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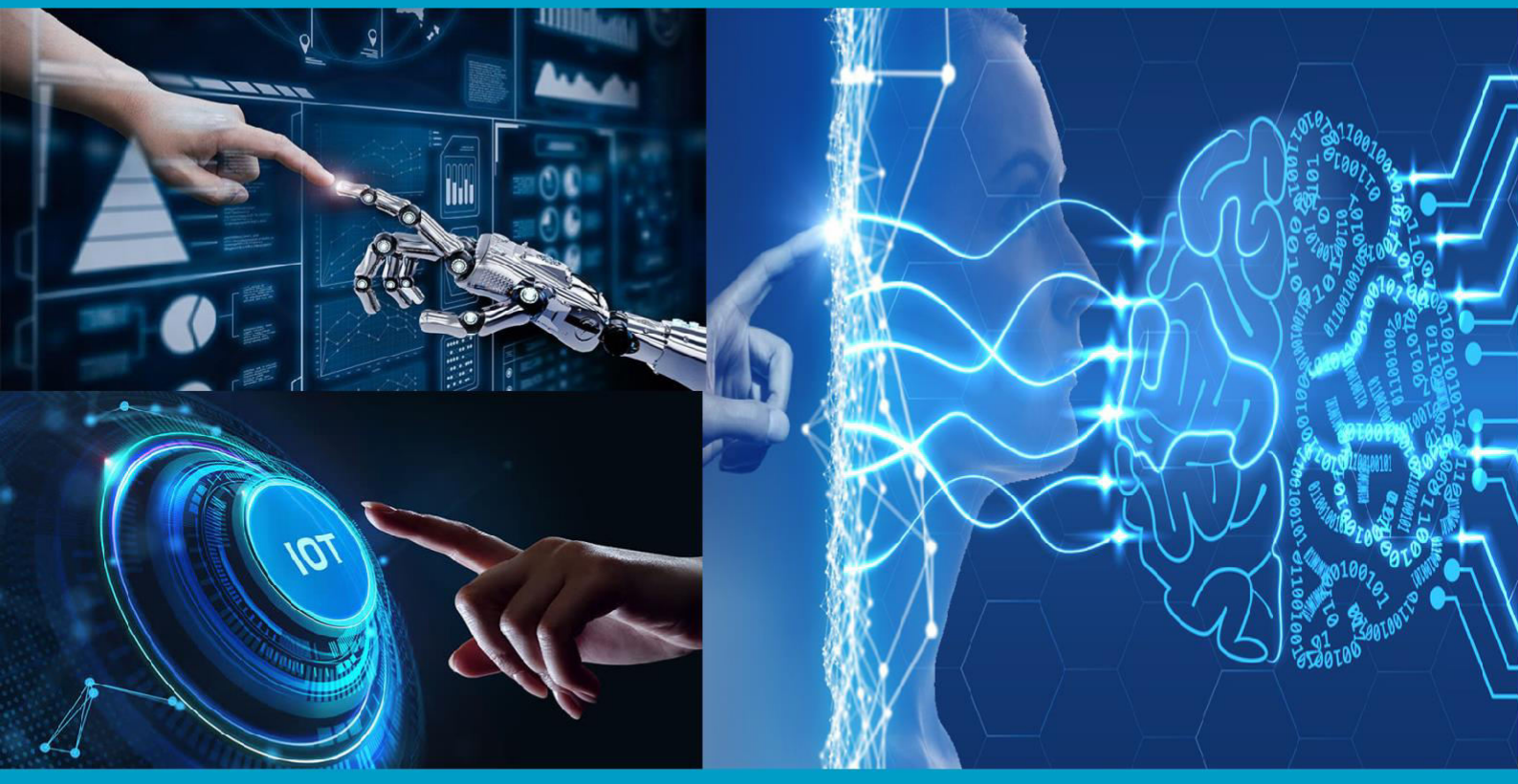

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Experimental Study on Bubble Deck Slab Using Polypropylene Ball

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ABSTRACT- This study is performed on bubble deck slabs, invented by Jorgen Bruenig in 1990's who developed the first bi-axial hollow slab in Denmark, the slab is constructed using void former's which merely create voids commonly referred to as bubbles and the slab, as bubble deck also known as voided slab. The use of spherical balls to fill the voids in the middle of a flat slab reduces 35% of a slab self-weight compared to solid slab having same thickness without affecting its deflection behaviour & bending strength. The behaviour of Bubble Deck slabs is influenced by the ratio of bubble diameter to slab thickness. From this experiment, it is observed that for the bubble deck slab of thickness 125mm, the average flexural strength of the slab is 8.09 N/mm^2 and 8.72 N/mm^2 for specimens in which the spacing between the balls is 20mm and 30 mm respectively. For the bubble deck slab of thickness 100 mm, the average flexural strength of the slab is 8.22 N/mm^2 and 8.99 N/mm^2 for specimens in which the spacing between the balls is 20mm and 30mm respectively.

