A Comparative Design of RCC and Prestressed Concrete Flyover along with RCC Abutments

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Abstract— Flyover construction today has achieved a worldwide level of importance. Flyovers are the key elements in any road network. Use of PSC Girder has gained popularity in bridge engineering because of its better stability, serviceability, economy, aesthetic appearance and structural efficiency. In the present study a simply supported PSC Girder Bridge of 25m span is analyzed for moving loads as per Indian Road Congress codes- IRC: 6 and IRC: 18 specifications. The analysis and design will be carried out using Working Stress Methodology. Firstly, proportioning of the girder and calculation of section properties will be carried out. Then, the different loads-dead, superimposed and live loads, coming onto the structure will be estimated. The analysis will be performed and section forces- bending moments, shear forces and stresses are arrived at to proceed with the further design. All the analysis will be carried out for two sections- running section and end section and internal, external and cross girders. As a conclusion, the analysis results will be presented and an optimization of the design is discussed. Prestressed (Post tensioning) concrete is well suited for the construction of Flyovers in the medium to large span range. These structures gained popularity due to their versatility in construction and economy in cost and maintenance; also they can be cast in any convenient shapes and forms to meet architectural requirement as well as can utilize locally available materials such as stone chips, gravels, sand etc. it can be cast at site thereby eliminating carriage of heavy bridge components hence are widely used in construction of medium to large span structures. Precast PSC (Post tensioning) girder is by far the most commonly adopted type in the span range of 20m to 30m. The structure so named because the main longitudinal girders are designed as I girders integral with the part deck slab, which is cast monolithically with the girders. For a particular girder span and structure width, a large number of parameters control the design of the structure such as girder spacing, cross sectional dimensions of girder, grade and type of high tensile steel, type of tensioning, first stage stressing, no. of prestressing stages, deck slab thickness, deck slab reinforcement, concrete strength, materials of construction, reinforcement in cross girder and intermediate girders etc. By studying proper design procedures of Precast PSC (Post tensioning) I girder we will get pre assigned parameters, design variables or decision variables, design constraints, design vectors and objective functions. By using these all parameters we can convert normal design problem of Precast PSC I (Post tensioning) girder into optimization problem and this optimization problem can be solved with the help of various optimization techniques or software’s which are available so as to achieve desired objective function, so as to optimize the design.
III. LOADS ON FLYOVERS

A. Dead Load

The deck of the bridge subjected to dead loads comprising of its self-weights due to wearing coat, parapet, kerb etc. which are permanently stationary nature. The dead load acts on the deck in the form of the distributed load. These dead loads are customarily considered to be done by the longitudinal grid members only giving rise to the distributed loads on them. The distributed load on the longitudinal grid member is idealized into equivalent nodal loads. This is specially required to be done when the distributed load is non-uniform. On the other hand, if the self-load is uniform all along the length of longitudinal grid line then it is not necessary to find the equivalent nodal load and instead it can be handled as a uniformly distributed load (udl) itself. Further, if the dead load is udl but its center is not coincident with the longitudinal grid line then it is substituted by a vertical udl.

B. Live Load

The main live loading on highway bridges is of the vehicles moving on it. Indian Roads Congress (IRC) recommends different types of standard hypothetical vehicular loading systems, for which a bridge is to be designed. The vehicular live loads consist of a set of wheel loads. These are distributed over small areas of contacts of wheels and form patch loads. These patch loads are treated as concentrated loads acting at the centre of contact areas. This is a conservative assumption and is made to facilitate the analysis. The effect of this assumption on the result is very small and does not make any appreciable change in the design. IRC Class A two lane, Class AA Tracked and Wheeled, Class 70R Tracked and Wheeled loads are shown in Figs. Three different wheel arrangements for Class 70R Wheeled loads are in existence Class 70R Tracked load may be idealized into 20 point loads of 3.5tons each, 10 point loads on each track. The total load of the vehicle in this case is 70 tons. One Class A or Class B loading can be adopted for every lane of the carriageway of the bridge. Thus, for a two lane bridge, we can have two lanes of Class A or Class B loading. However, for all other vehicles, only one vehicle loading per two lanes of the carriageway is assumed.

