CHAPTER

SEVEN
7.00. The various aspects covered in this investigation are

1) Elastic deflections of typical flexible, semirigid and rigid base course layers on sand subgrade in masonry tanks with four loading configurations

2) Elastic deflections of typical square model layers of flexible, semirigid and rigid layers and a perspex model plate, on sand and soil subgrades

3) Repeated loading cycles of limited numbers on the above flexible, semirigid and rigid layers of bigger size and model size with different load configurations

4) Breaking or ultimate loads of the typical flexible, rigid and semirigid layers under single central loading

5) Deflection contours of selected layers of rigid (concrete) and semirigid (soil-cement) layers in the masonry tanks

6) Penetration tests on a range of model layers (single and two layers) on different subgrades in 15 cm dia. and 22.5 cm dia. circular moulds.

The observations made from the test results and further analysed data in connection with the above aspects, are discussed in this chapter. Under each of these aspects, the discussion is brought out first, layer-wise and then the comparative aspects are presented. Reference is made to the data and the test results presented through tables and figures in this thesis and to the relevant studies covered under the review of literature and other references used.
7. 01. **Elastic Deflections and Stiffnesses of Layers on Sand Subgrade in Masonry Tank** (Ref. Table 37 B1.)

A 1) **Sand Subgrade under the Water - Bound Macadam Layers:**

The stiffness values reduce with deflection under all the four configurations in the second cycle of loading. In the first cycle, however, the trend for the configurations (3) and (4), i.e., dual and twin - sandpads plate assemblies, are slightly different. There is an increase first and then decrease in case of configuration (3) while an increase is seen for configuration (4). In the second cycle of loading, which seems to be more stable, in the trend of deflection, the reduction in stiffness with increase in deflection level is maximum \( (21.36 \times 10^{-3}) \) to \( 9.12 \times 10^{-3} \) for configuration (4) and minimum \( (5.24 \times 10^{-3}) \) to \( 2.02 \times 10^{-3} \) for configuration (2). The stiffness values for configurations (1) and (3) coincide at a deflection level of 0.0625 cm. For deflection level below this, stiffness under configuration (1) is more than the stiffness under configuration (3) and above the level of 0.0625 cm, it is reverse. The sand subgrade layers indicated maximum stiffness values under configuration (4) and minimum under configuration (2). The \( S_o \) values reduced from \( 12.56 \times 10^{-3} \) to \( 6.24 \times 10^{-3} \) for config. (1) and from \( 21.36 \times 10^{-3} \) to \( 9.12 \times 10^{-3} \) for config. (4) in the second cycle of loading for deflection levels of 0.025 cm to 0.125 cm respectively.

A 2) **Sand Subgrade Under the Cement Concrete and Soil - Cement Slabs in Masonry Tanks:**

The trend of stiffness variation with deflection level and loading configuration are the same as in the case of sand subgrade under water bound macadam layers. Only the relative values of stiffness are slightly different, since the preparation of the subgrade in the separate tanks cannot be made.
the same. The stiffness values of the subgrade under configuration (1) have been higher than the values under configuration (3) for all levels of deflection. In the second cycle of loading the stiffness ($S_o$) values reduced from $9.36 \times 10^3$ to $4.48 \times 10^3$; from $5.24 \times 10^3$ to $2.29 \times 10^3$ from $6.82 \times 10^3$ to $4.16 \times 10^3$ and from $16.8 \times 10^3$ to $8.45 \times 10^3$ for configurations (1), (2), (3) and (4) respectively.

( B ) WATER BOUND MACADAM LAYERS

The load deflection behaviour of the three thicknesses 7.5 cm, 15 cm and 22.5 cm of water-bound macadam layers laid on sand subgrade can be seen from figures 6.1 to 6.3 and tables 4 A and 4 B. Also the stiffnesses of these layers at different deflection levels, for the second cycle of loading only, are given in table 37 A. The loads and stiffnesses indicated, are in fact the values for the water-bound macadam layer-sand subgrade combination. The stiffnesses of the sand subgrade alone are given in table 37 B. and the effective stiffness values of the water-bound macadam layers in table 37 C. The addition of a 7.5 cm water-bound macadam layer, on sand subgrade has improved the stiffness at 0.02 cm deflection from $12.7 \times 10^3$ to $21.35 \times 10^3$ for loading configuration (1); from $5.45 \times 10^3$ to $12.95 \times 10^3$ for configuration (2); from $17.4 \times 10^3$ to $21.7 \times 10^3$ for configuration (3) and from $21.7 \times 10^3$ to $22.9 \times 10^3$ for configuration (4) under the 2nd cycle of loading.

The total stiffness values ($S$) have increased with the increase in thickness of the layer, but it is not in the same proportion as the thickness. (Ref. table 37 A). The increase is different for each configuration of loading and for various
levels of deflection. For configuration (1) the increase of stiffness from 15 cm layer to 22.5 cm layer is much more than the increase from 7.5 to 15 cm layer. For configuration (4) the increase of stiffness is proportional to thickness for the deflection level of 0.02 cm but it is again similar to configuration (1) at deflection level of 0.06 cm. For configuration (2), it is seen that the stiffness $S_2$ has decreased slightly from layer thickness of 7.5 cm to 15 cm while it increased from 15 cm to 22.5 cm thickness. This is so, for all the three levels of deflection. In the case of configuration (3), i.e., dual plate loading, the increase of stiffness $S_3$ is more for the thickness range of 7.5 cm to 15 cm than for the range of 15 cm to 22.5 cm. Thus the combined action of water bound macadam layer and subgrade or mobilisation, varies with the thickness as well as the load configuration. However, for the thicknesses and the load configuration considered, the stiffness values decreased with increase in deflection levels. The decrease is more for configurations (1) and (4) than for configurations (2) and (3). The maximum decrease of stiffness values with increase in level of deflection, is for thickness of 15 cm under configuration (4), followed by the configurations (1) and (4) for (22.5 cm) slab. The least variation is for the thickness of 15 cm under configuration (2), followed by thickness of 22.5 cm under configuration (2). The variation curves are generally either straight line or with slight concavity upwards, for configurations (1), (2), (3) and (4) excepting for the values under configuration (1) for 15 cm; and 22.5 cm layers.

C 1 D  
Cement Concrete Layers 105 cm x 105 cm

The stiffnesses $S$ of the 105 cm x 105 cm x 5 cm
cement concrete slab - sand subgrade combination under different deflection levels, are lower than the stiffness of 7.5 cm water-bound macadam layers, included in this study. The values did not vary with increase in deflection level, as much as in the water-bound macadam layers. For the 5 cm cement concrete slab the stiffness values increased with increased deflection level for all the configurations of loading. The layer subgrade mobilisation thus seems to improve with greater deflection level. The increase is maximum for configuration (4) and minimum for configuration (1). The stiffness values of the 10 cm cement concrete slab are much higher than the values for the 5 cm slab. The increase of stiffness over the 5 cm slabs, is nearly ten times for configuration (1) five to six times for configuration (2) twelve times for configuration (3) and only three and half to four times for the configuration (4). The stiffness values under configuration (1) and (3) are close to each other and also uniform for different levels of deflection. Under configurations (2) and (4), there is decrease in stiffness values, with an increase of deflection level. The reduction is greater for configuration (4) than for configuration (2). For the 5 cm slab, the stiffness values \( S \) ranged between \( 10.65 \times 10^3 \) to \( 24.88 \times 10^3 \) and for the 10 cm slab, the values ranged from \( 55.26 \times 10^3 \) to \( 142.6 \times 10^3 \) for the deflection levels of 0.02 cm to 0.08 cm.

(C2) CEMENT CONCRETE SLABS 60 cm x 60 cm

The stiffness values of 5 cm slab of 60 cm x 60 cm size at 0.02 cm deflection level are about 2 to 3 times of the values for the same thickness of 105 cm x 105 cm size cement concrete slab. For 10 cm slab, the stiffness values
for the corresponding bigger size slab. The values are about half to one-fourth (1/2 to 1/4) for configurations (1), (3) and (4), but only about two-thirds of the corresponding values for configuration (2) on the bigger size slab. For the thicknesses of 5 cm and 7.5 cm, the stiffness values increased slightly with increase in deflection level for the 10 cm thick slab under all the four configurations. The decrease is maximum for configuration (4) and minimum for configuration (2). Under the deflection range of 0.02 cm to 0.03 cm and the four load configurations considered, the stiffness value (5) varied from $32.15 \times 10^3$ to $40.9 \times 10^3$ for the 5 cm slab. For the deflection range of 0.02 to 0.05 cm, the stiffness values ranged from $36.30 \times 10^3$ to $52.02 \times 10^3$ for the 7.5 cm slab, and for the deflection levels between 0.02 cm to 0.10 cm, the stiffness values ranged from $35.67 \times 10^3$ to $46.3 \times 10^3$ for the 10 cm thick cement concrete slab. The values are the highest for the thicknesses of 5 cm under configuration (4). For the 10 cm slab, maximum stiffness occurred under the configuration (3). The stiffness values under configurations (1) and (2) coincided at deflection levels of 0.0225 for the 5 cm slab; at deflection of 0.0325 for 'T' of 7.5 cm and at deflection of 0.065 for 'T' of 10 cm.

The stiffness values (6) ranged from $35.5 \times 10^3$ to $47.22 \times 10^3$ under different load configurations and deflection range of 0.02 to 0.035 cm for the 10 cm thick soil-cement slab. The values ranged from $55 \times 10^3$ to $65.9 \times 10^3$ under deflection levels of 0.02 to 0.025 cm, for the 15 cm thick soil-cement slab. Under the configurations (1), (3) and (4) and the increase of stiffness is around 1 1/2 times from the 10 cm slab to
15 cm slab, thus indicating proportionate increase with thickness. Under configuration (2) however, the increase is only between 1 to 1.25 times. For both the thicknesses, the stiffness values decreased with increase in deflection level, and under different loading configurations, excepting the case of configuration (3) of 10 cm slab, where the stiffness showed a ten percent increase. The stiffness under configuration (2) is the maximum, for the 10 cm slab, at 0.02 cm deflection followed by configurations (1), (4) and (3) in order, while the maximum value for the 15 cm soil - cement slab is indicated under configuration (1), followed by configurations (4), (3) and (2). At the higher value of deflection the trend is same for both the thicknesses i.e., maximum stiffness under configuration (1) followed by others.

The stiffness values of the 10 cm soil - cement layer under respective configurations is more than the stiffness value of 15 cm, water - bound macadam and 5 cm thick cement concrete layers, but slightly lower than the values of 22.5 cm water - bound macadam layer under configuration (4) only. The stiffness values of 15 cm soil - cement layer are more than the stiffness values of 22.5 cm water bound macadam layer, but much lower than the values for the 10 cm cement concrete slab.

Under the different loading configurations and for deflection levels between 0.02 cm to 0.06 cm, the stiffness values ranged from $10.5 \times 10^3$ to $31.6 \times 10^3$ for the 5 cm slab, the maximum values being under configuration (4). Similarly, the values for deflection range of 0.02 cm to 0.08 cm, ranged from $26.4 \times 10^3$ to $43.75 \times 10^3$ for slab thickness of 10 cm; from $29.10 \times 10^3$ to $53.45 \times 10^3$ for 15 cm slab, and from
38.76 x 10^3 to 60.35 x 10^3 for the 20 cm slab. In all the slabs, under different configurations, the stiffness values decreased with increase of deflection levels, excepting the cases of 5 cm slab under configuration (2) and 20 cm slab under configuration (3), where certain increases occurred in stiffness values. The decrease is maximum under configuration (2) for the 10, 15 and 20 cm slabs and under configuration (3) for the 5 cm slab. For all the four thicknesses the least decrease is under configuration (1). The increase of stiffness values with increased thickness is more from thickness of 5 to 10 cm, than from 10 to 15 cm or from 15 cm to 20 cm, slabs. The stiffness values at 0.02 cm and 0.04 cm deflections for 20 cm slab are lower compared to corresponding values for 15 cm slab under configuration (3) while under configuration (4), the stiffness value of the 15 cm thick slab at all the deflection levels, are more than the values for the 20 cm thick slab.

The stiffness values of 60 cm x 60 cm x 10 cm soil - cement slabs are lower than the stiffness values of the 105 cm x 105 cm x 10 cm soil - cement slab for configurations (1) (2) and (3) while they are nearly equal under configuration (4). Similarly, the stiffness values for the 15 cm soil - cement slab of 60 cm x 60 cm size are much lower than the corresponding values for the 105 cm x 105 cm x 15 cm soil - cement slab. The 20 cm thick slab of smaller size showed greater values of stiffness than the 15 cm thick slab of 105 cm x 105 cm size only under configuration (2) but still they are less than the corresponding values under the other three configurations.
7.02. EFFECTIVE STIFFNESS OF LAYERS IN MASONRY TANK

(A) WATER BOUND MACADAM LAYERS

Table 37 (C) shows the values of effective loads (P_e), the effective stiffness (S_e) and the ratio P_e / P_0. The effective stiffness values are in general found to be more under configuration 1 and 4 than for configuration 2 and 3. The maximum values occurred under the configuration (4) while the maximum values are under configuration (2). The effective stiffness (S_e) values, under deflection of 0.025 and 0.05 cm and different loading configurations on the 7.5 cm layer, varied from $4.84 \times 10^3$ to $12.76 \times 10^3$ in the 1st cycle of loading and from $5.68 \times 10^3$ to $18.12 \times 10^3$ in the 2nd cycle of loading. The values of (S_e) for the 15 cm layer, varied from $9.42 \times 10^3$ to $28.6 \times 10^3$ in the 1st cycle and $5.32 \times 10^3$ to $28.56 \times 10^3$ for the 2nd cycle. Similarly for the 22.5 cm water-bound macadam layer the values of (S_e) varied from $13.84 \times 10^3$ to $81.96 \times 10^3$ for the 1st cycle and from $11.44 \times 10^3$ to $53.4 \times 10^3$ for the 2nd cycle.

The increase of effective stiffness from layer of 15 cm to 22.5 cm thickness, is much more than the increase in the values of (S_e) from layer thickness of 7.5 cm to 15 cm. This has been so, for the configuration (1), (2) and (4) only. In case of configuration (3), the increase of (S_e) from layer of 15 cm to 22.5 cm is not appreciable, while the trend is same as in other configurations for increase of thickness from 7.5 cm to 15 cm. The effective stiffness values increased with increase in deflection level under all the four loading configurations, for the first as well as the second cycle of loading. The increases are also
more for the 22.5 cm layer, than the 7.5 cm or 15 cm layer.
For configuration (1) and (3) the increase is more under second cycle of loading than under the 1st cycle of loading, while for configuration (2) and (4) the increase of stiffness with deflection level is more under first cycle than the second cycle. In the first cycle of loading effective stiffness values at 0.05 cm deflection level for all the layers under all configurations, are 1.5 to 2.0 times the $S_3$ values at 0.025 cm. For the 2nd cycle of loading also, similar trend of increase is maintained.

For configuration (1), on all the layers, and at the respective deflection levels of 0.025 and 0.05 cm, the effective stiffnesses under 2nd cycle of loading are between 1.0 to 1.5 times the effective stiffness values under the 1st cycle of loading. For the thickness of 7.5 cm only, the same relation existed under configuration (2), (3) and (4). For the layer thicknesses of 15 cm and 22.5 cm of water-bond macadam, the effective stiffness values under the second cycle of loading, at the respective deflection levels of 0.025 and 0.05 cm, are either nearly equal or in some cases found to be less than the corresponding values under the 1st cycle of loading. This indicates that the increase of stiffness from 1st to 2nd cycle of loading, occurs for layers thinner than 15 cm.

