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## Analysis of Layered Beam Behavior with ANSYS

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**ABSTRACT:** Reinforced concrete structures are becoming increasingly significant in both civil and industrial construction, especially with advancements in new concrete materials technology. Properly designed layered or infilled sections can enhance crack resistance, as well as improve the shear and flexural behavior of beam members. This study uses ANSYS 2021 R2 software to analyze and compare the bending stresses, shear stress, and deflection of simply supported homogeneous beams made from conventional solid concrete and those made from brick-filled layered composites. The findings indicate that brick-filled layered beams exhibit improved shear and flexural behavior. The substitution of lightweight materials like bricks in the midsection results in fewer stresses near the neutral axis. Additionally, brick-filled beams reduce the overall structure weight and are more economical.

KEYWORDS: Concrete brick-filled layered beam, Concrete beam, In-filled replacement zone, Ansys.

#### I. INTRODUCTION

In civil construction engineering, reducing the weight and cost of structures is a major concern for engineers. This can be achieved through modern technological advancements and innovative construction methods. Over the past few decades, extensive research has focused on making construction components lighter, more economical, and energy-efficient. For large open floors and high-rise buildings, designers aim to create lightweight structures. Various options exist to simplify such construction projects, such as pre-stressed concrete, which reduces the dimensions and weight of structural components. Other advanced methods include bubble deck technology and composite construction. These techniques require highly skilled personnel for both design and site development [1]-[6].

New approaches are continually being developed to enhance structural strength while reducing weight. One such method is the use of sandwich or layered beams, which combine different materials to create a structural component. In sandwich construction, the stiffness of the materials is crucial. Typically, strong materials form the outer layers, while a lightweight, compatible material constitutes the core. For example, carbon fiber reinforced polymer skins or glass fiber reinforced polymer layers combined with a lightweight core can produce robust yet lightweight members capable of sustaining loads effectively [7]-[10].

In civil construction, lightweight structures can also be achieved using concrete made from lighter materials, such as lightweight aggregates, autoclaved aerated blocks, and foamed concrete. These technologies significantly reduce the weight of structural components, making structures more economical and environmentally friendly by utilizing cheaper waste materials [11]-[14].

Flexural members are vital in civil structures as they transfer loads laterally to columns, which then transfer the loads to the ground. In RCC beams, the concrete near the neutral axis is not efficiently utilized, as indicated by bending stress diagrams. This concrete can be replaced with other economical and strong materials, such as AAC blocks and bricks, to create infilled beams. These beams combine the benefits of both materials, improving economy and strength. Before using any material in combination with concrete, its bonding and other properties must be considered [15]-[19].

This study analyzes the stress and deflection behavior of conventional concrete and brick-filled layered composite beams using ANSYS 2021 R2 software. First, the analysis of a conventional concrete beam was conducted and validated against analytical results. Using stress block diagrams, the optimal brick replacement zone was determined,

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and concrete brick-filled layered composite beams were designed and analyzed under uniformly distributed load (UDL) to compare their behavior with conventional concrete beams [20], [21].

#### **II. METHODOLOGY**

To gain a better understanding of the stress and deformation behavior of the infilled beam, the solid concrete beams were first analyzed and validated against analytical results. The generalized equations for a simply supported conventional concrete beam under a uniformly distributed load (UDL) are as follows: -

Moment of inertia, $I = \frac{bd^3}{12}$	(1)
Maximum bending moment at the center of the beam M = $\frac{wL^2}{8}$	(2)
Maximum bending stress, $\sigma_{max} = \frac{M}{I}y$	(3)
Maximum deflection at the center, $\delta_{max} = \frac{5}{384} \frac{wL^4}{EI}$	(4)

Next, the calculation for the replacement zone in the infilled layered beam was performed. The replacement zone is the area in the structural component where the primary material can be substituted with a compatible lightweight material, used as the infill. In this study, bricks were used as the infill material. Bending stress analysis of the beam indicates that the material near the neutral axis (NA) is minimally stressed. Therefore, a material with a lower Young's modulus and weight can be used to make the structure lighter and more sustainable. The infill material can be placed within the beam's cross-section near the calculated depth of the NA. The estimation of this infill replacement zone, where concrete near the NA can be substituted, was determined using the stress diagram from limit state design [8]. This infill replacement zone is illustrated in Figure 1 with shaded lines.

Equating total tension with total compression in the beam gives,

$X_u = (0.87 f_v * A_{st}) / (0.36 f_{ck} * b)$ as per IS:456-2000	(5)
d' = (2 * cover + bar diameter)	(6)

where Xu is the depth of the neutral axis from the top fiber, fy is the yield strength of steel, Ast is the area of tension steel, and fck is the characteristic compressive strength of concrete. To ensure a proper bond between the steel and the concrete below the infill materials, a concrete layer thickness, d, is required. In this calculation, it is assumed that providing a minimum concrete thickness, at least equal to the cover, on both sides of the reinforcement satisfies the durability and bond requirements.

