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Assessment of Bubble Deck Slab

Sudhir Kapgate[1], Rohit Bhosle[2], Onkar R. Khupse[3], Ashish V. Meshram[4], Gauri B. Bhajikhaye[5], Umair Anwar[6], Pradeep F. Nishad[7]

[1st & 2nd] *Professor, Department of Civil Engineering, Nagpur Institute of Technology*
[3, 4, 5, 6 & 7th] *Student, Department of Civil Engineering, Nagpur Institute of Technology*

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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

***Key Words*:** Bubble deck slab; Biaxial slab; Voided slab; Hollow recycled plastic balls; Reinforced concrete slab

1.INTRODUCTION *(Size 11, Times New roman)*

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, 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, 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.

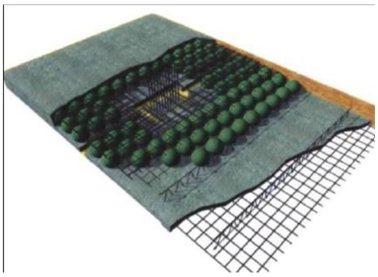

Fig. Bubble Deck Slab

Bubble deck slab is the slab in which some amount of the concrete is replaced by the plastic hollow bubbles which are made by the waste plastic material, which reduces the self-weight of the structure. The main effect of the plastic sphere is to reduce the dead load of the deck by1/3 in compare to solid slab having same thickness without effecting its deflection behavior & bending strength It locks spheres between the top and bottom reinforcement meshes, thereby creating a natural cell structure, acts like a solid slab. The slab is cast with the same capabilities as a solid slab, but with considerably lesser weight due to elimination of excessive concrete.

This technology will then be applied to create lightweight bridge deck 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. Modular deck components for pedestrian bridges that is notably lighter but comparable in strength to typical reinforcement concrete section will be designed This. floor system is designed to reduce the strength to weight ratio of typical concrete slab.it replaces or removes concrete from center of slab, where not or less useful.in place of that concrete, this design system uses hollow HDPE spheres to decrease the dead load of concrete floor.

However, it also reduces the slab resistance to fire and shear.

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 is 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. 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 result 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.

2. Materials used

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

2.1Concrete:

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

2.2Steel:

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. High grade steel of Fe 550 or Fe 500 is generally used. The same grade of steel is used in both in top and bottom steel reinforcement. Reinforcement shall be accurately placed and secured in position in a manner

that will prevent its displacement during the placement of concrete. Reinforcement provided in both transverse and longitudinal direction in the form of welded reinforcement mesh.

2.3Plastic spheres:

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

Generally, we used HDPE recycled balls because to reduce wastage of plastics instead of burning the plastics. The Bubble Deck slabs being entirely recyclable. Recycled balls can be recovered during the demolition of the building to meet the goal of sustainable construction.

FIG. Plastic Spheres

3. PERFORMANCE AND ANALYSIS

3.1 STRUCTURAL PROPERTIES

3.1.1 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 is 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

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.

3.1.2. 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

3.1.3 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, fct multiplied by 0.8 (to reduce the crack moment as mentioned above. This is mainly significant in the computation of uncracked 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.

3.1.4 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 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

3.1.5 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 18 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.

3.1.6 FIRE RESISTANCE

The fire resistance 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.

3.2 TESTING OF BUBBLE DECK SLAB

3.2.1Contact 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.

3.2.2. Deflection & Bending Stiffness

The bottom reinforcement steel and the top compressive portion of stress block contributes to flexural stiffness in bending.

3.2.3. 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.

3.2.4 Punching Shear

The average punching shear is calculated to 91% in comparison to solid slab It must be firstly analyzed that whether the applied shear is lesser or greater than the shear capacity of bubble Deck slab. Firstly, it is determined by the designer whether the applied shear is greater or less than the bubble Deck capacity. If it is found to be lesser than no father check is required. But if it founds to be greater, the spheres should be omitted surrounding the column & then check the shear in newly solid section. Then if shear resistance of solid concrete portion is lesser than applied shear, than shear reinforcement is required.

