam-slab floor types, with troublesome discontinuous formworks, the flat soffit of Contruss floor expedites the installation of concrete formwork roughly by 25 percent.

c) Free of sophisticated technology to install:

The use of complex technology in building construction raises the expenditure of time and cost and requires protection and surveillance of the instruments. In addition, Contruss floors need no highly skilled labor to install and are easily manipulated by conventional workers of simple training.

d) During-installation advantages over other permanent fillers:

Because permanent fillers remain inside the floor, the installation costs depend mainly on the materials used in the manufacturing process. The recycled plastic applied in earlier fillers presented varying resistance to cold and warm conditions. The high quality and the competitive price of Contruss composite fillers and the resultant floor prove to be the turning point in the field.

The innovative application of a combination of polypropylene, compatible adhesive, and polystyrene core brings the following benefits:

1 – Avoiding fracture and concrete penetration into the fillers during construction due to the solidity of the fillers:

Daily thermal interactions of hollow recycled plastic fillers offer them a lower strength and fracture them during or before concrete pouring. Therefore, earlier hollow fillers allowed concrete penetration into the spaces allocated to the fillers and a growth in floor weight.

The solid body of Contruss filler withstands fracture while maintaining high flexibility under heavy loads.

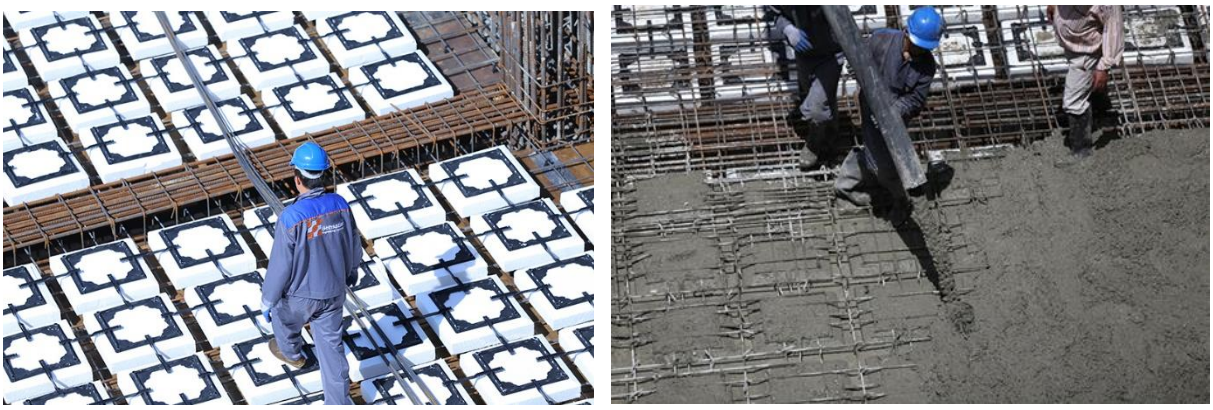


Figure 4.14. Contruss system construction

2 – Possibility of boring a hole to forward concrete pouring:

By increasing the filler dimensions in double-sided voided slabs, concrete consumption drops, though it may cause honeycombing in the lower parts of the concrete. The engineers of the research and development department of Contruss company managed to devise a middle hole that is drilled into the Contruss filler in order to facilitate concrete pouring below the filler and prevent the formation of concrete honeycombs.

The variability of the filler dimensions and the possibility of drilling a middle hole are the distinctive benefits of the Contruss filler, which encourage its employment as the most optimized voided slab.

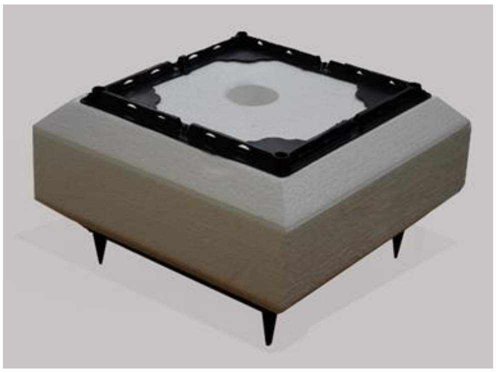


Figure 4.15. Perforated Contruss filler

The advantages gained from the use of polypropylene trays:

a) Increased filler flexural strength due to tension in trays:

The Contruss filler has been qualified to resist bending fracture, shear punch, and overturning in an experimental test for a load of 150kg applied on a surface with a dimension of 8*8cm.

One of the main satisfactory characteristics of Contruss fillers is their strength under construction loads. Once the fillers undergo loading during construction, the trays are stretched to prevent the filler from deflecting, while hollow fillers without trays are deflected or fractured in an analogous situation.

Figure4.16. Contruss filler

b) Providing appropriate clearance:

Most earlier plastic cuboid fillers used in voided slabs are manufactured in a form that provides rebar clearances in the middle of the filler, a troublesome rebar arrangement as it is not practically viable or not appropriately performed in many projects. The hollow trays on Contruss fillers easily provide a 2-cm clearance.

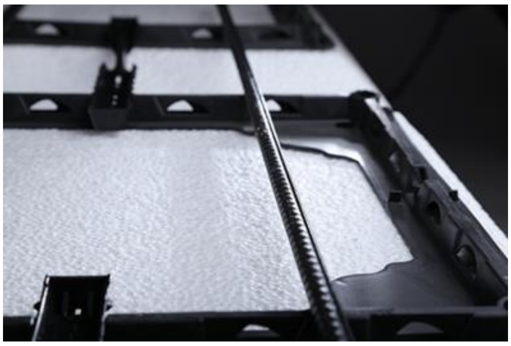


Figure 4.17. Providing appropriate clearance

c) Piles to preserve the thickness of lower concrete layer:

The filler piles are considered to set the thickness of the lower concrete layer and prevent it from floating upward.

Figure 4.18. Contruss piles

d) Indicators to bear the thickness of the upper concrete layer:

After positioning the fillers and rebar, the long-standing problem of concrete level guesswork arises during the concrete pouring of the floor. With the indicators installed on the top tray, the workers quickly notice the concrete pouring level, managing to accurately pour the concrete and even out the floor surface.

Figure 4.19. Indicators showing concrete thickness

e) Installation of belts:

One of the integral components of Contruss fillers is the belt, which prevents changes in the spacing, uniform or predefined arrangement, and position of fillers and ensures the orthogonality of integrated ribs in two directions of the slab. Based on the technical concept, the ribs must be orthogonal, and the fillers have to be arranged in such a way to form perpendicular ribs. However, the real situation on construction sites, the workers passing, and the material temporarily laid on the floor often change the filler arrangement. Contruss fillers are equipped with integrated belts that attach the fillers tightly, protecting them from any unwanted movement.

