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Use of Rubber Ball in Deck Construction

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ABSTRACT

The Lean Thinking of Construction is Apply in a Construction of slab. The composite slabs are made of Bubble Deck type slab elements with spherical gaps, poured in place on transversal and longitudinal directions. By introducing the gaps leads to a 30-50% lighter slab which reduces the loads on the columns, walls and foundations, and of course of the entire building. Bubble Deck slab elements are plates with ribs on two directions made of reinforced concrete or precast concrete with spherical shaped bubbles. These slab elements have a bottom and an upper concrete part connected with vertical ribs that go around the gaps. It Improves the strength of slab and also modify weight and resulting in a Light weight Concrete.

Keywords - Lean Thinking; concrete slab; spherical bubbles; reinforcement; process optimized.

I. INTRODUCTION

Concrete Floor Systems -

Reinforced concrete slabs are components commonly used in floors, ceilings, garages, and outdoor wearing surfaces. There are several types of concrete floor systems in use today.

- Two-way flat plate (biaxial slab)-

There are no beams supporting the floor between the columns. Instead, the slab is heavily reinforced with steel in both directions and connected to the columns in order to transfer the loads.

- Two-way flat slab with drop panels-

This system differs from the two-way flat plate system by the drop panel used to provide extra thickness around the columns. This strengthens the column to floor connection in consideration of punching shear.

- One-way beam and slab- This is the most typical floor system used in construction. The slab loads are transferred to the beams, which are then transferred to the columns.

- One-way joist slab-

The joists act like small beams to support the slab. This floor system is economical since the formwork is readily available and less reinforcement is required.

- One-way wide module joist slab-

This system is a variation on the one-way joist slab with wider spaces between the joists.

- Two-way joist slab (waffle slab)-

This floor system is the stiffest and has the least deflection of those mentioned since the joists run in two directions (Concrete Reinforcing Steel Institute). Reinforced concrete has many advantages for floor systems- it provides resistance to high compressive stresses and to bending stresses; it is relatively cheap to produce and construct; and it can be molded into virtually any shape and size.

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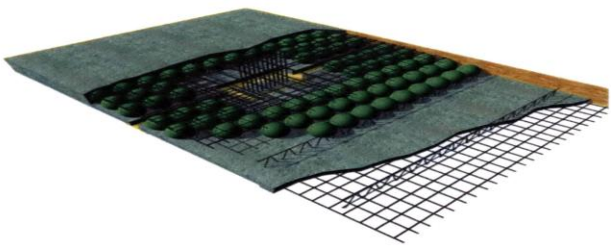
II. PROBLEM STATEMENT.

In the 1990's, Jorgen Breuning invented a way to link the air space and steel within a voided biaxial concrete slab. The Bubble Deck* technology uses spheres made of recycled industrial plastic to create air voids while providing strength through arch action for a section cut of a Bubble Deck. As a result, this allows the hollow slab to act as a normal monolithic two-way spanning concrete slab. These bubbles can decrease the dead weight up to 35% and can increase the capacity by almost 100% with the same thickness. As a result, Bubble Deck* slabs can be lighter, stronger, and thinner than regular reinforced concrete slabs

III. A. Disadvantages include a high weight-

To strength ratio and difficulty in structural health monitoring (Reinforced Cement Concrete Design).The Bubble Deck slab is a revolutionary biaxial concrete floor system developed in Europe. High-density polyethylene hollow spheres replace the ineffective concrete in the center of the slab, thus decreasing the dead weight and increasing the efficiency of the floor. These biaxial slabs have many advantages over a conventional solid concrete slab: lower total cost, reduced material use, enhanced structural efficiency, decreased construction time, and is a green Technology. Through tests, models and analysis from a variety of institutions, Bubble Deck was proven to be superior to the traditional solid concrete slab. The reduced dead load makes the long-term response more economical for the building while offsetting the slightly increased deflection of the slab. However, the shear and punching shear resistance of the Bubble Deck floor is significantly less than a solid deck since resistance is directly related to the depth of concrete. Design reduction factors have been suggested to compensate for these differences in strength. This system is certified in the Netherlands, the United Kingdom, Denmark and Germany. In this investigation, after verifying the validity of the prior research through a finite element analysis of an office floor in SAP2000, the Bubble Deck® slab was tested for a pedestrian bridge deck. Bridge design is dominated by the dead weight of the structure and by concentrated stresses from vehicular traffic. This new slab can solve both of these problems by reducing weight with the plastic spheres and by applying it to a pedestrian bridge to limit the high stresses



