Contruss
Engineering Company

# Comparison of ConTruss voided slab with spherical voided slab system

Contruss Engineering Company

www.contruss.com | info@contruss.com

## Contents

## Introduction:

The use of innovative technologies as well as optimizing methods in constructions have been developed in recent years. One innovative system practiced in constructing of slab is Contruss voided slab system, which was issued and certified in 2014. In this report, spherical permanent filler will be illustrated and compared to the Contruss voided slab system, from technical and economic point of views.

# 1- Introduction of spherical permanent filler system

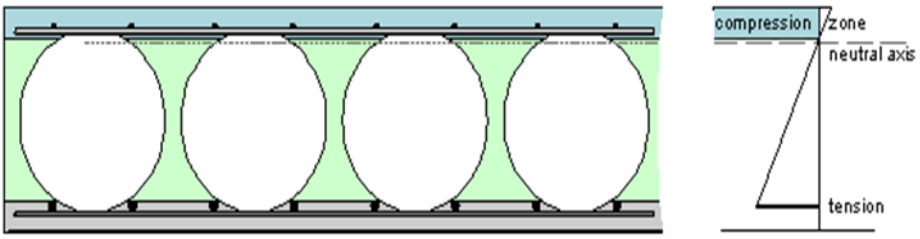
## 1-1- Spherical permanent filler history:

The use of spherical permanent filler in ceiling is a method for constructing two-way voided slab, which is implemented by hollow plastic spheres. Considerations and studies over this system have been initiated in 1985 in German universities, while corporations engaging in spherical filler technologies have been established in 1997 by engineers and experts from Switzerland and other Europe union countries.

## 1-2- Concept of creating spherical permanent filler:

The major concern about designing concrete slab for engineers is referred to its heavy weight, because dead load of slab will restrict the span length of ceiling. Therefore, the most parts of engineering innovations upon increasing span length of concrete ceiling have been concentrated on two aspects: 1) reducing ceiling weight, 2) removing additional concrete with no structural benefit.

In spherical voided slab technology with hollow permanent plastic spheres, the middle unloadable concrete with no structural benefit will be removed and I-shaped elements will be created in two directions. In fact, non-structural dead load is eliminated and biaxial strength will be created. Consequently, by creating rigid concrete membrane in the upper and lower parts of slab as well as forming internal ribs in two directions, high bearing capacity will be created for the slab.

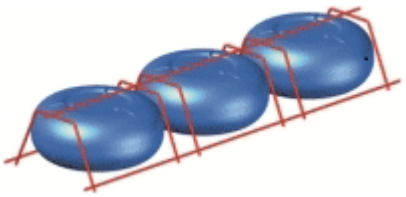


## 1-3- Components of ceiling:

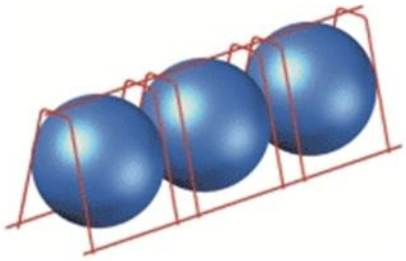
a) Spherical-shaped fillers, which are manufactured by recycling industrial plastics or polypropylene material. These fillers can reduce slab weight up to 35 percent compared to flat slab with equal thickness, that will result in considerable increase in bending capacity of slab.

The initial design of spherical voided slab is done according to deflection control. Two types of Spherical fillers are used in spherical voided slabs:

First is known as Slim-Line with thickness ranging from 199 to 229 mm.



Second is Eco-Line type with thickness ranging from 189 to 459 mm, which are used in 35 to 60-cm-thick slabs.



b) Reinforcement bars: Based on designing, reinforcement bars with different strength can be used in voided slabs with spherical permanent fillers. These bars will be applied in form of steel cages to hold the fillers. It must be note that these cages are just designed to hold the fillers, not operating as shear reinforcement.

c) Concrete consumed in these slabs are common concrete. The use of accelerating admixture is not necessary in these slabs and curvature of spherical fillers will help for casting of lower concrete layer as well as slab installation.

