Bubble Deck Slab as an Innovative Biaxial Hollow Slab – A Review

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Abstract. Slab is the most important member in any building structure which consume large amount of concrete. The slab self-weight is large due to large consumption of concrete in producing slab. Therefore, bubble deck slab is an innovative and newly designed biaxial hollow slab system that had been introduced in order to overcome this problem. Bubble deck slab is a revolutionary method which was developed by Jorgen Bruenig from Denmark in 1990s. The bubble deck slab had been designed and constructed with plastic hollow bubbles in the middle part of slab to eliminate the concrete which does not perform any structural function and at the same time reducing the slab self-weight. Thus, the self-weight of bubble deck slab can be reduced about 30-50% than conventional concrete slab; that can reduce the loads acting on columns, walls and foundations. Finally, the use of bubble deck slab can give many benefits as compared to conventional concrete slab such as improve the structural performance of slab, reduce the materials and cost, efficiency and faster construction time, and it is also a green product. The aim of this paper is to give some of the reviews from previous studies related to bubble deck slab.

1. Introduction

Slab is one of the largest member that consume concrete and the most important member in any building structure which the slab was designed to resist the vertical load acting on it. The deflection of slab would increase when the load acting on slab increased. Thus, at the same time increasing the slab thickness and slab self-weight which may consume high amount of concrete in slab production [1-2]. Therefore, the biaxial hollow system is recommended as an alternative slab in order to overcome this problem. Biaxial hollow slab which is also known as biaxial voided slab, is a reinforced concrete slab which consist of voids that allow concrete volume become lesser than conventional reinforced concrete slab and it self-weight can be reduced about 30-50% [3].

The bubble deck slab is an innovative and newly designed of biaxial hollow slab developed by Jorgen Bruenig from Denmark in 1990’s that reduce the self-weight by eliminating the concrete in the middle of slab which does not contribute to the structural performance [4-7]. Bubble deck is a unique system that is radically improves building design and performance while reducing the overall cost by eliminating concrete dead weight at the middle of a floor slab. The concrete consumption is reduced as 1 kg of recycled plastic bubble replaces 100 kg of concrete [4-5]. Bubble deck slab replacing the
inactive concrete by placing the plastic balls in the between of two layers of reinforcement meshes. Therefore, the dead load of bubble deck slab become lower and allow higher span due to substitution of air bubble in the slab [8].

Other than that, carbon in the slab could save up to 40% by using less concrete. Carbon emissions from transportation and equipment usage will also decrease with the use of fewer materials. Additionally, the consumption bubbles can be salvaged and reused for other projects, or can be recycled [9]. Bubble deck slab has many benefits as compared to conventional concrete slab as example reduced material consumption, lower total cost, efficiency, faster construction time, and it is a green technology [10].

Therefore, the aim of this paper is to give some of the reviews from previous studies related to bubble deck slab.

2. Schematic diagram of bubble deck slab
The cut-through section of bubble deck slab is illustrated in Figure 1.

![Figure 1. Cut-through section of bubble deck slab [9]](image)

3. Types of bubble deck slab
There are three (3) types of bubble deck slab which are reinforcement modules, filigree elements and finished plank [11].

3.1. Reinforcement modules
The reinforcement modules type of bubble deck slab consists of a pre-fabricated bubble deck slab where the plastic balls are well-positioned between reinforcement steels, as shown in Figure 2. These components are then transported to the site and placed on traditional formwork linked with additional reinforcement before pouring concrete mix using conventional method. The advantage of this type is that, it is suitable for small construction area as the components can be stacked in the site before installing these components [11].
3.2. Filigree elements

The filigree elements type of bubble deck slab is a combination of in-situ and pre-cast construction, where 60 mm thick of bottom concrete layer is pre-cast and transported on the site with the plastic balls and reinforcement steels unattached as shown in Figure 3. Then, these elements are casted on site. For casting the plastic balls on the top of the concrete layer, temporary stands are used to hold the plastic balls. This type might need additional steel depending on the design of the building and is suitable for new construction, where the designer has the freedom to position the plastic balls and the reinforcement steels. This type is the best to apply for slab that has opening, such as opening for stairs [11].

