Design and Analysis of Filler Slab Using Terracotta Fillers

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Abstract - In the gracefully developing industry of construction, the cost of the project plays an important role which is mainly acquired by the concrete. To reduce the quantity of concrete without compromising the strength of concrete, filler slab technology has been used. The primary idea behind employing filler-slab technology is to decrease the amount of concrete in the tension zone, as not all concrete in this zone contributes to the tensile properties. Instead, lightweight, inert, and inexpensive filler materials are utilized to replace this non-contributing concrete, without compromising the quality and structural stability of the building. In the design of a two-way slab, the filler material is positioned between the reinforcement spacing, ensuring adequate cover. Terracotta pots are used as filler materials. Both conventional slabs and filler slabs are analyzed using STAAD.Pro and a comparison is made between the filler slab and a standard slab of the same size. This research proves that filler slabs are cost-effective and structurally safe as compared to conventional slabs. Overall, filler slabs offer a cost-effective and sustainable alternative to traditional solid slab construction, with several benefits such as improved thermal insulation, aesthetic appearance, and reduced environmental impact.

Key Words**:** Lightweight, Filler slab, Terracotta.

1.INTRODUCTION

Concrete is widely used in the construction industry and ranks as the second most consumed material on Earth, following water. However, there is a growing interest in reducing the usage of concrete while maintaining construction quality. Such efforts not only lead to cost-effective buildings but also contribute to the reduction of carbon emissions on a large scale. Among various innovative and economical methods, filler slab technology stands out as a viable and cost-effective solution for reducing the dead load of slabs by replacing concrete. Concrete possesses excellent compressive strength, while steel is known for its tensile strength. By employing filler-slab technology, the primary objective is to minimize the amount of concrete located below the neutral axis, as not all concrete in the tension zone contributes significantly to tensile properties. Instead, lightweight, inert, and affordable filler materials are used to replace this non-contributing concrete, ensuring that the quality and structural integrity of the building are not compromised. Reducing the quantity and weight of concrete in the slab leads to cost savings, while the strength must remain comparable to that of conventional slabs. In addition, filler-slab technology offers thermal insulation benefits in regions where heat impact during hot weather is a concern. This technology acts as an excellent insulator, effectively reducing the temperature inside the building at an economical cost.

1.1 Need of Alternatives

The construction segment in India is accountable for the major input of energy resulting in the major emission of CO_2 (22%) into the atmosphere. To reduce the harmful effect, sustainable technology is required. This technology is used to remove a substantial portion of concrete from the tension zone and replace it with lightweight, inert, and inexpensive filler. This technology can not only reduce the cost of the materials but will also reduce the amount of carbon emission by lowering the use of energy-consuming materials. Overall, it is concluded that 30% of carbon emissions are reduced.

1.2 Selection of Filler Materials

The selection of filler materials is governed by the following conditions:

1. The material must be inert (non-reactive) in nature.
2. The limitation must be applied for water absorption as the hydration of concrete is affected.
3. It must be lightweight, which will result in the reduction of the overall dead load of the structure.
4. It must be cost-effective.
5. The size of the selected material must satisfy the available reinforcement spacing and the size of the slab.
6. Aesthetic views must be considered to avoid the ugly faces of the ceiling.

2. METHODOLOGY

The main intention of the research work is to study is to design and analyze a filler slab using terracotta fillers. The design will be done for a slab spanning in two directions with dimensions 4mX5m and the materials like M20 grade concrete and Fe 415 grade steel will be used.

The following steps are followed for the execution of the project:

1. Finding the properties of the basic materials and the filler materials.
2. Designing two-way slabs and providing filler materials in the tension zone between the reinforcement spacing along with the optimum cover.
3. Using the basic properties and other literature, modeling is done using STAAD.Pro software.
4. Results are extracted from the analysis. These results of filler slab and conventional slab are compared with each other.
5. A cost comparison between the conventional slab and filler slab is done.

