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Structural Assessment of Rigid Pavement Systems Under Heavy Loading Conditions

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Abstract

This study presents an analysis of pavement and foundation layer design subjected to heavy vertical loads and upward soil pressure. A total load of 1716 tonnes transmitted from the superstructure is considered acting on the pavement system. Due to upward soil pressure, tensile stresses develop in the foundation layers, requiring adequate thickness of sand and aggregate layers to ensure structural stability. Based on the tensile strength of sand (2 N/mm²), the required thickness of the sand layer is calculated as 477 mm. Similarly, considering the tensile strength of aggregate, the required thickness of the aggregate layer is determined as 318 mm. The design of the plain cement concrete (PCC) road is carried out assuming uniformly distributed Class AA loading. As the load-induced deflection is minimal under such conditions, reinforcement is not required for the PCC pavement. However, when the pavement is constructed over weak soil strata, higher deflections occur, necessitating reinforcement and the adoption of reinforced cement concrete (RCC) roads. The study highlights the importance of layer-wise strength consideration in pavement and foundation design under heavy loading conditions. When a PCC road is constructed on weak soil, more deflection occurs; hence, reinforcement is used when an RCC road is constructed on weak soil. In the case of a foundation base slab, concentrated loads from columns cause greater deflection than a uniformly distributed load (UDL); therefore, reinforcement is provided in the foundation base slab.

Keywords: Heavy vertical loading, layer thickness optimization, pavement design, PCC and RCC roads, upward soil pressure

INTRODUCTION

The design of rigid pavements and foundation base slabs is governed by the bending behavior induced by the applied loads and upward soil pressure. In the present study, a plain cement concrete (PCC) road of M30 grade concrete is considered, for which a slab thickness of 320 mm is adopted. Although both the PCC road slab and foundation base slab are subjected to upward soil pressure, their structural behaviors differ depending on the nature and distribution of the loads [1–3].

In beam elements, bending occurs owing to the applied loads, and the required depth is initially determined using classical bending equations. The calculated depth must subsequently be checked against the tensile stress developed in the concrete to ensure that it remains within permissible limits. If the induced tensile stress exceeds the allowable tensile strength of concrete, the depth of the member must be increased to satisfy the strength and serviceability requirements [4–6].

Concrete is inherently weak in tension; therefore, when bending-induced tensile stresses are significant, reinforcement is provided to resist the tensile forces. The amount and placement of

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reinforcement are designed to safely carry the tension developed after cracking, thereby ensuring adequate structural performance [7–9].

In the case of foundation base slabs, bending and deflection occur primarily because of concentrated loads transmitted from columns onto the slab, in combination with upward soil reaction. Consequently, the thickness of the foundation base slab is determined using bending theory, similar to slab analysis, rather than pavement design principles. This approach ensures that the tensile stresses induced at the bottom of the slab remain within the permissible limits, thereby preventing cracking and excessive deformation [10–12].

Thickness of PCC Road

$$\frac{1716 \times 1000 \times 10}{18000 \times t} = 3 \text{ \{M30 grade concrete\}}$$

t = 320 mm

In both cases, the PCC road and foundation base slab, upward soil pressure is acting.

In beam → Bending occurs; hence, the depth of the beam is found by using the bending equation.

$$\frac{M}{Z} = f$$

But the depth obtained is to be checked against the tensile stress of concrete:

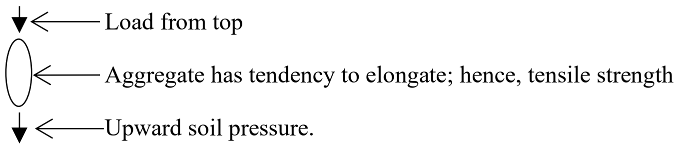
$\frac{Load}{Cross\ sectional\ area\ of\ beam}$ = tensile stress (It should be less than the permissible tensile strength of concrete).

If the tensile stress exceeds the permissible tensile strength. We must increase the depth of the beam. The cross-section of the beam is determined using the bending equation, that is, for concrete material.