B ) CEMENT CONCRETE SLABS 105 cm x 105 cm SIZE

The effective stiffness values of the 5 cm cement concrete slab appears to be very low. For all the configurations, under the deflection levels of 0.025 and 0.05 cm, the $S_3$ values ranged from $1.52 \times 10^3$ to $6.32 \times 10^3$ for the 1st cycle of loading and from $1.12 \times 10^3$ to $5.32 \times 10^3$ for the 2nd cycle.
of loading. Some of the values under configurations (3) and (4) are found to be negative, the reason for which may be lack of proper subgrade support below the slab, thus making the slab freely deflect under the load. These values are therefore not considered. The corresponding ranges of stiffness values for the 10 cm thick cement concrete slab, are from $31.84 \times 10^3$ to $9.6 \times 10^3$ and from $38.08 \times 10^3$ to $121.92 \times 10^3$ for the 1st and 2nd cycle of loading, respectively. The effective stiffness values decreased with increase in deflection levels, under 1st as well as 2nd cycle of loading, excepting in the case of the configurations (2) and (3) in the 1st cycle for the thickness of 5 cm and configuration (3) in the 2nd cycle of loading for the 10 cm thick slabs. In these cases there is a slight increase.

For all the configurations at deflection level of 0.0125 cm and for configuration (1) at deflection level of 0.025 cm, the effective stiffness values under the second loading cycle are found to be lower than the ($S_e$) values under the 1st loading cycle. For the deflection level of 0.025 cm under the configurations (2) (3) and (4) the ($S_e$) values for the slabs thickness of 10 cm, are greater under 2nd cycle than the values under the first cycle.

The maximum value of effective stiffness ($7.712 \times 10^3$) for the 5 cm slab occurred under configuration (3) and the minimum value under configuration (1). For the 10 cm thick slab, the maximum value of effective stiffness occurred under configuration (3) while the minimum occurred under configuration (4).

The values of effective stiffness for the 5 cm slab under 1st cycle ranged from $8.96 \times 10^3$ to $27.08 \times 10^3$ and under 2nd cycle
of load from $6.16 \times 10^3$ to $30.92 \times 10^3$. The maximum values occurred under configuration (2), while the minimum occurred in configuration (4). For the 7.5 cm thick slab, the range of $(S_e)$ values for first cycle is from $13.04 \times 10^3$ to $35.52 \times 10^3$ and for the second cycle from $20.4 \times 10^3$ to $37.92 \times 10^3$. The maximum occurred under configuration (2) and the minimum under configuration (1). For the 10 cm cement concrete slab, the values of the effective stiffness ranged from $14.76 \times 10^3$ to $32.0 \times 10^3$ for the first cycle of loading, and from $16.32 \times 10^3$ to $38.96 \times 10^3$ for the second cycle of loading. The maximum values occurred under configuration (2) and the minimum values under configuration (4) for both the cycles.

The increase of effective stiffness with thickness is more between 5 cm to 7.5 cm thickness from 7.5 cm to 10 cm slab thickness for configuration (2), (3) and (4) while the increase is more between 7.5 cm to 10 cm thickness for configuration (1). Under configuration (4) the increase of $(S_e)$ between 7.5 cm to 10 cm layer thickness is either small or there is a slight decrease also in the second cycle of loading. The increase of effective stiffness values for deflection level of 0.0125 cm to 0.025 cm has been more for the 5 cm slab, than for 7.5 cm to 10 cm slab. From the first cycle of loading to the second cycle of loading, under both the levels of deflection the effective stiffness values increased under all configurations for the 7.5 cm and 10 cm thick slabs, and only under configuration (1) and (2) for the 5 cm slab. At deflection level of 0.0125 cm, for the 5 cm slab, the values under second cycle are lower than under the first cycle, for configuration (3) and (4). The effective stiffness of the 5 cm thick slab (60 x 60 cm) are much greater
than the values for 5 cm thick cement concrete slab of 105 cm x 105 cm size, but the values of \( S_e \) for the smaller slab of 10 cm thickness are much lower than the corresponding values of the bigger slab of 10 cm thickness. This indicates that the T/B ratio of the slab controls the stiffnesses at different deflection levels and different loading cycles, separately. In general, the cement concrete slabs of 5 cm 60 x 60 cm size exhibit greater stiffness values than the 7.5 cm and 15 cm thick water-bound macadam layers and the 10 cm cement concrete slab is stiffer than the 22.5 cm water-bound macadam at 0.025 cm deflection level under the configurations (1), (2) and (3). Under configuration (4) the water-bound macadam layer of 22.5 cm is found stiffer than the 7.5 cm and 10 cm cement concrete slabs.

For the 10 cm thick soil-cement slab, the values of \( S_e \) varied from 10.72 x 10^3 to 25.36 x 10^3 in the first loading cycle and from 10.16 x 10^3 to 52.16 x 10^3 in the second loading cycle under deflection levels of 0.0125 to 0.025 cm. The maximum values occurred under configuration (2) for both cycles, and the minimum values occurred under configuration (3) for the first cycle and under configuration (4) for the second cycle. For the 15 cm thick soil-cement slab, the \( S_e \) values ranged from 16.8 x 10^3 to 31.44 x 10^3 in the first cycle of loading and from 20.52 x 10^3 to 57.04 x 10^3 in the second cycle. The maximum values for both the cycles are under configuration (1) and the minimum values is under the configuration (3) for the first cycle and under configuration (4) for the second cycle.
The effective stiffness ($S_e$) values increased with increase in thickness and also from first cycle to second cycle loading excepting in the case of configuration (4). The increase of ($S_e$) with increased level of deflection, for the first loading cycle to second loading cycle is more for the 15 cm soil-cement slab than the 10 cm slab. Also the increases are more under configurations (1) and (2) than under configurations (3) and (4). The increase of stiffness ($S_e$) from first to second loading cycle under configurations (1) and (2) is more at the deflection levels of 0.0125 cm than at 0.025 cm. Under configurations (3) and (4) in the first cycle of loading, the effective stiffness ($S_e$) values at 0.025 cm deflection level are lower than the ($S_e$) values at 0.0125 cm level. In the second cycle of loading under the configurations (3) and (4), the ($S_e$) values at 0.025 cm deflection level are greater than at 0.0125 cm for slab thickness of 10 cm, while the former values are smaller than the latter for the 15 cm thick slab, indicating transition or equal values of effective stiffness $\phi$F at a thickness of about 12.5 to 13 cm. The effective stiffnesses as well as the variation of stiffness with cycle of loading and deflection level have been more under configurations (1) and (2) than under (3) and (4), the values under configuration (4) being minimum. The ($S_e$) values at deflection level of 0.025 cm for the 10 cm soil-cement slab are observed to higher than the ($S_e$) values of the water-bound macadam layers of 15 cm under all the configurations and both cycles of loading. At 0.0125 cm deflection, the effective stiffness ($S_e$) for the 10 cm soil-cement slab for the second cycle is observed to be lower than the corresponding ($S_e$) values for the first cycle, under configurations (3) and (4).
The effective stiffness increased with thickness under some configurations and decreased with thickness under other configurations. Also the increase or decrease is not uniform for the first and second cycles of loading, nor it is so for the different levels of deflection. In the first cycle of loading, the variation of \( S_e \) with deflection level is not appreciable for configurations (1) and (2). In the second cycle also the values of \( S_e \) for 0.0125 cm and 0.025 cm deflection levels are not varying appreciably under configurations (1) and (4) while under configurations (2) and (3), the effective stiffness values at 0.025 cm deflection level are much lower than the values at 0.0125 cm deflection level. In both the cycles of loading, the increase of \( S_e \) values with thickness is maximum and also of uniform trend, under configuration (2). The increase is minimum under configuration (1).

### Table: \( S_e \) values

<table>
<thead>
<tr>
<th>Thickness</th>
<th>1st Cycle</th>
<th>2nd Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 cm</td>
<td>1.68x10³ to 12.04x10³</td>
<td>(1) (2)</td>
</tr>
<tr>
<td>10 cm</td>
<td>3.84x10³ to 26.48x10³</td>
<td>(2) (3)</td>
</tr>
<tr>
<td>15 cm</td>
<td>4.00x10³ to 17.6x10³</td>
<td>(4) (3)</td>
</tr>
<tr>
<td>20 cm</td>
<td>7.64x10³ to 22.00x10³</td>
<td>(3) (4)</td>
</tr>
<tr>
<td></td>
<td>23.44x10³ to 46.04x10³</td>
<td>(4) (2)</td>
</tr>
<tr>
<td></td>
<td>6.12x10³ to 25.08x10³</td>
<td>(2) (4)</td>
</tr>
<tr>
<td></td>
<td>18.32x10³ to 71.04x10³</td>
<td>(2) (4)</td>
</tr>
</tbody>
</table>
Under the respective loading cycles and the deflection levels, the effective stiffnesses of the 10 cm and 15 cm slabs, of 60 cm x 60 cm size are found to be lower than the corresponding \( S_e \) values for the 105 cm x 105 cm slabs of 10 cm and 15 cm respectively under configurations (1), (2) and (4). Only under configuration (3), the \( S_e \) values of the smaller slabs (E=60 cm) are greater than the values for the bigger slab.

Under the first cycle of loading, the \( S_e \) values for the soil-cement slabs of 5 cm, and 10 cm thickness are only about half to two-thirds of the \( S_e \) values for the corresponding cement concrete slabs. In the second cycle however, the ratios of stiffness values for the corresponding cement concrete and soil-cement slabs are between 1.25 to 1.5 times. The \( S_e \) values for soil-cement slabs are observed to be only 1 to 1.25 times the values for the water-bound macadam layers.

7.03. VALUES OF THE \( P_e / P_o \) RATIOS FOR VARIOUS LAYERS

The ratio of the effective load \( P_e \) of the layer to the load \( P_o \) taken by the sand subgrade, indicate the relative reinforcement effect of the respective layers. The values of the ratio for the different layers are given in the table.

A) WATER BOUND MACADAM LAYERS

The maximum values of \( P_e / P_o \) ratio for water-bound macadam layers, occurs under configuration (4) and the minimum under configuration (1) in the first cycle while the maximum and the minimum values were observed under configurations (2) and (3) respectively in the second cycle of loading. At the respective deflection levels the ratio decrease from first cycle to second cycle. The decrease is more at deflection of 0.025 cm.
than at 0.05 cm. Generally, there is an increase in the value of the ratio with increase in deflection level from 0.025 to 0.05 cm, except in the cases of configurations (2) and (3) in the first cycle and configuration (2), (T=7.5 cm) and configuration (4) (T=15 cm) in the second cycle. The increase or decrease is more for the thickness of 7.5 cm and 15 cm than for 22.5 cm. There is always an increase in the values of $P_e/P_0$ with increase in thickness. The increase is more from 15 cm to 22.5 cm, than between 7.5 cm to 15 cm, under configurations (1) (2) and (4) while the increase is more from 7.5 to 15 cm, under configuration (3).

B) CEMENT CONCRETE SLABS 105 cm x 105 cm

For the 5 cm slab the maximum value of $P_e/P_0$ is under configuration (2) of the first cycle and the minimum value is under configuration (2) of the second cycle. The negative values indicate that the stiffness of the slab is less than the stiffness of the subgrade itself. This is so, perhaps due to lack of subgrade support under the middle portion of the thin slab, allowing it to deflect freely under the load. There is a small decrease in the value of the ratio, for the increase in the deflection level from 0.025 cm to 0.05 cm. Also, there is generally, a decrease in the value from the first loading cycle to second loading cycle. The effective load ratio ($P_e/P_0$) for the 10 cm cement concrete slab and sand subgrade are much higher than the values for the 5 cm slab. The maximum and the minimum values occurred under the configurations (3) and (4) in the first cycle and under configurations (2) and (4) in the second cycle respectively. The ratio decreased with deflection level in all other cases excepting configuration (4) of the first cycle.
and configuration (3) of the second cycle. Also the ratio decreased from first cycle to second cycle at the respective deflection levels under configurations (1), (3) and (4) while it increased under configuration (2).

(c) **SOIL CEMENT SLABS 105 cm x 105 cm**

For the 105 cm x 105 cm slab, the maximum and minimum values of $p_e/p_o$ for both the thicknesses, 10 cm and 15 cm occurred under configurations (2) and (4) respectively in the first as well as the second cycle of loading. With increase of deflection level leading from 0.0125 cm to 0.025 cm, the value for 10 cm slab increased under configurations (1) and (2) and decreased under configurations (3) and (4) in the first cycle. In the second cycle, the increase of the ratio with deflection level occurred under configurations (1), (3) and (4) and decreased under configuration (2) for 10 cm slab. For the 15 cm thick slab, under all the configurations and both the cycles, the ratio decreased with increased level of deflection. There is always an increase of $p_e/p_o$ ratio from thickness of 10 cm to thickness of 15 cm. This increase is more under configurations (3) and (4) than under (1) and (2) in the second cycle, while it is more under configurations (2) and (3) than under (1) and (4) in the first cycle. This is also more at deflection level of 0.0125 cm than at 0.025 cm.

D) **CEMENT CONCRETE SLABS (60 cm x 60 cm)**

With increase of thickness there is an increase in the value of $p_e/p_o$ ratio at both the deflections for first and second loading cycles under configurations (1) and (2). But, under configurations (3) and (4), there is no definite trend. Generally,
the value increased from first cycle to second cycle, for all thicknesses, under configurations (1) and (2) but it was so only for deflection level of 0.0125 cm, under configurations (3) and (4). At 0.025 cm deflection level, the value of the ratio decreased from first to second cycle. The maximum values occurred under configuration (2) for 10 cm slab and the minimum value under configuration (4), for 7.5 cm slab in the first cycle. The maximum and minimum values in the second cycle occurred under configuration (2) for 7.5 cm slab and configuration (4) for 5 cm slab respectively. The values of the ratio for the 60 cm size slab are more than the values for the bigger 105 cm size cement concrete slabs for thickness of 5 cm, while they are much less than the corresponding values for the bigger slab for 10 cm slab.

3) SOIL CEMENT SLABS (60 cm x 60 cm)

There seems to be no definite trend in the increase or decrease of values of Pe/Po, with increase of thickness, or with increase of deflection level. However, at the respective deflection level, for each of the slab thickness and configuration, there is in general an increase in the value of the ratio, from the first to the second cycle of load under configurations (1) and (2). The trend is again not definite under configurations (3) and (4). The maximum and minimum values occurred under configuration (2) for thickness of 20 cm and configuration (4) for thickness of 10 cm respectively in the first cycle of loading, while they occurred under configuration (2) for thickness of 20 cm and configuration (4) for thickness of 5 cm respectively in the second cycle of loading. The ratios of Pe/Po for the small size...
soil - cement slabs at the thicknesses of 5 cm and 10 cm respectively, are much smaller than the values for the corresponding thicknesses of the cement concrete slabs, but they are in general more than the values for the bigger size soil - cement slabs at corresponding thicknesses.

7.03. Effect of the Loading Cycle on the Load - Deflection Behaviour of the Layers in Masonry Tanks (Ref. Table 39)

The ratios of the loads in second cycle of loading to the load applied in the first cycle of loading i.e., \( P_2/P_1 \) values given in table 39, indicate the improvement of strength of the layer-subgrade combination, for different layers at specified deflection levels under the four configurations of loading.

(a) Water-bound macadam layers

Upto a deflection level of 0.10 cm, the \( P_2/P_1 \) ratio varied from 1.227 to 3.149, for the layer thickness of 7.5 cm, from 0.953 to 2.085 for the 15 cm layer and from 0.938 to 1.673 for the 22.5 cm layer, thus indicating reduction in the range as well as the maximum value with increased thickness. The maximum values occurred under configuration (4) for 7.5 cm and 15 cm slabs and configuration (3) for the 22.5 cm slab and the minimum values occurred under configuration (2) for 7.5 and 15 cm layers and configuration (4) for the 22.5 cm layer. The above figures indicate an improvement of layer capacity ranging from 93.8 % to 314.9 % from first to second cycle of loading.

(b) Cement concrete slabs (105 cm x 105 cm)

For the deflection range of 0.025 cm to 0.05 cm, the
improvement of load from first to second cycle of loading ranged from 79.9% to 191.9% (for layer thickness of 5 cm and 10 cm). The maximum increase is under configuration (1) and the minimum under configuration (2). The values are in general, lower than those for the water bound macadam layers. The improvement is more for 10 cm slab than for 5 cm slab. The maximum value occurred under configuration (1) and the minimum under configuration (2).