KEYWORDS: Bubble Deck Slab, Polypropylene Ball, Concrete, Slab, Compressive Strength

I. INTRODUCTION

This study is performed on bubble deck slabs, invented by Jorgen Bruenig in 1990's who developed the first bi-axial hollow slab in Denmark, the slab is constructed using void former's which merely create voids commonly referred to as bubbles and the slab, as bubble deck also known as voided slab. The use of spherical balls to fill the voids in the middle of a flat slab reduces 35% of a slab self-weight compared to solid slab having same thickness without affecting its deflection behaviour & bending strength. The behaviour of Bubble Deck slabs is influenced by the ratio of bubble diameter to slab thickness.

These bubble deck slabs have many advantages over a conventional slab. The total cost is lower, material is reduced, structural efficiency is enhanced, and construction time is decreased and is a green technology. The slabs are designed as biaxial flat slabs. The spheres are not placed at the edges of the slab where the shear forces acting are more. About one third of the thickness is reduced when spheres are introduced and thus provides more head room and thus helps in construction of many stories. The structure constructed thus has overall less self-weight and thus the seismic performance of the structure is also increased. The spheres also act in better acoustic performance of the structure. Bubble Deck slab is a unique method in which concrete is eliminated in the middle part of the slab which does not contribute to the structural self-weight and also leads up to 50 % lighter slab which reduces the loads on the columns, walls and foundation, and of course of the entire building.

According to the Bubble Deck, 100 kg of concrete is replaced by 1 kg of recycled plastic. The reduction in dead load makes the long-term response more economical for the building. Since resistance is directly related to the depth of concrete, the shear and punching shear resistance of the bubble deck floor is significantly less than a solid deck. This weight reduction creates many benefits that should be considered by engineers determining the structural system of the building.
Plastic voided slabs remove concrete from non- critical areas and replace the removed concrete with hollow plastic void formers while achieving similar load capacity as solid slabs.

Voided slab principles have been applied in different applications dating back to the early 1900s. Similarly the reduction of concrete in bridge deck modal (light weight Pedestrian Bridge). In this thesis work our main focus on the reduction of concrete.

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A concrete slab is a common structural element of modern buildings. Horizontal slabs of steel reinforced concrete are most often used to construct floors and ceilings, exterior paving. A slab being the essential part of the Structure has to be effectively designed and utilized. It tends to use more concrete than requirement, hence has to be optimized. 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 by 1/3 in compare to solid slab having same thickness without effecting its deflection behavior & bending strength. The slab is cast with the same capabilities as a solid slab, but with considerably lesser weight due to elimination of excessive concrete. The spheres could be recycled even after the building is demolished or renovated in the future. The dead air space in the hollow spheres provides insulating value and can be introduced with foam for additional energy efficiency, this also increases fire resistance as well as sound insulation.

II. LITERATURE REVIEW

[1] Experimental Study on Bubble Deck Slab using Polypropylene balls (2017)

Bubble deck slab is an innovatory floor system of reinforced concrete which contains spherical hollows as concrete saving elements. It is a revolutionary method which virtually eliminates all concrete from the middle portion of a floor slab. The structural dead weight is reduced due to the non-performance of any structural function by the middle portion of the slab. High density polypropylene spherical balls replace the in-effective concrete in the center of the slab. Voids in the middle of the slab provide thermal insulation and also leads to 30 to 50% lighter slab. Bubble deck slab allows longer spans between columns supports. In this paper, flexural strength of the slab was determined by two-point load test. The main aim of this study is to determine the optimum spacing and diameter of balls to achieve maximum strength. Crack pattern of bubble deck slab is also studied by varying the spacing and diameter of balls.

