Bubble Deck Slab

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Abstract— Bubble deck slab is a method of virtually eliminating all concrete from the middle of a floor slab, which is not performing any structural function, thereby dramatically reducing structural dead weight. High density polyethylene hollow spheres replace the in-effective concrete in the Centre of the slab, thus decreasing the dead weight and increasing the efficiency of the floor. By introducing the gaps leads to a 30 To 50% lighter slab which reduces the loads on the columns, walls and foundations, and of course of the entire building. The advantages are less energy consumption - both in production, transport and carrying out, less emission - exhaust gases from production and transport, especially CO2 .The aim of this paper is to discuss about various properties of Bubble deck slab based on the various studies done abroad. Moment, deflection and stress distributions are verified using Finite Element Method (FEM) in SAP2000.

Key words: Bubble Deck Slab

I. INTRODUCTION

BUBBLE deck slab is a biaxial hollow core slab invented in Denmark. It is a method of virtually eliminating all concrete from the middle of a floor slab not performing any structural function (fig 1), thereby dramatically reducing structural dead weight. Bubble deck slab is based on a new patented technique which involves the direct way of linking air and steel. Void forms in the middle of a flat slab by means of plastic spheres eliminate 35% of a slab's self-weight [1], removing constraints of high dead loads and short spans Its flexible layout easily adapts to irregular and curved plan configurations. The system allows for the realization of longer spans, more rapid and less expensive erection, as well as the elimination of down-stand beams.

II. BUBBLE DECK SLAB

According to the manufacturer, Bubble deck slab can reduce total project costs by three percent. Bubble deck slab is a new innovative and sustainable floor system to be used as a self-supporting concrete floor. The application of the Bubble deck slab floor system in the Netherlands is manifested as the world-wide first application. The Bubble deck slab floor system can be used for storey floors, roof floors and ground floor slabs. A Bubble deck slab floor is a flat slab floor, therefore without beams and column heads. The principal characteristic is that hollow plastic spheres are incorporated in the floor, Clamped in a factory-made reinforcement structure. This reinforcement structure constitutes at the same time the upper and lower reinforcement of the concrete floor.

The reinforcement structure with spherical shapes and possibly a thin concrete shell as precast slab floor are supplied to the construction site in factory-made units with a maximum width of 3 meters; they are installed on site and are assembled by installing connecting rods and by pouring concrete as shown in fig 2. After the concrete has set, the floor is ready to be used. The ratio of the diameter of the plastic spheres to the thickness of the floor is such that a 35 % saving is achieved on the material or concrete consumption for the floor in comparison with a solid concrete floor of the same thickness.

The saving on weight obtained in this way has the result that a Bubble deck slab floor can provide the required load-bearing capacity at a smaller thickness this leads to a further advantage, resulting in a saving of 40 to 50 % of the material consumption in the floor construction. This is not the last of the advantages of the Bubble deck slab floor system: because of the lower weight of the floor system itself, also the supporting constructions such as columns and foundations can be less heavy. This can results eventually in a total weight or material saving on the building construction of up to 50 %. Since the weight of the structure reduced, this type of structure can useful to reduce earthquake damage.

Bubble deck slab is composed of three main materials; they are steel, plastic spheres and concrete

1) Concrete

The concrete is made of standard Portland cement with max aggregate size of 20 mm. No plasticizers are necessary for concrete mixture.

2) Steel

The steel reinforcement is of grade Fy60 strength or higher. The steel is fabricated in two forms -meshed layers for lateral support and diagonal girders for vertical support of the bubbles.

3) Plastic Spheres

The hollow spheres are made from recycled high-density polyethylene or HDPE.

A. *Types of Bubble Deck*

All of the Bubble Deck versions come in three forms- filigree elements, reinforcement modules, and finished planks. They are depicted in Figure 2-2. For all types of Bubble Deck, 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

1) Type A- Filigree Elements

Bubble Deck Type A is a combination of constructed and unconstructed elements. A 60 mm 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 Bubble Deck is optimal for new construction projects where the designer can determine the bubble positions and steel mesh layout.

2) Type B- Reinforcement Modules

Bubble Deck 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 Bubble Deck is optimal for construction areas with tight spaces since these modules can be stacked on top of one another for storage until needed

3) 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).