(c) Soil - cement slabs (105 cm x 105 cm)

For the thicknesses of 10 cm and deflection range of 0.00625 cm to 0.025 cm, the ratio of $P_2/P_1$ varied from 1.258 to 2.212, the maximum being under configuration (3) and the minimum under configuration (4). For the 15 cm layer, the range of load improvement varied from 1.427 to 2.787, the maximum and minimum values occurring under configurations (3) and (2) respectively.

There is greater improvement for the 15 cm slab than for 10 cm slab under configurations (1), (3) and (4) but, it is more for 10 cm slab under configuration (2). Excepting for 15 cm slab under configuration (4), there is a decrease in the value of load ratio, with increase in deflection levels. In general, the improvement ratios for the soil - cement slabs are observed to lie between the values for the water - bound macadam and cement concrete layers at the respective deflection levels, thus indicating their intermediate position between flexible and rigid layers.

(d) Cement Concrete slabs (60 cm x 60 cm)

At deflection range of 0.0125 cm to 0.05 cm, the load improvement ratios ($P_2/P_1$) ranged from 0.978 to 1.606 for
5 cm slab, from 1.262 to 1.892 for 7.5 cm slab and from 1.084 to 1.784 for 10 cm slab, thus indicating a smaller range for greater thickness. The maximum values for the slabs of 5 cm and 10 cm occurred under configuration (1) and for the 7.5 cm slab under configuration (2). The minimum values for the thicknesses of 5 cm and 10 cm occurred under configuration (2) and for 7.5 cm slab under configuration (3). In general it is seen that the range of variation in $P_2/P_1$ values for increased thickness or increased deflection level and also the absolute values of $P_2/P_1$, are greater than the values for the cement concrete slabs of 105 cm x 105 cm size, but lower than the values for the soil-cement slabs of 60 cm x 60 cm size.

(e) Soil-Cement Slabs (60 cm x 60 cm)

For deflection range of 0.0125 cm to 0.05 cm, the values of $P_2/P_1$ under different loading configurations, varied from 1.106 to 3.684 for 5 cm slab, from 1.458 to 2.157 for 10 cm slab, from 1.485 to 2.581 for 15 cm slab and from 1.487 to 2.393 for the 20 cm slab. The maximum and the minimum values occurred respectively under configurations (3) and (2) for 5 cm slab, under configurations (1) and (2) for 10 cm slabs and 15 cm slabs and under configuration (2) for 20 cm slab. Excepting for the smallest slab of 5 cm under configuration (1), the ratio of $P_2/P_1$ decreased with increase in deflection level. Also, generally, an increase in the value of the load improvement ratio occurred from slab thickness of 5 cm to 15 cm under configurations (1) and (2), the increase being more at lower deflection levels (0.0125 cm and 0.025 cm) than at 0.05 cm level. Under configurations (3) and (4), there is generally a decrease in the
value of the ratio with increase in slab thickness.

(f) **IMPROVEMENT OF THE LOAD VALUES FROM 2ND TO 3RD CYCLE OF LOADING**

From figures 5.1 A to 7.5 D, it can be seen that the third cycle of loading has been conducted on the layers over sand subgrade, the improvement of loads from second to third cycle are much smaller than the improvement from first to second cycle of loading. Thus the layers - subgrade system gets stabilised and for subsequent cycles, beyond the third cycle, the increase of load may be very little. Some values of the ratios, \( \frac{P_3}{P_2} \) are given below for deflection level of 0.0125 cm.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness in cm</th>
<th>( \frac{P_3}{P_2} ) values under configurations (1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>1. Water bound Macadam</td>
<td>7.5</td>
<td>1.170</td>
<td>1.010</td>
<td>1.180</td>
<td>1.335</td>
</tr>
<tr>
<td></td>
<td>15.0</td>
<td>0.905</td>
<td>1.270</td>
<td>1.000</td>
<td>1.015</td>
</tr>
<tr>
<td></td>
<td>22.5</td>
<td>1.005</td>
<td>0.998</td>
<td>1.048</td>
<td>1.080</td>
</tr>
<tr>
<td>2. Cement Concrete 105 cm x 105 cm</td>
<td>5.0</td>
<td>1.175</td>
<td>0.918</td>
<td>0.965</td>
<td>1.070</td>
</tr>
<tr>
<td></td>
<td>10.0</td>
<td>1.035</td>
<td>1.000</td>
<td>1.030</td>
<td>1.030</td>
</tr>
<tr>
<td>3. Cement Concrete 60 cm x 60 cm</td>
<td>5.0</td>
<td>1.060</td>
<td>1.065</td>
<td>1.280</td>
<td>0.900</td>
</tr>
<tr>
<td></td>
<td>7.5</td>
<td>1.010</td>
<td>1.095</td>
<td>0.977</td>
<td>0.948</td>
</tr>
<tr>
<td></td>
<td>10.0</td>
<td>1.020</td>
<td>0.920</td>
<td>1.130</td>
<td>1.060</td>
</tr>
</tbody>
</table>

The ratios of \( \frac{P_3}{P_2} \) for water bound macadam layers are seen to range from 0.905 to 1.335, the minimum and maximum values being under configurations (1) and (4) respectively. The range of values for the concrete layers of 105 cm x 105 cm size is from 0.918 to 1.175 and for the cement concrete layers of 60 cm x 60 cm sizes from 0.90 to 1.28. Thus the values are around 1 only.
indicating that between the second to third cycles of loading, there is no appreciable improvement of the load is not appreciable or in other words, that the layer-subgrade combination has got stabilised by the third cycle. The values of $P_2/P_1$ for soil-cement layers are not given, as the third cycle of loading has not been applied on them. Some values of $P_2/P_1$ and $P_1/P_2$ (given in previous tables) are below 1, suggesting that there is decrease in the load values from second to third cycle or from first to second cycle. This may be due to the permanent deformation or set in the sand subgrade on loading in the previous cycles and the elastic rebound of the layers above, causing a lack of full subgrade support and hence reduction in the load taken by it at deflections in the subsequent cycles of loading.

7.04. Elastic Rebound of Various Layers on Sand Subgrade in Masonry Tests (Ref. Tables 17A and 17B)

From Load-Deflection Tests:

For the cement concrete and soil-cement layers of 60 cm x 60 cm size, the ratios of the rebound values of deflection to the total deflection under the respective loads applied in the deflection tests and also the rebound value expressed in percentage are given in Table 17A. The effect of the cycle of loading (3 or 2) and the load configurations on these values can be seen from the tabulated results.

1) Sand subgrade only:

From the first to the second cycle of loading, the values of total deflection decreased to a great extent (1/3 to 1/4) while the deflection values for 3rd cycle are about 80 to 85% of the values in the second cycle. Maximum reduction from first to third cycle is under configuration (2) followed by
configurations (1), (3) and (4). The rebound values varied only marginally, (within 5%) between the first and third cycles for configurations (1), (3) and (4) while under configuration (2) the rebound value increased marginally between first to second cycle and by about 20% from second to third cycle of loading. The rebound values are more for configurations (1) and (2) than for (3) and (4), at least being under configuration (4). The percentage values of rebound are however nearly equal for the first, second and third cycles under configurations (1), (3) and (4). The rise in percentage is about 50% from first to third cycle. But under configuration (2), the percentage rebound increased by only 30 to 35%.

2) Cement concrete Slabs (thickness of 5cm, 7.5cm, and 10cm)

For these slabs, the total deflection values reduced from first to second cycle by 30 to 50%, while they remained almost the same for the second and third cycles. The reduction from first to second cycle is greater for configurations (4) and (1), than under configurations (2) and (3). The deflection values generally decrease with thickness of layer. The rebound values are of the same order for configurations (1), (3) and (4) but lower for configuration (2). The values of rebound did not vary much for loading cycles I, II and III, under each configuration. For all the thicknesses the percentage rebound values for configuration (1), varied between 40% to 90% from first to third cycle, the increase being more from first to second, than from second to third. Under configuration (2) the values of percentage rebound varied between 86 to 95.5 for thickness of 5 cm, between 47 to 83.5 for thickness of 7.5 cm and between
70 to 90% for thickness of 10 cm. By the third cycle of
loading the rebound of the layer in any case has been 80 to 90% of the total rebound. But the sand subgrade rebounded only about
70% under configurations (1), (3) and (4) and 42.5% under
configuration (2), thus leaving a gap between the layer of
subgrade in the central portion. Under configurations (2) and (3),
the 5 cm slab rebounded by 95 to 96% of the total deflection
in the second and the third cycles because of the elastic nature
of the thin slab. But it is not so under the thinner slabs,
which showed a non-recoverable deflection of 10 to 20% at the
third loading cycle also. This is perhaps due to the combined
effect of the non-recoverable action of the subgrade sand and
the lack of subgrade support to the slab.

3) Soil-cement Slabs (50 cm x 50 cm size) (Thickness 5, 10, 15 and 20 cm) (Ref. Table 17 A)

The soil-cement layers have been tested only to a
smaller intensities of loading and hence the deflection values
are also smaller than for the concrete layers. The deflection
values decreased to about 50% from 1st to 2nd cycle of loading.
Under the configurations (1), (2) and (4) the rebound values
generally increased from first cycle of loading to the second
cycle for the layers of 10, 15 and 20 cm only by a small margin
(less than 10%) or remained constant. Under configuration (3),
for all the thicknesses, the rebound values decreased from
first to second cycle of loading. For the different layer
thicknesses, the percentage rebound values ranged from 30.5 to
91 under configuration (1); from 33 to 96 under configuration
(2); from 30.5 to 77.5 under configuration (3) and from 27 to
86 under configuration (4). Except under the configuration (1)
on the 5 cm layer, the percentage rebound value increased by about 1.5 to 2.5 times from first to second cycle of loading. For the 5 cm layer, the percentage rebound values are higher for configurations (1), (2) and (3) and the increase from first to second cycle is less under configurations (1) and (2).

For the soil-cement slabs, the percentage rebound values under the respective load configurations in the first and the second cycles of loading are lower than the values for the corresponding thicknesses of the cement concrete slabs, the difference being more in the first cycle and only marginal in the second cycle. The rebound values for the soil-cement layers are much higher than the values for the sand subgrade alone, indicating reinforcing effect as well as the elastic nature of the layers. The trend of the rebounds in the soil-cement slabs is more uniform than for the cement concrete slabs. This is perhaps due to the partly flexible nature of the soil-cement slabs, which ensures a closer contact or support by the subgrade.

4) Water-bound Macadam Layers (105 cm x 105 cm) Ref. Table 17B

The deflection values decreased with loading cycles, but the rebound values either increased or remained stationary. The percentage rebound values increased by more than three times from first to the third loading cycle for the 7.5 cm layer, while the increase is about twice times for the 15 cm layer and 1 ½ to 2 times for the 22.5 cm layer. The values of percentage rebound under configurations (1), (2) and (3) for 2 cm layers are nearly the same for second and third cycles. For the layers of 15 cm and 22.5 cm, no such stabilisation is indicated. The increase from second to third cycle is also appreciable as in the case of first to second cycle. The 5 cm water-bound macadam layer
did not show adequate re-inforcing effect under loading configuration (1). Also it is seen that the rebound values for the 22.5 cm layer under configurations (1) and (2) are smaller than the values for the 15 cm layer. But the maximum rebound values of 55%, 85% and 96% for cycles I, II and III are obtained under configuration (4) for the 22.5 cm layer, indicating its high stiffness value.

5) **Cement concrete Slabs (105 cm x 105 cm)**

For the 5 cm slab, the deflection and rebound values are higher than the values for the water bound macadam layers. The deflection and the rebound values for the 10 cm slab are lower. The rebound values under each configuration for first, second and third cycles of loading are almost constant. The percentage rebound values varied from 42 to 88 in the first cycle, from 33.3 to 87.5 in the second cycle and from 64 to 98 in the third cycle. The values of percentage rebound for cycle one are more for the 5 cm slab than the 10 cm slab, under configurations (2), (3) and (4). Under the second and third cycles, the 10 cm slab showed more percentage rebound. The values for the 10 cm slab under configuration (2) are unusually low. Generally there is a stabilisation in rebound values in the second and third cycles of loading.

6) **Soil - Cement slabs (105 cm x 105 cm)**

Under each configuration, the deflection values decreased with increase in slab thickness and also from first to second cycle of loading. Under each configuration, the rebound values remained very nearly the same, for the first and second cycles of loading. The rebound values decreased from slab thickness
of 10 to 15 cm. Also the values of the 15 cm slab (28 days curing) are much lower than the rebound values for the 15 cm slabs of 7 days curing. The percentage rebound values increased from first to second cycle of loading by one and half to two times. The percentage rebound values of the 10 cm slab are generally lower than the values for 5 cm slabs for the first loading cycle, but they remained close to each other under second cycle. In general, the soil-cement slabs of 7 days curing showed more elastic behaviour than the slabs of 28 days curing, indicating greater percentage rebound values even at higher levels of deflection. The 15 cm soil-cement slab of 7 days curing showed slightly greater percentage rebound than the 15 cm water-bound macadam layer. For the soil-cement slabs, the maximum values of percentage rebound under the first, second and third cycles of loading occurred under configuration (4) and the minimum values occurred under the configuration (3).

7.05. DEFLECTIONS AND REBOUND VALUES OF LAYERS IN MASONRY TANK UNDER STEPPED LOADING (Ref. Table 13.)

The values of deflection, rebound values and percentage deflection values at various intensities of loading applied in steps are only for loading configuration of 15 cm diameter plate (configuration (2)). Only three soil-cement slabs and four cement concrete slabs are covered under this. The deflection values as well as the rebound values are maximum for the 5 cm thick cement concrete slab of 105 cm x 105 cm size. These values are minimum for the 105 cm x 105 cm x 15 cm soil-cement slab of 28 days curing. Under the increase of the loading intensities from 1.264 kg/cm² to 5.057 kg/cm², the percentage rebound deflections varied from 45% to 68% for the bigger
soil-cement slab of 10 cm. For the same range of loading intensities, the percentage rebound values varied from 23% to 67% for the 15 cm soil-cement slab. The ratios of the percentage between the 5 cm and 10 cm soil-cement slabs reduced at higher intensity and at the pressure of 5.057 kg/cm² the ratio is nearly 1.

The values of percentage rebound for each step of loading are much lower for the 15 cm soil-cement slab (28 days curing) than the above two slabs. For the bigger cement concrete slabs of 10 cm and the small size slabs of 5 cm and 7.5 cm also, there is certain increase in percentage rebound values with increased loading intensity. For the 5 cm slab of bigger size there is reduction in the value from 100 to 62.5%. The rebound values decreased with an increase in the slab thickness for the bigger and the smaller size cement concrete slabs. For the smaller size cement concrete slabs, there is an increase in percentage rebound values up to certain load intensity and then a decrease. Thus, under stepped loading the increase of rebound with load intensity is rather uniform for the soil-cement slabs, but the trend is that of increase followed by decrease for the cement concrete slabs. The resilience of the cement concrete layers is about 1.5 to 2 times that of the soil-cement slabs at lower load intensity and it may be around 1 to 1.5 times at higher intensity of loading.

7. 06. BREAKING OF ULTIMATE LOADS AND DEFLECTION OF LAYERS IN MASONRY TANKS (Ref. Tables 14 and 15)

A) 105 cm x 105 cm layers:

The yield loads \( (P_y) \) and the ultimate or breaking loads \( (P_u) \) for the bigger size layers and the respective
deflections $\Delta$ and $\Delta'$ are given in table 14. These values for the smaller size layers are given in table 15.

In the layers of 105 cm size, the maximum values of yield and ultimate loads are for the cement concrete slabs of 10 cm followed by 5 cm thick cement concrete slab and then others. For the water-bound macadam layers, the yield as well as the ultimate loads at failure are proportionate to the thickness of the layers. The ratio of $P_u / P_y$ are 2.0 for the layers, while the ratio of deflections $\Delta / \Delta'$ are 2.33, 2.13 and 2.79 for the 7.5 cm, 15 cm and 22.5 cm layers respectively. The yield load of the 22.5 cm layer of water-bound macadam and the 10 cm soil-cement slab are nearly equal but, the ultimate load of the former is only 70% of the latter.