Since bending tension develops, reinforcement is used to take tension; hence, a proper amount of reinforcement should be provided to take tension. In the case of the foundation base slab, deflection or bending occurs owing to the concentrated load from the column on the foundation base slab; hence, the thickness of the foundation base slab is determined using the bending equation [13–16].

Load coming from top = 1716 t

Since upward soil pressure is acting



The thickness of the sand layer provided at the bottom

$$= \underbrace{\frac{1716 \times 1000 \times 10}{18000 \times t}}_{\text{Length of one vehicle}} = \frac{10}{100} \times 20 = 2$$ = Tensile strength of sand = 2 N/mm²

36000 t = 17160000

t = 477 mm (Thickness of sand layer)

Thickness of Aggregate

$$\frac{1716 \times 1000 \times 10}{18000 \times t} = \frac{10}{100} \times 30 = 3$$

(Tensile strength of aggregate)

54000 t = 17160000

t = 318 mm (thickness of aggregate)

Thickness of Plain Cement Concrete Road

Since a uniformly distributed load is acting on the PCC road for class AA loading:

3.5 m × 1.2 m = 70 t

1 $m^2 = \frac{70}{4.2} = 17\ t/m^2$

Hence, very little deflection occurs; hence, we do not reinforce the PCC road.

Design of Foundation Base Slab

The foundation base slab was designed to safely resist the combined effects of the concentrated column load and upward soil reaction. For the present analysis, a square foundation base slab of size 2 m × 2 m was considered. The load transferred from the column to the foundation slab was considered to be 120 t, which produced a uniformly distributed soil reaction acting upward on the slab.

The foundation base slab primarily behaves as a slab subjected to bending due to the applied column load and the opposing soil pressure. Therefore, the required slab thickness is first determined using the bending equation. For M30 grade concrete, the permissible compressive stress in bending (σcbc) is taken as 10 N/mm^2. Since lateral bending is considered, the effective width of the slab is assumed to be 1000 mm. Using the bending moment equation, the effective depth required to resist bending is obtained as approximately 300 mm. A check for tensile stress confirms that the stress developed is within permissible limits. Hence, the thickness of the foundation base slab required to satisfy bending criteria is taken as 300 mm.

In addition to bending, the slab is subjected to direct tensile stress owing to the upward soil pressure. The upward soil reaction tends to elongate the slab, inducing tensile stress within the concrete. Therefore, the slab thickness was also checked against the tensile strength of M30 grade concrete. Based on the tensile stress calculation, the required slab thickness to resist the direct tension was found to be approximately 200 mm.

A comparison of the two design criteria shows that the slab thickness governed by bending (300 mm) is greater than that required based on the tensile strength considerations (200 mm). Hence, bending governs the design of the foundation base slab. Accordingly, a slab thickness of 300 mm was adopted to ensure adequate safety against bending and tensile failure.

If the base size of the foundation base = 2 m × 2 m.

Load acting on the foundation base slab due to column = 120 t

Hence, load intensity $w = \frac{120}{2 \times 2} = 30 t/m^2$

$$M = \frac{30 \times (2)^2}{8} = 15\ t - m$$

Using the Bending Equation

$$\frac{15 \times 1000 \times 10 \times 1000}{\frac{1}{12} \times 1000 \times d^3 \times \frac{2}{d}} = 10$$ [M 30 grade concrete σcbc = 10 N/mm^2]

Since, the lateral load; hence, b = 1000 mm

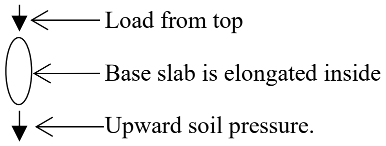
$1667\ d^2 = 150000000$
$d^2 = 89982$
$d = 300$ mm

Check for tensile stress $= \frac{1200000}{2000 \times 300} = \frac{12}{6} = 2\ N/mm^2 < 3\ N/mm^2$

Hence, okay.