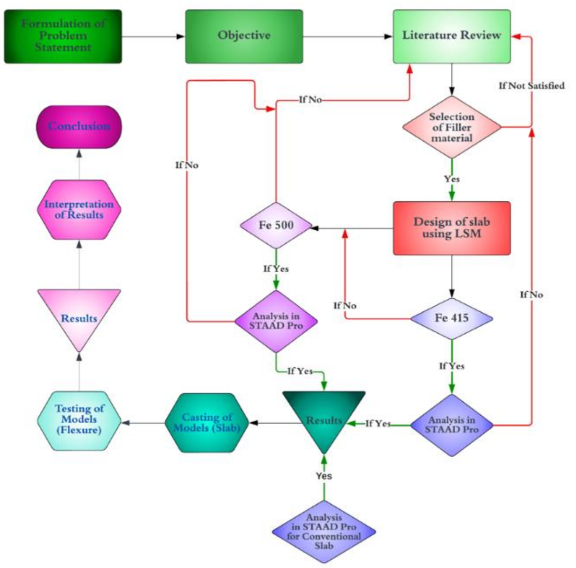

Fig 1. Methodology

3. MATERIALS.

3.1 Cement

Ultratech 53 grade Ordinary Portland cement will be used confirming to IS 12269:1987.

3.2 Fine Aggregate

Vaitarna river sand was used as fine aggregate. The specific gravity and water absorption of the sand should be 2.6 and 1% respectively. Sieve analysis of sand will be conducted as per IS 383:1970 and confirmed to zone – I sand.

3.3 Coarse Aggregate

20 mm and 10 mm crushed stones were used as coarse aggregate at 60:40 by weight proportions. The specific gravity and water absorption of the coarse aggregate were 2.66 and 0.4% respectively.

3.4 Terracotta

In applied art, craft, construction, and architecture, terracotta is commonly referred to as the material used for creating sculptures in earthenware and for its practical applications, such as utensils, roofing tiles, bricks, etc. in building construction. Locally sourced terracotta pots will be utilized.

Test to be conducted on Terracotta fillers:

1. Absorption Test.
2. Color Test.
3. Soundness Test.
4. Presence of soluble salts (Efflorescence Test).

3.5 Water

The Reverse Osmosis filtered water will be used which satisfies water standards as per IS 456–2000.

3.6 Steel Reinforcement

Concrete works excellent in compression but is weak in tension. Tensile property for concrete structures is obtained by providing steel reinforcement. The steel reinforcement is strong in tension. A steel of grade 500 will be used for the project.

4. STAAD ANALYSIS RESULTS

4.1 Conventional Slab

The stress experienced due to the application of maximum load is Absolute stress. Stress contour is obtained as shown in Fig.2 resulting the maximum stress of 3.13 N/mm2 acting along the diagonal and minimum stress of 0.291 N/mm2 acting at the mid-corners of the slab.

These are the forces that resist flexural activity along both directions. The shear force contour along the X-direction and Y-direction are shown in Fig.3 resulting the maximum value being 0.158 N/mm2 and the minimum value being -0.181 N/mm2.