C. Impact Load

Another major loading on the bridge superstructure is due to the vibrations caused when the vehicle is moving over the bridge. This is considered through impact loading. IRC gives impact load as a percentage of live load. As per IRC code, impact load varies with type of live loading, span length of bridge and whether it is steel or a concrete bridge. The impact load, so evaluated, is directly added to the corresponding live load. The dynamic effect caused due to vertical oscillation and periodical shifting of the live load from one wheel to another when the locomotive is moving is known as impact load. The impact load is determined as a product of impact factor, I, and the live load. The impact factors are specified by different authorities for different types of bridges.

IV. PRESTRESSED CONCRETE

- In prestressed concrete, a prestress force is applied to a concrete member and this induces an axial compression that counteracts all, or part of, the tensile stresses set up in the member by applied loading.
- In the field of bridge engineering, the introduction of prestressed concrete has aided the construction of long-span concrete bridges. These often comprise precast units, lifted into position and then tensioned against the units already in place, the process being continued until the span is complete.
- For smaller bridges, the use of simply supported precast prestressed concrete beams has proved an economical form of construction

A. Design Procedure

- Assume section
- Calculate section properties
- Estimate Bending moment / Shear force
- Select no & size of cables
- Apply prestress force
- Estimate prestress losses
- Determine stresses in concrete
- Check with permissible stresses
- Check ultimate moment / shear
- Design shear reinforcement
- Design end block

B. Limiting Stresses

<table>
<thead>
<tr>
<th>Condition</th>
<th>Transfer Condition</th>
<th>Service Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression</td>
<td>0.50 fck</td>
<td>0.33 fck</td>
</tr>
<tr>
<td>Tension</td>
<td>0.05 fck</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Table 3 Limiting Stresses

C. Basic Theory

![Fig. 1: Stresses at transfer condition](image-url)
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D. Prestress Losses (As per IRC: 18)

- Elastic deformation of concrete (Clause 11.1)
- Anchorage slip (Clause 11.5)
- Friction losses (Clause 11.6)
- Concrete shrinkage (Clause 11.3)
- Concrete creep (Clause 11.2)
- Steel relaxation (Clause 11.4)

For Columns Prismatic (Rectangular, Square and Circular)

V. CONCLUSIONS

1) Life span of prestressed concrete structures is very more as compared to reinforced concrete structures and Steel structures.
2) Under working loads, the cross section area of prestressed member is very less as compared to reinforced concrete member and simultaneously dead weight can be reduced.
3) Prestressed concrete members are very stiffer than the reinforced concrete members.
4) It is possible to formulate and to obtain solution for the minimum cost design for PSC I girder.
5) The minimum cost design of PSC I girder is fully constrained design which is defined as the design bounded by at least as many constraints as there are the design variables in the problems.
6) Actual percentage of the saving obtained for optimum design for PSC I girder depend upon the grade of prestressing steel, grade of concrete, first stage stressing, no. of prestressing stages, deck slab thickness and depth of girder.
7) The optimum cost for a PSC I girder is achieved in uncoated stress relieved low relaxation 7-ply 12.7 mm dia strands conforming to IS: 14268, M45 grade of concrete and Fe500 grade of steel.
8) The cost of PSC girder unit increased rapidly with respect grade of concrete increases and grade and type of high tensile steel increases whereas cost of PSC I girder decreases as the span of flyover reduces, also the cost of girder decreases with the increase in the girder depth.
9) Significant savings in cost over the normal design can be achieved by the optimization. However the actual percentage of the saving obtained for optimum design for PSC I girder depend upon the span of girder and grade of material.
10) The cost of girder is directly proportional to grade of concrete and high tensile steel.

REFERENCES