Hence, the thickness of the foundation base slab against bending = 300 mm.

Since upward soil reaction is acting, designed for the tensile strength of concrete.



Hence, $\frac{120 \times 1000 \times 10}{2000 \times t} = \frac{10}{100} \times 30$ (Tensile strength of M30 grade concrete)

$6000\ t = 120000$
$t = 200$ mm

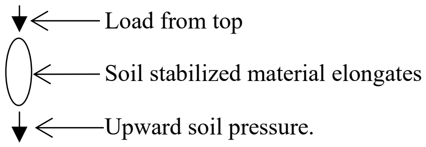
We obtain a lesser thickness of the foundation base slab designed for tensile stress inside the foundation base compared to bending.

Hence, for design, we take more depth of foundation base slab = 300 mm.

For Soil-Stabilized Road

Since soil-stabilized roads have 5 N/mm^2 strength (compressive).

Hence, we have to apply a load on the soil-stabilized road = 450 t less than 500 t/m^2 (strength of soil-stabilized road). Since the load is coming from the top and upward soil pressure, the soil-stabilized material has a tendency to elongate inside; hence, it is designed for tensile strength.



Hence, $\frac{450 \times 1000 \times 10}{10000 \times t} = 5$

Length of one vehicle = 10 m.
$50000\ t = 4500000$

$$t = \frac{4500000}{50000} = 90\ mm$$

Hence, providing a 100 mm thickness of soil-stabilized road.

The strength of the soil-stabilized material is 5 N/mm^2, as the material is soil (less strength); hence, the bending strength); hence, bending strength = tensile strength = compressive strength = 5 N/mm^2.

Because the load is from the top, that is, from the vehicle coming on the soil-stabilized material, it has a tendency to deflect; hence, the flexural strength of the soil-stabilized material is determined.

The soil-stabilized material tends to deflect owing to the load applied from the vehicle.
Hence, it is designed against flexural strength using the bending equation $= \frac{M}{Z} = f$
If we apply 450 t < 500 t/m^2, the compressive strength of soil-stabilized material.

$$w = \frac{450}{\underset{\substack{\downarrow \\ \text{Length of one vehicle}}}{10} \times \underset{\substack{\downarrow \\ \text{Width of one vehicle}}}{3}} = \frac{450}{30} = 15\ t/m^2$$

Bending takes place in a shorter direction:

$$M = \frac{15 \times (3)^2}{8} = 16.875\ t-m$$

Using the bending equation $\frac{16.875 \times 1000 \times 10 \times 1000}{\frac{1}{12} \times 1000 \times d^3 \times \frac{2}{d}} = 5$

d = 450 mm

Whenever bending is performed, bending tension develops; hence, the tensile stress of the material must be checked.

Tensile stress of soil-stabilized material

$= \frac{Load}{Cross\ Sectional\ Area} = \frac{4500000}{3000 \times 450}$ = 3.33 N/mm^2 < 0.5 N/mm^2

Actually, the tensile stress of soil-stabilized material $= \frac{10}{100} \times 5$ = 0.5 N/mm^2

Hence, we have to apply a lesser load with respect to its tensile stress of 50 t/m^2 (0.5 N/mm^2).

Hence, a lesser load of 20 t is applied on soil-stabilized material.

Hence, $w = \frac{20}{10 \times 3}$ = 0.67 t/m^2

$$M = \frac{0.67 \times (3)^2}{8} = 0.75\ t-m$$

Hence,

$$\frac{0.75 \times 1000 \times 10 \times 1000}{\frac{1}{12} \times 1000 \times d^3 \times \frac{2}{d}} = 5$$

Because the strength of the soil is less, the bending strength = compressive strength.