3.3 CONSTRUCTION METHODOLOGY (BUBBLE DECK SLAB)

3.3.1 Selection of Materials:-

These materials use for the research where obtained within Aurangabad city. Ordinary Portland cement (OPC) (ultratech brand) Was used for the project, the fine aggregate (sharp sand) use was obtained from a flowing river it was dried for some days in the laboratory and then sieved to be free from deleterious material. Coarse aggregate was purchase from a quarry site. And instead of bubble we used plastic balls. Ordinary cline tap water free for drinking was used for the experiment. We used steel having 8mm diameter for the project.

3.3.2 Making steel mesh for conventional slab (one way):-

We take 8mm diameter bar of 30 feet's, and cut it in to 26 inches each strip, bent the main bar in 45o from one side and place it in alternate manner in 3 inches distance on the distribution bar as shown in fig. And tied it perfectly to each other.

3.3.3Making steel mesh for Bubble Deck slab:-

We take 8mm diameter bar of 30 feet's and cut it in to 22 inches each strip. In that system no bent up is required in a main bar, only straight bar mesh is provided in bottom and top of bubbles. The main and distribution bar is place in 2.5 inches in distance. And that these two meshes we fix a Bubble (HDPE) in proper manner

3.3.4 Provision Bottom Reinforcement:-

The initial step is laying the bottom reinforcement for increase the tensile strength of the structure. It fetches the ball and aligns it in a straight line. Bottom reinforcements are two directionally righted reinforcement meshes.

3.3.5Provision of Top Reinforcement:-

After placing the balls, top reinforcement meshes are provided on the top of the sphere. It is positioning the ball and also acts as a cover for the balls. The two mashes are connected after placing the spheres into places in order to form a rigid shell. In order to achieve the reinforcement modules for Bubble Deck slabs with gaps. The following operations must take place:

- Making the steel reinforcement meshes.
- Placing the pipelines, cables and element of electric fittings.
- Fixing small boxes or pieces of polystyrene on reinforcement meshes for marking the position of the walls or the columns and installations.
- Placing of the polystyrene spheres between the meshes according to plans

3.3.6 Location of balls:-

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The balls are placed in between the reinforcement instead of concrete. Bottom reinforcement and diagonal girders keep the bubbles in position. Diagonal girders fixed between the top and bottom reinforcement. During the final positioning of the slab elements it is checked if the displaying of the spheres is according to the plans. Also, it is checked the reinforcement in the 22 over concreting areas. The transversal reinforcement bars must be embedded in the adjacent slab elements. To maintain the building configuration partially pre-casted elements are made and designed. They are delivered with pieces of polystyrene included that mark the position of the walls or the columns.

3.3.7Mix proportions of conventional and bubble deck slab Batching operation by weight approaches was adopted in the study. Preliminary mixes of 1:2:4 (cement: fine sand: coarse aggregate) were investigated with water/cement ratio of 0.80, and 0.70 respectively so as to obtained the required w/c ratio for the actual mixes.

3.4 CASTING AND CURING OF CONVENTIONAL AND BUBBLE DECK SLAB

3.4.1 Bottom Concrete:- Concrete is provided at the bottom of the assembly line. It acts as a bonding material for ball because the ball attached with the concrete. We take waste tiles for casting of slab for better smooth finishing. Then apply oil on it and place steel mesh of conventional slab and bubble deck slab mesh in the two different formwork mould. Concrete provided over the slab by trowel. Concrete is poured in between the ball gaps. Immediately after pouring, the surface of the concrete is cleaned with under pressure water to remove the dust and to moister the surface. Especially in times of high temperatures the surface of the precast element is kept wet to ensure the needed adherence and the connections of the partially prefabricated elements are not rigorously followed according to the design the concreting is adjusted with fluid mortar or with a thin layer of silicon pumped at the bottom part of the connection. In order to adjust the connections, one should never use expanded foams that may lead to reducing the thickness of the concrete layer and therefore to reducing the durability of the reinforcement and the fire resistance. 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, without the standard consolidation efforts. After concreting, vibration is provided for bottom and top concrete setting. Removing air content from the slab. Thin vibrator should be used for compaction as there is less space between the spheres. The surface of the poured concrete in levelled with a metallic profile. Finally, concrete surface finished with finishing tools. There is no further work required, the slab is complete unless requirement for exposed soffit. Then place it to 24 hr. for final setting. After setting we removed the formwork and place the slabs for curing for 7 days