B.Advantages of Bubble Deck

Material and Weight Reduction

The dominant advantage of a Bubble Deck slab is that it uses 30-50% less concrete than normal solid slabs. The HDPE bubbles replace the non-effective concrete in the center of the section, thus reducing the dead load of the structure by removing unused, heavy material. Decreased concrete material and weight also leads to less structural steel since the need for reinforcement diminishes. The building foundations can be designed for smaller dead loads as well. Overall, due to the lighter floor slabs, the several downstream components can be engineered for lower loads and thus save additional material (Wrap).

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A. Structural Properties

Due to the lower dead weight of the slab and its two-way spanning action, load-bearing walls become unnecessary. BubbleDeck is also designed as a flat slab, which eliminates the need for support beams and girder members. As a result, these features decrease some of the structural requirements for the columns and foundations Additionally, BubbleDeck slabs can be designed and analyzed as a standard concrete flatslab according to research performed on its strength and ductility, which will be discussed in depth later in the report. As summarized by Table 3-2, the dead load-to-carrying capacity of a solid slab is 3:1 while a BubbleDeck of the same thickness has a 1:1 dead load-to-carrying capacity ratio (Wrap).

B. Construction and Time Savings

On site construction time can be shortened since BubbleDeck slabs can be precast. Type A includes a 60 mm precast concrete plate as the base and formwork for the slab. This type of slab would eliminate the need for onsite erection of formwork, thus significantly cutting down construction time. Similar to modem precast concrete flooring modules, BubbleDeck can be fully shop fabricated and transported on site for installation as well. Figure 3-3 is an example of how BubbleDeck* sections can be lifted into place at the construction site. Time savings can also be achieved through the faster erection of walls, columns and BMEPs due to the lack of support beams and load bearing walls for this innovative flat slab. Addition time may be saved from the quicker curing time since there is less concrete in the slab

C. Cost Savings

In relation to the savings in material and time, cost reductions are also typical with the Bubble Deck system. The decreased weight and materials mean lower transportation costs, and would by more economical to lift the components. With less on-site construction from the full and semi-precast modules, labor costs will decrease as well. In addition, money can be saved downstream in the design and construction of the building frame elements (columns and walls) for lower loads. There is a slight rise in production costs for the Bubble Deck slab due to the manufacturing and assembly of the HDPE spheres. However, the other savings in material, time, transportation and labor will offset this manufacturing price increase (Stubbs).

D. Green Design

The number of owners, designers and engineers who desire green alternatives is growing exponentially. BubbleDeck is a fitting solution for lowering the embodied carbon in new buildings. According to the BubbleDeck* company, 1 kg of recycled plastic replaces 100 kg of concrete. By using less concrete, designers can save up to 40% on embodied carbon in the slab, resulting in significant savings downstream in the design of other structural members. Carbon emissions from transportation and equipment usage will also decrease with the use of fewer materials. Additionally, the HDPE bubbles can be salvaged and reused for other projects, or can be recycled.

E. Thermal stresses

These balls are able to take the thermal stresses of the member very effectively because they are elastic in nature.

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F. Light weight structures

These balls are lighter than aggregates so the structure constructed by this type of concrete are lighter in weight it also reduces the quantity of concrete.

G. Economical construction

These balls are very cheap in price so economy for the construction can be achieved.