## 2- Approvals and certificates

Limited conditions required for applying reinforced concrete voided ceiling system with hollow spherical fillers according the international building regulations:

1- Total non-structural dead load acting on this ceiling such as partitions, flooring and joinery loads are restricted to 350 kg/$m^2$. In addition, applying this ceiling will be just allowed for parking lots bearing maximum weight of 4 tons with concentrated load of 1.35 ton.

2- Concrete thickness around the fillers is determined according to the shear punch, while it must not be less than 5 cm.

3- Slab designing for flexure in each direction must be done in the weakest section of slab according to executive details as well as considering the voids.

4- In the connection zone of shear walls to spherical voided slabs, transfer of shear toward wall from the slab must be controlled in the weakest section of the wall.

5- Involving boundary elements in the vicinity of openings and slab edge must be considered according to the codes criteria.

6- Observations of technical requirements considered in approval number Z-15.1-282 by DIBT institute will be necessary for spherical voided ceiling system.

7- Spherical fillers must be positioned in two orthogonal directions.

8- The basis and piers practiced for installation must be capable to applied by adequate camber before concrete-pouring.

9- Reduction factor of strength and rigidity must be considered for calculating rigidity, bending and shear strength of the slab.

# 3- Installation

## 3-1- Spherical permanent fillers are installed by two methods:

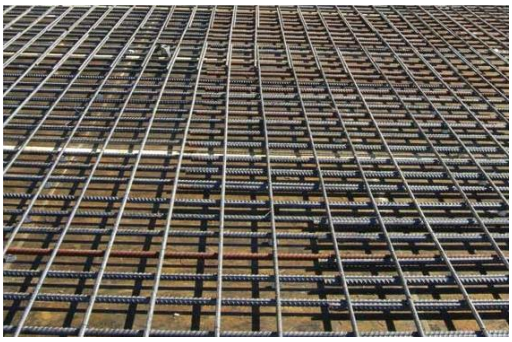
a) Prefabricated cages with no concrete are transported to the site; after fillers installation, the upper and lower concrete layer will be casted.

b) Prefabricated cages along with lower concrete layer are transported to the site, then the upper concrete layer will be casted.

## 3-2- Slab installation steps:

a) Ceiling formwork

b) Positioning lower reinforcement mesh



c) Positioning spherical fillers

d) Positioning upper reinforcement mesh

e) Concrete-pouring and vibration

f) Final levelling

g) Removing formwork

# 4- Technical and economic comparison of Contruss with spherical filler

By engaging modern technology in double-sided voided slabs, Contruss filler has been able to refine many defects of spherical permanent fillers. It will be illustrated in the following.

## 4-1- Difficult installation:

Spherical permanent fillers are made of recycling plastic which are positioned in steel cages in longitudinal direction and these cages are located beside each other during installation. With regard to the recycling essence of fillers as well as impossibility of quality control of plastic used in the fillers, workers are not allowed to tread the fillers because it may fracture or deform the fillers as well as curving of reinforcement bars under pressure.

In addition, the spherical forming of the filler will make it difficult for the workers to pass over the ceiling for reinforcement performance, that causes difficulties and delays for ceiling installation.

But in the Contruss ceiling, there is no need for applying steel cages. Additionally, the strength and material of Contruss filler is completely different. Based on the tests on Contruss fillers implemented by the road, housing and urban development research center, it has been certified that the Contruss filler provides much high strength compared to others. In the last test by the mentioned research center, Contruss filler was able to bear load with amount of 150 kg acting on the area 64 $cm^2$. This amount for loading is much higher compared to the constructing loads of the building.

## 4-2- Movement of spherical fillers and cages on ceiling:

Steel cages in this system are approximately 4 to 6 meters long that must be positioned in two longitudinal and transversal directions on the ceiling. For positioning of cages and setting distance between them, a wood index is usually practiced for locating of cages according to the design. But the cages will be displaced due to the passing of workers and special forming of the fillers. This task will cause technical problems in terms of two-way function of the slab.

Basically, voided slabs are designed for large spans; therefore, suitable positioning of the fillers is necessary. For the Contruss fillers, the positioning is conducted by the belts. The belts have two tasks. First, it holds the fillers regularly with specified distance beside each other in order to create an integrated shear web and also holding the fillers stable during reinforcement performance and concrete-pouring. Second, it can be used as a vault for positioning of the upper reinforcement bars of the ribs.