Hence, 833.33 d^2 = 7500000
d = 95 mm

Hence, tensile stress $= \frac{200000}{\underset{\substack{\downarrow \\ \text{Cross sectional area} = \underset{\substack{\downarrow \\ \text{Width of one vehicle}}}{3000} \times \underset{\substack{\downarrow \\ \text{Depth}}}{95}}}{3000 \times 95}}$ = 0.7 N/mm^2 > 0.5N/mm^2

Hence, we have to increase the thickness of the soil-stabilized road.
Take a 150 mm depth of soil-stabilized road.
Tensile stress $= \frac{200000}{3000 \times 150}$ = 0.44 N/mm^2 < 0.5 N/mm^2

Hence, okay.

Hence, the thickness of the soil-stabilized road = 150 mm.

When bending is taken after bending, tension develops; hence, the depth of the member or material is to be found by using the bending equation, and that depth obtained is to be checked for the tensile stress of the material, that is, tensile stress.

$= \frac{Load}{Cross\ sectional\ area}$ be less than the permissible value of the tensile strength of the given material.

Load at foundation base = 120 t

Lateral load at foundation base = 0.271 × 120

Where, $\frac{1-Sin\varphi}{1+Sin\varphi} = 0.271,\ [\varphi = 35^o]$ = 32.52 t acting on a 2 m length and thickness of the foundation base slab.

2 m is much more than the thickness of the foundation base slab; hence, it is the case of a transverse load like a beam.

Hence, load intensity $w = \frac{32.52}{2} = 16.26\ t/m$

Since, bending along 2 m.

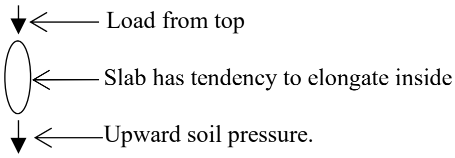
Hence, $M = \frac{16.26 \times (2)^2}{8} = 8.13\ t-m$

Hence, using the bending equation $\frac{8.13 \times 1000 \times 10 \times 1000}{\frac{1}{12} \times 1000 \times d^3 \times \frac{2}{d}} = 10$ (M30 grade concrete σcbc = 10 N/mm^2),

Since it is a slab; hence, b = 1000 mm is taken.

d = 221 mm

It is the same as $= \frac{Load}{Length \times t} =$ Tensile strength



The design was made for tensile strength with two-point loading for the flexural strength test. A concentrated load gives more deflection, and we are interested in more deflection in the design of the structure.

Hence, a concentrated load is acting in the flexural strength test.

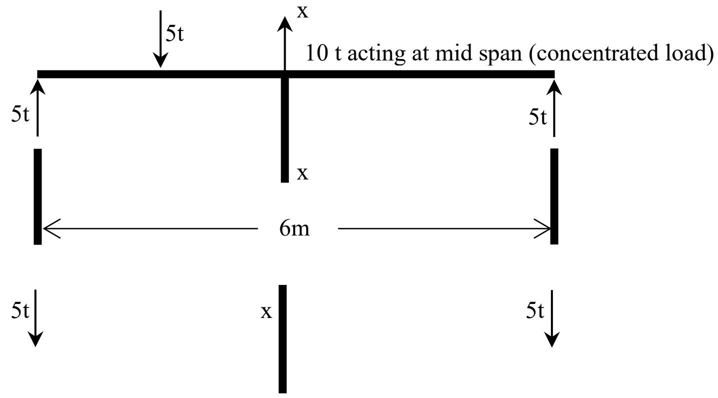
In a beam:

Because the maximum bending moment (BM) or maximum deflection occurs at mid-span, we are interested in the maximum BM or maximum deflection for the design of the structure.

Maximum BM $= \frac{WL}{4} = \frac{10 \times 6}{4} = 15\ t-m$

BM at mid-span of beam [when load is divided into two equal loads]

