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Comparative Study of Prestressed Concrete Girder and Steel Plate Girder for Roadway Over Bridge

Bhagyashree C Jagtap*, Prof. Mohd. Shahezad
Department of Civil Engineering, P.R.M.I.T. & R, Badnera, Amravati, Maharashtra, India

ABSTRACT

Bridge design is an important as well as complex approach of structural engineer. As in case of bridge design, span length and live load are always important factor. These factors affect the conceptualization stage of design. Prestressed Concrete and Steel plate are commonly used for constructing bridges. This project presents the comparative study of prestressed concrete girder and steel plate girder for roadway over bridge. This work includes the cost analysis and design of prestressed concrete girder and steel girder. In the good olden days, for higher spans, steel girders whether plate girders or triangulated girders were pre-dominantly used. After the advent of pre-stressed concrete, its use in higher span bridges increased tremendously. Main reason behind use of PSC girders is due to its initial economical cost. No doubt, PSC girders are economical in the initial stage of construction, but the same may not be true if we consider the life cycle cost including other factors. The aim of this work is to design prestressed concrete and steel girder for various span and then compare the result. . Based on the understanding of the manual design procedure, a computer program in MS EXCEL was developed for designing both prestressed concrete and steel plate girder. The goal of study is to determine most favourable option from above two.
Keywords: Prestressed Concrete Girder, Steel Plate Girder, Bridge and Comparative Study.

I. INTRODUCTION

A. Importance & Necessity

In any infrastructural development of a country, Bridge construction is one of the most important constructions. It is very costly structure as compared to others. Lots of considerations are required in doing the investigation, deciding its configuration, type of span and final construction of the bridge. A Bridge properly constructed will serve the cause successfully without any hindrance for a longer period and at the economic cost.

In recent trend pre-stressed concrete bridges have been expanding the applicable span, length and are becoming a hard competitor against steel bridges and concrete bridges. Steel bridges, therefore, need new ideas to regain competitiveness. Steel plates have high tensile strength but are relatively vulnerable to buckling caused by compressive forces and need to be stiffened and strengthened.

Prestressed concrete is the most recent major form of construction introduced in the structural engineering. It has become a well-established method of construction as the technology is now available in all developed and in many developing countries. The aim of this work is to design prestressed concrete and steel girder for different grades and various spans and then compare the result.

B. Scope

This work includes the design and estimate of girders of various spans, ranging from 12.0 M to 36.0 M, by Steel plate girder and prestressed concrete girder techniques. For smaller spans, associated with normal loading, prestressed concrete construction becomes too cumbersome, irrespective of the economics involved. For very large spans, the depth required less as

compared to the steel plate girder. Intensity of assumed loading is kept large enough, so that the factored bending moment will be comparable to that developing in case of small spans. Post-tensioning is preferred as it is in vogue, in construction of large span girder.

II. THEORETICAL INVESTIGATION

A. Plate Girder

Plate girders became popular in the late 1800's, when they were used in construction of railroad bridges. The plates were joined together using angles and rivets to obtain plate girders of desired size. By 1950's welded plate girders placed riveted and bolted plate girders in developed world due to their better quality, aesthetics and economy. Plate girders can have a greater height than rolled steel girders and are not limited to standardized shapes. The ability to customize a girder to the exact load conditions allows the bridge design to be more efficient. Stiffeners are occasionally welded between the compression flange and the web to increase the strength of the girder. The use of plate girders rather than rolled beam sections for the two main girders gives the designer freedom to select the most economical girder for the structure. Plate girders are often used in structures having spans more than 15-20m. Normal plate girders are provided with intermediate post buckling strength of the webs. A plate girder is basically an I-beam built up from plates using riveting or welding. It is a deep flexural member that can be carried by rolled beams.