For the soil-cement slabs of 105 cm size, the ratio of yield load for the 15 cm and 10 cm slabs is 1.43, but, the ratio of the ultimate load is 0.873. For the 15 cm soil-cement slab of 28 days curing, the yield and ultimate loads are higher than the values for the 15 cm slab of 7 days curing. For all the layers, excepting the cement concrete slabs of 5 cm thickness of both sizes, the ratios of deflections at ultimate and yield loads $\Delta / \Delta'$ are greater than the ratios of the respective ultimate load to the yield load. For the cement concrete slabs of 105 cm size, the ratios of yield loads for the 10 cm and 5 cm slabs is 3.65 and the ratio of ultimate loads for these slabs is 2.21 only. The breaking load for the 5 cm cement concrete slab comes between the values for the 10 cm and 15 cm soil-cement slabs of 7 days curing and the 15 cm soil-cement slab of 28 days curing. It is only 1.06 times the ultimate load for the 10 cm soil-cement slabs and respectively of 3.27, 2.22 and 1.635 times the ultimate load for the 7.5 cm, 15 cm and 22.5 cm, water-bound macadam layers. For all the layers, the deflection
values at yield loads reduced with increase of layer thickness, but, the deflections at ultimate loads decreased with thickness for cement concrete and soil-cement slabs and increased for the water-bound macadam layers. The values of \( P_u/P_y \) for the different layers varied from 1.35 to 3.0. The maximum value is for the 10 cm soil-cement slab and the minimum for the 10 cm cement concrete slab.

B) **60 cm x 60 cm Slabs of Cement Concrete and Soil-Cement**

For the cement concrete slabs of 5, 7.5 and 10 cm and the soil-cement slabs of 5, 10, 15 and 20 cm, the variations of yield load and ultimate loads \( P_y \) and \( P_u \) are linear, indicating uniform rate of increase with thickness. For the soil-cement slabs, there is a deviation from linear trend in the ultimate load curve after 15 cm thickness. For the cement concrete slabs, the increase in \( P_y \) values from 5 cm to 10 cm slabs is at the rate of 577 kg/cm of layer thickness and the increase in \( P_u \) value is 709 kg/cm. For the soil-cement slabs, the rates of increase of \( P_y \) and \( P_u \) are 115 kg and 182 kg per centimeter of slab thickness respectively.

The yield loads of 7.5 cm and 10 cm cement concrete slabs are 1.84 and 3.1 times the respective values for the 5 cm slab. The ultimate load values for the 7.5 cm and 10 cm cement concrete slabs are respectively 1.91 and 2.57 times the \( P_u \) values for the 5 cm slab. The \( P_y \) values of the 10, 15 and 20 cm soil-cement slabs are respectively 2.44, 3.68 and 5 times the \( P_y \) values of the 5 cm slab and the \( P_u \) values of the respective values thicknesses are 2.32, 3.22 and 3.41 times the values for the 5 cm slab.

The yield load \( P_y \) values of the 5 cm and 10 cm
Cement concrete slabs and the soil - cement slabs of 10 and 15 cm of 60 cm size are more than the values for the corresponding layers of the larger size (105 cm) slabs. But, the ultimate loads for the smaller slabs are less than the corresponding ultimate load values of the bigger slabs. Of course, they are nearly equal in the case of 15 cm soil - cement slabs of 7 days curing. The large size slabs being more elastic, deflect better and keep in contact with the subgrade, which requires greater load for development of the initial tensile crack (yield load condition), but, at the ultimate stage, the smaller slabs being more stiff, break at an earlier load.

In the smaller size slabs, the 5 cm cement concrete slab is 3.18 times better in yield load capacity and 2.03 times better in ultimate load capacity than the 5 cm soil - cement slab. The yield and ultimate load capacities of 10 cm cement concrete slab are similarly 4.02 times and 2.24 times better than the respective values of the 10 cm soil - cement slabs.

It may be noted, that while in the bigger slabs (105 cm size), the deflection values $\Delta_y$ and $\Delta_u$ decreased with increased thickness of layer, these values increased with layer thickness for the smaller slabs (60 cm size). For the cement concrete slabs, the values of $P_u/P_y$ varied from 1.37 to 1.685 and the values of $\Delta_u/\Delta_y$ varied from 1.625 to 3.12. These values ranged from 1.77 to 2.59 and from 2.379 to 2.67 respectively for the soil - cement slabs.

The ratios of ultimate and yield loads for cement concrete pavements of 12.5 cm to 20 cm thickness, at interior region reported by Seera (Ref. 104) varied from 1.88 to 2.27 and the actual values of the yield and ultimate loads for a 12.5 cm slab were reported as 7450 kg and 15700 kg respectively.
7. 06 C STIFFNESS VALUES OF LAYERS AT YIELD AND BREAKING ON ULTIMATE LOADS (Ref. Table 41)

The values of stiffness of various layers on sand subgrade in Masonry tanks at yield load and breaking loads are given in Table 41. The $S_y$ and $S_u$ values as well as the $S_u/S_y$ ratios are given, with the values of $T/B$ and $T/a$ for the respective layers.

Out of all the layers, the $S_y$ value is maximum for the 15 cm cement concrete slab ($B=105$ cm) and minimum for the 5 cm soil - cement slab ($B=60$ cm / 7 days cured.) The next highest value is for the cement concrete slab of 105 x 105 x 10 cm size.

The maximum and minimum values of $S_u$ are for the 10 cm cement concrete slab and 5 cm soil - cement slab, respectively.

The second highest value is for the soil - cement slab of 15 cm (28 days curing).

For the water - bound macadam layers, the $S_y$ and $S_u$ values increased with increase in layer thickness of 7.5 cm to 22.5 cm but not in the same proportion. The increase in $S_u$ values shows a more definite and gradual trend, than for the $S_y$ values. The $S_y$ values of the 7.5 cm and 15 cm W B M layers are one fourth of the respective values for 60 x 60 x 7.5 cm cement concrete and 105 x 105 x 15 cm soil - cement slabs. The $S_u$ values for these W B M layers are 1/3.5 and 1/3.0 of the $S_u$ values of the corresponding cement concrete and soil - cement layers mentioned above.

The stiffness values $S_y$ and $S_u$ of 10 cm cement concrete slab (105 cm size) are about 4 times the respective values of corresponding 5 cm cement concrete slab. This ratio seems
to tally closely with the values of $T^2/a \times b$ for the respective slabs. As in the case of water-bound macadam layers, there seems to be a definite trend in the values of $S_y$ for the cement concrete and soil-cement slabs. They increased with increase in layer thickness. The $S_y$ values for the 60 x 60 cm size cement concrete slabs decreased with thickness, while the $S_y$ values increased from 5 to 7.5 cm thickness and again decreased from 10 cm slab.

A definite trend of increase is indicated in the $S_y$ values for the soil-cement slabs. The value for the 15 cm soil-cement slab of 28 days curing is 1.73 times and 2.31 times the $S_y$ values of the 15 cm and 10 cm soil-cement slabs of 7 days curing. The $S_y/S_y$ ratios of $S_y$ values for the above soil-cement slab are 2.82 and 2.32 respectively. The ultimate stiffness values of the 10 cm soil-cement slab and 5 cm cement concrete slab of 60 cm size are nearly equal. The stiffness at yield load for the 10 cm soil-cement slab is more than the value for the 15 cm soil-cement slab of 105 cm size. This is perhaps due to the greater flexibility of the 10 cm slab and the subgrade combination, allowing it to deflect more and yield at a much higher value of load than the 15 cm slab (Ref. Table 14) which is stiffer and develops crack at a lower load.

The stiffness values at breaking loads for the soil-cement slabs of 60 x 60 cm size increased steeply from 5 cm to 10 cm slab but have a gradual increase from 10 cm to 15 cm and 15 cm to 20 cm. The stiffness values at yield also rise steeply from 5 cm to 10 cm, but remain nearly equal for higher thicknesses.
The $S_u$ value for the 20 cm slab is nearly equal to the stiffness of the 5 cm cement concrete slab of 105 cm size. The $S_u$ value for the 20 cm soil-cement slab is 2.48, 1.54 and 1.04 times the respective $S_u$ values for the 5 cm, 10 cm and 15 cm soil-cement slabs. The stiffness at yield $S_y$ for the 20 cm soil-cement slab is 2.29, 0.97 and 1.22 times the $S_y$ value for the 5, 10 and 15 cm slabs.

The $S_u / S_y$ ratio values for the different layers range from 0.445 to 1.127, the lowest ratio being for the 15 cm soil-cement slab of 28 days curing and the highest value is for the 5 cm cement concrete slab of 105 cm size. Low values indicate a close range between the yield and the ultimate stage and a high value indicates greater interval of loading between these two stages for the layer.

Assuming the stiffness values $S_y$ and $S_u$ for the 7.5 cm water-bound macadam layer as unity, the relative stiffness values for the various layers to 15 in table 41 are 1.40, 6.76, 4.54, 3.96, 3.28, 5.70, 4.69, 1.32, 0.945, 2.24, 2.17, 2.16, 1.00, 1.15 and 1.90 and the relative values of $S_u$ for the various layers will be, 1.335, 7.25, 2.93, 3.35, 3.22, 2.98, 4.04, 6.35, 0.755, 1.37, 1.80, 1.86, 1.00, 1.26 and 1.59 respectively. These values suggest the equivalencies for the layer from ultimate or yield load criteria. The range is very close for all the layers except the cement concrete slab of 60 x 60 x 5 cm size and soil-cement slab of 105 x 105 x 10 cm and the soil cement slab of 60 x 60 x 15 cm, the maximum discrepancy being for the last one.
The crack patterns at breaking loads for the cement concrete and soil-cement slabs are shown in figures 10.1 and 10.2. The mode of failure of water-bound macadam layers at ultimate load is physically observed by excessive depression in the central portion of the layer and indicated by very rapid movement of the deflection dials with slight increment of load since the plate diameter of 15 cm is very small, heavy shear occurs around the periphery of the plate, causing punching of the layer. At yield no clear indication could be seen on the water-bound macadam layers, but can be only known by the starting of deviation from uniform to non-uniform rate of deflection. At ultimate load, for the layers of 22.5 and 15 cm, a circular cleavage in the layer at a distance of 10 to 15 cm around the plate could be seen. For the thin layer, radial cracks or separation lines were observed, emanating from edges and spreading towards the middle portion of the layers.

The yield of the cement concrete slabs and thick soil-cement slabs is indicated by the occurrence of the initial tensile crack at bottom of slab, causing a sudden jump of the dial pointers and a reduction in the load value. For thin soil-cement slabs, the yield stage is indicated by constancy of loads for continued deflection, with slight increase of further loading the deflection value increasing rapidly. Gradually, the tensile crack at bottom extends and appears at the edges of the slab. Fine cracks, then developed at the top of the slab, indicating the reaching of the ultimate stage. They spread and join the cracks at the edges. Once the full length of the cracks develop from
centre to the edges, increase of load beyond the ultimate of breaking stage, causes widening of the cracks. In thick layers, the cracks become very wide, causing a separation of slab into fragments. Also they show punching at the periphery of the loading plate. The crack lines for the cement concrete slabs are straight lines and are observed to be near to the central line of the slab, causing breaking of the slabs into equal fragments. For the soil-cement slabs, the crack lines may be slightly curved or irregular (fig. 10.1 C, D, E, F and G). More than four cracks are seen to develop radially in different directions at the ultimate or breaking loads. In the thin soil-cement slabs, punching under the plates and for the thin cement concrete slabs, fragmentation near the central portion was observed (fig. 10.2 C). Some of the crack patterns in the cement concrete and the soil-cement cracks can be seen in the photographs.

7. 07. A. DEFORMATION BASINS FOR THE 105 cm x 105 cm SIZE SOIL-CEMENT AND CEMENT CONCRETE SLABS

The maximum deflection values, the area and the volume of deflection basin, at different loading intensities on 15 cm dia plate, for the large size cement concrete slabs and soil-cement slabs are given in table 18 and the results are plotted in figure 12. The increase of the volume of deflection basin and the maximum value of deflection with increase in loading pressure are the steepest for the cement concrete slabs. The curve showing the increase of values are the flattest for the 10 cm thick cement concrete slab. They become steeper only after loading intensity of 28 kg/cm², i.e., at a load of 4860 kg, which is also just above the yield load for the 10 cm cement
concrete slab. The steepness of the curve for the 15 cm soil-cement slab (28 days curing) is slightly more than the steepness for 10 cm cement concrete slab. The curvature of deflection and the volume curves for the 15 cm soil-cement slab increased at a pressure of 12 to 15 kg/cm², i.e., at a load of 2120 kg, to 2760 range, indicating a value between the yield load and the ultimate load. The transition is over longer duration, unlike the case of cement concrete layers. For the soil-cement slabs the increase of deflection and the deflection volume are the steepest for the 15 cm slab of 7 days curing. The curves for the 10 cm soil-cement slab are below that of 15 cm slab. This is because of the rigidity of the steeper layer and a little flexibility of the 10 cm slab, which provides a better support by the subgrade. In all the cases, the deflection curves (dotted) for a particular layer, followed closely the trend of the curve for the volume of the deflection basin. From the area of deflection, the radius of area of contact of the slab with the subgrade can be calculated. Using this volume and maximum value of deflection, for the particular value of loading pressures, the curvature of deflection basin can be calculated.

7. 07 B. DEFLECTION CONTOURS FOR THE CEMENT CONCRETE AND SOIL CEMENT SLABS OF 105 cm x 105 cm ON SAND SUBGRADE (Ref. Fig. 11.1 to 11.5)

The patterns or trend of deflection contours for two cement concrete slabs of 5 cm and 10 cm and three soil-cement slabs of 10, 15 cm sizes of 7 days curing and 15 cm slab of 28 days curing, are given in figures 11.1 to 11.5. The contours have been plotted by interpolation and are shown for one quadrant only under each intensity. The contours for the 5 cm
cement concrete slab indicate that with the increase of loading intensity, the contours change from concavity inwards to straight shape and then to concavity outwards. The corners of the slab get turned up more and more and reduce the effective area of contact of the slab with the subgrade. The contours get crowded near the centre and also the curvature gets steepened with increase of loading intensity. The negative contours in the lifted portions of the slab, however, remain straightened.

For the 10 cm cement concrete slab, the contours are shown in figures 11.3 A and 11.3 B, for eight intensities of loading. The contours become steeper with increase in loading intensity, indicating the rapid depression at the centre, but beyond the pressure of 15,181 kg/cm² (203.52 psi) the contours become less steeper, though the deflection values are higher. This is perhaps due to the slab getting a full support from subgrade beyond this limit of loading. Also no lifting of the corners is indicated as all the contours are positive. The rate of deflection of the slab is more than the rate of increase of the load.

The 10 cm soil-cement slab (figure 11.2) behaved in a similar manner as the 5 cm cement concrete slab, by indicating upward lifting of corners at higher loading intensity, but all the contours are bent inwards only. The depression of the slab with increase in loading intensity is much less than that for the 5 cm cement concrete, but about 2 times more than the depression of the 10 cm cement concrete slab.

For the 15 cm soil-cement slab (28 days curing), the contours have rapidly steepened with increase of pressure beyond 7,58 kg/cm² (101.76 psi). All the contours are positive.
indicating no upward lifting of the corners (Figs. 11.4).

The central depression of the slab are less than half the values for the 15 cm slab of 7 days curing, upto a pressure intensity of 15.18 kg/cm$^2$. The rate of depression is also gradual upto 11.376 kg/cm$^2$.

For the 15 cm soil-cement slab of 7 days curing (Fig. 11.5), the deflection contour lines are flattered than the curves for the corresponding soil-cement slabs of 28 days curing, though the central depression increased at a greater rate. Lifting of the slab corners with increased loading intensity is indicated, though the extent is not as much as in the case of 5 cm cement concrete layer. This is because of the flexibility of the layer, which allowed it to rest on the subgrade evenly with increase of loading intensity.