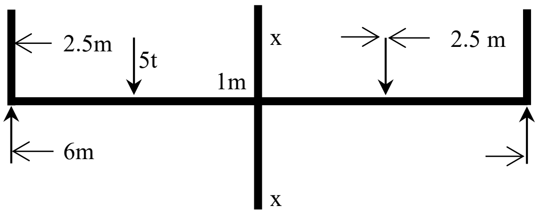
$\sum M_B = 0$



If this 10 t concentrated load is divided into two parts, that is, each load = 5 t
RA × 6 – 5 × 4 – 5 × 2 = 0
RA × 6 -20 – 10 = 0
6RA = 30

$$RA = \frac{30}{6} = 5\ t$$

Hence, RA = RB = 5 t
BM at mid-span of beam: 5 × 3 – 5 × 1 = 15 – 5 = 10 t-m
5 × 3 – 5 × 0.5 = 15 – 2.5 = 12.5 t-m



For this arrangement, we get the maximum BM at mid-span; hence, the maximum BM stress, and we design the beam for maximum stress; hence, two-point loading is used for the flexural strength test.

Application of Compressive Stress

If load on column = 120 t

The lateral load was 0.271 × 120 = 32.52 t acting on the depth of the beam and the width of the beam (300 mm). A beam depth of 500 mm was assumed. Since both dimensions are comparable, it is a case of lateral load.

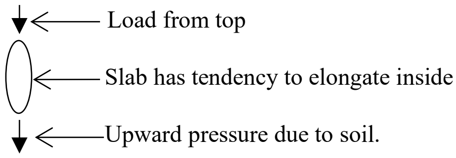
In case of lateral load intensity $w = \frac{32.52}{0.3 \times 0.5} = \frac{32.52}{0.15} = 216.80\ t/m^2$

Bending along 0.3 m takes place.

Hence, $M = \frac{216.80 \times (0.3)^2}{8}$=*2.439t-m*

Using the bending equation: $\frac{2.439 \times 1000 \times 10 \times 1000}{\frac{1}{12} \times 300 \times d^3 \times \frac{2}{d}} = 10$ (σcbc of M30)

$500\ d^2 = 24390000$
$d^2 = 48780$
d = 221 mm [Thickness of beam]



Hence, $\frac{30 \times 1000 \times 10}{300 \times d} = 3 \rightarrow$ Tensile strength of M30

Width of beam

Load for one beam = 30 t since four beams meet at the intermediate column, that is, $4 \times \frac{wl}{2} = 120$)
900 d = 300000
d = 333 mm.

Hence, the greater thickness of the beam is 333 mm.

At the support, shear stress is acting; hence, 30 t is acting along a 300 mm width and depth of the beam.

Hence, $\frac{30 \times 1000 \times 10}{300 \times d} = 1.8$ [Shear strength of M30 grade concrete]
540 d = 300000
d = 556 mm

Hence, the maximum value of the depth of the beam, considering the compressive stress and shear stress, that is, depth of beam = 556 mm, was considered.

Load on column = 700 t
Lateral load = 0.271 × 700 = 190 t
Where, $\frac{1-Sin\varphi}{1+Sin\varphi} = 0.271$

$\phi = 35^{\circ}$ for concrete.
This lateral load is acting at the middle of the column height $= \frac{4}{2} = 2m$ from base.

Hence, overturning moment at base: 190 × 2 = 380 t-m

Restoring moment produced by the strength of the surrounding soil around the column bearing capacity of soil (Average) = 30 t/m^2 at the top and 220 t/m^2

Hence, average bearing capacity $= \frac{30+220}{2} = 125\ t/m^2$
Strength of soil = 125 × 1 × 15 = 1875 t

1875 t acting at the middle height of depth of foundation, where depth of foundation = 15 meters.

Since the load on the column = 700 t
Self-weight column: 1 × 1 × 4 × 24 = 9.6 meter
4 m = height of column, 1 × 1 m^2 = cross sectional area.

Hence, total load of column = 710 t
10% weight of foundation $= \frac{10}{100} \times 710 = 71\ t$
Total weight at foundation base = 781 t
Lateral load at foundation base = 0.271 × 781 = 212 t

Hence, the bearing capacity of soil required 220 t/m^2 > 212 t.
Hence, the foundation base size required:

Foundation base size = $\frac{Load\ at\ foundation\ base}{Bearing\ capacity\ of\ soil} = \frac{781}{220} = 3.55\ m^2$

Hence, size of the foundation base = 1.88 m × 1.88 m
Hence, the depth of the foundation $D_f = \frac{220}{1.85} \times 0.111$ = 13.20 meter depth of foundation required.
Hence, the restoring moment given by the strength of the soil $1875 \times \frac{15}{2}$ [where, the depth of the foundation = 15 m] = 14063 t-m > overturning moment; hence, it is safe.