[2] Experimental Study on Bubble Deck Flat Slab (2019)

Bubble Deck is a method of eliminating concrete from the conventional flat slab which does not perform any structural function, hence reducing structural dead weight and increasing efficiency of the floor. Bubble Deck slab uses hollow plastic balls. In the Bubble deck technology reduce the concrete volume by replacing plastic balls which are locally available. This system can be used for roof and ground floor slabs also it does not require beams and column heads. This technology reduces cost of construction. In this experimental study comparison between conventional flat slab and bubble deck flat slab is done.
This paper presents a study on the properties and advantages of Bubble Deck flat slab system. The balls are made using poly vinyl chloride materials. These are usually made with nonporous, non-toxic environmentally friendly material that does not react chemically with the concrete or reinforcement bars. The balls have enough strength and stiffness to support safely the applied loads in the phases before and during concrete pouring. Diameter of ball is 70 mm for slab thickness 120 mm is used. The distance between two balls is 36mm.

[3] An Experimental Study on Bubble Deck Slab System using HDPE balls (2019)

Concrete slab is an important two dimensional or planar element, used in all types of structures such as floors and roof covering. Bubble Deck slab is a futuristic method which can effectively eliminate all the concrete from middle of slab by replacing it with High Density Polyethylene Balls (HDPE) and provides thermal insulation. In this technique, the reinforcement mesh acquires, allocates and attached the balls at exact position and also stabilizes the lattice. By this technique structural weight can be reduced from 25% to 50. The main aim of this study to comparatively study of Bubble Deck slab and conventional slab under cost analysis, load bearing capacity .i.e. strength and efficiency too and also families and create awareness to all. The advantages of this technique are less energy consumption - both in production, transport and carrying out, less emission - exhaust gases from production and transport, especially CO2.

[4] The Study of Bubble Deck Slab Using High Density Polyethylene Balls - A Review (2022)

Construction field requires new technique in order to enhance the construction procedure. As the traditional method of building construction require huge consumption of materials and the time as well. Thus, it becomes necessary to search new approach in construction. Slab is one of the important elements of the building consuming large amount of concrete. The load transmitted on the slab is more and the clear span between the columns is large which results in usage of massive amount of concrete and steel. Due to this, the dead weight and the cost of construction increases so to minimize the above issues, Bubble deck technology can be used. Bubble deck slab is a biaxial hollow core slab. In this method concrete in the mid span of the slab is replaced by high density polyethylene balls (HDPE). HDPE balls are

recycled materials derived from gasoline products under controlled temperature and prove to be eco-friendly. The diameter of the ball depends upon the depth of the slab. The ratio of bubble diameter to the depth of the slab plays a vital role. The concrete placed in the central portion of the slab acts as a filler material and it does not carry structural load. In this thesis the theoretical, analytical and experimental study has been done. Flexural test is carried out on the slab in order to check the strength. 24 specimens of slabs are casted, 12 specimens of conventional slab and 12 specimens of Bubble Deck slab. The grade of concrete used in casting the slab is M25. The approach includes making of moulds, forming the reinforcement mesh, placing the HDPE balls between the mesh, concreting, curing and testing. The test is performed on UTM and the results are analyzed. From the results it is obtained that the volume of concrete is reduced by 28.8% in bubble deck slab as compared to conventional slab and Bubble deck slab is lighter by 25% as compared to conventional slab also. The load bearing capacity of bubble deck slab is also increased by 11.68%.

[5] Review on Bubble Deck with Spherical Hollow Balls (2017)