H. More strength

As compared with the normal concrete structure rubber deck gives more compressive strength and if reinforcement is added to the concrete then it also gives more compressive strength to the structure

IV.STRUCTURAL PROPERTIES AND DESIGN

Research has been performed at several institutions in Denmark, Germany and the Netherlands on the mechanical and structural behavior of Bubble Deck. Studies include bending strength, deflection, shear strength, punching shear, fire resistance, and sound testing. This paper focuses on stiffness and shear resistance. Since all of the available research on Bubble Deck was performed in Europe, only European design codes and certifications will be mentioned in this section.

V. SCHEMATIC DESIGN

BubbleDeck is intended to be a flat, two-way spanning slab supported directly by columns. The design of this system is generally regulated by the allowed maximum deflection during service loading. The dimensions are controlled by the span (L) to effective depth (d) ratio (L/d) as stated by BS8 110 or EC2. This criterion can be modified by applying a factor of 1.5 that takes into account the significantly decreased dead weight of the BubbleDeck slab as compared to a solid concrete slab. In addition, larger spans can be achieved with the use of posttensioningas the L/d ratio can be increased up to 30%. (Bubble Deck*-UK)

$L/d < 30$ for simply supported, single spans

$L/d < 41$ for continuously supported, multiple spans

$L/d < 10.5$ for cantilevers

There are five standard thicknesses for BubbleDeck, which vary from 230 mm to 450mm, and up to 510 mm and 600 mm for specific designs pending KOMO certification. All of the BubbleDeck versions come in three forms- filigree elements, reinforcement modules, and finished planks. They are depicted in Figure 3-2. For all types of BubbleDeck, the maximum element size for transportation reasons is 3 m. Once the sections are connected on site however, there is no difference in the capacity.

A. Hollow-Core Slabs

In the mid-20th Century, the voided or hollow core floor system was created to reduce the high weight-to-strength ratio of typical concrete systems. This concept removes and/or replaces concrete from the center of the slab, where it is less useful, with a lighter material in order to decrease the dead weight of the concrete floor. However, these hollow cavities significantly decrease the slabs resistance to shear and fire, thus reducing its structural integrity. This floor system typically comes in the form of precast planks that run from 4 ft to 12 ft wide and consist of strips of hollow coring with pre-stressed steel strands in between. Figure 2-2 illustrates several types of hollow-core planks used in the industry. They are combined on site to form a one-way spanning

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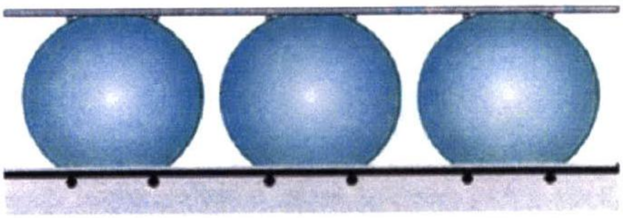
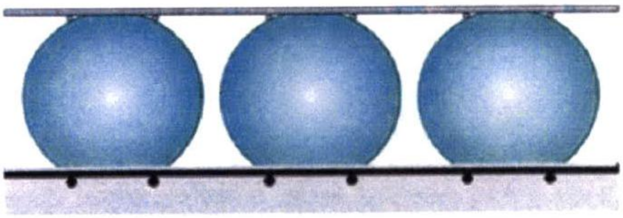
slab and topped with a thin layer of surfacing Currently, this innovative technology has only been applied to a few hundred residential,high-rise, and industrial floor slabs due to limited understanding. For this investigation, the structural behavior of Bubble Deck* under various conditions will be studied in order to gain an understanding on this new technique and to compare it to the current slab systems. This technology will then be applied to create lightweight bridge decks since a significant portion of the stress applied to a bridge comes from its own self-weight. By applying the knowledge gathered during the behavioral analysis, a modular deck component for pedestrian bridges that is notably lighter but comparable in strength to typical reinforced concrete sections will be Designed.