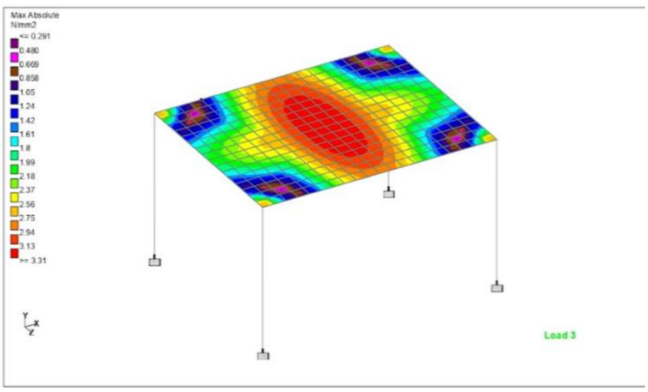

Fig 2. Absolute Stress Contour

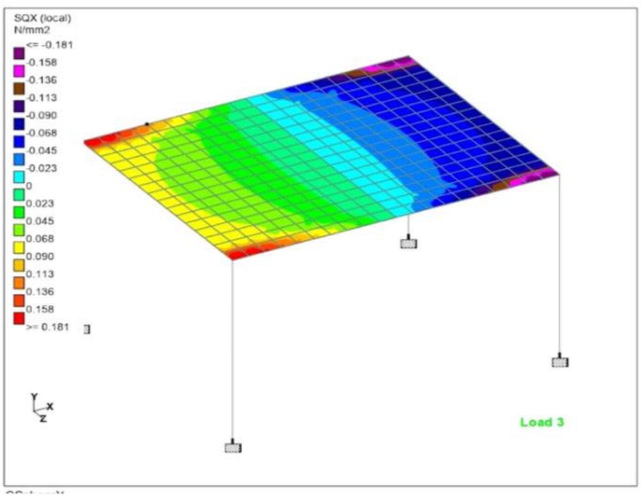

Fig 3(a). Shear force contour along X-direction

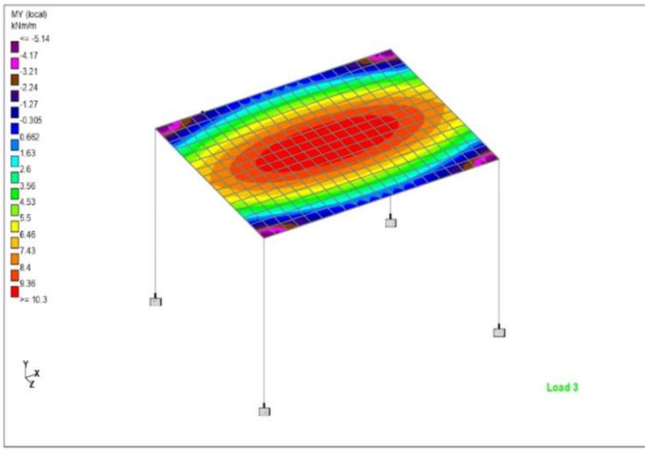

Fig 4(b). Bending moment contour along Y-direction

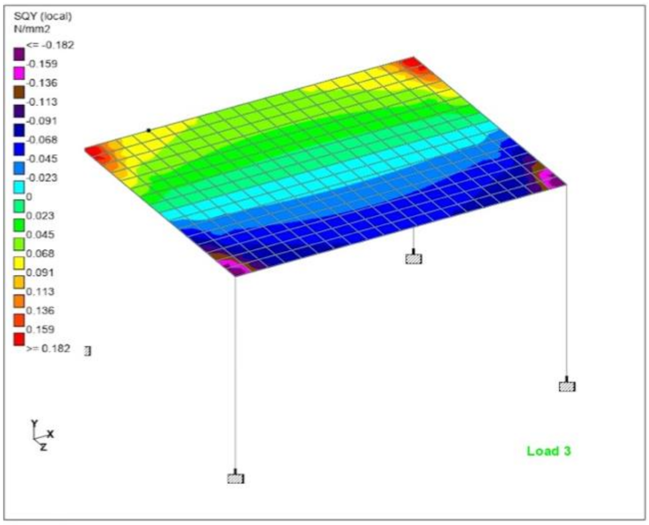

Fig 3(b). Shear force contour along Y-direction

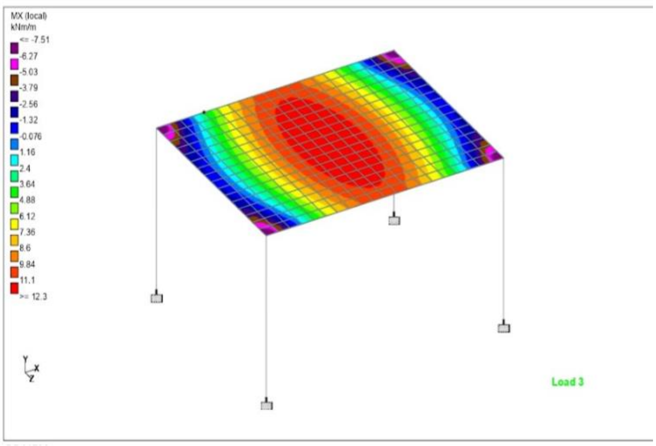

Fig 4(a). Bending moment contour along X-direction

The slab is allowed to deflect after applying the loads and was observed to have maximum deflection at the centre as shown in Fig.5. The slab experienced maximum deflection of 5.978 mm.