While keeping the fillers at a standstill, the belts are capable of supporting the rib upper rebar of size 32 and smaller, that were impossible to be held in their position in earlier types of permanent fillers, which were not equipped with belts. Consequently, the builders were required to use prefabricated bar chair, which resulted in the use of unnecessary rebar in the slabs.

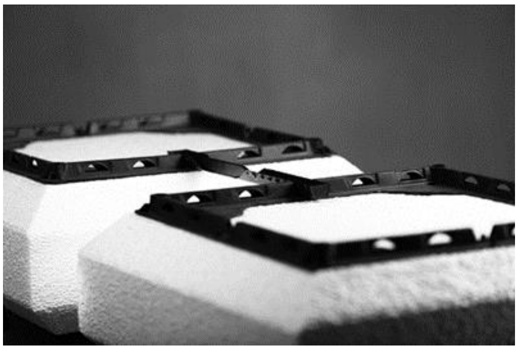


figure 4.20. Belt of Contruss fillers

figure 4.21. Filler susceptibility during construction

Figure 4.22. Positioning of upper rebar over belts

f) Easy to store and transport:

Contruss fillers fit together through the piles and firmly attach to each other, facilitating storing and transporting to the site.

Figure 4.23. Attached fillers

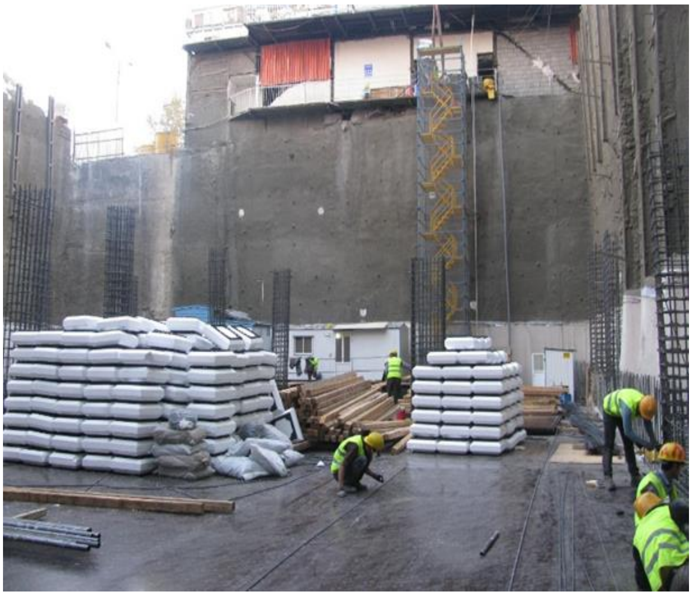


Figure 4.24. Storing the fillers

5- Comparison with other systems

5-1- Comparison of Contruss system to rib and block floor:

a) Flexibility in architecture:

Great architects have always dreamed of designing over large spaces without columns and long cantilevers. In Contruss voided slab system, some middle columns can be eliminated to create adequate room in the plan to provide architectural freedom and facilitate occupancy change.

In rib and block systems, the span created is up to 7-meters long, beyond which it is difficult to be deployed because of the high amount of deflection and vibration induced as well as the necessity of using double ribs. The integration of two concrete layers and the perpendicular webs into Contruss floor has brought such a high rigidity that enables it to be constructed over much larger spans, up to 20-meters long.

Figure 5.1. Floor made of Contruss voided slab

b) One-way vs two-way slab and seismic function:

The concept of applying ribs and blocks in the floor is based on the formation of T-shaped elements, which transfer the loads to the supports in a single direction and also allow the elimination of tensioned concrete, leading to a lower floor weight.

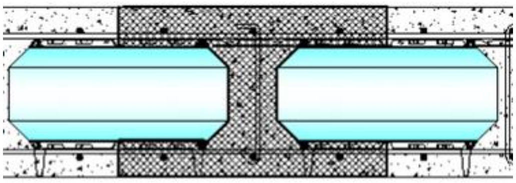


Figure 5.2. Schematic section of Contruss voided slab

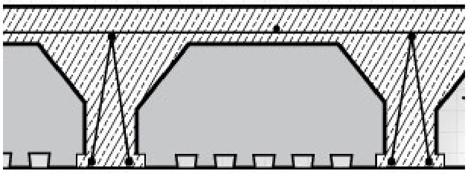


Figure 5.3. Schematic section of ribs and block

By supplying Contruss permanent composite fillers in the concrete, the unloadable concrete in the slab with no structural efficiency is omitted, creating I-shaped ribs with a two-way performance. Due to the two integrated concrete layers as well as mutually perpendicular ribs, the slab provides a much higher bearing capacity.

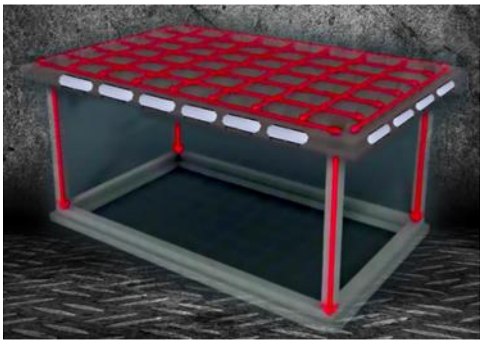


Figure 5.4. Two-way Contruss voided slab

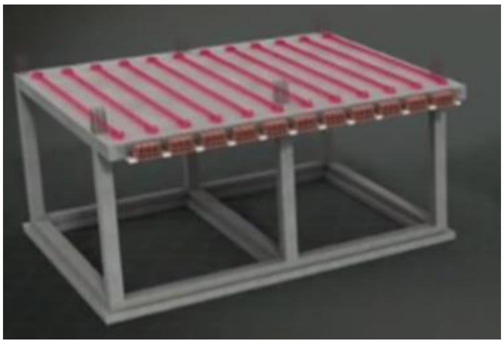


Figure 5.5. One-way rib and block

The Contruss voided slab is constructed continuously in two layers forming a rigid diaphragm under the earthquake, with lateral forces transferred suitably towards the supports. It operates much more effectively than rib and block slabs, in which just a few centimeters of tensioned rebar contribute to the structural performance of the floor.


Figure 5.6. Contruss system construction


Figure 5.7. Rib and block construction

c) Floor thickness:

In the Contruss system, the total thickness of the floor is lower than that of rib and block slab system. For instance, the floor is 35-cm thick in a span of 12-meters long, and it creates a flat soffit that offers a smoother and simpler passage for mechanical services. While in rib and block slab floor, creating beams of 80 cm height, drop panels and drop beams, and uneven intrados surface along with the resultant irregular passage of mechanical tubing creates a floor much thicker than the Contruss floor.