4. CASE STUDY AND RESULTS

4.1 CASE STUDY

4.1.1 MPCC (Multipurpose community Centre) Building:-

The MPCC in the Perth suburb of Beckenham, Western Australia is the first public building in Australia Built by PACT Construction and completed in October 2016.The design and construction of the building area was required 2,300 sq.m. In this 132 BD semi precast panels have been used for the suspended slabs. The light weight of the entire structure using BD voided two-way slabs decreasing foundation loads and offering flexibility to configure footings to reduce differential settlement of the building. Finally, the MPCC is estimated to have saved 250 m3 of concrete and 20% of mass compared to Traditional alternative. The MPCC to attain six-star rating for design and construction and also won the category for excellence in Environment and Sustainability building.

Fig.4.1 MPCC Building

4.1.2 Millennium Tower:- The Millennium Tower in the city of Rotterdam in the Netherlands, was the first work to be constructed with slabs bubble deck. Initially, the project included the use of Bubble deck hollow slabs. But before construction was started it was decided to use the concept of slabs bubble deck, which resulted in an acceleration of 10 cycles of floors for 4 days. It also meant a reduction by 50% of the pillars used in the work, and a saving of five hundred truck trips. It was possible to add two floors the most due to the decrease of the right foot, since the technology does not use beams. Millennium Tower is 130.8m height with 35 storey and was completed in 2000 and it is the second largest building in the Netherlands designed by WZMH Architects and AGS Architect. The first high rise building erected with Bubble Deck filigree elements and the second highest building in Netherlands, 34 stories and 131 meter high.

Bubble Deck was chosen, in spite of being a completely new product, because of its advantages in cost , construction time and flexibility and because of environmental issues. Beams could be excluded resulting in two more stories than planned in the beginning for the same building height. Built in 1998-2000.

Fig.4.2 Millennium tower

4.2 RESULT DISCUSSION: -

1. The shear strength of concrete slab mainly depends on effective mass of concrete in the slab. Due to presence of HDPE spheres, the shear resistance of Bubble deck slab is largely decreased in comparison to normal solid slabs.
2. The internal forces & maximum stresses in the voided deck were up to 40% lesser than solid slab due to reduced dead weight by use of HDPE spheres.
3. The deflection was little greater by 10% since the stiffness reduces from presence of bubbles.
4. The reduction in the self-weight of the slab results in lesser material quantity and hence the cost of the construction of member by up to 10%.
5. These results say that this type of slab will provide better long durable floor slab with better long-term result under a dominant gravity and uniform load.

5. CONCLUSION

5.1 CONCLUSION

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.

1. Concrete usage was reduced, reducing material consumption. It led to reduction dead load up to 10.07%.
2. It was observed that deflection of bubble deck flat slab is higher as compared to conventional slab.
3. Ultimate load carrying capacity was reduced in bubble deck flat slab by 11.22%.
4. The bottom cracks are longitudinal as well as diagonal. Most of the cracks are longitudinal and similar in both the cases.
5. Cost was reduced to 10.84% when compared with conventional concrete.

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.

This analysis proves that Bubble Deck technology is more useful and efficient than a solid conventional slab in office floor system. The models of the slabs created for the analysis verifies the prior analysis & experiments. however, the performance of bubble slab is not as successful in pedestrian deck. this does not reduce the use of bubble deck in bridge deck, but requires more studies to completely analyse the feasibility of slab.

5.2 LIMITATIONS

1. There is an increase in cost of production due to assembly and manufacturing of HDPE spheres.
2. Punching shear capacity is low.
3. Difficulty in structural health monitoring.
4. Skilled labours required
5. Not applicable to slabs having limited Thickness.

5.3 FUTURE SCOPE

In conclusion, we can conclude that Bubble Deck slabs will be constructed in the future, and that research, studies and experiments on the various sizes and slab thicknesses of HDPE balls are necessary to gain popularity and use of this technology. These systems reduce the concrete within the middle of the slab by a lighter material to reduce the weight of the structure. The result coming from lower grades of concrete can also be checked.

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