- Type A- Filigree Elements

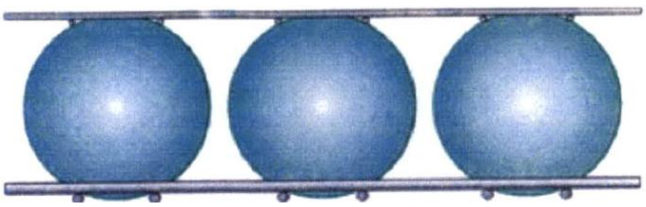
Bubble Deck Type A is a combination of constructed and unconstructed elements. A 60mm thick concrete layer that acts as both the formwork and part of the finished depth is precast and brought on site with the bubbles and steel reinforcement unattached. The bubbles are then supported by temporary stands on top of the precast layer and held in place by a honeycomb of interconnected steel mesh. Additional steel may be inserted according to the reinforcement requirements of the design. The full depth of the slab is reached by common concreting techniques and finished as necessary. This type of BubbleDeck is optimal for new construction projects where the designer can determine the bubble positions and steel mesh layout.





- **Type B- Reinforcement Modules**

BubbleDeck Type B is a reinforcement module that consists of a pre-assembled sandwich of steel mesh and plastic bubbles, or "bubble lattice". These components are brought to the site, laid on traditional formwork, connected with any additional reinforcement, and then concreted in place by traditional methods. This category of BubbleDeck is optimal for construction areas with tight spaces since these modules can be stacked on top of one another for storage until needed.



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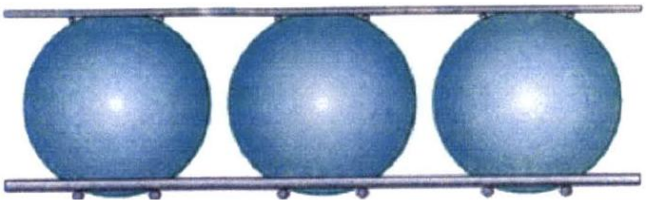
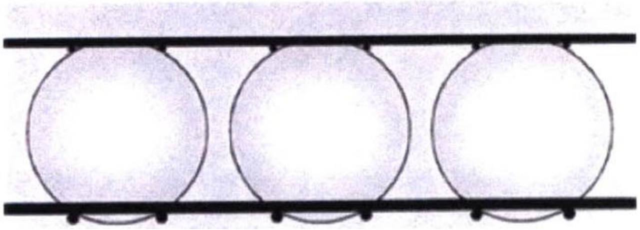
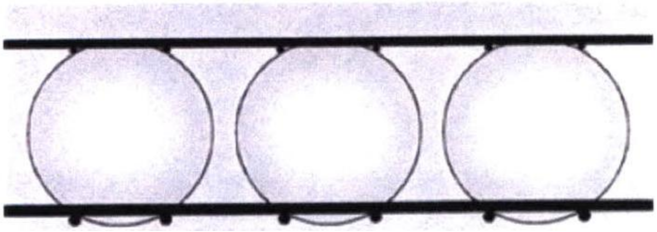


- **Type C- Finished Planks**

Bubble Deck Type C is a shop-fabricated module that includes the plastic spheres, reinforcement mesh and concrete in its finished form. The module is manufactured to the final depth in the form of a plank and is delivered on site. Unlike Type A and B, it is a one-way spanning design that requires the use of support beams or load bearing walls. This class of Bubble Deck is best for shorter spans and limited construction schedules (Bubble Deck*-UK).