![Figure 3. Filigree Elements](image)

3.3. Finished plank

The finished plank type of bubble deck slab is where the whole material is pre-fabricated to its finish form by the manufacturer as shown in Figure 4. Then, the final product is transported to the site. This type has disadvantages when compare to other type because it’s required support beams or load bearing wall. This type of bubble deck slab is suitable for short spans and fast construction [11].

![Figure 4. Finished plank](image)

4. Materials for bubble deck slab

Bubble deck slab is composed of three (3) main materials which are hollow bubbles, concrete and reinforcement bar [4, 10, 12].

4.1. Hollow bubbles

The hollow bubbles are usually made with nonporous material that does not react chemically with the concrete or reinforcement bars. The bubbles have enough strength and stiffness to safely support the applied loads. Bubble diameter varies between 180 mm to 450 mm. Depending on this, the slab depth is 230 mm to 600 mm where the distance between bubbles must be greater than 1/9th of bubble diameter. The bubble used can be of spherical or ellipsoidal in shape [4, 10, 12].

4.2. Concrete

The concrete used for joint filling in the Bubble Deck floor system must be above class 20/25. Usually self-compacting concrete is used, either for the casting of prefabricated filigree slab, or for the joint filling on the site. Self - compacting concrete can be poured into forms, flow around congested areas.
of reinforcement and into tight sections, allow air to escape and resist segregation. The nominal maximum size should be less than 15 mm and M30 Grade and above should be used [4, 10, 12].

4.3. Reinforcement bar
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 steel is fabricated in two forms - the meshed layers and diagonal girders for vertical support of the bubbles. The distance between the bars correspond to the dimensions of the bubbles that are to be used and the quantity of reinforcement from transverse ribs of the slab [4, 10, 12].

5. Literature review
The experimental and numerical study on bubble deck slab with the aim of reducing the amount of concrete in the middle of the slab by using hollow balls made by recycled plastic had been studied. The numerical Finite Element Analysis Software ANSYS had been carried out to study structural behaviour of the slab. It was reported the technology of bubble deck slab is an alternatives method which does not contribute to the structural self-weight and also leads to 30 to 50% lighter slab reduces the loads on the columns, walls and foundation, and also the entire building. The conventional RC slab carried the load of 365 kN and causes the deflection of about 14.46 mm. The bubble deck slab carried the load of 341.5 kN and causes the deflection of about 18.56 mm. Crack occurs at side face of the slab due to bending. The bubble deck slab can withstand 75% of loading carrying capacity when compared to conventional RC slab. 45.238 kg of concrete can be eliminated from 1000 mm x 1000 mm x 150 mm of slab by using 100 mm ball which results in reduction in weight of slab. Bubble deck slab is better in stress criteria and its weight than that of conventional concrete slab [12].

The loadbearing capacity between bubble deck slab conventional RC slab with different bubble diameter to slab thickness ratios (B/H) had been compared. M30 grade of concrete and 150 mm thickness were designed and used in their study. Three slabs were casted, one conventional slab and another two slab with bubbles consist of two different bubble diameter size which were 90 mm and 120 mm. The bubble deck with two different (B/H) ratios which were 0.60 and 0.80 designated as BD1 and BD2. The conventional slab was casted without bubble with 183.35 kg of concrete while BD1 and BD2 were casted with 164 kg and 151.54 kg of concrete having 35 and 16 spherical balls respectively. The conventional slab carried a load of 429.2 kN and cause 12.26 mm deflection with crack occurring after a load of 164 kN. BD1 slab with B/H ratio of 0.6 carried a total load of 350.78 kN and caused 12.6 mm deflection with crack occurring after a load of 158 kN while the BD2 slab with B/H ratio of 0.8 carried a total load of 398.2 kN and causes 13.2 mm deflection with crack occurring after a load of 123 kN. According to their study, it was reported that the stiffness reduction of 0.891 and 0.773 while the weight reduction of 10.55% and 17.43% in the BD1 and BD2 slabs compared to the conventional RC slab. Thus, this an added advantage for the bubble deck slabs especially in structures where load is an issue [13].

