CHAPTER 7
CHAPTER 7

INFLUENCE OF STEEL REINFORCEMENT

7.1 INTRODUCTION: -

The concrete components having possibility of development of tensile zones need provision of steel reinforcement to produce a safe design. In case of shell structures however the need and amount of steel reinforcement required was of quite a lower order as compared to the requirements in case of the concrete slabs. Yet it was felt that the kind of analysis presented up till now should at least be repeated by considering the presence of reinforcement. Especially, the analysis pertaining to the linear elastic behaviour which corresponds to the need of conventional design process should be analysed. In addition, it would be of interest also to derive the elasto-plastic deformation characteristics, which was likely to lead to a relatively higher level of collapse load.

As pointed out the influence of steel reinforcement on the behaviour would be only marginal therefore a method of incorporating the steel reinforcement in the idealized system was demonstrated by considering the model having 4 noded quadrilateral elements. Fig 7.1 shows, the arrangement of steel plate and concrete. Logically, similar arrangement could also be followed for the remaining element types. Though, such consideration was not likely to throw any more light on the phenomenon of influence of the provision of the steel reinforcement.

For the investigation following details of the cylindrical shell were taken up:

1) Shell thickness of 12.5cms;
2) The L/r ratios of 1, 2 and 3;
3) The Load cases pertaining to Vertical Surcharge and Longitudinal applications;

Here it was assumed that, steel plate and concrete were in full contact and the strain in steel \( \{(E_s / E) = m\} \) times the strain of concrete at the interface.

Since steel has considerable capacity to take the load in elastic limit, it was assumed that steel does not yield.
In the idealized system the presence of steel reinforcement was introduced by pasting steel plates over the concrete plates typically, as indicated in fig. 7.1.

![Diagram of reinforced concrete plate](image)

*Fig. 7.1 Combined Elemental Details of Concrete and Steel Reinforcement*

In view of this kind of modified idealization it was easy to note that the number of elements gets doubled but number of nodes remains same.

### 7.2 LINEAR ELASTIC RESPONSE:

The linear elastic response for the reinforced concrete shell was derived whose details were presented in fig. 7.2 with a view to compare the response of the RCC shell vis-à-vis the concrete shell as already considered in chapter 4; the corresponding results were superposed over the result of the RCC shells.

![Graphs of v and w](image)

a) $L/r$ Ratio = 1
**b) \( L/r \) Ratio = 2**

**c) \( L/r \) Ratio = 3**

Fig. 7.2 Comparison of Elastic Response between Concrete Shells and RCC Shells

It might be observed that the difference was more or less insignificant though it was possible to conclude that the difference was function of the thickness of steel plate and the span ratio.

### 7.3 ELASTO-PLASTIC ANALYSIS:

The elasto-plastic analysis had shown significant influence on the ultimate collapse loads. In general, it was being more in case of the RCC shells compared to the concrete shells. Once again the feature of the progress of the plastic zone development for various thicknesses of steel plate as also for the concrete shells was presented in fig. 7.3.
a) Ratio 1 Vertical Surcharge

b) Ratio 1 Longitudinal Force
c) Ratio 2 Vertical Surcharge

d) Ratio 2 Longitudinal Force
e) Ratio 3 Vertical Surcharge

f) Ratio 3 Longitudinal Force

Fig. 7.3 Comparison of Percentage Progress of Plastic Zone between Concrete Shells and RCC Shells
7.4 OBSERVATIONS:

Following observations could be made:

1) For the longitudinal applications of the load the collapse loads of the RCC shells were found to be increasing in comparison with that of the concrete shells and the increase was of a more order with increase in thickness of the steel plate.

2) In general, the percentage progress of the plasticity signified the similar variations in case of all the systems considered.

3) For the sake of the comparisons, the values of final collapse loads in case of the problems investigated were presented table 7.1.

Table 7.1 Comparison of the Values of Collapse Load

I) Vertical Surcharge

<table>
<thead>
<tr>
<th>L/r Ratio</th>
<th>Concrete</th>
<th>Steel 1mm</th>
<th>Steel 2mm</th>
<th>Steel 3mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>110</td>
<td>149</td>
<td>160</td>
<td>192</td>
</tr>
<tr>
<td>2</td>
<td>45</td>
<td>61</td>
<td>67</td>
<td>72</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
<td>28</td>
<td>30</td>
<td>33</td>
</tr>
</tbody>
</table>

II) Longitudinal Load

<table>
<thead>
<tr>
<th>L/r Ratio</th>
<th>Concrete</th>
<th>Steel 1mm</th>
<th>Steel 2mm</th>
<th>Steel 3mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1190</td>
<td>1472</td>
<td>1614</td>
<td>1735</td>
</tr>
<tr>
<td>2</td>
<td>1248</td>
<td>1337</td>
<td>1441</td>
<td>1524</td>
</tr>
<tr>
<td>3</td>
<td>1056</td>
<td>1186</td>
<td>1283</td>
<td>1366</td>
</tr>
</tbody>
</table>

In the above table the values of collapse loads were in KN.

From the above details, it was shown that the collapse load in respect of longitudinal loading was more or less same for all the steel plate thicknesses considered.
### Table 7.2 Percentage Increase in Load Carrying Capacity by Steel

<table>
<thead>
<tr>
<th>L/r Ratios</th>
<th>Concrete with 1mm Steel Plate</th>
<th>Concrete with 2mm Steel Plate</th>
<th>Concrete with 3mm Steel Plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Case 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>35.45%</td>
<td>45.45%</td>
<td>74.55%</td>
</tr>
<tr>
<td>2</td>
<td>35.50%</td>
<td>48.89%</td>
<td>60.00%</td>
</tr>
<tr>
<td>3</td>
<td>12.00%</td>
<td>20.00%</td>
<td>32.00%</td>
</tr>
<tr>
<td>Load Case 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>23.70%</td>
<td>35.63%</td>
<td>45.80%</td>
</tr>
<tr>
<td>2</td>
<td>7.13%</td>
<td>15.46%</td>
<td>22.12%</td>
</tr>
<tr>
<td>3</td>
<td>12.31%</td>
<td>21.50%</td>
<td>29.36%</td>
</tr>
</tbody>
</table>

#### 7.5 SUMMARY AND CONCLUSIONS:

1) Once again the progressive trend for the development of the plastic zone was displayed.

2) It was clearly seen that in the shell of L/r ratio 1, for the vertical surcharge with the application of steel plate as a reinforcement, the load carrying capacity increased from 35.45% to 74.55%, as the thickness of the steel plate increased from 1mm to 3mm.

3) This trend remained same for L/r ratio 2, where the load carrying capacity increases from 35.5% to 60%.

4) However for L/r ratio 3, this capacity increased from 12% to 32%.

5) A similar increase in the load carrying capacity could be observed for longitudinal loading also by the application of steel plate with the increase in the thickness of the steel plate.

6) The collapse loads of RCC shells were found to be increasing in comparison with those of the concrete shells and this increase in loads was parallel to the increase in the thickness of the steel plate.

7) In the ultimate behaviour the important role of provision of reinforcement can be recognized.