$X_{b} = \frac{4}{7} X_{u} (1 - f_{bk} / f_{ck})^{1/2}$	(7)
$d_{\min} = 3 X_u / 7 + X_b$	(8)
$d_{max} = D - d'$	(9)
Infill replacement zone = $d_{max} - d_{min}$	(10)



Figure 1. Replacement zone of brick infill beam [Patel et al. 2013]

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Conventional concrete beam

\*Dimensions are in mm

Figure 2. Cross sections of solid and infill beam.

Engineering Data: Material View		Engineering Data: Material View	
CONCRETE	/ 🗊	BRICK	/ 🖬
Structural	~	Structural	
✓Isotropic Elasticity		♥ Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio	Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	22360 MPa	Young's Modulus	4840 MPa
Poisson's Ratio	0.15	Poisson's Ratio	0.1
Rulk Modulus	10648 MPa	Bulk Modulus	2016.7 MPa
Shear Modulus	9721.7 MPa	Shear Modulus	2200 MPa

Figure 3. Material properties used in the ANSYS model design



Figure 4. Contact region of the beam in ANSYS design modeler for different layers

Figure 2 shows the cross-sections of both solid and brick-infused beams, each with a width of 450mm and a depth of 800mm. The beam length is set at 4000mm with a load of 25 KN/m. The analysis was performed using ANSYS 2021 R2 software. Figure 3 presents the properties of the materials used in the analysis. The Design Modeler tool was utilized to construct the geometry of the beam. During the modeling of the layered beam geometry, a proper connection was established between the different layers to ensure better relative motion, as illustrated in Figure 4. After constructing the geometry, uniform meshing was applied for meshing the 3D solid elements.

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Figure 5. Contour plot of solid concrete and concrete brick in-filled beam

#### **III. RESULT AND VERIFICATION**

Equations for the analytical calculation of a conventional concrete beam with a homogeneous cross-section were derived, as shown in equations (1) to (4). A three-dimensional model was developed using ANSYS Mechanical, and the results for the solid beam were compared with the analytical results, as displayed in Table 1. Table 2 presents the effects of the brick-infused beam. The results for the brick-infused concrete beams are higher (almost twice) than those for the solid concrete beams due to the low Young's modulus of the brick material. However, this discrepancy can be addressed with reinforced fiber, aligning the results with the desired outcomes. Figure 5 illustrates the variation of normal and shear stresses, as well as the deflection of solid concrete and brick-infused concrete beams. As shown in Figures 5a, b, c, and d, the shear and flexural behaviours are significantly enhanced with brick-filled layered beams. Fewer stresses were observed near the neutral axis due to the replacement of the midsection with lightweight bricks. It is evident that approximately 35-45% of the concrete can be replaced with brick material reinforced with fiber, maintaining comparable performance.

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Table 1. Comparison of anal	ytical and ANSYS results	for solid concrete beam
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Results	Solid beam	Solid beam	% Variation
Bending stress	1 04 MPa	$\frac{(ANOID)}{1.05 \text{ MPa}}$	1 02 %
Deflection	0.19 mm	0.21 mm	10.52 %
Shear stress	0.20 MPa	0.18 MPa	9.45%

Results	Brick in-filled beam	
	(ANSYS)	
Bending stress	2.00 MPa	
Deflection	0.40 mm	
Shear stress	1.10 MPa	

#### **IV. CONCLUSIONS**

This study focuses on analyzing layered beams filled with bricks using numerical computation, with a thorough validation of the numerical results. The findings demonstrate that flexural behavior is significantly improved with brick-filled layered beams, showing reduced stresses near the neutral axis due to the substitution of lightweight materials like bricks in the midsection.

The investigation covers the stress and deflection behavior of both solid and brick-filled beam members. Based on the results obtained from ANSYS and analytical calculations, the following conclusions can be drawn:

- 1. There is minimal discrepancy between the numerically computed results and those analyzed by the software.
- 2. Table 1 indicates that bending stress, shear stress, and deflection of the members fall within acceptable ranges.
- 3. Table 2 shows that using lightweight infill materials like bricks results in higher bending stress and shear stress, which remain within permissible limits. However, there is a significant variation in deflection.
- 4. The results for layered beams are approximately double those for solid beams, primarily due to the lower Young's modulus of the infill material, such as bricks. This can be mitigated by reinforcing with fibers, such as semi-precast reinforced sections.

Using a brick-filled concrete beam reduces the structure's weight and improves economy. Approximately 35-45% of concrete can be replaced with brick material when reinforced with fibers.

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