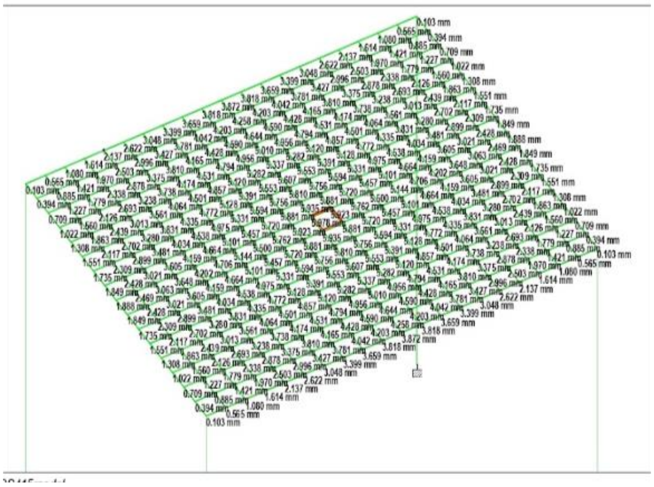

Fig 5. Deflection of Conventional Slab

3.2 Filler Slab

Stress contour is obtained as shown in Fig.6 resulting the maximum stress of 3.56 N/mm2 acting along the diagonal and minimum stress of 0.186 N/mm2 acting at the mid-corners of the slab.

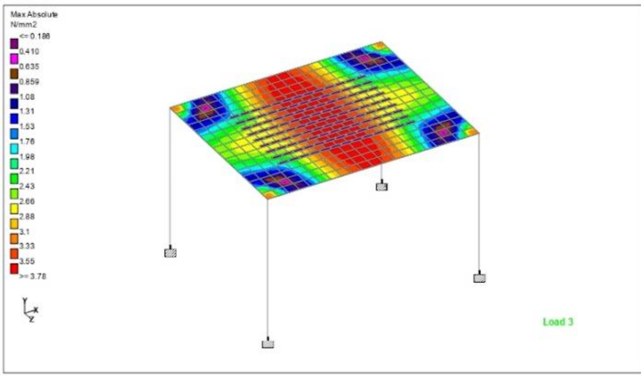

Fig 6. Absolute Stress Contour

These are the forces that resist flexural activity along both directions. The shear force contour along the X-direction and Y-direction are shown in Fig.7 resulting the maximum value being 0.158 N/mm2 and the minimum value being -0.181 N/mm2.