III. BUBBLE DECK SLAB

A. Flexural Strength

Bubble deck slab is conceived to omit a significant volume of concrete (compared to a solid slab) in the central core where the slab is principally un-stressed in flexure [3]. In slabs, the depth of compressed concrete is usually a small proportion of the slab depth and this means that it almost always involves only the concrete between the ball and the surface so there is no sensible difference between the behavior of a solid slab and Bubble Deck. The only elements working are the outer 'shell' of concrete on the compression side and the steel on the tension side. In terms of flexural strength, the moments of resistance are the same as for solid slabs provided this compression depth is checked during design so that it does not encroach significantly into the ball

B. Shear Strength

In any flat slab, design shear resistance is usually critical near columns. The shear stresses remote from the columns diminishes rapidly and outside the column zones it has been demonstrated by testing and calculation the transverse and longitudinal shear stresses are within the capacity of the Bubble deck slab system. Near the columns, bubbles are left out so in these zones a Bubble deck slab is designed exactly the same way as a solid slab. Shear resistance of Bubble deck slab is 0.6 times the shear resistance of a solid slab of the same thickness [3].

If this is exceeded by the applied shear, at a column for example, we leave out the balls and use the full solid shear values. Using Euro code 2, we would calculate the applied shear at 2d and subsequent perimeters from the column face as per the code requirements, as well as at the column face itself. We would then compare this to our calculated resistance. If the applied shear is less than the un-reinforced hollow slab resistance, no further check is required. If the applied shear is greater than the hollow slab resistance we omit balls and make it solid and then check the solid part. The shear capacity is measured for two ratios of aid (distance from imposed force to support divided by deck thickness).

The results are shown in table 2. If the resistance is still greater than the solid slab resistance and less than the maximum allowed, we provide shear reinforcement. For these reasons, it is demonstrated that the design may be carried out in every way treating the slab as a solid slab, with the provisions mentioned above, which are all taken account of in the design process. We therefore use Euro code 2, which is fully compatible with the system, for our design and which is somewhat more up to date than BS811O. Punching shear [3] the average shear capacity is measured to 91 % compared to the calculated values of a solid deck.

C. Durability

The durability of bubble deck slab is not fundamentally different from ordinary solid slabs. The concrete is standard structural grade concrete and combined with adequate bar cover determined in accordance with EC2 or BS811O[5] provides most control of durability commensurate with normal standards for solid slabs. When the filigree slabs are manufactured, the reinforcement module and balls are vibrated into the concrete and the standard and uniformity of compaction is such that a density of surface concrete is produced which is at least as impermeable and durable, arguably more so, to that normally produced on site. Bubble deck slab joints have a chamfer on the inside to ensure that concrete surrounds each bar and does not allow a direct route to air from the rebar surface. This is primarily a function of the fire resistance but is also relevant to durability

Cracking in Bubble deck slab is not worse, and probably better, than solid slabs designed to work at the same stress levels. In fact Bubble deck slab possesses a continuous mesh, top and bottom, throughout the slab and this ensures shrinkage restraint is well provided for and that cracking is kept to a minimum whether it is intrinsic or extrinsic cracking. Unlike an off-the-shelf product, this is a system that is bespoke designed for each and every project. All the peculiarities of a project are therefore taken into account in the design; therefore there is no risk of the product being misused by applying it to uses for which it is not intended.

D. Deflection

Span depth ratio calculations for deflections are very approximate and are not appropriate in flat slabs of irregular layout except for the most simple or unimportant cases. FE modeling, including non-linear cracked section analysis is used to calculate the deflection using normal structural concrete with a Young's Modulus (secant) Ecru, multiplied by 0.9 and a tensile strength, FCTM multiplied by 0.8 (to reduce the crack moment as mentioned above. This is mainly significant in the computation of untracked curvatures where the geometry of the concrete section is significant but is of increasingly negligible significance after cracking). The deflections in Bubble deck slab and solid slab are explained in terms of stiffness as shown in table 1 [6]. It is not presently possible to calculate for the difference in age related properties in the filigree and in-situ concrete parts. This is not considered to be a significant weakness.