The stiffness and economy between conventional slab and bubble deck slab had been compared. Conventional slab and bubble deck slab with size 1 m x 1 m and bubble deck slab consist with different bubble diameter of 60 mm and 70 mm were casted and tested. The load and deflection of conventional slab and bubble deck slab had been recorded and the stiffness of the slabs were recorded. The stiffness of bubble deck slab with smaller diameter balls with 60 mm was found to be greater than that of 70 mm diameter bubble slab and conventional slab. The concrete amount that had been used to cast the slabs had been calculated using estimation and costing methods. The concrete volume used for conventional slab and bubble deck slab had been compared and it was reported about 14% of money can be saved by using bubble deck slab of 60 mm diameter and 9.41% by 70 mm diameter. Therefore, the volume of concrete for 60 mm balls was found to be more economical among all the slabs tested. In conclusion, the bubble deck slab of 60 mm diameter is more effective in terms of weight, strength, stiffness and economy compared to conventional slab [14].
Bubble deck slab improved flexural capacity, stiffness and shear capacity of at least 70% when the same amount of concrete and the same reinforcement is used as in the solid slab, 30-50% concrete economy than conventional solid slab. Concrete usage is reduced as 1 kg of recycled plastic replaces 100 kg of concrete. Thus, reduce dead weight up 50% [4]. The weight of bubble deck slab was reduced from 30-50% than conventional slab and it was reported that bubble deck slab performs better than normal conventional solid slab [5].

Studies have shown that bubble deck slab is in fact cheaper as compared to conventional concrete slab. The biggest reasons for this is due to the significant reduce in concrete usage in case of bubble deck technique. Bubble deck uses more plastic balls with much lesser concrete while conventional concrete slabs uses concrete entirely. Economic savings as a result of bubble deck is not obtained by itself. The largest savings are obtained through reductions and implications throughout the entire construction [15]. Table 1 presented the summary of factors affecting cost reduction of using bubble deck slabs as the innovative biaxial hollow slabs. The information has been collected from previous research studies.

Table 1. Summary of factors affecting cost reduction of using bubble deck slabs

| No. | Factors affecting cost | Summary |
|-----|------------------------|---------|
| 1.  | Less concrete usage     | - Concrete usage is significantly reduced as 1 kg of recycled plastic replaces 100 kg of concrete. The overall result is significant cost saving of between 2.5% to 10% [10]. |
| 2.  | Faster construction     | - On site construction time can be shortened since bubble deck slabs can be precast. Bubble deck slabs would eliminate the need for on-site erection of formwork, thus significantly cutting down construction time. Time savings can also be achieved through the faster erection of walls, columns and due to the lack of support beams [9]. |
| 3.  | Lower transportation costs | - The decreased weight and materials mean lower transportation costs and would be more economical to lift the components [9]. |
| 4.  | Lower labour cost       | - With less on-site construction from the full and semi-precast modules available in bubble deck slabs, labour costs will decrease as well [9]. |
| 5.  | High spans in bubble deck slabs | - For the same span, bubble deck slabs reduce the amount of concrete with 33% and reduces the price with 30% compared to conventional solid slabs [16]. |

6. Conclusion
The literature on the bubble deck slab has been reviewed. The self-weight of bubble deck slab can be reduced about 30-50% than conventional concrete slab. Concrete usage is reduced as 1 kg of recycled plastic replaces 100 kg of concrete that avoid the cement production and allows reduction in global CO2 emissions. In summary, bubble deck slab is better than conventional concrete slab such as improving the structural performance of slab, reduce the materials and cost, efficiency and faster construction time. Hence, this technology is environmentally green and sustainable.

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