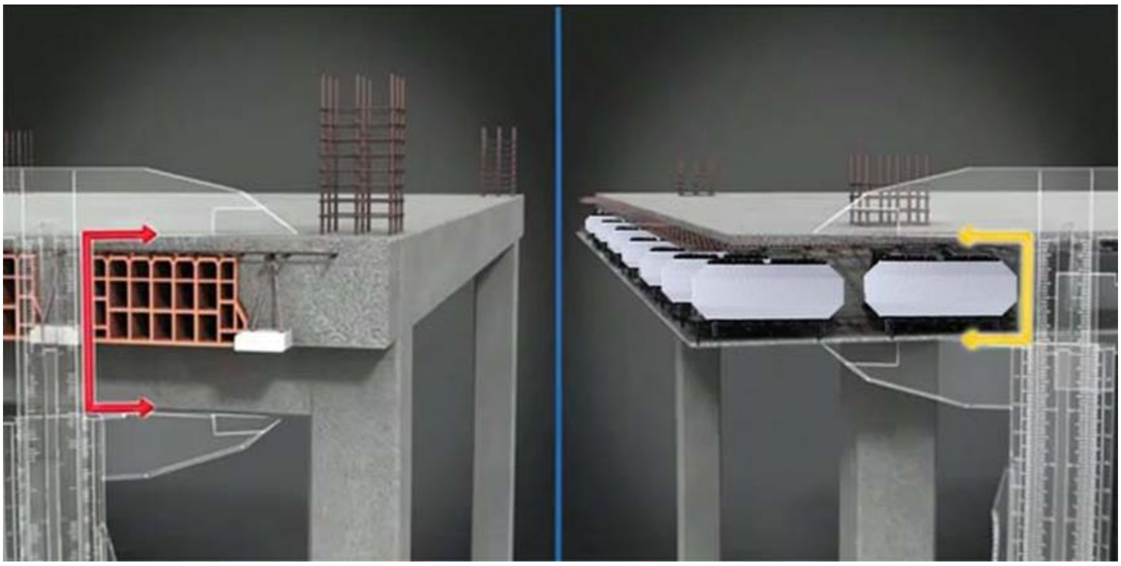


Figure 5.8. Contruss floor thickness compared to that of rib and block floor

d) Allowing large openings:

One of the main restrictions in the use of the rib and block slab system is the structurally unachievable openings. As regards the one-way functionality of rib and block systems, cutting the ribs disrupts the load transfer, resulting in a greater cost to create openings in the floor.

On the contrary, one of the major properties of Contruss system is its capability to afford large irregular openings, confronted particularly in reception halls, villas, and commercial and educational centers.

Figure 5.9. large opening made into Contruss floor

e) Floor weight:

For spans beyond 7 meters long with heavy loads such as that of parking floors, applying the rib and block slab system requires the application of double ribs as well as huge costs. Although for shorter spans, the Contruss system weighs more, it will provide much savings for spans up to 7-meters long due to the high moments of inertia.

f) Final cost:

The Contruss system formwork is continuous and provides a flat intrados floor; the rib and block slab floor needs no integrated formwork and reduces the costs but presents an uneven surface for the floor.

As the use of the Contruss voided slab system results in the absence of secondary beams, drop beams and drop panels, the total height of the building decreases, and the consumption of materials falls. In addition, it is not necessary to provide heavy sub-frames for the dropped ceiling in tall buildings, thus proving doubly cost-effective. Furthermore, removing the beams running between columns simplifies the passage of service tubing, offering further cost reduction., making the Contruss system costs approximately equal to the traditional rib and block slab system.

Figure 5.10. Dropped ceiling subframe

g) Simplified construction:

The Contruss system is so straightforward to install that it can be constructed by conventional labor of simple training and does not need any special advanced technology. From a constructional point of view, Contruss system is closely analogous to rib and block floor.

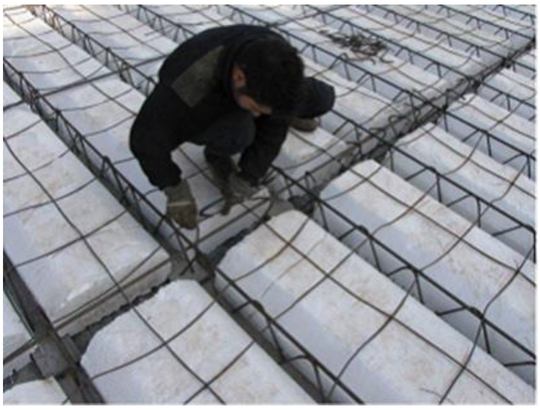


Figure 5.11. Rib and block slab construction

Figure 5.12. Contruss system construction

h) Construction pace:

In comparison to rib and block floors, the construction of Contruss floor formwork takes a longer time by 5 percent, which is negligible.

The required construction duration is roughly equal to that of rib and block slab construction. Both of the floor types need 15 days for the completion of each floor.

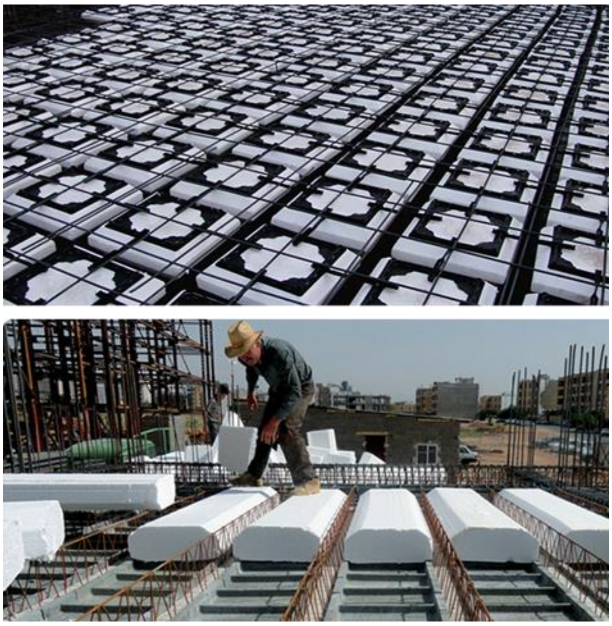


Figure 5.13. Contruss floor compared to rib and block floor

i) Floor deflection and vibration:

The benefits resulting from the gain in the moment of inertia and the drop in the floor mass indicate that in Contruss floor, the deflection and vibration amplitude are much lower than the values expected in rib and block floor.

j) Compatible with highly irregular supports:

The Contruss system can be adapted to irregular support arrangements because of its bidirectional function. Consequently, it provides the possibility of changing the column arrangement or positioning the columns in the retaining walls, which is impossible in rib and block slabs.

k) Fire resistance:

Concrete structures generally resist fire better than steel structures. Due to the existence of two concrete layers, the Contruss floor functions properly in the transmission of heat when subjected to fire and provides more strength than other floor systems. The polystyrene used in the Contruss filler has already been certified to be flame retardant.