Due to the sheer amount of concrete required to produce these slabs, the dead weight of them tend to be very large. Heavier structures are less desirable than lighter structures in seismically active regions because a larger dead load for a building increases the magnitude of inertia forces which the structure must resist, as large dead load contributes to higher seismic weight. Bubble Deck is a revolutionary method which was developed in the 1990s in Europe and is gaining popularity and acceptance worldwide. This method virtually eliminates concrete from the middle of the conventional slab, thereby dramatically reducing structural dead weight. Bubble Deck slab uses hollow spherical or elliptical balls made by recycled plastic. Plastic voided slabs are capable of reducing the amount of concrete necessary to construct a building by 30 percent or more. Voids in the middle of a flat slab eliminate up to 35% of a slab's self-weight removing constraints of high dead loads and short spans. This provides a wide range of cost and construction benefits.
Depending on the manufacturer, plastic voided slab systems are constructed by two primary methods: a filigree method in which part of the system is precast off site, and a method in which the entire system is constructed on site. Both methods use the same three basic components. In both methods, the main component is the plastic balls containing void. These voids are often spherical, hollow, and made of recycled plastic. The voids allow the slabs to be lighter than traditional concrete slabs since the voids are nearly weightless and replace concrete in the center of the slab. The next main component is the steel cage. Steel reinforcement is added to resist flexure for the slab, but a cage of thin steel is also used to hold the voids in place, keeping them in the center of the slab. The third main component is the concrete, which surrounds the voids and forms the slab. The concrete ultimately determines slab strength. Though both methods use each of these components, the two methods use different approaches. The voids are assembled in steel cages and then concrete is poured to a height part way up the voids. The filigree slab panels are then transported to the construction site and lifted in place by crane. Once in place, the top layer of concrete is placed, covering the voids and completing the slab. Wire trusses run between the precast and cast-in-place layers of concrete to ensure that the two layers bond properly.

[6] Behaviour of Bubble deck slab by model making and performing compressive strength (2021)

In western country for a construction of high-rise building large projects the bubble deck slab is widely use to modified slab structure. This constructive system could not be brought into practice in so many projects achieved, the test that prove project that will be performed is useful in so many project, therefore tests were made concerning: bending behavior, reaction in the slab, the behavior of mountings, the reaction to fire, the achievement of economy. Bubble deck slab make the slab lighter than convectional slab of by eliminating all concrete from the middle of a floor slab, which is dormant concrete function, thereby dramatically reducing structural dead weight. Plastic hollow balls replace the in-effective concrete in the center of the slab, thus decreasing the dead weight and increasing the efficiency of the floor. The advantages are less energy consumption - both in production, transport and carrying out, less emission - exhaust gases from production and transport, especially CO2 and reduce the material, the load, lower the cost and it is also a green technology.

[7] An experimental study on two-way bubble deck slab with spherical hollow balls (2016)

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. The advantages are less energy consumption - both in production, transport and carrying out, less emission - exhaust gases from production and transport, especially CO2 and reduce the material, the load, lower the cost and it is also a green technology. In the bubble deck technology reduce the concrete volume by replacing the spherical bubbles, these are locally available which is called as PEPSI balls, these balls are made up of

HDPE (High Density polyethylene). In this experimental program conventional slab and bubble deck slab are cast with various bubbles arrangement which is continuous arrangement of bubbles within whole slab and two types of alternative bubbles arrangement in the slab. And trying to enhance the increasing strength of that slab. This implies the realization of a monolithic slab element, which will be subjected to static gravitational loadings in order to determine the deformation (deflection), cracking and failing characteristics. The resultant conclusions will be used in defining the failing mechanisms.

[8] A Review on Bubble Deck Slab Technology (2021)

Bubble deck is the patented integration technique of linking air, steel and concrete in a two-way structural slab. Hollow plastic balls are inserted into the slab and held in place by reinforcing steel. The structural behaviour of the bubble deck slab has been assessed through flexural strength, shear strength, punching shear, anchoring, crack pattern, fire resistance, creep. This system can be used for roof and ground floors slabs also it does not require beams and column heads. Bubble deck slabs uses hollow plastic balls. Bubble deck slabs have less load carrying capacity compared to the conventional slab. Efficient volume is the way of using concrete in the most efficient way possible by substituting materials. Bubble deck slab allows longer spans between columns supports. Bubble deck slabs are more economical and efficient with respect to structural integrity while comparing with conventional slabs. This system can be used for roof and ground floor slabs also it does not require beams and column heads. This technology reduces cost of construction. In this paper they worked on structural behaviour of bubble deck slab. They aimed to discuss about various properties of bubble deck slab based on various studies done on Abroad. Moment, deflection and stress distributions are verified using finite element method in SAP 2000. They concluded that the market of construction floors in the building industry consists mainly of massive concrete floors, fabricated filigree slab floors and hollow core slab floors. But this innovative slab construction technology was proven to be more efficient than a traditional biaxial concrete slab. They concluded that bending stresses in the bubble deck slab are found to be 6.43% lesser than that of a solid slab, deflection is 5.88% more than the solid slab, shear resistance is 0.6 times the shear resistance of solid slab, weight reduction is 35% compared to the solid slab.