VI. APPROVED RESEARCH

The Eindhoven University of Technology and the Technical University of Delft in the Netherlands have performed experiments on the bending stiffness of Bubble Deck slabs. They focused on the smallest and largest depths of the available slabs, 230 mm and 455 mm. The researchers found that the flexural behavior of Bubble Deck is the same as a solid flat concrete slab, practically and theoretically, and in short- and long-term situations. The Technical University of Darmstadt in Germany also performed tests on the stiffness

of a BubbleDeck slab. The results verified with the theoretical analysis and with the physical tests done in the Netherlands. For the same strength, BubbleDeck has 87% of the bending stiffness of a similar solid slab but only 66% of the concrete volume due to the HDPE bubbles. As a result, the typical deflection was marginally higher than that of a solid slab, as expected. However, the significantly lower dead weight compensated for the slightly reduced stiffness, and therefore gave BubbleDeck a higher carrying capacity. Table 4-1 summarizes the findings of their experiments (BubbleDeck Tests and Reports Summary). Analyses have also proven that deflections under service loads were a little higher than that of an equivalent solid slab. On the other hand, the reduced permanent load positively affects the long-term response in the serviceability limit state (SLS) design, which governs crack propagation. It has been concluded that adding a minimal amount of extra reinforcing steel would satisfy the criteria (BubbleDeck* Slab Properties).

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Table 4-1: Stiffness Comparison (adapted from BubbleDeck Tests and Reports Summary)
*On the condition of the same amount of steel. The concrete itself has 220% greater effect.

(in % of solid deck)	*Same Strength*	*Same Bending Stiffness*	*Same Concrete Volume*
Strength	100	105	150*
Bending Stiffness	87	100	300
Volume of Concrete	66	69	100

Researchers conducted tests on the punching behavior of Bubble Deck and published their results in a paper called, "Darnstadt Concrete", in the journal Concrete and Concrete Structures. They experimented on slabs with depths of 230 mm and 450 mm. They found that the crack pattern was similar to that of a solid slab, and that local punching failure did not occur within the given load cases. The average experimental value of the shear capacity of this slab was about 80% of a solid slab. The test specimens actually performed better than the theoretical models, but still not as good as a solid concrete slab. See Figure 4-4 for the plotted results (Bubble Deck Tests and Reports Summary).

Martina Schnellenbach-Held and Karsten Pfeffer from the Institute for Concrete Structures and Materials as the Darnstadt University of Technology conducted another large study on the punching behavior of Bubble Deck. Two different depths, 240 mm and 450 mm, were used to model the shallowest and deepest variety of the slabs. The slab was made of standard B25 and B35 concrete with a maximum aggregate size of 16 mm, and attached to a short column in order to simulate the response. The slabs were radial supported at eight points and were monitored by strain gauges, deflection gauges, and extensometers. Figures 4-5 and 4-6 illustrate the test set-ups.

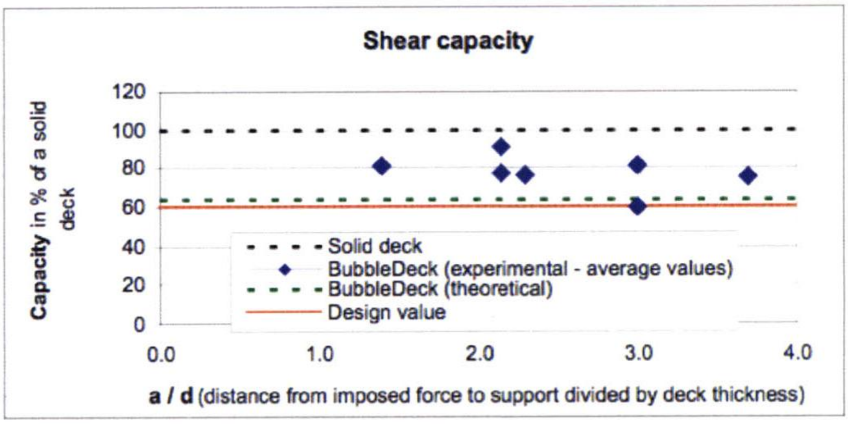

Figure 4-4: Experimental Shear Capacity (BubbleDeck Tests and Reports Summary)