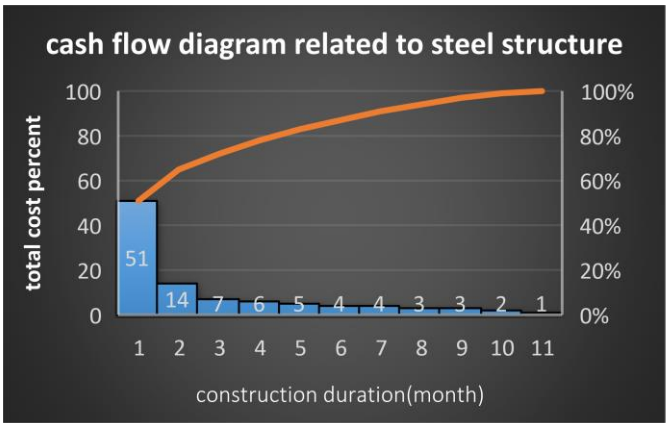
Figure 5.14. Slower transmission of heat in the Contruss system

5-2- Comparison of Contruss system with metal deck floor:

a) Cash flow:

The major distinction between Contruss and metal deck floors is their financial aspect. In general, construction of steel structures with metal deck floor costs much higher than concrete structures by 35 to 50 percent, mainly because the metal deck floor increases the costs.

Moreover, the concrete structure offers a better opportunity for builders who want to pay for the construction step by step during project progression. Using steel members in steel structures incurs a higher expenditure at the beginning of the project.



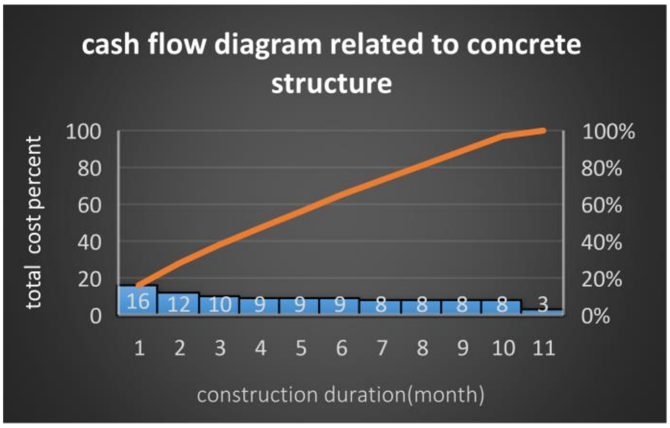


Figure 5.15. Comparison of concrete and steel structure expenses

b) Floor thickness:

Contruss floor formwork is performed continuously, creating a flat intrados floor. On the contrary, metal deck floor performance requires thick girders that reduce the useful height due to the eventually thick dropped ceilings. For large spans up to 10-meters, the Contruss system lowers the total thickness of the dropped ceiling.

Figure 5.15. Passage of mechanical services below girders

Figure 5.16. Thick girders in metal deck floors

In the metal deck floor, the girders and the lower level of the mechanical systems which need to be installed in a straight line reduce the useful height of the floor.

Figure 5.17. Increased thickness and cost of dropped ceiling

c) Compatible to openings:

As a one-way slab, cutting the ribs will disrupt load paths, resulting in difficulty creating openings in the metal deck system. In order to have openings (for the passage of mechanical services, lifts, etc.) after construction, the decking and its reinforcement must be trimmed a priori.

The high rigidity and the two-way function of the Contruss system ensure that large irregular openings are no longer a burning issue concerning the structural performance of the rigid diaphragm, especially for the construction of reception halls, villas, and commercial and educational centers. Moreover, creating additional openings for the passage of mechanical services is possible even after the realization of the slab.

d) Fire resistance:

Inefficiency in resisting fire is one of the fundamental defects of metal deck systems.

Figure 5.18. Metal deck collapse because of fire

Due to the existence of two concrete layers, the Contruss floor functions properly in the transmission of heat when subjected to fire and provides more strength than other floor systems. The polystyrene used in the Contruss filler has already been certified to be flame retardant.

e) Construction speed:

Although steel structures are capable of being constructed faster than concrete structures by 30 percent, there are two parameters to be considered:

1) Quickening the construction of concrete structures, in the so-called fast-track projects, increases the construction time even up to twice that of steel structures. At the same time, it is more economical even with doubled daily labor.

2) After constructing a few bottom stories in tall concrete structures, it is permitted to begin the brickworks and service installation in the bottom stories and to simultaneously keep the formwork in the upper stories. This approach equalizes the construction speed for concrete and steel structures.

Figure 5.19. Contruss system compared to metal deck

f) Protection from noise and vibration:

Material resistance to the transmission of sound is investigated in two fields: 1) airborne noise and 2) stomping noise.

With respect to airborne noise, concrete enjoys satisfactory sound-proofing properties; the Contruss slab operates more suitably against percussion noise because of having two concrete layers and the trapped air bubbles inside the polystyrene. As a result, the Contruss slab functions more desirably than metal deck floors when subjected to both airborne and percussion noise.

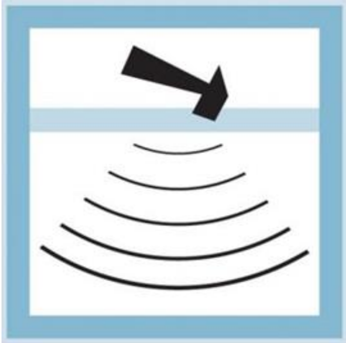


Figure 5.20. Percussion noise

On the other hand, resistance to the transmission of vibration is known to be one of the characteristics essential for the residents' benefit. Providing such strength requires a high expenditure in steel structures. On the contrary, due to the high rigidity of the Contruss voided slab, it performs more suitably against vibration, thus protecting the residents from being filled with panic.

Figure 5.21. Noise and vibration transmission through floors

g) Floor weight:

Contruss voided slabs weigh more than metal deck slabs, but it is counteracted by the lower costs, compatibility with large spans, less floor thickness in large spans, high rigidity, and other superior properties related to Contruss system.

h) Providing a large span:

A metal deck has a simple detailing scheme for spans up to 8 meters; while beyond that, it requires a higher cost as well as a thicker floor. The integration of two concrete layers along with perpendicular webs in Contruss floor helps to form a highly rigid slab that provides a rigid diaphragm under lateral forces. It also offers the possibility of having spans up to 20-meters long.

Figure 5.22. Floor made of Contruss voided slab

In general, from an architectural point of view, one of the major defects related to concrete structures is the large dimensions of columns, which can be corrected by removing the middle columns and creating large spans, thanks to the Contruss system. Providing large spans results in numerous benefits such as greater exposed spaces, increasing the number of parking spots, possibility of occupancy change, and architectural freedom.