An important distinction of Contruss filler belts compared to others is that it will be capable of adjusting various distances between the fillers.

## 4-3- Fracturing and deforming of plastic spherical fillers:

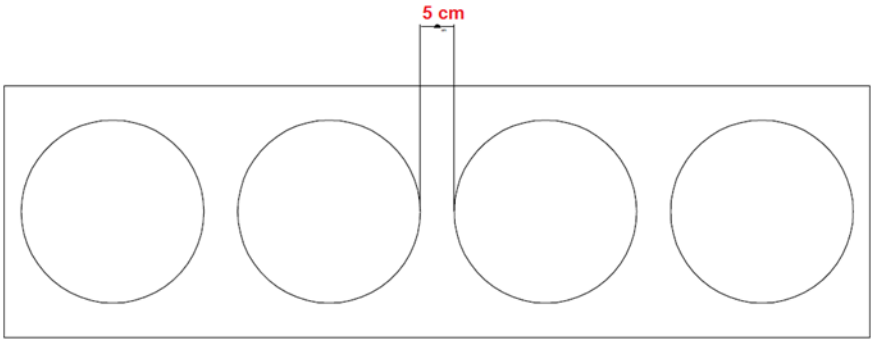
Recycling plastic used in the fillers has low thickness, that makes it get warm subjected to the sunlight, leads to deforming and fracturing of the filler under the pressure caused by passing of workers. Fracturing and deforming of the fillers increases consuming concrete that will result in increased ceiling weight or appearing cracks in the ceiling. As a result, applying spherical voided slab is not recommended in warm conditions, while the Contruss filler is resistant subjected to various environmental conditions.

After discovering defects of available fillers since 2017, the road, housing and urban development research center has considered new tests for qualifying the fillers, which include fillers strength subjected to fire, overturning, punching, deformations and fracturing subjected to loading.

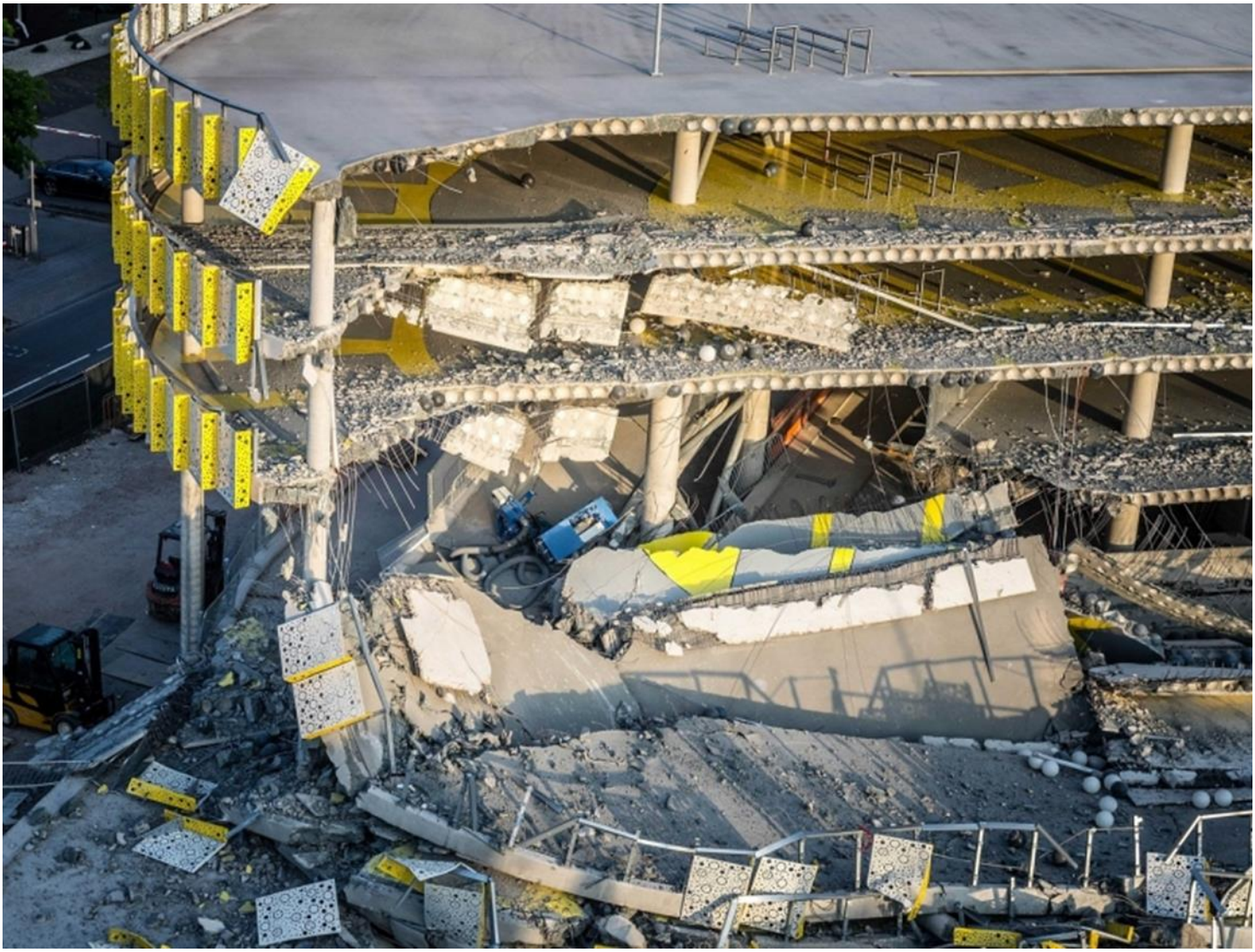
Contruss engineering company has been qualified to pass the test to bear the load by amount of 150 kg/cm$^2$ on a square area with dimension of 8 cm as well as resisting in overturning, punching, deforming, fracturing and also resistant subjected to fire, succeeded to renew the approvals by the road, housing and urban development research center of Iran.