7.07 C. RADII OF DEFLECTION BASINS AND THE LOAD ENERGY AT DIFFERENT INTENSITIES.

The curvatures of the deflection bowl for the various layers under loading have been assumed to be circular. The radii of curvatures $r$ in meters, calculated as indicated in para 0.07 A and the load energy $E_1$ values in kg/cubic centimeter volume of the deflection basin are tabulated in table 18 A.

From the results, rapid decrease of radius of curvature with increase in pressure is indicated for the 15 cm soil-cement slab (28 days curing) followed by cement concrete
slab of 10 cm and then the others. Gradual or minimum decrease of radius of curvature is indicated for the soil - cement slab of 15 cm (7 days curing). The radius values for the 15 cm soil - cement and 10 cm cement concrete slab are nearly the same (300 m) at a loading intensity of 19 kg/cm². Similarly the 15 cm soil - cement slab of 7 days and 10 cm soil - cement slab maintain equal curvatures at a loading intensity of 22 kg/cm².

For the cement concrete slab of 10 cm the decrease of radius of curvature seems to be nearly linear, beyond the loading intensity of 11 kg/cm². In general, the radius of curvature at different levels of loading indicate the magnitudes of strains at the various levels, the yield or the end of the elastic range for the layer may be at the stage, where the trend of the variation in curvature of the deflection basin changes.

The values of the load energy per unit of deflection volume (E₁) show different trends for the cement concrete and the soil - cement layers. For the 5 cm cement concrete slabs the value of E₁ increased with higher intensity of loading, but in a much smaller proportion. The uniformity of this trend indicates continuous deflection. For the 10 cm cement concrete slab, the E₁ value increased up to the load intensity of 11.376 kg/cm² and then maintains constancy up to a pressure of 30,454 kg/cm² and then decreases suddenly. This may be due to the increasing subgrade support with deflection in the beginning, then stabilisation of the support and reaching the initial yield stage at the last value of the loading pressure. For the soil - cement slab of 10 cm and 15 cm,
similar trend i.e., generally increase in $E_1$ value with increase in loading pressure is observed. The maximum decrease is for the soil-cement slab of 10 cm and the least value is for the 15 cm slab of 28 days curing. The values of $E_1$ are greater for the soil-cement slabs up to a pressure of 7.586, but at higher values the cement concrete slabs of 10 cm maintain greater load energy than soil-cement slab. In this higher stage, the 15 cm soil-cement slab (28 days curing) comes next to the 10 cm cement concrete slab. Both of them, thus, exhibit their greater stiffness and more uniform contact with subgrade, at higher levels of deflection.

7.98. **DEFLECTION COEFFICIENTS FOR DIFFERENT LAYERS ON SAND SUBGRADE IN MASONRY TANKS**

If the deflection $w$ of a layer is expressed as $W Q x p$, the deflection coefficient $Q$ for the layer will be $w/p$, where $p$ is the intensity of loading under particular configuration. As described in photographs 6.05 to 6.08, the deflection coefficient values have been computed by different theories for flexible, semirigid and rigid layers and presented in tables 23 A to 25 C. From the deflection test results on these layers, the experimental values of these coefficients are also calculated and given in tables 26 A to 32. Abstract of the computed values and the experimental values are given in tables 27. Since the equations of deflection by Uesheta, Naussbaum, Burmister and Westergaard and other theories used in this study, deal with only a single circular plate loading, the dual and dual-tandem loading configurations are also converted into equivalent circular loading plates, in computing the coefficients. Hence the computed values of coefficients
for configuration (1) and (4), whose areas are equal, happen to be same. However, they are also separately shown in the tables to have a comparison with the experimental values derived from actual test results. The trend of these theoretical and experimental values for different layers is discussed below. The deflection coefficients reported in this study are nothing but the deflection values at unit pressure intensities.

A) DEFLECTION COEFFICIENT $Q_f$ FOR WATER BOUND MACADAM LAYERS

(Theoretical values of deflection coefficients $Q_f$ decreased with increased thickness under all configurations, by the equations of Uesheta, Naussbaum and Burmister as well. The decrease in the values is more from layer thickness of 7.5 to 15 cm than from 15 cm to 25 cm under all the configurations and by all the theories. The range of decrease is more under configurations (1) and (4) than under (2) and (3). Values by Burmister's equation are the greatest and values by Naussbaum's equation are the least for all thickness and configurations. Maximum range of decrease with increase in thickness is by Uesheta's equation and the minimum range is by Naussbaum's equation. The respective ratios of $Q_f$ values by Burmister's equation and Uesheta's equation are uniform for all the configurations and different thicknesses. Only for the ratio of the thickness of 7.5 cm under configuration (1) is less than others. The values of the ratio by Burmister's and Uesheta's equation range from 1.5 to 2.36 and Burmister's Naussbaum's range from 2.75 to 3.5. With in the layers and configurations adopted, the theoretical values of $Q_f$ by Uesheta's equation varied from 0.217 to 0.0895, values by Naussbaum's equation from 0.0136 to 0.0435 and by Burmister's...
The experimental values of $q_f$ at different deflection levels for different layers thicknesses and load configuration are given in Tables 26 A and the abstract in Table 27 A II.

The values of $q_f$ increased with increase in deflection level for each thickness and configuration, the increase being maximum for thickness of 22.5 cm followed by 15 cm and 7.5 cm layers.

The $q_f$ values decreased with increased layer thickness, the decrease being maximum under configuration (1) followed by configuration (4), (3) and (2) in the same order for all the deflection levels. For the layer thicknesses of 7.5 cm to 22.5 cm, the $q_f(1)$ values varied from 0.01686 to 0.03983, the $q_f(2)$ values from 0.00949 to 0.0211, the $q_f(3)$ values from 0.0129 to 0.02334 and the $q_f(4)$ values from 0.01404 to 0.02879. In general, the experimental values of $q_f$ within the elastic deflection of 0.07 cm under different layer thicknesses and configurations, are much smaller than the theoretical values of $q_f$ by Burmister's and Uesheta's equation, but a little closer to the values of Naussbaum's equation. The closeness is more for the configurations (1) and (4) than for (2) and (3). For these configurations (2) and (3), Naussbaum's values are likely to reach the experimental values of $q_f$ at deflection levels of 0.010 to 0.15 cm.

B) DEFLECTION COEFFICIENTS 'q_e' FOR SOIL-CIMENT SLABS

(Ref. Tables 27 B 1, B 2 and B 3)

The theoretical values of the deflection coefficients $q_e$ for the four thicknesses of 5, 10, 15 and 20 cm, under configurations (1), (2), (3) and (4) as calculated by the
equations of (i) Naussbaum's (ii) Justo and Khanna (iii) Burnmister and (iv) Westergaard and presented in tables 24 A, B, C, D, are abstracted in table 27 B. 1. By the first two equations, the soil - cement layers are treated as semirigid and in equation three as a flexible layer and in equation four as a rigid layer. The theoretical values of $Q_e$ by Naussbaum's equation varied from 0.00372 to 0.0525; by Khanna-Justo equation from 0.000423 to 0.0683; by Burnmister's equation from 0.0108 to 0.1033 and by Westergaard's equation from 0.00282 to 0.2502. The values by the semirigid layer theories of Naussbaum and Justo and Khanna are close to each other, the latter being generally higher for thickness s of 5 and 10 cm and the former values higher for 15 and 20 cm slabs. Values by Burnmister's and Westergaard's equation are much higher than the values by Naussbaum or Justo-Khanna equation. Amongst the values by Burnmister's equation and Westergaard's equation, the former values are higher under configurations (2) and (3) generally and the latter are higher under configurations (1) and (4). Values of $Q_e$ by all the methods are maximum under configurations (1) and (4) followed by (3) and (2) in that order. The $Q_e$ value decreased with increase of slab thickness by all methods, under all configurations. The decrease for slabs of 5 cm to 20 cm is by 8 to 9 times by Naussbaum's theory; by 10 to 11 times under Justo-Khanna theory; by 5 to 6 times with Burnmister's theory and 7 to 8 times by Westergaard's theory. The rate of decrease is more between 5 cm to 10 cm slabs than from 10 cm to 15 cm or 15 cm to 20 cm slabs.

The experimental values of $Q_e$ for the soil - cement slabs of 60 x 60 cm size are shown in table 26 B and for the
105 x 105 cm size slabs in table 26. The abstracts are given in tables 27 B 2 and 27 B 3 respectively. For the 60 cm slabs of 5 to 20 cm thickness and deflection range of 0.02 cm to 0.08 cm, the $Q_{s(1)}$ values ranged from 0.01538 to 0.02846; the $Q_{s(2)}$ values from 0.002933 to 0.01686; the $Q_{s(3)}$ values from 0.007701 to 0.01714 and the $Q_{s(4)}$ values ranged from 0.01325 to 0.02517. At each deflection level, the $Q_s$ values decreased with increase in slab thickness; the maximum range of decrease occurring from 5 to 10 cm and a small decrease for the other thicknesses. It may be seen that the values of $Q_s$ for the respective thicknesses under configurations adopted, did not appreciably increase with higher deflection level, as they did in the case of water bound macadam layers. The increases may be only between 5 to 10 for the 5 and 10 cm slabs under a deflection rise by four times. The experimental values of $Q_s$ did not tally with the theoretical values by any method for the thickness of 5 cm, while for higher thicknesses, the values of $Q_{s(1)}$, $Q_{s(2)}$, $Q_{s(3)}$ and $Q_{s(4)}$ are somewhat closer to the corresponding theoretical values by Naussbaum's equation only and varying widely with other methods. Generally the experimental values are higher than the theoretical values for the 5 and 10 cm slabs and the theoretical values are more for the 15 cm slabs.

The experimental values of $Q_s$, under configurations (1), (2), (3) and (4) for the 10 cm and 15 cm soil-cement slabs of bigger size are evaluated only for a small deflection range of 0.015 cm to 0.035 cm. Similar trend, i.e., decrease of $Q_s$ values with increase in slab thickness and small increase with increase in deflection level, as in the case of 60 cm size, is indicated. The values for the 10 cm slabs of both sizes under
each configuration, run close to each other. The values for the 15 cm thick slab of 105 cm size are greater than the corresponding slab of 60 cm size. For the 10 cm and 15 cm slabs, the $Q_s(4)$ values are maximum, followed by the values of $Q_s(1)$, $Q_s(3)$ and $Q_s(2)$ respectively at each deflection level. At the deflection level of 0.02 cm the coefficients for the 15 cm slabs are about 2/5ths to 1/5th, 1/2 and 2/3rds of the respective coefficients for the water bound macadam layers of 15 cm under the configurations (1), (2), (3) and (4) respectively.

C) DEFLECTION COEFFICIENTS $Q_s$ VALUES FOR THE CONCRETE SLABS. (Ref. Table 27 C1, C2 and C3.)

Theoretical values of the deflection coefficients calculated by (i) Watergaards (ii) Wang and Sargious equations as rigid pavements and (iii) by Burmister's equations as a layered pavement are given in tables 25 A, B, and C and abstracted in table 27 C (1). Values by Watergaard's and Burmister's equations are irrespective of the layer sizes, while they are shown separately for the 60 cm and 105 cm sizes for the Wang - Sargious' equation. It is interesting to note that for the 5 cm, 7.5 cm and 10 cm concrete slabs the coefficients $Q_c$ by Watergaard's equation considering the slab as rigid and the value by Burmister's equation considering the slab and the subgrade as two-layer system, tally closely with each other, the variation being not more than 20% in any case. The values by Watergaard's equation are more under configurations (1) and (4) and those by Burmister's equations for 5 cm are more under configuration (3) for all thicknesses and under configuration (2) for the 7.5 and 10 cm slabs. Values by Wang - Sargious' equation, which is originally meant for
uniformly loaded slat, are much smaller than the values by Bannister or Westergaard. They are also constant for different thicknesses. Values by Bannister and Westergaard's equation reduced with increase in thickness under all configurations the decrease being maximum under configuration (2) followed by configuration (3), (1) and (4) respectively. Values by Wang-Sargious's equation for the 60 cm slab are about one and half to two times the values for the 105 cm slabs. Maximum values of $Q_c$ are under configuration (1) and (4) followed by (3) and (2). This shows the trend of greater deflection coefficients with greater area of loading. The computed values of $Q_c$ for 5 cm and 7.5 cm cement concrete slab by Westergaard's equation tally with computed values of $Q_f$ for 7.5 cm and 15 cm water bound macadam layers by Naussbaum's equation, under configurations (1) and (4) while they are half to one third the respective values under configuration (2) and (3). Thus the equivalencies under deflection varied from thickness to thickness and for different loading configurations.

The experimental values of $Q_c$, for the 60 cm cement concrete slabs of 5 cm and 10 cm thicknesses, for deflection levels of 0.01 to 0.11 cm varied from 0.01657 to 0.04345 under configuration (1); from 0.004343 to 0.00560 under configuration (2); from 0.007704 to 0.01287 under configuration (3) and from 0.01242 to 0.01876 under configuration (4). The $Q_c$ (experimental) values for the 60 cm cement concrete slabs reduced with increase in deflection level only for the 5 cm slab under configurations (1), (2) and (3), but for other thicknesses generally values increased, although the trend is not uniform. The reduction of $Q$ values with higher slab thickness is more under configurations
(1) and (4) than under configurations (2) and (3). The experimental values of $Q_c$ (refer table 27 C 3) for the 105 cm slabs of 5 and 10 cm thickness varied from 0.004968 to 0.05005 under configuration (1); from 0.002554 to 0.01662 under configuration (2); from 0.002558 to 0.0316 under configuration (3) and from 0.007603 to 0.03708 under configuration (4). The values reduced with increased deflection level under all configurations for the 5 cm slabs, but they remained either constant or increased by a small extent for the 10 cm slab. The maximum values of $Q_c$ are under configuration (1) followed by configurations (4), (3) and (2) for the 5 cm slab and the maximum value is under configuration (4) followed by configurations (1), (2) and (3) for the 10 cm slab in that order. The $Q_c(1)$ values decreased by 10 times from 5 cm slab to 10 cm slab. For these slabs the $Q_c(2)$ values decreased by 5 to 6 times, the $Q_c(3)$ values by 10 to 11 times and the $Q_c(4)$ values by 3.5 to 7 times.

7.09. EQUIVALENCIES OF LAYERS IN HOLLOW TANKS

A) Values on the basis of equal deflection level

(Refer table 43 A.)

With 7.5 cm water bound macadam layer as the base (equivalency of one) the relative values of equivalencies of the different layers on the sand subgrade varied from 0.67 to 7.95 under configuration (1); from 0.378 to 3.24 under configuration (2); from 0.525 to 7.71 under configuration (3) and from 0.894 to 4.57 under configuration (4). The maximum values of 7.95 are for 105 x 105 x 10 cm slab of cement concrete under configuration (1) and the minimum value of 0.378 is for the 15 cm water bound macadam layer under configuration (2). Within the limits of
deflection (0.02 cm to 0.06 cm) consider for each layer, the equivalencies are different under different configurations. The lowest values are generally under configuration (2) and highest values are either under configuration (1) or (4). Under each configuration the values of equivalency increased with deflection level, for the soil - cement and cement concrete slabs. But the values for the water bound macadam layers are of 7.5 and 15 cm, decreased with increase in deflection level and showed a slight increase for the 22.5 cm layer. Nearly uniform values of equivalencies are indicated for all deflection levels and configurations for (i) 60x60x20 cm soil - cement slabs (ii) 60x60x10 cement concrete slabs. Maximum variations in the values (2.99 to 7.95) is obtained for the 10 cm cement concrete slab of 105 cm size.

E) Values on the basis of Equal loads (Ref. Table 43 B)

The equivalency values of the respective layers on the basis of equal loads, are slightly more under the respective configurations than the corresponding values from equal deflection basis. The trend of variation between the different configuration is similar in both cases. There is always an increase in the equivalency values from the load load of 500 kg to 1000 kg load, for all the layers, except for the 7.5 cm water bound macadam layer under configurations (3) and (4) considering both the loads. The values ranged from 0.687 to 8.0 under configuration (1); from 0.284 to 3.86 under configuration (2); from 0.561 to 7.76 under configuration (3) and from 0.975 to 5.23 under configuration (4). Generally there is an increase in the equivalency values with increase in the layer thickness for each material, excepting the water bound macadam layer under configuration (2). Out of all the layers, the cement
concrete slab of 105 cm x 105 cm x 10 cm size has maximum range of (3.332 to 8.0) of equivalency values and the minimum range of (0.529 to 1.244) is for the 5 cm cement concrete slab of same size.