The tests proved that although the HDPE spheres did not influence the crack pattern along the slab, the resistance to punching shear was less than a solid slab. When sawn open, the cross section showed that the crack angle varied from 30' to 400. See Figure 4-7 for the approximate crack patterns found in the test subjects. In order to further understand the structural mechanics of the Bubble Deck, the researchers generated a 3D nonlinear finite element model of the slab with DIANA. The FEM analysis conformed to the results of the physical investigations and verified the punching shear behavior of Bubble Deck. They suggest reducing the allowable shear area if any bubbles intersect the control perimeter so that those spheres will not play a role in the punching shear resistance.These findings correspond with other studies in that they recommend mitigating the punching shear response by excluding HDPE spheres from the shear perimeter. Other groups advise the removal of bubbles in the vicinity of the column zone rather than minimizing the impact area.

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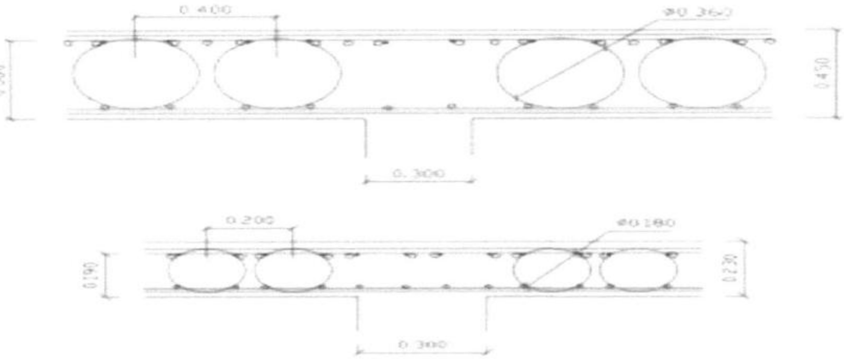

Figure 4-5: Cross-Section of BubbleDeck Test Slabs (Pfeffer)

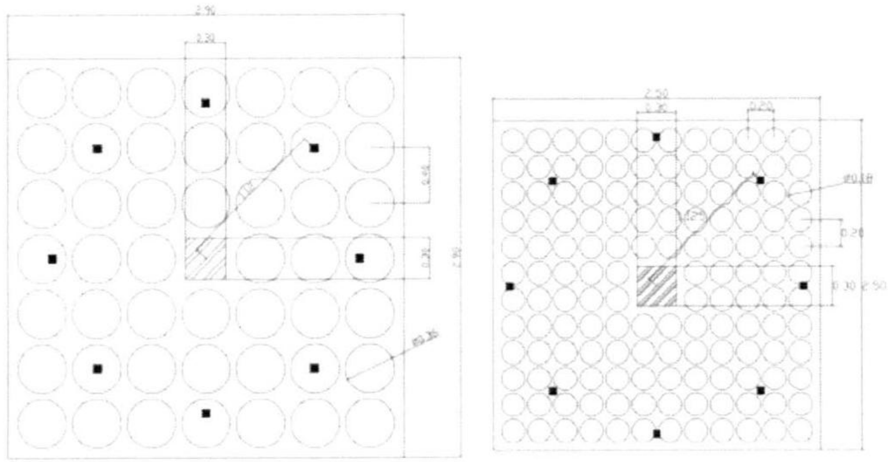

Figure 4-6: Test Set Up (Pfeffer)

VII. THEORETICAL CONTENT

The Bubble Deck method for the two directions reinforced composite concrete slab with gaps was invented in Denmark, it is licensed and it was conceived to achieve saving of concrete and energy in buildings construction. The composite slabs are made of Bubble Deck type slab elements with spherical gaps, poured in place on transversal and longitudinal directions. By introducing the gaps leads to a 30...50% lighter slab which reduces the loads on the columns, walls and foundations, and of course of the entire building. ”Bubble Deck” slab elements are plates with ribs on two directions made of reinforced concrete or precast concrete with spherical shaped bubbles . These slab elements have a bottom and an upper concrete part connected with vertical ribs that go around the gaps. The reinforcement of the plates is made of two meshes one at the bottom part and one at the upper part that can be tied or welded. The distances between the bars correspond to the dimensions of the bubbles that are to be embodied and the quantity of the reinforcement from the longitudinal and the transversal ribs of the slab. The two mashes are connected after placing the spheres into places in order to form a rigid shell. The bubbles are made by embodying high density polypropylene in the concrete, arranged according to the project and placed between the reinforcement meshes. The material that are made of don’t react chemically with the concrete or the reinforcement, it has no porosity and has enough rigidity and strength to take over the loads as much as from the pouring of the concrete as from the subsequent.The main presentation module of the product in version A – reinforcement modules in which the gaps are foreseen. Spheres of polypropylene are