E. Sound Insulation

A comparison was made between Bubble Deck and one way prefabricated hollow deck of similar height. The noise reduction with Bubble Deck was Idb higher than the one way prefabricated hollow deck [2]. The main criterion for reducing noise is the weight of the deck and therefore Bubble Deck will not act otherwise than other deck types with equal weight. The Bubble deck slab construction is following every usual criterion, and can be calculated according to usual principles. Test results are as shown in Table 3[4]. The construction is not deviating, in any way, from what is already known and used. The construction is analogous to an equivalent solid deck.

F. Vibration

RC slab structures are generally less susceptible to vibration problems compared to steel framed and light weight skeletal Structures, especially using thin slabs. However, Bubble deck slab is light and is not immune from vibration [7] in all cases so this must be checked just as it should be in appropriate solid slab applications. Where deflections are large, as indicated by the static design, it is often an indication that the structure is Sensitive to vibration SLS issues. The lighter weight of Bubble deck slab may be exploited if it can usefully alter the modal frequencies of a slab - generally raising them compared to a solid slab. The most effective weapons against vibration [4], particularly resonant vibration, are stiffness and damping. If we consider damping to be similar to solid slabs, and concentrate on stiffness, we may observe that a Bubble deck slab can provided over 2 times the stiffness obtained from a solid slab for the same quantity of concrete used. This can be exploited in vibration sensitive applications. At the present time, the static modification to the flexural stiffness is applied.

G. Fire Resistance

The fire resistance [8] of the slab is a complex matter but is chiefly dependent on the ability of the steel to retain sufficient strength during a fire when it will be heated and lose significant strength as the temperature rises. The temperature of the steel is controlled by the fire and the insulation of the steel from the fire. In any case, all concrete is cracked and, in a fire, it is likely that the air would escape and the pressure dissipated. If the standard bubble material is used (HDPE), the products of combustion are relatively benign, certainly compared to other materials that would also be burning in the vicinity. In an intense, prolonged fire, the ball would melt and eventually char without significant or detectable effect. Fire resistance depends on concrete cover nearly 60-180 minutes. Smoke Resistance is about 1.5 times the fire resistance. Depth of smokeless is than 10 m on both sides. Balls simply carbonize. No toxic gasses will be released

IV. CONTACT BETWEEN BUBBLES & REINFORCEMENT

The potential for any contact is only theoretical because the balls do not perfectly fit between reinforcement bars and moves slightly during assembly I site concrete compaction so that some grout surrounds it and provides a measure of passivation. However, even if there were contact between the ball and the steel, the environment inside the void is very dry and protected - there is also no breach (apart from micro cracking) of the concrete to the outside air. It is a better situation than exists with inclusion of plastic rebar spacers within solid slabs that create a discontinuity within the concrete between the outside air and the rebar in solid reinforced concrete slabs.

We therefore have a situation that is better than existing with plastic rebar spacers and these have been permitted for many years. Tests carried out in Denmark, Germany and Holland showed that the flexural stiffness is approximately 87% to 93% of the same thickness of solid slab - In design we use an average of 90% and, in addition, the cracking moment is factored by 80% as recommended in Dutch research. In fact one of the major benefits of the system is its virtue of reducing deflections for a given span because the one-third weight reduction overwhelmingly more than compensates for the very small reduction in stiffness

V. CONCLUSIONS

The market of construction floors in the building industry consists mainly of massive concrete floors, prefabricated filigree slab floors and hollow core slab floors. This situation has not changed for more than 20 years. But this innovative slab construction technology is proven to be more efficient than a traditional biaxial concrete slab in an office floor system.

The finite element models of the office slabs created for this study in SAP2000 verify the prior analysis and experiments.

a) Bending stresses in the bubble deck slab are found to be 6.43% lesser than that of a solid slab.
b) Deflection of Bubble deck is 5.88% more than the solid slab as the stiffness is reduced due to the hollow portion
c) Shear resistance of bubble deck slab is 0.6 times the shear resistance of the solid slab of same thickness. However required resistance can be achieved by providing vertical reinforcement.
d) Weight reduction is 35% compared to solid slab.

This innovative slab system with considerable reduction in self-weight and savings in materials combines all advantages of the other floor systems, solving all problems caused by their disadvantages in the same time. Besides that the new floor system enhances the structural possibilities in combination with an improved cost-effectiveness. Further on the floor system gives a tremendous contribution to sustainable development.

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