5-3- Comparison of Contruss system with beam and slab floor system:

a) Floor thickness:

The large soffit and drop beams has the following disadvantages:

1- Increased total height of structure due to increased floor height

2- Higher cost and difficulty of shuttering, concrete pouring, and rebar placement

3- Additional costs with regard to the dropped ceiling

4- Architectural restrictions

5- Difficulty in the passage of mechanical services

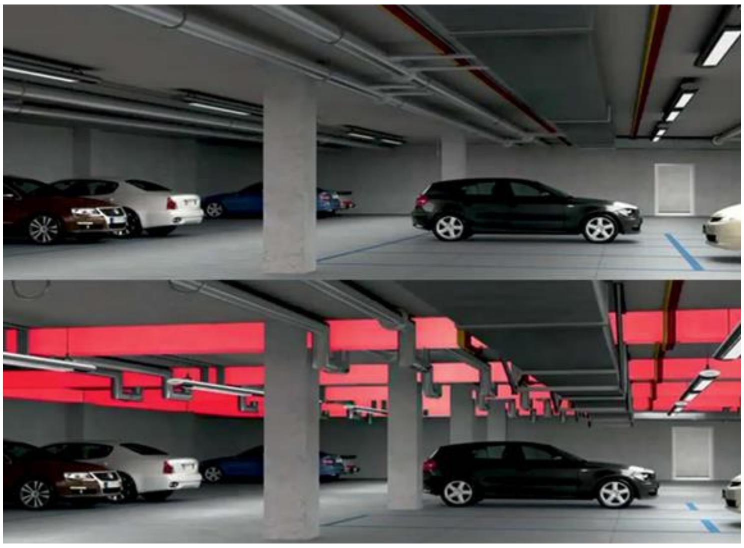


Figure 5.23. Easy to install service systems due to the flat soffit

Figure 5.24. Aesthetic qualities after removing drop beams

b) Construction costs for spans up to 8 meters:

Contruss voided slab has developed the conventional beam and slab system by eliminating the unloadable concrete at the mid-height that offers no structural benefit. Contruss voided slab system weighs less compared to solid slabs, up to 50 percent, with equal rigidity in some cases.

The high rigidity, low weight, and two-way performance of voided slabs enable the creation of large spans with a low floor thickness. For example, in a 35-cm-thick double-sided voided slab, the concrete poured is estimated to be equivalent to a 22-cm height, indicating an optimized concrete consumption. Moreover, a 22-cm-thick flat slab can be designed for a span of up to 7 meters, proving the voided slab advantages.

Moreover, the loads are transferred first to secondary beams and main beams, then to the columns in the beam and slab floor system. In the Contruss system, the loads are transferred directly to the columns because of the two-way function of the floor. Therefore, the Contruss floor system offers a better behavior and lower costs in large spans; however, for spans lower than 7 meters, the bending moment at the middle of the slab is lower, and the conventional beam and slab floor system costs less.

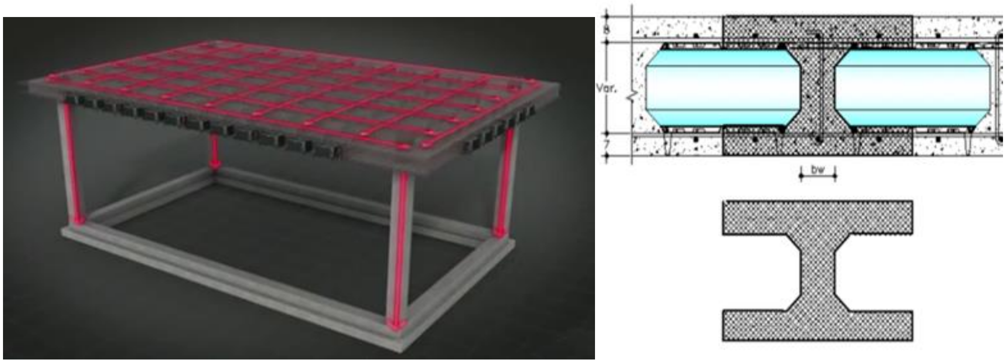


Figure 5.25. Two-way function of Contruss system

Like the formwork of flat slabs, that of the Contruss system provides a flat intrados floor. Due to the existence of beams and large soffit in the beam and slab floor system, dropped ceilings are required, increasing the construction duration and formwork costs.

c) Construction speed:

For the Contruss system, it is enough to provide a flat integrated formwork, leading to an easy and quick construction.

Figure 5.25. Beam and slab floor system

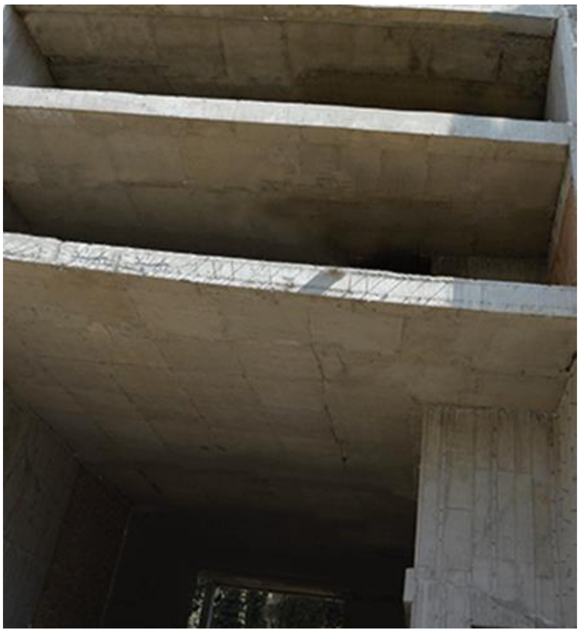


Figure 5.26. Contruss voided slab system

d) Compatibility to large and irregular openings:

In the Contruss system, the loads are transferred to supports through I-shaped bidirectional ribs. In the beam and slab floor system, however, such transfer is accomplished by secondary beams, and it is not justifiable to cut the beams for the creation of the openings.

e) Constructional convenience:

The use of advanced technology in building construction requires the expenditure of much time and cost as well as protection and surveillance of the instruments during construction in some cases. In addition, Contruss floors need no highly skilled labor to install in spite of being known as an innovative technology that can be constructed easier than beam and slab floors.

Figure 5.27. Positioning the Contruss fillers of voided slab

f) Fire resistance:

Concrete structures generally withstand fire better than steel structures. Due to the existence of two concrete layers, the Contruss floor functions suitably in the transmission of heat when subjected to fire and provides more resistance in comparison to the beam and slab floor systems. In addition, the polystyrene used in the Contruss filler is slow-burning, and it is already certified to be a flame retardant material.

g) Insulation against noise and vibration:

Material resistance to the transmission of sound is investigated in two fields: 1) airborne noise and 2) stomping noise.