Are there any beam and column provisions in a long stone masonry wall?
Distance in brickwork from column to column = 7 m taken.
Hence, stone masonry is also 7 m in length of the wall taken.
Weight of 7 m length of wall for height 50 m (Long height taken)
Weight of wall: 7 × 50 × 0.30 × 2.64 = 277 t
Lateral load = 0.217 × 277 = 60 t
$\frac{1-Sin\varphi}{1+Sin\varphi} = 0.217$ [40°]
This lateral load is acting on a 7 m and 50 m height
Hence, load intensity $w = \frac{60}{7 \times 50} = 0.171\ t/m^2$
Since it is a vertical member, bending takes place along the height of the wall.
Hence, $M = \frac{0.171 \times (50)^2}{8} = 54.44\ t-m$

Since bending occurs; hence, depth is found by using the bending equation.

Hence, using the bending equation: $\frac{54.44 \times 1000 \times 10 \times 1000}{\frac{1}{12} \times 1000 \times d^3 \times \frac{2}{d}} = \frac{1}{3} \times 20 = 7N/mm^2$

Since the lateral load b = 1000 mm is taken
[Where, bending strength $\frac{1}{3}$ of compressive strength]
1167 d^2 = 544400000
d^2 = 466495
d = 683 mm

Hence, the depth of the very long wall and the long height of the stone masonry thickness of the wall, 683 mm, is required without column and beam provision.

MIX DESIGN

Proportion of Cement, Fine Aggregate, and Coarse Aggregate

For M15 grade of concrete proportion = 1: 2: 4
1 Part → Cement
2 Pats → Fine aggregate or sand.
4 Parts → Coarse aggregate

For M20 grade concrete proportion = 1: $1\frac{1}{2} : 3$
For an increase of 5 N/mm^2 in the strength of concrete
Fine aggregate ratio is decreased by 0.5, taking the M15 grade of concrete as reference.
For M25 grade concrete strength 25 N/mm^2

Compare M15 and M20
For a 5 N/mm^2 increase in strength, the fine aggregate ratio is decreased by 0.5
$1 \rightarrow \frac{0.5}{5}$
For 10 N/mm^2 [Comparing M15 and M25] strength.
$\frac{0.5 \times 10}{5}$
Hence, for = 1
M25 grade concrete fine aggregate ratio is decreased by (2-1) = 1.

Hence, for M25 grade concrete, the fine aggregate ratio will be 1, and the coarse aggregate ratio for M25 grade concrete.

For a 5 N/mm^2 increase in the strength of concrete (comparing M15 and M20), the coarse aggregate ratio is decreased by 1.
In 1 N/mm^2, an increase or decrease is $\frac{1}{5}$
In 10 N/mm^2 (with respect to M15) $\rightarrow \frac{1 \times 10}{5}$
Hence, the ratio of coarse aggregate = (4-2) → 2 decreased.

Hence, the ratio of M25 grade concrete for cement, fine aggregate, and coarse aggregate = 1:1:2. Thus, for any grade of concrete, the proportion of cement, fine aggregate, and coarse aggregate is determined.

For low-grade concrete M15, M20, M25 → Cement amount was 400 to 450 kg/m^3 taken.

For high-grade concrete (→ M30, M35, and M40), the amount of cement is 500 to 550 kg/m^3.

Water cement ratio → 0.4 to 0.45 taken.