[9] An Experimental Study on the Utilization of Steel Slag Aggregate for Performance Enhancement of Bubble Deck Slab (2022)

Bubble deck slab is technology in which high resistance bubble are installed in slab to reduce is self-weight and concrete value. The purpose of bubble deck slab is to reduce self-weight of individual number structure with ultimately results in minimizing the use of natural material and reduce the structural size. In this paper bubble deck technology is use in which plastic ball of 50mm diameter and M40 concrete grade with an 8mm diameter bar of Fe 500. In case-I The balls are placed a) Centre of two reinforcement, b) On intersection of reinforcement c) The balls are placed intersection as well as center. Case-II casting the slab according to case I by replacing coarse aggregate by 0%, & 10% steel slag aggregate all the slabs are tested for load Vs deflection test.

In this study, it is proposed to utilize steel slag aggregate as replacement of coarse aggregate in the production of concrete. Bubble deck slab were cast with Steel slag aggregate with 0% & 10% replacement of coarse aggregate. We need to determine the flexural strength of the bubble deck slab after casting it by performing a load vs deflection test on an UTM machine for 28 days.

[10] A Robustic Analysis on Structural Behaviour of a Bubble Deck Slab over Conventional Deck Slab (2019)

Bubble deck slab is a method of virtually eliminating all concrete from middle of floor slab which is not performing any structural functions, thereby dramatically reducing structural dead weight. High density rubber hollow spheres replace in-effective concrete in centre of the slab thus decreasing dead weight and increasing the efficiency of floor. Bubble deck slab has less material consumption, hence it reduce emission of carbon dioxide in to atmosphere, thus we can achieve green construction.. Thus structural behaviour of a bubble deck slab is compared with conventional deck slab and advantages of using bubble deck slab is highlighted. Many journals are collected related to the topic area. The aim is to reducing the dead weight to attain the light weight structure without reducing the strength of the concrete. In journals different types of balls are used such as polyethylene balls, polypropylene balls, rubber balls, plastic balls etc..with different diameter. The behaviour of bubble deck slab is influenced by the ratio of bubble diameter to slab thickness. These bubbles can decrease the dead weight up to 30 – 50% and can increase the capacity by almost 100% with same thickness. As a result bubble deck slab can be lighter, stronger and thinner than regular reinforced concrete slabs.

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III. PROPOSED METHODOLOGY

MATERIALS

Bubble Deck is composed of three main materials - steel, plastic spheres and concrete. The steel is fabricated in two forms - meshed layers for lateral support and diagonal girders for vertical support of the bubbles. The hollow spheres are made from recycled high-density polypropylene. 60mm and 75mm diameter balls are used in bubble deck slab. Balls are arranged at a spacing of 20 mm and 30 mm. The concrete is made of Ordinary Portland cement with a maximum aggregate size of 3/4 in. No plasticizers are necessary for the concrete mixture. The arrangement of hollow spherical balls is shown in figure 4.1 and 4.2.

[Fig.4.1: 60 mm diameter ball arranged at 20 mm spacing in a slab of size 600mm*300mm*100mm]

[Fig.4.2: 75 mm diameter ball arranged at 20 mm spacing in a slab of size 600mm*300mm*100mm]

IV. EXPERIMENTAL SETUP

Grade of cement is OPC 53. Grade of concrete is M30. Specific gravity of cement, fine aggregate and coarse aggregate is 3.15, 2.65 and 2.7 respectively. Size of coarse aggregate is 10mm. Bubble Deck slab is tested in Universal Testing

Machine (UTM) as shown in Figure 4.3. In this experiment, two point loading principle is carried out as shown in Figure 4.4.

[Fig.4.3: Universal Testing machine (40 ton capacity)]

[Fig.4.4: Two point load test setup]

When designing a reinforced concrete structure, a primary design limitation is the span of the slab between columns. Designing large spans between columns often requires the use of support beams and/or very thick slabs, thereby increasing the weight of the structure by requiring the use of large amounts of concrete. Heavier structures are less desirable than lighter structures in seismically active regions because a larger dead load for a building increases the magnitude of inertia forces, thus the structure must resist larger dead load and it contributes to higher seismic weight.