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placed between the reinforcement at the bottom part ant the reinforcement at the top part hashes of this process. The main presentation module of the product in version B – Slab elements with Bubble Deck gaps, partially precast.

Types of slab	Thickness of slab (mm)	Sphere diameter(mm)	Own weight(daN/M)		Own weight (daN/M)
			Width of element 3000mm	Width of element 2400mm	
BD -230	230	180	380	390	1608
BD -280	280	225	450	490	1642
BD -340	340	270	550	580	1617
BD -390	390	315	650	660	1641
BD -450	450	360	740	720	1622

Obs. Own weight of the Bubble Deck slab element with gaps (BD) is function of the gaps dimensions.

The nominal diameter of the gaps may be of: 180, 225, 270, 315 or 360 mm. The minimum distance between gaps is 1/9 of the gaps diameter. The total height of the Bubble Deck slab elements is constant. Function of the diameter of the bubbles that are used, the total height may be: 230, 280, 340, 390 or 450 mm. The weight of Bubble Deck slabs is function of its dimensions and indicated in Table 1. It's a fact that regardless of the diameter of the bubble used, respectively the thickness of the slab, the own weight stays practically constant. In order to increase the shear strength capacity and bending moment in the areas with stress concentration (for example near the columns or walls) it is possible that in these areas gaps are not Bubble Deck composite slab: 1fill area without gaps; 2 – transversal reinforcement for shear force provided The surface of the filled (no gaps) areas are chosen function of the loads and the thickness of the slab. The Bubble Deck slab gaps elements can be delivered in the following versions: Version A. Reinforcement modules in which the spheres are placed to produce the gaps and if the case, tubes for HVAC (electrical, heating, etc.), modules that are to be placed in formworks. The plates are cast in place. Version B. Partial precast concrete elements. They have the bottom part made of precast concrete and the connections between elements and the over concreting are cast in place. In this version the elements are delivered as manufacturing made elements, consisting of a precast concrete layer with 60 mm thickness in which is embedded the bottom part of the reinforcement shell of the entire slab element, the bottom part of the spheres that make the gaps and, function of situation the HVAC tubes. The precast concrete layer from the bottom part is used also as horizontal formwork at the bottom part. The partially precast elements are made with widths of 2,400 mm or 3,000 mm and spans up to 14 m. The concrete used for the precast layer can be of common concrete or self veiling concrete. Minimum class of concrete is C20/25. The minimum class of the cast in place concrete is C20/25. The reinforcement modules for Bubble Deck slabs in version A are identified through a label that specifies, in Romanian language, the producer's name, client's name, code of the element, the dimensions of the element. In the case of slab elements partially precast, version B, each slab element is identified through a label that specifies, in Romanian language, the producer's name, the client's name, the code of the slab element, the sizes of the slab element, the weight of the element, the date of the manufacturing, risk warnings regarding the formwork removing.

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VIII. CONCLUSION

This project is very beneficial in the point of construction as lot of materials like aggregate sand and cement is been saved. we look positive about this idea should be further used by all the builders and make a revolution to the civil society.As there is lot of shortage of sand in India and aggregates and artificial sand are obtained from the rocks which belongs to the mountains , by the implementation of this idea we can actually save the mountains. As this idea uses rubber which is obtained by industrial wastes .so the problem of rubber waste can be minimized.

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