With respect to airborne noise, concrete enjoys satisfactory sound-proofing properties; as a consequence, both the Contruss slab and the beam and slab floor system perform suitably subjected to airborne noise. However, the difference appears over percussion noise.

By introducing trapped air bubbles inside the polystyrene, the Contruss system tempers the sound power level of percussion noise through the slab. Polystyrene is known to be the second available material that offers the best acoustic properties against sound transmission according to the building codes. Overall, deploying polystyrene along with two concrete layers in the Contruss fillers provides excellent resistance to airborne and percussion noise transmission.

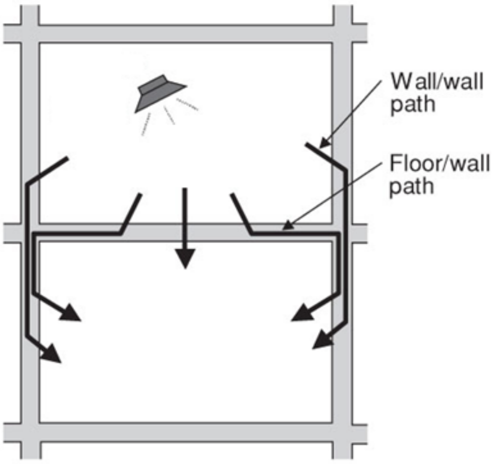


Figure 5.28. Noise transmission through walls and floor

Furthermore, in comparison to the beam and slab floor system, the higher rigidity of the Contruss voided slab reduces the floor vibration, providing comfort to the residents.

5-4- Comparison of Contruss system with prestressed slab system:

a) Requiring advanced technology and skilled labor to construct:

Employment of complex technology in building construction requires spending more considerable time and cost. As regards scientific and technical complications, the prestressed system requires a specially complicated pre-tensioning, high advanced technology materials, and difficult labor, which may discourage the builders from using it unless for bridges or large spans up to 30 meters. Consequently, the Contruss system is more acceptable from a technical and economic point of view.

Figure 5.29. instruments of prestressed construction

One example of the complexity of the prestressed system is the release of post-tensioning cables, which are required to be inspected in buildings, though they can be controlled after a while in bridges.

Figure 5.30. Pre-tensioning process

Another example of the complexity of the prestressed system is when an opening is needed after the completion of the slab. As the cables exert much resistance to the forces applied on the slab, in order to protect the cables while creating openings in the floor after slab construction requires a high accuracy.

Figure 5.31. Post-tensioning the cables

Placement of cable pods according to the predefined curvature is another difficulty in the prestressed construction, which requires skilled labor to position, tension, and cover the cables.

On the contrary, construction of Contruss floors is done by the placement of the fillers, lower and upper rebar, and concrete pouring, that is done as simply as conventional floor systems, while it is capable of providing large spans up to 20 meters.


Figure 5.32. positioning of Contruss fillers


Figure 5.33. Pre-tensioned arch cable pods

b) Construction speed:

The following observations indicate why the prestressed system takes more time to complete than the Contruss system:

1- Concrete must be hardened before pre-tensioning:

Concrete is required to be hardened before applying the pre-tensioning force in the post-tensioned system, so the constructional labor has to complete the process after concrete hardening. Afterwards, the formwork is stripped for use in the next floor.

2- In many prestressed floors, the formwork is needed not only for the slab but also for the drop beams and drop panels, resulting in an increase in the construction duration and costs.

3- The involvement of highly skilled labor means that each delay in their presence elongates the project’s duration.

c) Existence of drop panels, drop beams, and large soffit in most prestressed floors:

As the cables must be restrained in two directions in the slab, a thick and large section forms around the beams in the prestressed systems, creating a large soffit.


Figure 5.34. Construction with prestressed system


Figure 5.35. Construction with Contruss system

Figure 5.36. Floor constructed with prestressed system

d) Weight of materials used:

By involving the total concrete section in compression, the neutral axis is driven upward, resulting in decreased material consumption and a downsized concrete section in the prestressed floor. On the contrary, creating mid-height concrete-free spaces in the floor, increases the moment of inertia and reduces the concrete consumption in the Contruss system, offering a floor of a 5 to 15 percent lower weight compared to the prestressed system.

e) Cost:

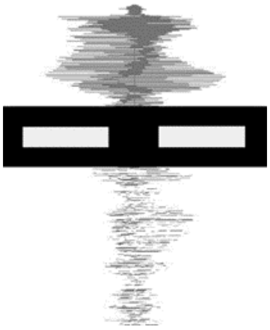
Due to the simplified construction process, the Contruss system costs less by 5 to 10 percent than the prestressed system.

f) Compatibility to openings:

The openings in prestressed slab systems bring some trouble since they disrupt the cables' trajectory, and in some cases of irregular openings, it is totally impossible to actualize them. In the Contruss system, however, creating large irregular openings in floors is so simple that they are easily designed and constructed in reception halls, villas, and commercial and educational centers.

g) Acoustic properties of the floor:

The trapped air bubbles inside the polystyrene decrease the sound power level and boost the insulation capacity against the passage of airborne noise through the slab, proving to be particularly important in religious and educational centers.



h) Fire resistance:
Due to the existence of two concrete layers along with the flame retardant polystyrene between them, the Contruss floor functions efficiently in the transmission of heat and provides more strength than the prestressed system. The polystyrene used in the Contruss filler has already been certified to be flame retardant.
The major defect related to the prestressed floor under fire is the release of the post-tensioning cables. As regards providing resistance for the total strength of the slab, the cables will be expanded and fail in fire, leading to the collapse of the floor.