For any grade of concrete: M15 grade: 1:2:4

Cement = 1 part
Fine aggregate = 2 parts
Coarse aggregate = 4 parts
M15 grade concrete → strength 15 N/mm^2
M20 grade concrete: $1\!:\ 1\frac{1}{2}\ :\ 3$ strength = 20 N/mm^2
Hence, as the strength increases, the proportion of cement, fine aggregate, and coarse aggregate decreases. Hence, strength $\alpha \ \frac{1}{Pr\,oportion}$; hence, for M15 grade concrete with respect to M20 grade concrete strength $\alpha \ \frac{1}{Pr\,oportion}$.

For M15
Hence, the strength of cement = 1 part = 1 × 17 = 17 N/mm^2
Where strength of cement = 17 N/mm^2
Strength of fine aggregate $= \frac{1}{2} \times 20 \ = \ 10\ N/mm^2$ since strength $\alpha \ \frac{1}{Proportion}$
Where the strength of fine aggregate = 20 N/mm^2
Strength of coarse aggregate $= \frac{1}{4} \times 30 \ = \ 7.5\ N/mm^2$ [Since for M15 → Proportion increases, strength reduced with respect to M20]
Hence, average strength of M15 grade concrete for 1: 2: 4 ratios $= \frac{17\ +\ 10+\ 7.5}{3} \ = \ 12\ N/mm^2$
This gives rough ideas.

When some additives, supposed to be 20% by weight of cement fly ash, are mixed in the M15 grade concrete. Hence, due to the addition of fly ash, the strength is increased; hence, $\frac{20}{100}$ of 1 part of cement $\frac{1}{5}\times 1 \ \ = \frac{1}{5}$ part of the fly ash is mixed.

Hence, the strength of fly ash $= \frac{1}{5} \times 20 = 4\ N/mm^2$. The strength of M15 grade concrete is increased.

Hence, the strength of M15 grade concrete = 12 + 4 to 16 N/mm^2 owing to the addition of 20% fly ash by weight of cement.

For M25 grade concrete with respect to M20 grade concrete.
For M20 grade concrete → 1: $1\frac{1}{2} : 3$
For M25 grade concrete →1:1:2.
As the proportion decreases, strength increases.

Actually, for a smaller proportion, more strength; hence, strength α proportion.
For M25 grade concrete:

Strength

1	Part cement	=	1 × 17	=	17 N/mm^2
1	Part Fine aggregate	=	1 × 20	=	20 N/mm^2
2	Parts coarse aggregate	=	2 × 30	=	60 N/mm^2

Average strength $= \frac{17\ +\ 20+\ 60}{3} \ = \ 32\ N/mm^2$

Which is target strength; hence, okay.

Thus, we can determine the strength of a given grade of concrete for a given proportion. Due to the addition of the same percentage of additives, we obtained a higher strength of concrete.

The beam load is in the downward direction owing to the slab, and an upward reactive component owing to the column.

The reactive component due to the column is greater than that due to the slab on the beam.

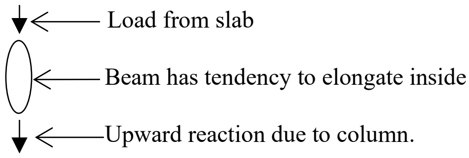
We designed the maximum load. The reactive component should be greater than the load coming from the top for safety.

Because $\frac{wl}{2}$. The load for one beam on the column is acting, and there are four beams meeting at the intermediate column.

Suppose the load acting on the column = 120 t.

Hence, for shear load, that is, upward load for one beam, taken as 30 t acting tangentially to the width and depth of the beam. Hence, 30 upward forces were considered.

However, when the load is due to the slab and the upward reaction due to the column (which is 120 t)



Hence, $= \frac{Load}{Width\ of\ beam \times depth\ of\ beam}$ $=$ Tensile strength of concrete

Hence, $\frac{120 \times 1000 \times 10}{300 \times d}$ $= 10$ [σcbc of M30 grade concrete]

Width of beam

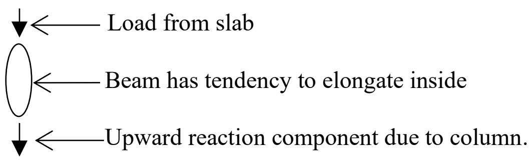
3000 d = 1200000

$d = \frac{1200000}{3000}$

Hence, the depth of the beam = 400 mm.