A new solution to reduce the weight of concrete structures and increase the spans of two-way reinforced concrete slab systems was developed in the 1990s in Europe and is gaining popularity and acceptance worldwide. Bubble deck or plastic voided slabs provide similar load carrying capacity to traditional flat plate concrete slabs but weigh significantly less. This weight reduction creates many benefits that should be considered by engineers in determining the structural system of the building. Plastic voided slabs remove concrete from non-critical areas and replace the removed concrete with hollow plastic void formers. Bubble deck can achieve larger spans as compared to a site cast concrete structure without the need for posttensioning or pre-stressed sections. The total construction time for the structure was reduced.

V. RESULTS

Flexural strength of the slab is found out by the formula,

$F = pl/bd^2$ (N/mm^2)

p = maximum load (kg) l = Supported length (mm)
b = width of specimen (mm) d = failure point depth (mm)

Ultimate load and flexural strength of bubble deck slab for the size 600mm*300mm*125mm is given in Table 5.1 The diameter of the hollow spherical ball used is 75 mm. The ratio of bubble diameter to slab thickness is 0.6. Number of plastic spheres used in 20mm and 30mm spacing specimen is 12 and 10 respectively. Flexure crack is observed in all the six specimens irrespective of the change in spacing of the balls.

Table 5.1: Flexural strength for 125mm depth of slab and ball diameter 75mm

Name of the specimen	Spacing between balls (mm)	Ultimate load (kg)	Flexural strength (N/mm^2)
BD 1	20	6420	8.06
BD 2	20	6320	7.96
BD 3	20	6580	8.26
BD 4	30	7120	8.94
BD 5	30	6900	8.66
BD 5	30	6840	8.58

Ultimate load and flexural strength of bubble deck slab for the size 600mm*300mm*100mm is given in Table 5.2. The diameter of the hollow spherical ball used is 60 mm. The ratio of bubble diameter to slab thickness is 0.6. Number of plastic spheres used in 20mm and 30mm spacing specimen is 21 and 18 respectively. Shear crack is observed in all the six specimens irrespective of the change in spacing of the balls.

Table 5.2: Flexural strength for 100mm depth of slab and ball diameter 60mm

Name of the specimen	Spacing between balls (mm)	Ultimate load (kg)	Flexural strength (N/mm^2)
BD 7	20	4180	8.2
BD 8	20	4120	8.08
BD 9	20	4280	8.39
BD 10	30	4320	8.47
BD 11	30	4880	9.57
BD 12	30	4560	8.94

Crack pattern observed in bubble deck specimen is shown in the figure 5.1 and 5.2.

[Fig.5.1: Flexure crack in specimen BD 6 of slab thickness 125 mm]

[Fig.5.2: Shear crack in specimen BD 8 of slab thickness 100 mm]

VI. CONCLUSION

From this experiment, it is observed that for the bubble deck slab of thickness 125mm, the average flexural strength of the slab is 8.09 N/mm^2 and 8.72 N/mm^2 for specimens in which the spacing between the balls is 20mm and 30 mm respectively. For the bubble deck slab of thickness 100 mm, the average flexural strength of the slab is 8.22 N/mm^2 and 8.99 N/mm^2 for specimens in which the spacing between the balls is 20mm and 30mm respectively.

- From this study, it is understood that when the spacing between the balls increases, the flexural strength of the slab increases irrespective of change in the thickness of the slab.
- It is also observed that the flexural strength of the slab in 60mm ball diameter is higher than the flexural strength of slab in 75mm ball diameter for both 20mm and 30mm spacing of the balls.
- It is finally concluded that the optimum diameter of the hollow spherical balls that can be used in bubble deck slab for normal purposes is 60mm and the optimum spacing between the balls can be 30mm.
- There is a 35 – 50 % reduction in use of concrete which leads to reduction in self-weight of slab with same flexural strength of the slab compared to the conventional slab.
- Due to the voids in the slab it has excellent thermal insulation property. Lower total cost, decreased construction time and green technology compared to conventional slab.

VII. FUTURE SCOPE

In building constructions, the slab is a very important structural member to make a space and it is one of the largest member consuming concrete. A slab being the essential part of the structure has to be effectively designed and utilized. It tends to use more concrete than requirement, hence has to be optimized. When the load acting on the slab is large or clear span between columns is more, the deflection of the slab is also more. Therefore the slab thickness is on increasing. Increasing the slab thickness makes the slabs heavier because of self-weight of slab also increase, and will increase column and foundations size. Thus, it makes buildings consuming more materials such as concrete and steel reinforcement.

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