C) VALUES ON THE BASIS OF YIELD AND ULTIMATE STAGES

The values of equivalency on the basis of loads at yield and ultimate failure stages and stiffness values at yield and ultimate stages, shown in table 43 C, are only for the configuration (2) (15 cm dia plate). Under these four criteria the range of equivalency values for the water-bound macadam layer is 1.00 to 1.999; for the soil-cement slab it is from 0.998 to 5.70 and for the cement concrete it is from 1.834 to 10.72. The values under these four criteria are within close range of variation are for the cement concrete slabs of 15 cm (28 days curing). In general, the equivalencies of the layers at yield and ultimate stages, appeared to be much higher than the values on the basis of equal loads or equal deflection within elastic limits.

D) GENERAL

From the various criteria considered and within the scope of the present investigation, the equivalency of values varied from (1) 0.284 to 2.80 for the W B M layers 7.5 to 22.5 cm (2) 0.492 to 5.70 for the 5 cm to 20 cm soil cement slabs (7 days curing) and (3) 0.498 to 10.72 for the cement concrete slab of 5 cm to 10 cm. The maximum value of 13.2 is, however, for the soil-cement slab of 15 cm (28 days curing) range of values for which, at the yield and ultimate stage is from.
The values computed are only with respect to sandy subgrade. Under soil subgrade, the values are likely to be different, probably less. The variation of the equivalency values under the separate aspects considered for slab only a range of equivalency values could be ascribed to a particular material and not a single value. For the different types of layers, in this study, the range of values obtained are shown in Table 43B.

7.10. **Elastic Deformations of Model Layers**

The load deflections of the various model layers under the single plate (50 mm dia) loading are compared, layer-wise. The influence of the subgrade, the thickness of the layer, rate of loading are pointed out. As the data presented in the tables and figures are self-explanatory, only the trends are discussed.

A) **Water-bound Macadam Model Layers** (Ref. Table 9A)

At each deflection level and rate of loading, the load increased from layer thickness of 12.5 mm to 19 mm but again decreased from 19 mm to 29 mm for both the subgrades. A similar trend was indicated by the large size WBM layers. The load values for the layers on the sand subgrade are always higher than the values on the soil subgrade. The increase of load from soil subgrade to sand subgrade is of the order of 2 to 2.5 times at higher level of deflection and higher rate of loading strain. At lower deflection levels, and strains, the increase of load is about 1.25 to 1.5 times for 19 and 25 mm layers.

For the thickness of 12.5 mm layer, the loads are nearly equal for soil and sand subgrades. The increase of load with increase in deflection level is nearly the same for the different layer
thicknesses. The increase is nearly of equal proportion to
increase of deflection level, for sand subgrade, but of smaller
proportion in case of soil subgrade. The values of loads
increased with rate of strain generally, but there is a small
decrease beyond the rate of 0.25 mm/min, at the lower level
of deflection. Under all the variables, the 12 mm water-
bound macadam layer showed greater load capacity than the 12.5
or 26 mm layers.

B) Soil – cement model layers (Ref. Table 10 A)

The loads taken by the soil – cement layers, under the
same level of deflection, loading rate, subgrade, layer thickness,
are much higher than the values for the corresponding WBM
model layers. The improvement of strength seems to range from
2 to 4 times. The trend of load deflection, with reference to
layer thickness and subgrades, seems to be different from that
of the WBM layers. The load values for the 19 mm thick soil-
cement layer, are found to be between the values for the 12.5 mm
and 26 mm thick layers. The layer of 12.5 mm thickness seems
to be greater in strength by its flexible action, creating full
subgrade support, while the 26 mm thick layer exhibits greater
capacity by its slab action. This may be the reason for these
two layers showing greater capacity.

The increase of load with deflection level is much more
for the soil – cement layers than the WBM model layers, especially
at lower rate of strain. Generally the load values for layers
on sand subgrade are higher than the values in case of soil
subgrade. But the values for the soil subgrade, for the smaller
thicknesses of 12.5 mm and 12 mm are higher, at deflection level
of 0.250 mm with 0.05 mm/minute rate of strain and at deflection of 0.125 mm with 0.25 mm/minute and 0.50 mm/minute strain. Thus there seems to be the effect of transition in strain rate and level of deflection on the behaviour of the smaller size soil-cement layer.

C) CEMENT MORTAR (1/3) MODEL SLABS (Ref. Table 11 A)

The values of loads at the two levels of deflection and the four rates of strain for the 19 mm and 26 mm cement mortar slabs are nearly 1.5 to 2 times the values for the corresponding soil-cement layers. The ratio is more at smaller rates of strain and lower level of deflection. Within the cement mortar slabs, the increase in load from 19 mm slab to 26 mm slab is more with the soil subgrade than with the sand subgrade. It is also more at smaller ratios of strain and lower level of deflection.

The load capacity of the cement mortar model slabs, did not show appreciable variation from soil subgrade to sand subgrade, as in the case of WBM and soil-cement layers. At deflection level of 0.125 mm with strain rate of 0.05 mm/min, and at both the deflection levels and strain of 0.025 the values of the load capacity of the slabs are more with soil subgrade and for the other variables the values are more for the sand subgrade. This again indicates the influence of the level of deflection and greater strain, with the transition effects on the load behaviour of the rigid model layer.

D) PERSPEX MODEL PLATE: - (Ref. Table 12 A)

Four sizes of single loading plates have been used for deflection tests on this model. Also a high value 1.25 mm deflection level is also adopted. Considering the loading plate size of 50 mm dia, the loads on a perspex plate 12.5 mm
thickness, at deflection level of 0.25 mm are higher than the values for 12.5 cm thick W B M model layer, but lower than the values for the 12.5 mm soil - cement and cement mortar model layers.

Under all the loading plate sizes the load increased with increase in rate of strain from 0.025 to 0.05 values, beyond which the improvement is not appreciable. A clear trend is seen in the effect of subgrade and plate diameters. At deflection level of 0.25 mm, the loads are more with the sand subgrade than with the soil subgrade, under the plate size of 72 mm and 50 mm. But the load values with the soil subgrade are more than those with the sand subgrade under loading plate sizes of 38 mm and 24 mm. At deflection level of 1.25 mm, the load values for sand and soil subgrades varied only within 5 to 15 %, while they differed by about 80 - 100 % at the deflection level of 0.25 mm. Except, under the loading plate size of 38 mm, for all other loading plates, the values are more for the sand subgrade. With the soil subgrade the maximum value of the load is under loading size of 50 mm, and with the sand subgrade the maximum load is with 72 mm dia plate. There seems to be more pronounced effect of the loading plate size, than the rate of strain, at low deflection level of 0.25 mm. The perspex plate exhibited higher elastic behaviour, by undergoing a deflection of 1.25 mm, without failure, though at low level of deflection, its strength is not appreciable compared to equal thickness of cement mortar slab.

7. 11. EFFECT OF LOAD CONFIGURATION ON THE MODEL LAYERS

( Ref. Tables 9 B, 10 B, 11 B and 12 B. )

A) W B M layers:

For the water - bound macadam layer ( Ref. Table 9 B )
the increase of load is more from single wheel to dual wheel configuration, than from dual to dual - tandem configuration, at deflection level of 0.125 mm. Under the different variables, the load values ranged from 2.5 kg to 16 kg for single wheel configuration (b), from 5.0 to 28 for dual wheel configuration (c) and from 5.0 to 28 only for the dual - tandem wheel configuration (d). The load values under all these configurations are lower than the values under load configuration of 50 mm dia plate.

B) Soil - Cement:

For the soil - cement model layers (Ref. Table 10 A) the influence of wheel configuration is more with the soil subgrade than with the sand subgrade, also at 0.7250 mm / min deflection level strain than at 0.125 mm deflection level. The load values, under the different variables of subgrade, deflection level and layer thickness and rate of strain, varied from 7.5 kg to 57 kg on the load configuration (b) from 12 to 64 under configuration (c) and from 16 kg to 59 kg under configuration (d). Values with the sand subgrade are more under single and dual wheel configuration for the thickness of 26 mm and 19 mm and the values for the four wheel assembly are more with the soil subgrade.

C) Cement Mortar (1:3) Slab:

For the cement mortar 1:3 model slabs, (Ref. Table 11 B) that is, the rigid layer, load values for the single wheel are more than the values for dual or twin - tandem load assembly at 0.125 mm deflection level. At higher level of deflection the dual - wheel of twin - tandem carried greater capacity. Except for two or three values at the lower rate of strain, the load capacity of the cement mortar slabs with soil subgrade is higher than with the sand subgrade. The variation of load
capacity for different load configurations is more for slabs on soil subgrade than on sand subgrade. Under the different variables, the loads varied from 27 to 98 under single wheel, from 24 kg to 109 kg for the dual-wheel and from 24 kg to 92 kg for the dual-tandem load configuration. Similarly, the values with soil subgrade varied from 26 kg to 109 kg, and for the sand subgrade from 24 kg to 87 kg only.

D) Perspex Plate:

For the perspex plate (Ref. Table 12 B), there is a gradual rise in load capacity from single to dual wheel configuration and from dual to twin-tandem configuration, at deflection levels 0.125 mm as well as 0.25 mm and both the rates of strain. The variation ratio is more with soil subgrade than sand subgrade. The loads for the single wheel configuration, varied from 2 kg to 50 kg, from 2.5 to 21.5 for the dual wheel and from 3 kg to 26.5 for the twin-tandem. The variation with soil subgrade ranged from 2.0 to 15.5, and with the sand subgrade from 6.0 to 26.5. In general, the behaviour of the perspex plate is indicated to be more like an elastic flexible plate than a rigid and stiff plate, since the values under the sand subgrade have always been higher than the values under the soil subgrade, and since there is uniform-wise in load values with increase of deflection level or rate of strain.

7.12. EFFECT OF REPEATED LOADING CYCLES ON MODEL LAYERS

(Ref. Table 9 C, 10 C, 11 C and 12 C.)

The repeated load tests conducted with 50 mm dia plate only are considered here. The load values correspond to a deflection of 0.25 mm only.

A) MFB M Layers: (Ref. Table 9 C)
The load capacity increased from first cycle of loading to third cycle of loading and also from third to fifth cycle, almost equally under each rate of strain. Considerably under all the variables the increase is more for the smaller thickness layer, it is more for sand subgrade than for soil subgrade. The improvement of load from first to fifth cycle, ranged from 15 kg to 40 kg for the 26 mm layer; from 20 to 39 kg for the 19 mm layer and from 14 to 32 kg for the 12.5 mm layer.

B) Soil-cement layers: (Ref. Table 10 C)

There is a definite trend of improvement of loads from loading cycle one to cycle three and from third cycle to fifth cycle, the rise in the first case being more. This is so only at strain rate of 0.25 mm/min. At the higher rate of strain (0.50 mm/min) there is an increase from first to third and then decrease for the layer of 26 mm; slight increase or constant value for the 19 mm layer and a gradual rise as in the case of lower rate of strain for the 12.5 mm layer. The improvement of load with loading cycle is more for the soil-cement layer over sand subgrade, than with soil subgrade, though the values for the soil subgrade are more. The maximum increase with soil subgrade (54 to 70 kg) is for the 19 mm layer, and the maximum increase with sand subgrade for the 12.5 mm rate, corresponding both the rates of strain.

C) Cement mortar (1:3) Model Layers: (Ref. Table 11 C)

For both the rates of strain, both the subgrade, the load values increased from first to fifth cycle for the 26 mm layer, but they decreased from first to fifth cycle for the 19 mm layer. This may be due to the subgrade getting depressed more under the elastic thin slab in the first cycle causing
of support and hence lowering the load in further cycles.

The above increase and decrease in load values are more at the higher rates of strain than at the lower rate. There is increase of load from 19 mm layer to 26 mm layer, for both the rates of strain and both the subgrades only in the fifth cycle. In the first cycle, the values increased under first and third cycles, for soil subgrade and they decreased for the sand subgrade.

D) Perspex Plate : - ( 12.5 mm ) ( Ref. Table 12 G )

Ten number of repetitions and two levels of deflection ( 0.25 mm and 1.25 mm ) were adopted, with only one rate of strain ( 0.25 mm/min ) for this layer. At both the levels and for both the subgrades, the loads increased up to third cycle. Then they decreased up to fifth cycle, under soil subgrade. At the lower rate of strain on sand subgrade, the values remained nearly constant from 4 to 6th cycle and decreased. With soil subgrade and at lower rate of strain the load values decreased and increased for alternate cycles from the fourth cycle onwards. At higher rate of strain the decrease of increase of load for different cycles, are not systematic. Considering from first cycle of loading to tenth cycle of loading, the maximum and minimum values with soil subgrade, occurred under second and seventh cycles, respectively and under sand subgrade are under the third and first cycles. At the higher rate of strain, the maximum values are at the tenth cycle for both the subgrades, and the minimum values are at the first and second cycles, thus indicating a progressive increase for the ten cycle range.

E) Ratios of loads for different cycles of loading on Model layers : - ( Ref. tables 40 A, 40 B and 40 C)
For the W B M, soil - cement and cement mortar model layers, the ratios of loads (i) 3rd cycle to first cycle and (ii) fifth cycle to third cycle under loading configuration (a) of 5.0 mm dia plate are presented in table 40 A. For the perspex plate, on which ten cycles of loading were applied, the ratios between the consecutive even cycles of loading are presented in table 40 B. The effect of the subgrade, layer thickness and rate of strain or deflection level on the variation of these load ratios can be seen in these tables.

The $P_3/P_1$ values for the W B M soil - cement and cement mortar (1:3) model layers, varied from 0.896 to 1.319. All the values, except for the cement mortar model slab of 1.9 cm thickness, are above one, indicating a definite strain hardening between first to third cycle. The ratios are generally measured for the W B M layer, followed by the soil - cement and then the cement mortar layers. The $P_5/P_3$ values for the above model layers also indicated similar trend as $P_3/P_1$ ratios. Although they are lower than the $P_3/P_1$ values, the $P_5/P_3$ values are also above one except for the 19 mm layer of cement mortar. Maximum number of values are between 1.00 to 1.175.

For the perspex plate, the ratios of load at higher cycle to lower cycles considered, varied from 0.773 to 1.216. The trend of variation of these ratios with the subgrade are or the level of deflection is not uniform. There is also no fixed trend in the variation of ratios $P_2/P_1$ to $P_{10}/P_8$.

Table 43 C shows the values of $P_2/P_1$ for various model layers, under the loading configurations (b), (c) and (d).
...all the values of the ratio excepting 3 for the perspex plate are above one. Considering all the layers and all other variables, the ratio ranged from 0.964 to 1.159 under configuration (b); from 1.019 to 1.671 under configuration (c) and from 0.838 to 1.448 under configuration (d).

7.13. DEFLECTION COEFFICIENTS OF THE MODEL LAYERS

Calculation of the deflection coefficients for different layers from various theories are given in tables 28 A to 31 D and the abstract of the values are given in tables 36 A 1, B1, C1 and D1. The derivations of the coefficients from experimental results are presented in tables 32 A to 35 C; and the abstract of the values given in tables 36 A2, B2, C2 and D2. The trends of coefficients, theoretical and experimental values for each layer are discussed with respect to the abstracted results. The variable of subgrade is additional for the model layers.

A) Coefficients $Q_f(m)$ for Water-bound macadam model layers

(Ref. Table 36 A1 and A2)

The theoretical values of $Q_f(m)$, both under sand and soil subgrades are the highest from Burmister's equation and the lowest are from Haussebaum's equation. There is however, variation for the 19 mm thick layer on soil subgrade under configuration (d), where Uesneta's values is the highest. The trend of variation of the coefficients with load configuration is similar to the variation in case of large size water bound macadam layers. The values of the coefficients for the soil subgrade and the sand subgrade from Uesneta's and Haussebaum's equation indicated an approximate ratio of 3.0, which is also the ratio of the subgrade reaction values for the sand and soil.
subgrades. The values with sand and soil subgrades in Burmister's equation varied by a ratio of 1.25 to 2.25 only.