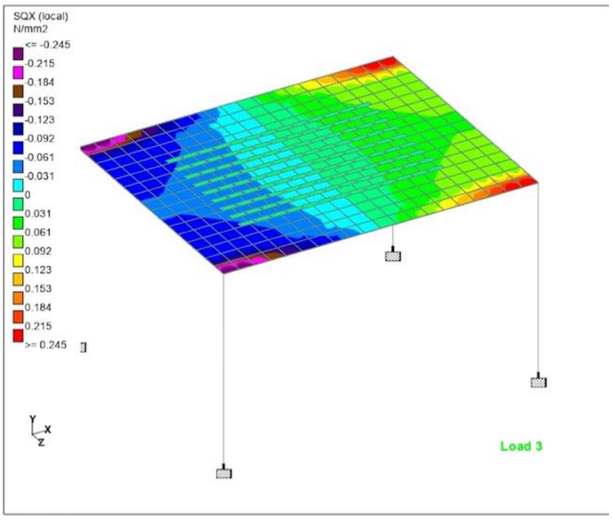

Fig 7(a). Shear force contour along X-direction

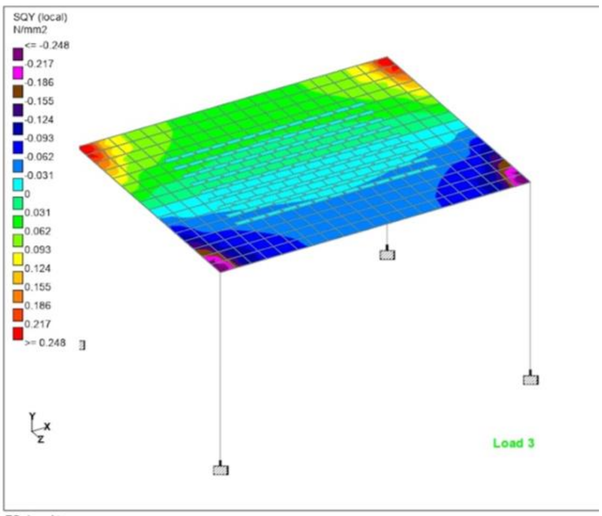

Fig 7(b). Shear force contour along Y-direction

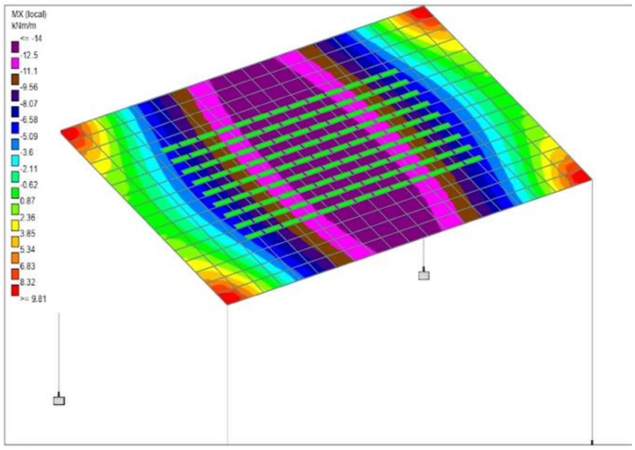

Fig 8(a). Bending moment contour along X-direction

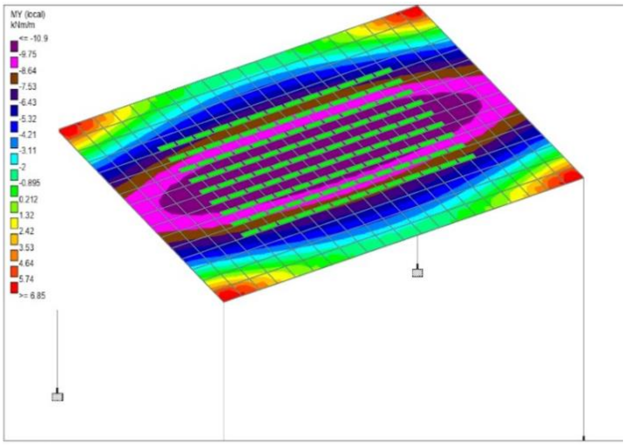

Fig 8(b). Bending moment contour along Y-direction

The slab is allowed to deflect after applying the loads and was observed to have maximum deflection at the centre as shown in Fig. 9. The slab experienced a maximum deflection of 5.978 mm.

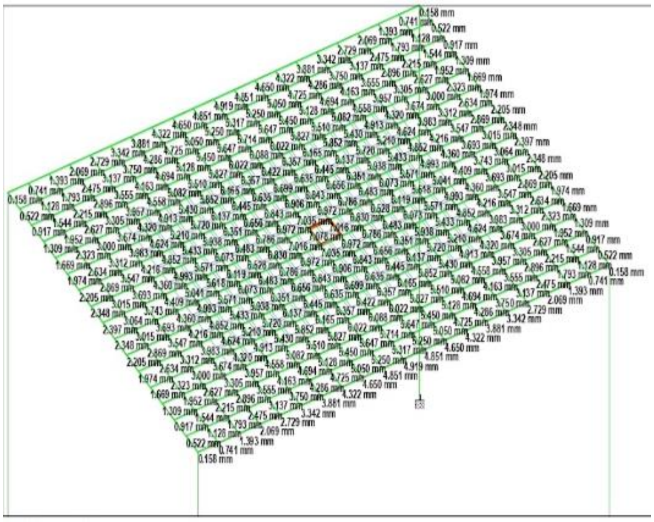

Fig 9. Deflection of Conventional Slab

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4. CASTING AND TESTING OF MODELS

4.1 Shuttering of Slabs

Shuttering has an inner size of 1m x0.5m. This is made of plywood. This is supported by concrete blocks from the sides.

4.2 Reinforcement

Here we used a 12mm diameter bar in the tension zone. 3 bars in the shorter direction and 2 bars in the longer direction. The cover of slab is 30 mm.

4.3 Placing of terracotta pots

Terracotta pots are placed in between the reinforcement, having a spacing of 300 mm.