6- Projects launched with Contruss system

- Pratham residential complex:

Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
6.5*10.5	24*55	8	residential	2731

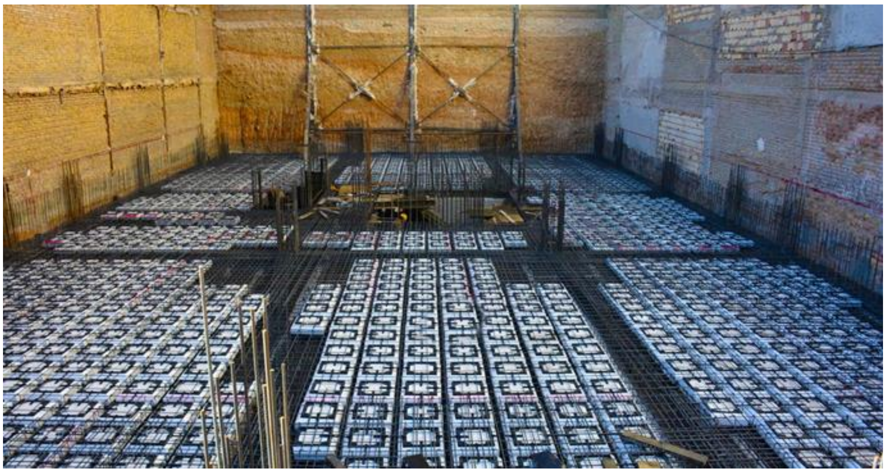
- Vaikunth official complex:

Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
6.5*10.25	20*55	7	official	1470

- Sivanta residential project:

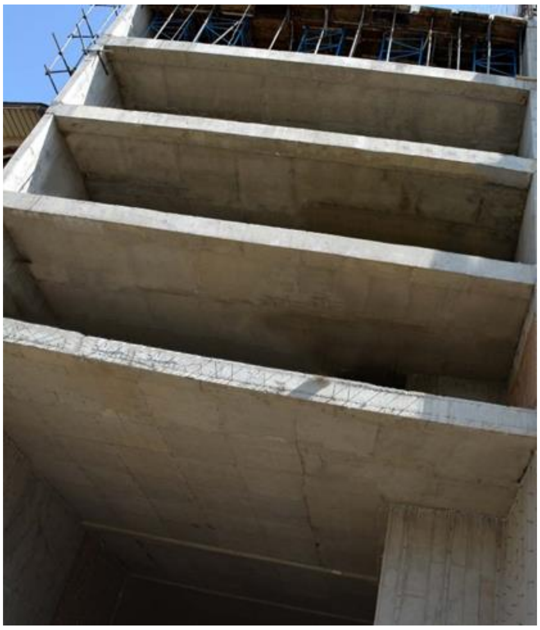
Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
10*12	13	22	residential	14334

- Anandvan residential project:



Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
11.5*10	20	9	residential	5422

- Diamond commercial project:

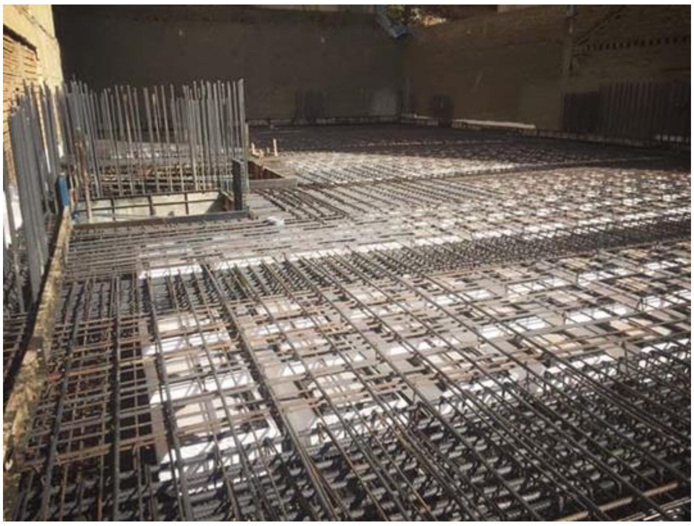


Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
13*8	24	10	commercial	3200

- Asha residential project:

Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
11*9	13	7	residential	1875

- Soham Residential project:

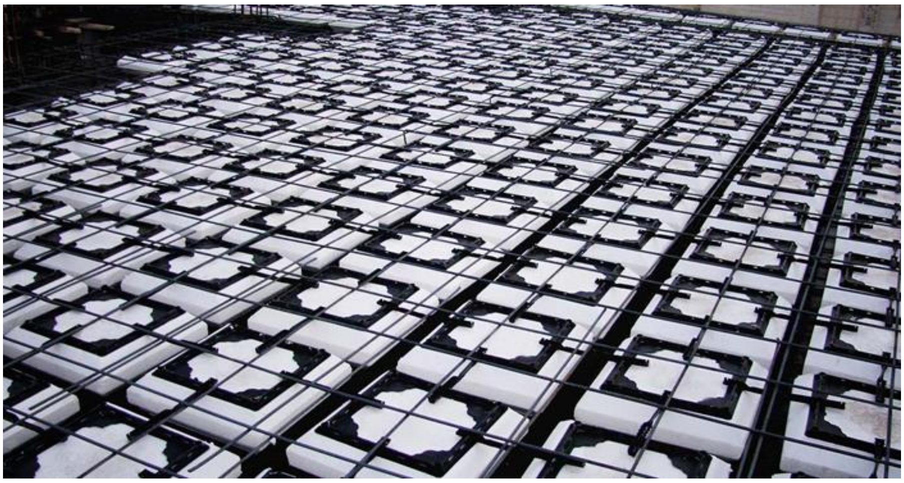


Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
12.5*10	24	8	residential	2731

- Kalpvan residential project:

Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
9.5*8	20	4	residential	1000

- Ashirward residential project:

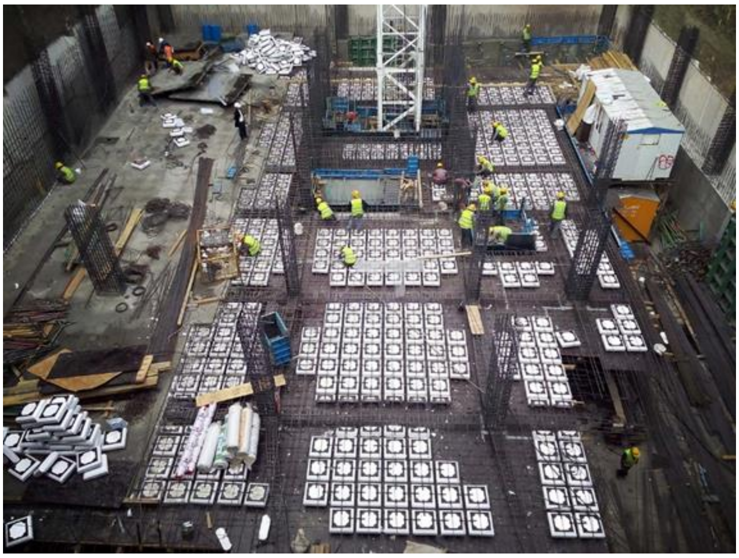


Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
11*7	20	5	residential	960

- Snakalp residential project:

Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
11.5*9.5	19	7	residential	1442

- Venus tower project:



Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
10.5*10	20	14	residential	11000