The experimental values of the coefficients under different variables are given in table 36 A2. The values of the coefficients for each rate of strain at deflection level, are the highest under the configuration (b) followed by configurations (a), (c) and (d) in that order. Since the derivation of the experimental values is based on the contact pressures, the effect of the configuration on the coefficients also includes the influence of the pressure \( P_m \) applied on the model layers. The experimental values of \( f(m) \) are much lower than the theoretical values under the corresponding variables, though the trend of variation with respect to load configuration, deflection level and the rate of strain are similar in both the cases. The ratios of the coefficients with soil and sand subgrades are only around 1.25 to 2 for most of the variables, which is also the trend of the results by Burmister's equation.

E) Coefficients \( g_6(m) \) for the soil-cement model layers:

(Ref. Table 36 B1 and B2)

The variations of the theoretical values of coefficients by the equations of Naussebaum, Justo and Khanna, Burmister and Westergaard are shown in table 36 B1. The values with both the subgrades by the equations of Burmister and Westergaard, are nearer to each other, than by the other two methods. The values by Westergaard's equation are the highest for layer thicknesses of 12.5 and 19 mm and Burmister's values are the highest for the 26 mm layer. The values by Naussebaum's equation are always the lowest. Coefficients by Naussebaum and Justo - Khanna
equations for layers with soil and sand subgrades indicate variations in line with the subgrade reaction values. The values by Westergaard and Burmister's equations, however, indicate a trend of variation with the soil and sand subgrade in tune with their C B A values showing a ratio of 1.5 to 2.

The experimental values of the coefficients $Q_{s(m)}$ under all the configurations (a), (b), (c) and (d) are much lower than the respective theoretical values. They are about half to one third. They are however nearest to the values by Naussbaum's equation, as in the case of the bigger size soil-cement layers. The ratios of coefficient values from soil to sand subgrade vary not only with the configuration but also the layer thickness, deflection level and rate of strain. The values are the lowest under configuration (d). Variation of coefficients with increase of deflection level or of the rate of strain are not appreciable for the thickness of 12.5 mm as for the 19 mm and 26 mm layers. The variation was more with the soil subgrade than with the sand subgrade.

C) Deflection coefficients $Q_{c(m)}$ for the cement mortar (4:1) model layers : - (Ref. Table 3d C1 and C2)

The computed values of $Q_{c(m)}$ from Westergaard's and Burmister's equation are closer for the slabs on both the subgrades than the values from Wang - Sargious equation. The closeness is more under configurations (a) and (d) than under (b) and (c) and also more for the 26 mm slab than for the 19 mm slab. The maximum values of the coefficients are under configuration (a) in all cases, followed by configurations (d), (c) and (b). The variation of the coefficients with load configuration is observed to be more than the variation with layer thickness. The ratio between values of the coefficients with sand and soil subgrades, by Burmister's equation is about
two, but it is about 1.5 times between the values by Westergaard's equation.

The experimental values of the coefficients of the cement mortar slabs also show similar trend as the theoretically computed values, as far as the variation with load configuration is concerned. The former values are much smaller (1/3rd to 1/5th), than the latter values. For the 19 mm slabs, the values of the coefficients ranged from 0.001616 to 0.009583 and for the 28 mm slab they ranged from 0.00145 to 0.008214; the minimum and maximum values occurring under configurations (b) and (d) respectively in both cases. The decrease of the coefficients is more with the increase of strain rate than with the increase of deflection level.

D) \[ \text{DEFLECTION COEFFICIENTS } q \quad \text{FOR THE PERSPEX MODEL} \]

\[ \begin{array}{c|c|c}
\text{PLATE} & \text{p(a)} & \text{q(a)} \\
\hline
\text{PLATE} & \text{p(a)} & \text{q(a)} \\
\end{array} \]

The coefficient values computed by Ueshiba's and Naussbaum's equation, considering the layer as flexible and the values computed by Justo-Khanna equation considering the layer as the semi-rigid, tally closely. The tally is better with greater areas of loading configurations (e), (a) and (d), than with the configurations having small contact areas (b), (c) and (f). Similarly the values of the coefficients from (i) Burmister's equation as flexible layer (ii) Westergaard's equation as rigid layer tally closely under configurations (e), (a) and (d). The range of the coefficient values computed from different theories is from 0.00333 to 0.06146 for the perspex plate on sand subgrade and it is from 0.00645 to 0.17220 with the soil subgrade. The maximum values of the ranges are with the largest plate diameter of 72 mm dia (configuration (e)).
from Justo - Khanna equation and the minimum values are with configuration (e), computed from Burmister's equation. The $Q_p(m)$ values by Nausbaum's equation as a flexible layer, seem to be nearer the values of $Q_f(m)$ for waterbound macadam layer of 12.5 mm thickness, under configurations (a) and (b) and to a smaller extent under the configurations (c) and (d). Similarly the values of the coefficient by Nausbaum's equation (as a semirigid layer) seem to tally with the $Q_s(m)$ values for the soil cement layers of 12.5 mm, for corresponding loading configurations. The values for the 12.5mm curve perspex and cement mortar slabs, by Westergaard's equation, do not tally. Thus it may be interpreted that the perspex plate, works as a model for the flexible and semirigid pavements and also that the Nausbaum's equation for granular and stabilised layers, are more applicable than other equations for use with the respective layers, in predicting their deflections.

The experimental values of the coefficients $Q_p(m)$ (Ref. Table 36 D2) under the rates of strain and deflection levels considered, ranged from 0.00371 to 0.03383 for the sand subgrade and from 0.00387 to 0.04847 for the soil subgrade, the maximum values of the range occurred under the configuration (e) and the minimum values are under configuration (b). As in the case of the other model layers, the experimental values of the coefficients are much lower than the computed values for the perspex plate also. The margin of difference is, however, smaller at higher rate of loading strain. The effect of the plate diameter and the subgrade can be seen from the trend of the increase or decrease of the values. At 0.25mm/min rate of
the trend is either of increase or decrease for one subgrade and the reverse for the other subgrade. At the higher rate of strain (0.50 mm/min) the coefficients decreased with increase in deflection level, under the configurations (a), (b), (c) and (d). Between the configurations (e) and (a), there is again a reversal of trend, i.e., a decrease with soil subgrade and increase with sand subgrade, with configuration (f) and vice versa with configuration (a).

7. 14. STIFFNESS VALUES OF THE DIFFERENT MODEL LAYERS UNDER ELASTIC DEFLECTION: (Ref. Tables 38)

The stiffness values of the different layers, for the two subgrades, two rates of strain and two levels of deflection are given in table 38. The variation of these values for different layer thicknesses and the four load configurations can be observed from the table. These in fact, are the combined resistances of the layer-subgrade combinations to undergo deflection or deformation. The values are expressed in kg/cm of deflection and as multiple of $10^3$. In the discussions only the values of the multiple are being mentioned for convenience.

A) Water-bound macadam model layers:

Under the different variables, the $S_m$ values ranged between 0.40 to 1.60 for sand subgrade and between 0.18 to 0.96 for soil subgrade. Thus, the ratios of the terminal values are between 1.7 to 2 and the other ratios will be in between. The stiffness values are the highest under the configuration (a) and the lowest under configuration (b). The values decreased with increase in deflection level for all the layers on the soil subgrade. With the sand subgrade, the stiffness values decreased with deflection for the 12.5 mm layer. For 19 and 26 mm layer, they decreased at the lower rate of strain (0.025 mm/min) and increased with increased level of deflection.
at the higher rate of 0.50 mm / min strain.

B) Soil - cement model layers:

The stiffness values for the 12.5 mm and 19 mm soil-cement layers, are higher under soil subgrade than under sand subgrade. But the $S_m$ values are more with the sand subgrade than with the soil subgrade for the layer thickness of 26 mm. The $S_m$ values with sand subgrade ranged between 0.80 to 3.40 and from 0.60 to 2.30 for the soil subgrade. The values generally increased with higher rate of strain and at higher deflection level under all configurations for the 19 mm and 26 mm slabs. For the 12.5 mm slab, under the configurations (b) and (c), the values remain constant for sand subgrade and decreased for the soil subgrade, with increase in rate of strain and deflection level. The maximum values of stiffness are under configurations (a) or (d) and the minimum values are under configuration (c) or (b).

(c) Cement mortar (1:3) model slabs:

The ranges of stiffness values with sand subgrade are from 1.72 to 3.48 and with the soil subgrade they are from 2.16 to 4.36. The increase of stiffness is more with the increased rate of strain than with rise in deflection level or the increase of layer thickness. With sand subgrade, at the rate of 0.25 mm / min under configuration (b), the stiffness values decreased with higher deflection level. Under configurations (a) and (d), the stiffness values for the slabs of 19 mm and 26 mm, are more with soil subgrade at lower rate of strain and less at higher rate of strain under configurations (b) and (c). For both the layers, the $S_m$ values with
the sand subgrade are more excepting one value under configuration (b) for the 26 mm layer.

\section*{D) Perspex Model Plate -}

Considering only the configurations (a), (b), (c) and (d), the range of stiffness value for the perspex plate on sand subgrade is from 0.44 to 1.80 and with the soil subgrade it is from 0.84 to 1.28. Under configurations (a), (b) and (d), at both the rates of strain and for configuration (c) at the lower rate of strain, the stiffness values increased with increase in deflection level for the soil subgrade. The values decreased under configuration (a), but increased under configurations (b), (c) and (d) for the sand subgrade. The stiffness values for the perspex plate, considered all the variables, are more than the values for the water bound macadam model layers, but lower than the values for the soil - cement layers. The stiffness values for the perspex plate, under configurations (e) and (f) (72 mm) and (38 mm) dia plates are much smaller than the values for the other configurations with both the subgrades, but they are marginally greater at lower levels of deflection than the values under configurations (c) and (d).

In contrast to values under other configurations, the stiffness values under the configurations (e) and (f), increase with rise in deflection level at both the rates of strain and for both the subgrades. Considering all the six configurations, the maximum and minimum values of stiffness with sand subgrade occurred under configurations (a) and (c) respectively and configurations (c) and (e) respectively with soil subgrade.
7.15. **ULTIMATE OR BREAKING LOADS OF MODEL LAYERS**

(Refer Table 16 A and B.)

Only the ultimate loads $P_u(n)$ and the deflections at ultimate loads are given in Tables 16 A and B, for four types of model layers. The values are the average of results on two models for each layer and thickness. For the water-bound macadam layers and the cement mortars, of each and lean mixes, on the sand subgrade, ultimate load values increased with layer thickness. The values are more on the sand subgrade than on soil subgrade for the water-bound macadam, cement mortar and lean cement mortar layers. In case of water-bound macadam layers on soil subgrade, particularly the values decreased with increase of thickness and for the soil-cement layers the values with the soil subgrade are more than with the sand subgrade. These trends indicate a uniform behaviour of the layers at ultimate load with sand subgrade, but a reverse trend in the case of flexible and semirigid layers with soil subgrade. The higher values for the water-bound macadam layers than the soil-cement or even the cement mortar slabs, may be explained by a full mobilisation of flexible layer subgrade system, than the semirigid and rigid layers. The soil-cement, having a better flexing action than the rigid slabs of cement mortar and lean cement mortar slabs exhibit a poor behaviour. The low values for the lean cement mortar slabs, also indicate the inherent weakness of the 1:9 cement mortar mix. The deflection values at ultimate loads for the water-bound macadam and soil-cement are of the same order and higher than the deflection values for the cement mortar and lean cement mortar slabs. For the
The breaking loads in general indicated an increase with decrease in loading plate diameter. The ultimate loads on cement mortar slabs at static loading, showed an increase with sand subgrade and a decrease with soil subgrade, when compared to the controlled strain test values.

The ultimate loads on water-bound macadam layers after other tests indicate a reduction in value due to excessive disturbance of the layer structure by the number of elastic tests. In case of soil-cement layers, the increase in the ultimate load values may be due to the adjustment of the sand subgrade at top level, creating a uniform support. Since the tests are very few, no definite conclusions can be taken in this regard.

7.16. **STIFFNESS VALUES OF MODEL LAYERS AT ULTIMATE OR BREAKING LOADS**

(Ref. Table 42 A and B)

The stiffness values for the water-bound macadam and soil-cement model layers in Table 42 A and B and for the cement mortar 1:3 and lean cement mortar 1:9 in Table 42 B, represent the ultimate loads at unit deflection value. They also indicate a similar trend as the ultimate loads for the different layers, discussed in paragraph 1.75.

The stiffness values in terms of 10 kg/cm, varied from 0.304 to 1.155 for the water-bound macadam model layers; from 0.551 to 1.908 for soil-cement layers; from 1.319 to 2.880 for the cement mortar slabs and from 0.76 to 2.402 for the lean mortar slabs. Excepting for the soil-cement layers on soil subgrade, there is generally an increase in ultimate...
stiffness value with thicknesses for the different layers. The water-bound macadam on soil subgrade slightly differs from this trend. The maximum increase or ratio of increase in stiffness values in the direct test, from 1.25 cm layer to 2.6 cm layer is for the water-bound macadam layers on sand subgrade. The increase in stiffness of the water-bound macadam and soil-cement are more for the layer thickness of 1.9 cm to 2.6 cm than from 1.25 cm to 1.9 cm. Comparing the cement mortar and lean cement mortar slabs, the maximum variation of stiffness values with loading plate diameter, is for 1.9 cm L.C.M. slabs on soil subgrade and the minimum variation is for the 2.6 cm cement mortar slabs, on soil subgrade.

7. 17. CRACK OR FAILURE PATTERNS IN MODEL LAYERS

(Ref. Fig. 10.3 to 10.7.)

The total failure in the water-bound macadam layers is indicated by a large depression in the layer with a circular cleavage around the test plate, showing separation in the aggregates. For thin layers of water-bound macadam and soil-cement, punching under the test plate occurred at the ultimate stage. The failure stage is physically indicated by either the load remaining constant or reducing with increase in deflection. In the thick layers of soil-cement and cement mortar slabs, the failure occurred suddenly with a jerk and sudden reduction of load or the development of the yield crack at the bottom and rapid decrease of load with crack development at top, at the ultimate or breaking load stage. The crack pattern normally divided the cement mortar slabs into diamond
or trapezoidal shapes starting from centre of the loading with a tendency to extend towards a point between the centre of the edges and the corner. Shattering of the slab under the loading plate, by compression failure was also observed for the thin slabs of lean cement mortar with more rigidity in the layers, the ultimate failure occurred at lower deflection levels. In the water-bound macadam and soil-cement layers, which were finally tested after other elastic tests, radial cracking around the plate was also observed. The ultimate load tests were not done on the perspex plate. Generally heavy depression and punching of the layers occurred for layers with sand subgrade and cracking in the layer occurred with soil subgrade.

7.16. **BEHAVIOUR OF THE MODEL LAYERS UNDER STATIC LOAD TESTS**

(Ref. Tables 128, 16 B and Figs. 4.1 C and D.)