## 4-4- Non-providing of minimum thickness for shear web:

Based on the ACI 318-08, the minimum thickness of web in ribs must be 10 cm, if the slab is supposed to be flat, but it will be reduced to 5 cm in voided slab with spherical permanent fillers.




Incompatibility of spherical voided slabs with the code criteria has led to emerging several restrictions in design and span length of this system, particularly for buildings in seismic hazard zone. This subject was mentioned in technical approvals for the use of spherical voided slab system in the past years in which, the maximum span length without beams created by this system was restricted to 8 meters. Overall, applying this system is accompanied by several restrictions because it is not compatible with valid international codes.



Partial collapse of voided slab with spherical fillers because of inadequate shear strength in a parking area of Eindhoven airport in 2017

## 4-5- Non-practicing of steel cages rebar in design of ceiling:

Based on the valid international codes, it is not allowed to involve steel cages rebar in shear strength of the ceiling and the minimum amount for this rebar must be as following according to the codes:

$$A_{sv\min} = ۰/۰۶\sqrt{f_c}\,\frac{b_w S_n}{f_{yv}}$$

Based on the design of cages, it will be concluded that the minimum diameter for cages rebar must be 6 mm according to the calculations. This rebar is just practiced to hold the cages, with no structural benefit.

Non-bearing of steel cages with no structural benefit in the ceiling will result in additional cost for the ceiling. Therefore, spherical fillers are usually the most expensive available permanent fillers. Unlike to the valid international codes, some companies and builders involve strength of the cages for slab design. The following points should be considered on this issue:

a) Welding of reinforcement bars is only viable in special circumstances that is not observed in steel cages and they have been welded before installation.

b) Reinforcement bars practiced in the slabs must be ribbed type, but #6 reinforcing bars are mostly smooth rebar.

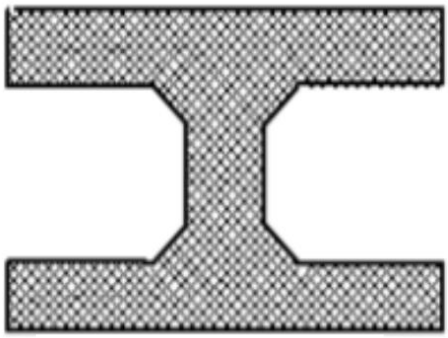
c) Observing of development length for reinforcement bar in the slab is necessary, but it will be not possible in this system due to forming of cages.