Fig 10. Placement of Terracotta Pots

4.4 Placing of Concrete

The grade of concrete used in the slab is M30 which was placed over the reinforcement and the terracotta pots. Concrete was placed in the compression zone; Reinforcements are provided in the tension zone.

4.5 Curing

Portable water and Gunny bags were used for curing, which was done for 14 days. Jute fiber bags (Gunny bags) are preferred for the curing process. After curing the specimen is taken for the testing.

Fig 11. Curing of Slabs

4.6 Testing Setup

The slabs were placed on concrete cubes in simply supported condition. A dial gauge was placed beneath the slab at the centre to measure the deflection. The slab was directly loaded with recognized loads by an incremental method. The defections for four loads were noted down and the deflections for the same loads on the filler slab were noted.

Fig.12 (a) Support conditions for testing

Fig.12 (b) Dial Gauge

5. RESULTS

5.1 Deflection Test

The testing of the conventional slab and filler slab was done after 14 days of curing. Two slabs of size 1m x 0.5m were cast and tested for deflection. The deflection values of the Conventional slab were almost the same as that of the filler slab and were checked by the theoretical deflection values.

Fig.13 Finished View of Filler Slab

- DEFLECTION IN SLABS

Load (KN)	*Conventional Slab (mm)*	*Filler Slab (mm)*
0.85	0.063	0.068
1.7	0.125	0.153
2.2	0.175	0.235
3	0.280	0.300

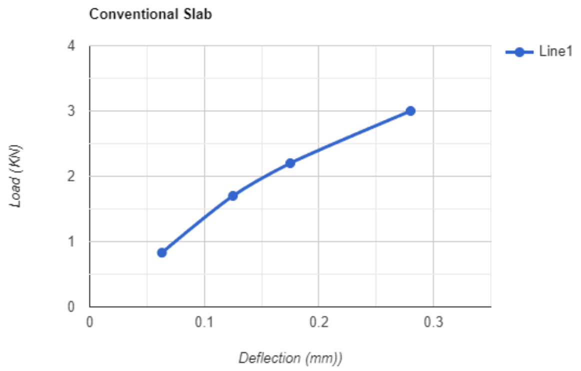

Fig.14 Load vs Deflection graph for Conventional Slab.

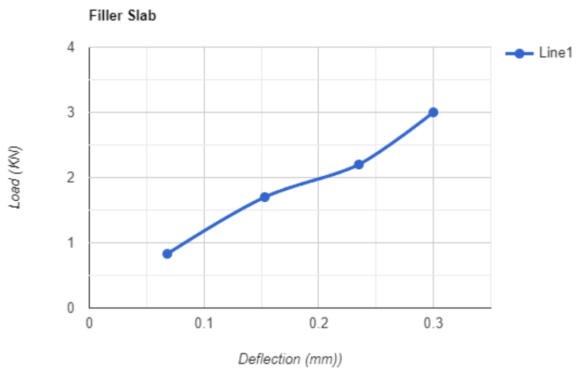

Fig.15 Load vs Deflection graph for Filler Slab.

6. COST ANALYSIS

After casting both conventional and filler slab, we analyzed the total cost required for the project. From our analysis it was discovered that filler slab was almost same.

TABLE 2 COST ANALYSIS

Materials	*Conventional Slab (₹)*	*Filler Slab (₹)*
Cost of Concrete	270	210
Cost of Filler	-	100
Cost ofFormwork	700	700
Cost of Reinforcement	375	375
Total	1345	1385

7. CONCLUSIONS

Terracotta pots are placed between steel reinforcement and concrete is placed into the space to make a filler slab. The structure requires less cement and it is also a good heat insulator. Reduces the use of concrete and saves cement by about 30%. It is an ideal option for low-income users who have limited space for building a house. The filler slab is lighter than the conventional slab, which reduces the load on the building's foundation and structure. This can be beneficial in areas where soil conditions aren't favorable. Filler slab offers better thermal insulation compared to solid slabs. This is because they have air pockets between the filler material, which helps to reduce heat transfer. Filler slabs require fewer raw materials, which means they have a lower environmental impact. They also provide an aesthetically pleasing interior to the building.

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