Only limited number of load tests within elastic limits were done on the model layers of perspex and the ultimate load tests were done on the water bound macadam and cement mortar models. The difference in the behaviour of these layers, in comparison to the controlled strain test, can be seen from the load deflection curves and the ultimate load values reported for the respective layers. The breaking loads for the cement mortar slabs under static load tests with plate diameter of 50 mm, are lower than the breaking loads in tests at strain rate of 0.25 mm/min over the sand subgrade and more with soil subgrade. The deflections at ultimate failure under static load are greater with sand subgrades and lower with soil subgrade, than the corresponding deflection values under controlled strain tests.
In static load tests with 50 mm dia plates, the load deflection characteristics of the 12.5 mm perspex plates under different support conditions can be seen from the results presented in table 12 D. With no subgrade below, the loads increase gradually with level of deflection. With provision of sand subgrade, the loads increased by 500 to 750 % initially up to 0.25 cm deflection. For further levels of deflection up to 0.125 cm the improvement is almost at a constant rate, i.e., about 350 % at slow rate of loading ( 5 minutes interval.) The improvement is much higher when the rate of loading is quick ( one minute interval). The difference between the beam action and the slab action of the perspex plate, under different support conditions can be seen from the load deflection values in tables 12 D and 12 E. The load deflections of 26 mm cement mortar slabs and 26 mm water - bound macadam layers can be seen from the figures 4.1 C1 and 2. The end of the elastic range of deflections for the cement mortar layer seems to be about 0.06 cm and for the water bound macadam layer it is around 0.075 cm. The cement mortar slab indicated nearly 2 times more capacity than the water bound macadam layer. Beyond the elastic range the load deflection curve for the cement mortar layers developed a steep curvature with concavity upwards. The curve is of reverse nature and also of irregular shape for the water - bound macadam layer. With a constant load of 200 kg, the water - bound macadam model layer of 26 mm, underwent a steep creep deformation, upto 60 hours period and thereafter a gradual and a steady rate of creep upto 90 days, when it seemed to fail ( refer figure 4.1 D ).
The equivalencies for different model layers have been calculated on the basis of (i) loads at equal deflection, for two levels of elastic deflection, two rates of strain under configurations 'a', 'b', 'c' and 'd'. (ii) ultimate or breaking loads and stiffnesses at ultimate or breaking loads under loading configuration of 50 mm dia plate only. In both the cases, the respective values for the water-bound macadam layers of 12.5 mm thickness, on soil subgrade are taken as the base values (equivalency of unity.) The equivalency of the water-bound macadam, soil-cement, mortar (1 : 3) and p-spx model layers under elastic deflections, with soil subgrade are given in 44 A and with the sand subgrade in table 44 B. The equivalencies on the basis of ultimate loads and stiffness at ultimate loads are given in table 44 C. For the W BM, soil-cement, cement mortar and lean cement mortar layers, the range of variation of equivalencies for each layer material on soil subgrade and sand subgrades are given in table 44 D.

The maximum range of equivalencies is for the cement mortar (1 : 3) layers and the minimum range is for the water-bound macadam layer, both with soil subgrade. The equivalency values with sand subgrade are generally higher than the values with soil subgrade, excepting a few values for the cement mortar. The values for each layer at ultimate loads or stiffnesses are in general lower than the values under elastic deflections. The values of equivalencies under consideration of ultimate loads and stiffnesses, did not vary much for the water-bound macadam and soil-cement layers. For the cement mortar (1 : 3) and lean cement mortar (1 : 9), values with stiffness criteria.
are much higher.

With consideration of elastic deflections, the equivalencies with sand subgrade are higher than the values with soil subgrade for the W B M and perspex layers, under all the loading configurations. For the soil - cement and cement mortar model layers, the values with soil subgrade are higher. In general, the maximum values of equivalencies for each layer are under configuration 'a' followed by configurations 'd', 'c' and 'b'. In a few cases the values under configuration 'd' are the highest. The variations of the equivalency values with load configuration are more for the water - bound macadam and the perspex layers. The minimum variation is for the cement mortar (1 : 3) model layers. The variation of equivalencies of different layers, with rate of strain, are lower than the variations with deflection level. The variation with reference to deflection level is maximum for the cement mortar layers.

The values of equivalencies for the perspex layer are observed to be higher than the values for the W B M layers, excepting for the lower level of deflection under configurations 'b' and 'c'. From tables 44 D and 43 D, it may be seen that the ranges of equivalencies for the model layers in the prototype layers, tallied more closely for the water - bound macadam layers than for the soil - cement or cement concrete layers.

7. 20. RESULTS OF PENETRATION TESTS ON MODEL LAYERS IN CIRCULAR MOULDS

(Ref. Tables 45 1 and 2, 46 and 47) and photographs

As indicated in paragraphs 4.5 E and 4.5 F of Chapter IV, C B A type penetration tests were conducted on different layers, laid on different subgrades, in 15 cm diameter moulds and 22.5 cm diameter moulds. The load was applied at a rate of
0.25 mm / min penetration with 50 mm dia plunger. The load-penetration curves plotted but not presented in the thesis for the sake of brevity. The abstracts of load values in kg for the penetration levels of 1.25 mm, 2.5 mm and 5 mm values are tabulated and presented. The tables show the details of the layer mixes and the layer thicknesses in mm.

Table 45.1, presents the load penetration values for single layers, laid on different subgrades in the 15 cm dia moulds. Table 45.2, presents the values for the tests on two layers of different mixes in the same moulds. The abstracts of load penetration values for single layers and different subgrades tested in the 22.5 cm dia circular moulds are presented in table 46 and the tests on two or three layers in these moulds are given in table 47. All the layers tested in the 15 cm dia moulds were laid on either soil, sand, moorum or clay of 12.5 cm depth, and the depth of the subgrades under the layers in the 22.5 cm dia mould was maintained at 15 cm. It may be noted that a greater number of mixes were used in these tests to cover a range of materials from flexible to rigid behaviour.

The results of these penetration tests indicate the penetration resistances of the different layers, their variation with layer thickness, the ratio of the plunger diameter to the mould diameter and the effect of the subgrade. Also the behaviour pattern of single and two or three layers in resisting failure under heavy shear or punching can be understood. Although the results cannot be directly correlated with the load deflection results of the layers in the two square size moulds, they are likely to provide an indication of the ultimate or breaking load strengths of the layers. The trend of the
load penetration values can be known from the tabulated results. The quantitative aspects are not therefore discussed.

A) Single modal layers in the 15 cm dia moulds:

A gradual increase in the load value occurred with increase of layer thickness and penetration depth, in case of layers with granular materials. Soil-cement layers did not show adequate resistance, when laid on sand subgrades and the sand asphalt layers had low strength when laid on sand subgrade. The brick powder-lime mix showed greater penetration resistance than the water bound macadam layer with moorum filling, as well as with 5% bitumen binder or 3% lime binder. The resistance of cement concrete layer on soil subgrade, did not show increase with penetration, as it did with increase in layer thickness. The cement concrete layers on sand subgrade showed increase of load resistance. The moorum subgrade, definitely help in increasing the capacity of the flexible layers and the semirigid layers, compared to other subgrades. The clay subgrade did not give adequate resistance to any of the layers.

B) Two layers on different subgrades in 15 cm dia moulds:

(Ref. Table 4-2)

The penetration resistance values did not improve sufficiently when two layers are laid. When the lower layer is granular or flexible, the upper layer is either rigid or semirigid, the resistance to penetration was high. When a flexible or a weaker layer is laid on a rigid or semirigid layer, the penetration resistance did not reflect the effect of the bottom layer. Low punching resistance of the top
layers were only indicated. The two-layer system on sand
subgrade showed a definite increase in the resistance capacity
over the soil subgrade. Also the effect of the stronger moorum
subgrade or the weak clay subgrade, are not indicate under
the covering influence of two layers.

3

C) Single layers in 22.5 cm dia moulds : -

(Ref. Table 46)

In these moulds, the layers were laid only on sand,
soil and moorum subgrades. The penetration resistance values
of the various layers in these moulds, are more uniform than
in the 15 cm dia moulds. This is perhaps due to the ratio of
mould diameter to plunger diameter, being more than 4 and the
mould walls offering less influence on the layer. The resistance
loads of soil-cement layers on the sand subgrade are more
than the values with soil or moorum subgrades. From the load
penetration results presented in the table, the relative
resistance values of the different layers on different subgrades
can be known. For the sand asphalt and the granular layers
with screenings, a much higher value of resistance is indicated
in the 22.5 cm moulds than in the 15 cm moulds. For the
soil-cement layer there is only marginal improvement and
for the rigid layer of cement concrete, the improvement of
penetration resistance is only at the higher depths of
penetration. With respect to moorum subgrade, there is a
reduction in the resistance value for sand asphalt in the
greater diameter mould.
D) **Two or three layers in the 22.5 cm dia moulds**

(Ref. Table 47)

There is certain improvement in the resistance values, with the addition of the second and/or third layer, but it is not equal to the strength of the newly added layer. When a flexible layer is added over a semirigid or rigid layer, the penetration resistance is low in the beginning and improves only at higher level of penetration. This indicates that the resistance to penetration picks up only when the stronger layer comes into the zone of influence.

E) **General**

The arbitrarily chosen layers in the 15 cm and 22.5 cm dia circular moulds cannot be used for comparison with the other square shape layers of smaller and bigger sizes. However, they indicate the effect of the layer size, the mould diameter and the subgrade on the penetration resistance. The results will be more tenable, when rigid or semirigid layers are laid over flexible layers or a stronger layer material is used over a weaker subgrade. If the subgrade as well as the layer of strong, adequate resistance to penetration is not developed, the flexible layers generally showed a hollow depression under the loading plunger and a heaving of the material around at failure, when they are thick and a punching under the load when the layer is thin. This stage occurred normally beyond 2.50 mm of penetration. In case of semirigid and rigid layers, the failure occurred at penetrations of 1.25 mm or even less in case of thick layers showing development of radial cracks. For thin layers, the punching failure occurred by partial depression
at the centre of the layer and slight punching at penetration depth ranging from 1.25 mm to 2.50 mm. These penetration test results are presented and the qualitative trends only have been discussed, to indicate the behaviour of the circular model layers. The analysis could be further done by the ultimate load concepts given by Mcloed, using the shear parameters of the materials and compare the load - perimeter - area relations given by Houseal, to understand the extent of mobilisation of each of the layers and the subgrade. This is not done within the scope of the present work.

7.21. COMPARISON BETWEEN THE LAYERS TESTED IN MASONRY TANK AND THE SQUARE MODEL LAYERS

The behaviour of the large size layers tested in masonry tanks and the small square model layers, with respect to various criteria of evaluation have been discussed in the preceding paragraphs. A comparative note will now be given, pointing out the effect or influence of the layer geometry and the strength properties of the layer on the deflection characteristics under the respective criteria. For the respective flexible, semirigid and rigid layers in the masonry tanks and the square model tanks comparisons will be limited to qualitative aspects. The model layers adopted are neither fully geometrically compatible nor structurally compatible models for the large size layers. They could be termed as distorted models. This will be evident from the geometric and structural data of the prototype in the models given in tables 2, 3 and 21.

The geometric relations between the prototype and the model size layers and the loading configurations, indicate a
narrow range of distortion. Some of the values nearly coincide and satisfy conditions of geometric similarity. However, the ratios of structural values, density modulus and relative stiffnesses, indicate a wider range of distortion. An attempt to develop the quantitative correlations with the vast data presented needs rigorous statistical analysis through the aid of computer facilities which are not available at hand. Therefore quantitative correlation will be left as a scope for further work. The individual aspects of comparison on qualitative basis will be dealt with briefly.

A) Elastic deflections: (Tables 4 A to 12 G)

The water-bound macadam layers of bigger size and model layers have similar load-deflection behaviour, with respect to layer thickness and load configurations. The 15 cm layer appears to be stronger than not only the 7.5 cm layer but also the 22.5 cm layer. Similarly the 19 mm model water-bound macadam layer indicated better load capacity than the 12.5 mm and 26 mm layers, thus exhibiting that the flexible or granular layer does not become structurally stronger beyond a certain thickness. In both cases the layers are stiffer under configurations with greater radii of loading (1 or 4 in case of large size layers and 'a' or 'd' in case of model layers). The soil-cement layers of big and small sizes definitely exhibited semirigidity, by taking improved loads compared to water-bound macadam layers. Also the rate of load capacity improvement with layer thickness is more. The thin layers behaved similar to the flexible layers, while the thicker layers tended to behave as rigid layers. The cement concrete layers in the masonry tank and the cement mortar (1:3) model slabs exhibited rigid behaviour commensurate with their
respective stiffness values. They exhibited a steep increase in loads from thin slabs to thick slabs. The effects of load configuration are at least pronounced for the cement concrete and cement mortar slabs, more so at greater layer thicknesses. The perspex plate exhibited deflection behaviour nearer to flexible and semirigid layers, than to rigid layers.

E) Deflection coefficients: - (Ref. Table 23 to 32.)

The prototype and model layers of the respective flexible, semirigid and rigid base course materials showed similar trends. In all cases, the experimental values of deflection coefficients are lower than the theoretically computed values. The water-bound macadam and soil-cement layers, exhibited experimental values somewhat tallying with the values by Naussbaum's equation for flexible and semirigid layers respectively. Burmister's values are the highest in all large size layers and model water-bound macadam layers. In case of prototype and models of soil-cement layers, Westergaard's equation gave the highest values for all thicknesses under configurations (1) and (4) or 'a' and 'd'; and Burmister's equation gave higher values under configurations (2) and (3) or 'b' and 'c'. The least values are by Naussbaum's Equation. For the cement concrete layers the coefficients by Burmister's and Westergaard's equation are within close range. For the cement mortar (1:3) model layers the values did not tally so closely. The values by Westergaard's equation are more than by Burmister's equation in case of sand subgrade, but values by Burmister's equation are more in case of soil subgrade.
The increase of load from first to second cycle of loading is nearly uniform for the model water-bound macadam layers under different variables and the ratio varied from 1 to 1.260. In the bigger size layers, the variation is between 0.938 to 3.149, the values of the ratio being higher for smaller layer thickness. For the soil-cement and cement concrete layers and the corresponding model layers a similar relation i.e., the improvement of ratios being higher for bigger size layers. The soil-cement and cement concrete layers showed increase of ratio with higher layer thickness, while a reverse trend is indicated for the water-bound macadam layers.

Similar trends are not indicated for the cement mortar, soil-cement and water-bound macadam model layers. They vary with the subgrade, the load configuration and the layer thickness.

The stiffness values under elastic deflections for the water-bound macadam layers showed similar variations as the prototype layers, with respect to deflection level. The prototype water-bound macadam layers showed increased stiffnesses for greater thickness, while the values for the 19 mm layers were more than for 12.5 mm and 26 mm model layers. Also, the prototype WBM layer showed greater values under configuration (4), while for the model layers, greater stiffness occurred under configuration (4). This is perhaps due to the variation in the ratios of B/b and the spacings of the dual-tension configurations. For the cement concrete layers the stiffness values did not vary much with deflection level, but the values increased sufficiently in case of the cement mortar model layers.
The cement concrete layers showed more variation of stiffness with load configurations 'c' and 'd' to 'b' and 'c', but in model layers of cement mortar the variation is not much under soil subgrade and it was only marginal in case of sand subgrade. The variations of stiffness values maintained similar trend in case of prototype and model soil-cement layers. The ratios of stiffness of prototype to model layers are maximum for the water-bound macadam layers and minimum between the cement concrete and cement mortar layers. In all cases, the ratios are much greater than the ratios of the layer thickness or the ratios of their relative stiffness values.

The stiffness values of perspex model layer are generally either equal to or slightly higher than the values of the thicker WBM and soil-cement layers, but are lower than the values for the cement mortar model layers. The stiffnesses of WBM at ultimate loads are quite low, compared to the values under elastic deflections. In case of cement concrete slabs and the soil-cement slabs, the variation is not so much. At elastic deflection range, the stiffnesses of cement concrete slabs bear higher ratios with the values of WBM layers, but it is not so with the corresponding model layer. In case of soil-cement and water-bound macadam layers, almost same trend is maintained for the prototype and the corresponding model layers.

3) Equivaelency values of layers: (Ref. Table 43 and 44)

The equivalency values of the prototype and model water-bound macadam layers did not vary, as the values did in the case of soil-cement layers and the rigid layers of cement concrete and cement mortar models. The range of variations of equivalency values are more for the model layers than the bigger size layers.
This is so, at greater deflection level and rate of strain. For the prototype layers, the maximum equivalency values for each layer are with configuration (4) and the minimum values are with configuration (2). In the case of W B M and soil cement model layers, the minimum values are with the configuration 'b', but the maximum values are under configuration 'a' for W B M model layers as well as soil subgrades, while some of the values are under configuration 'd' for the soil subgrade. Variations of equivalencies with load configuration for the cement mortar model layers is not as much as for the cement concrete layers, though the values for the model cement mortar layers are in general high, and also they vary to a good extent with deflection level and rate of strain. The variation of equivalency with greater layer thickness is also more for the model layers than for the prototype layers.

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