Based on above reasons, the bearing attribute of cages will be prohibited by the international valid codes and technical and engineering criteria.

* It has been observed that some companies have applied rebar in sizes less than 6 mm, which is not permissible according to the valid international codes.

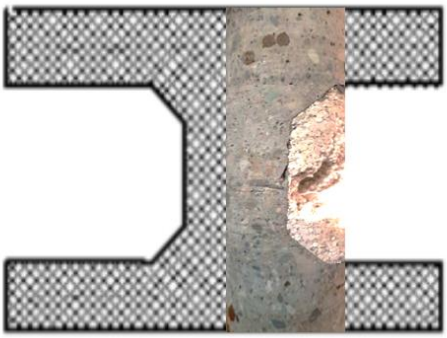
## 4-6- Increased weight of ceiling in spherical filler system:

Due to the spherical forming of the filler, created I-shaped section will be not optimized; consequently, the amount of consuming concrete will be increased by 15 to 20 percent that leads to increased weight of ceiling, increased base shear of earthquake as well as installation cost. The Contruss fillers have been designed with optimized I-shaped sections. In the following, stability of Contruss filler under concrete-pouring pressure is depicted:



Schematic section of Contruss filler

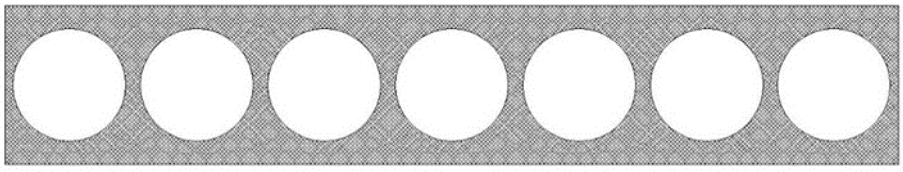
Core sample of Contruss slab



Non-deforming of filler in concrete

The unit weight related to both systems is compared in the following table:

| Filler | Ceiling height (cm) | Filler height (cm) | Filler dimension (cm) | Shear web thickness (cm) | Number of fillers in a square meter | Filler volume ($cm^3$) | Filler volume in a square meter ($cm^3$) | Weight of consuming concrete (kg) |
|---|---|---|---|---|---|---|---|---|
| Spherical filler | 37 | 27 | 27 | 5 | 9.77 | 10306 | 100689 | 646 |
| Contruss filler | 37 | 22 | 55 | 11 | 2.30 | 61550 | 141565 | 548 |



$$W = 646 \ {}^{Kg}/_{m^2}$$

$$W = 548 \ {}^{Kg}/_{m^2}$$

## 4-7- Existence of large drops:

Practicing solid drops without fillers will be required in voided slabs with spherical fillers in order to control shear punch in the vicinity of shear walls and columns, because there will be no shear reinforcement in the ceiling in this system. The drops might be so large in some cases that will cover the most of ceiling, similar to a flat slab instead of voided slab.

By using total shear capacity of ribs as well as applying shear reinforcement in the Contruss fillers, the ceiling will include minimum solid drops that result in less ceiling dead load.

## 4-8- Limited dimension of spherical fillers:

As regard to manufacturing of spherical fillers in the factory according to the design, it will not be possible to change the filler size in order to reach maximum optimization. But in the Contruss filler, manufacturing and installing will be possible for each sizes and dimensions that leads to most optimization of consuming materials and costs. Contruss filler is capable to be manufactured with dimensions ranging from 45 to 60 cm and height ranging from 12 to 65 cm.

## 5- Conclusions

For spans beyond 7 meters, voided slab with permanent fillers will be suitable, economically and technically. Among all available systems, voided slabs with spherical permanent fillers are accompanied by several defects, which have been resolved by the modern Contruss permanent fillers. Some defects related to spherical permanent fillers are as the following:

- Low strength of the filler subjected to loads due to recycling essence of the filler
- Difficulty and complexity of installation
- Increased amount of consuming concrete and rebar compared to other systems
- Non-providing the minimum thickness of shear web according to the codes
- Instability of fillers on ceiling due to spherical forming
- Limited dimensions and additional cost due to spherical forming
- Impossible to be slashed down