Because the reactive component of the 120 t load (reactive component on beam) is greater than the load coming from the slab on the beam. Hence, we take more loads, i.e., reactive components, for design purposes.

Hence, lateral load = 0.271 × 120 = 32.52 $\left[\frac{1-Sin\varphi}{1+Sin\varphi} = 0.271,\ \varphi = 35^o\ for\ concrete\right]$



Hence, this combination of loads will be taken for the member when the sandwich type is used.

This lateral load is acting on a 300 mm wide beam and a 500 mm depth of beam.

Hence, load intensity $= \frac{Load}{Area\ taken}$ because dimensions (300 mm and 500 mm are comparable to each other)

Hence, $w = \frac{32.52}{0.3 \times 0.5} = \frac{32.52}{0.15} = 217\ t/m^2$

Bending along a shorter direction takes place.

Hence, $M = \frac{217 \times (0.3)^2}{0.15} = 2.441\ t - m$

Using the bending equation

$\frac{2.441 \times 1000 \times 10 \times 1000}{\frac{1}{12} \times 1000 \times d^3 \times \frac{2}{d}}$ $= 10$ [σcbc of M30 grade concrete]

Since, lateral load b = 1000 mm

1667 d^2 = 24410000

d^2 =14643

d = 121 mm

Whenever bending occurs, bending tension occurs; hence, the depth of the structure is to be found by using the bending equation, and the tensile stress of concrete is to be checked by

$\frac{Load}{Cross\ Sectional\ Area}$ = Tensile stress, which should be less than the permissible tensile strength of the given grade of concrete.

Since, the lateral load of 32.52 t is producing bending and tension in the beam:

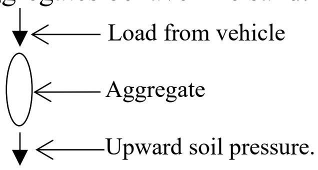
$\frac{Load}{Cross\ Sectional\ Area}$ = Tensile strength of concrete

$$= \frac{32.52 \times 1000 \times 10}{300 \times d} = 3\ \frac{10}{100} \times 30\ [M30\ grade]$$

900 d = 325200

d = 361 mm [depth of beam required against tensile stress].

This concept is to be considered for the design of the thickness of aggregates in roads because aggregates behave like sand.



CONCLUSION

This study presents a comprehensive assessment of rigid pavements, soil-stabilized roads, foundation base slabs, beams, columns, and masonry walls subjected to heavy vertical loads, lateral loads, and upward soil pressure. The analysis demonstrated that the upward soil reaction plays a critical role in inducing tensile stresses and bending in structural and pavement layers, often governing the thickness and reinforcement requirements.

For rigid pavements, PCC roads were found to be adequate under uniformly distributed Class AA loading when constructed on competent soil, whereas reinforced cement concrete (RCC) pavements became necessary over weak subgrades owing to increased deflection. In foundation base slabs, bending due to concentrated column loads governs the design over direct tensile stress, leading to greater slab thickness requirements. Similarly, soil-stabilized roads, owing to their low tensile capacity, require careful control of applied loads and increased thickness to satisfy flexural and tensile strength criteria.

The study also highlighted that concentrated loads produce higher bending moments and deflections than uniformly distributed loads and therefore control the structural design. For beams and columns, the reactive forces transmitted through the columns exceeded the slab loads, necessitating the design of maximum reaction forces to ensure safety. Long stone masonry walls were shown to resist lateral loads without beam and column provisions when an adequate wall thickness was provided.

Overall, the findings emphasize that structural and pavement elements subjected to combined downward loads and upward soil pressure must be designed primarily to resist bending and tensile stresses. Adopting a conservative design based on maximum load effects ensures the safety, serviceability, and durability of infrastructure constructed under heavy loading conditions.

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