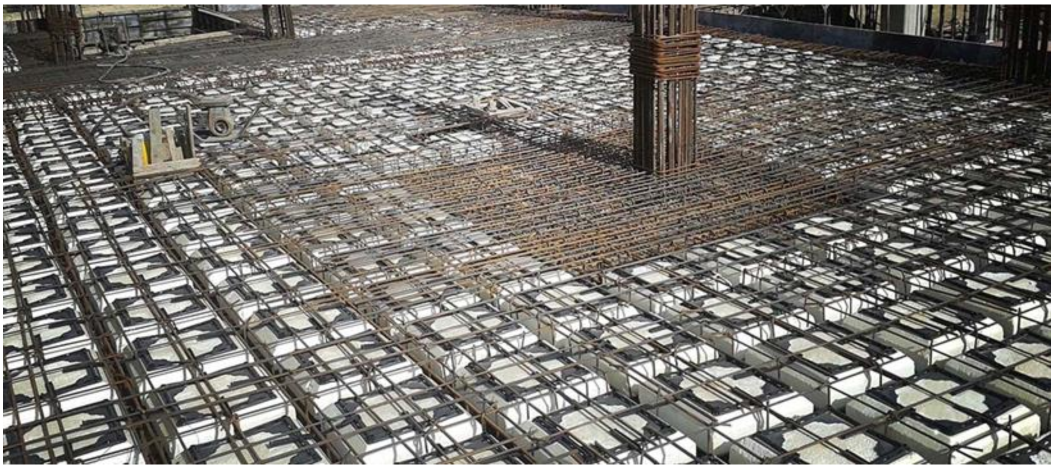
- Chamatkar villa project:

Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
10.5*7.5	19	5	residential	1315

- Kalpana terminal project:

Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
12	25	5	terminal	1300

- Ranjit residential project:



Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
19*16	32*19	2	residential	1394

- Preet project:

Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
10	25	7	residential	35000

- Sukharm project:

Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
11*12	20	5	residential	1600

- Arpan complex project:

Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
12	25	8	residential	11000

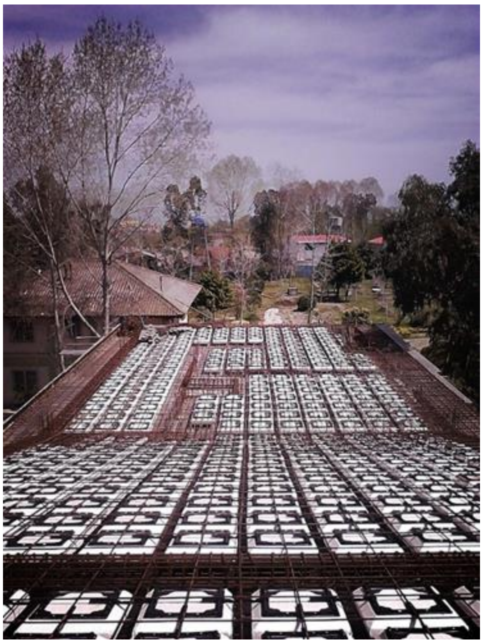
- Daya residential project:

Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
11.5*10	20	11	residential	3600

- Vivanta residential project:

Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
12*9	19	7	residential	1347

- Mannat villa project:



Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
12*9.5	15	2	villa	425

- Sumel reception hall& commercial complex:

Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)

13.5*10	32	10	commercial	900

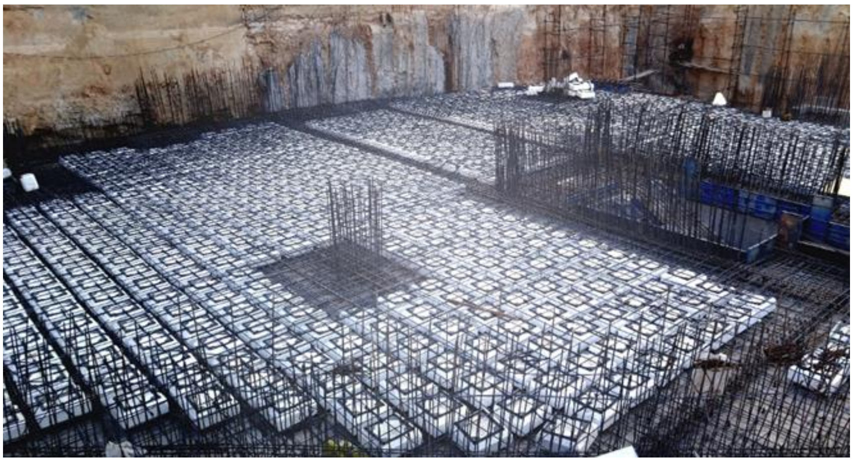
- Surabhi residential project:

Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
11*10	15	9	residential	9827

- Ahand shopping project:

Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
11.5*15	19	10	commercial	5370

- Doctors building complex:



Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
13.5*10	24	8	official	6497

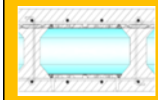
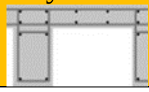
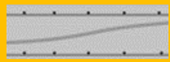
- Rajhans project:

Effective span (m)	Filler size (cm)	Stories	Occupancy	Area (m)
10*13	24	12	residential	4595

7- Conclusion and ultimate comparison table:

Thanks to modern Contruss voided slab systems, the technical advantages along with the simple construction method are combined with the numerous economic benefits for large spans. Due to the introduction of two concrete layers and bidirectional I-shaped ribs, the system presents a high rigidity under gravity and lateral loads, providing the possibility of creating spans up to 20 meters. Because of the inappropriate function of one-way floors for spans beyond 7 meters, the two-way performance of Contruss voided slab is advisable in such spans. The following table illustrates the attributes and advantages of the Contruss system in comparison to other building floor systems.

Comparison of Contruss voided slab system with other floor systems:

	Contruss 	Rib and block slab 	Beam and slab system 	Prestressed system 	Metal deck 
Adaptable large spans and cantilevers	★★★★★	½★	★★★★	★★★★★	★★★
Resistant in sound transmission	★★★★½★	★★★½★	★★★	★★★	★½★
No need for dropped ceiling	★★★★½★	★	★★	★★★	½★
Construction speed	★★★★	★★★★	★★½★	★★	★★★★★
Simplified implementation	★★★½★	★★★★★	★★★½★	★	★★★★
Lack of large soffit and drops	★★★★½★	★	½★	★★★	★★½★
Fire resistance	★★★★★	★★★	★★★★	★	★
Construction costs for spans shorter than 8-meters	★★	★★★★★	★★★½★	★½★	★
Construction costs for spans beyond 8-meters	★★★★★	½★	★★½★	★★★★	½★
Reduced vibration and deflection	★★★★★	★★	★★	★★★★	★
Reduced weight of structure	★★½★	★★★★	★★★	★★	★★★★★
No need for skilled labor to install	★★★★½★	★★★★★	★★★★½★	½★	★★★★
Compatible to irregular large spans	★★★★★	½★	★★	★★	★★
Adaptable to irregular supports	★★★★★	½★	★★½★	★★	★★★

Total points: ★★★★★