B. Prestressed Concrete Girder

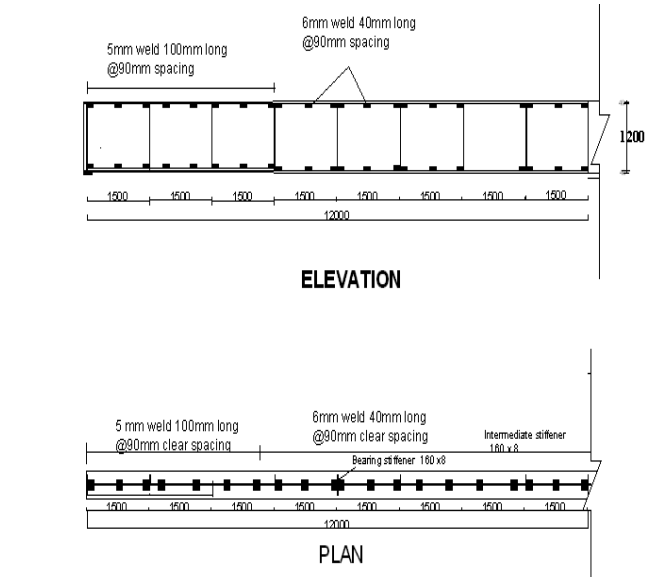
Pre-stressed concrete is basically concrete in which internal stresses of a suitable magnitude and distribution are introduced so that the stresses resulting from external loads are counteracted to a desired degree. In reinforced concrete members, the pre-stress is commonly introduced by tensioning the steel reinforcement. The earliest examples of wooden barrel construction by force-fitting of metal band sand metal tires on wooden wheels indicate that the art of pre-stressing has been practiced from ancient times. The tensile strength of plain concrete is only a fraction of its compressive strength and the problem of it being deficient in tensile strength appears to have been the diving factor in the development of the composite material known as "reinforced concrete". The development of early cracks in reinforced concrete due to incompatibility in the strains of steel and concrete was perhaps the starting point in the development of a new material like "pre-stressed concrete". The application of permanent compressive stress to a material like concrete, which is strong in compression but weak in tension, increases the apparent tensile strength of that material, because the subsequent application of tensile stress must first nullify the compressive pre-stress. In 1904 Freyssinet1attempted to introduce permanently acting forces in concrete to exist the elastic forces developed under loads and this idea was later developed under the name of "pre-stressing".

III. METHODOLOGY

To commence with, a steel plate girder was manually designed by using the limit state method based on IS: 800-2007. Based on the steps & formulas involved, a design program was prepared in MS EXCEL. The veracity of the program was checked by first designing the manually designed girder by using the program & comparing the result.

The prestressed concrete girder was manually designed by referring the book prestressed concrete by N. Krishna Raju. The program for designing the same fidelity was checked by first solving manual problem & comparing results. Programs were also prepared for estimating & costing. Rates are based on the latest CSR in Maharashtra. In case of prestressed concrete, some of the rates were obtained from well knows private infrastructure company.

Based on the designed the detailing was made for different span. The following figures show the detailing of plate girder & prestressed concrete girder of 24 m span.



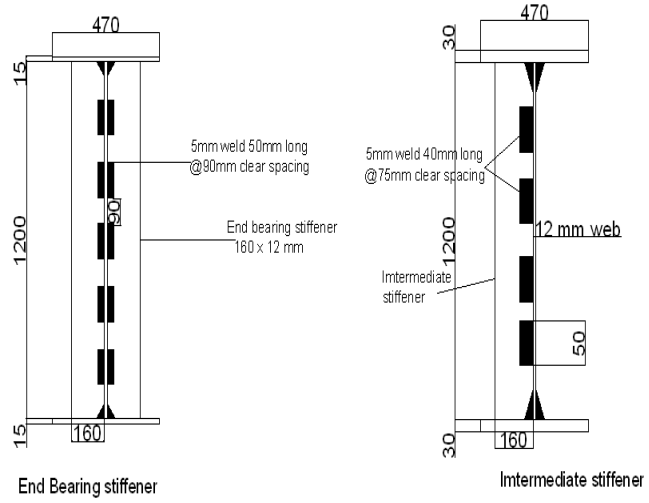
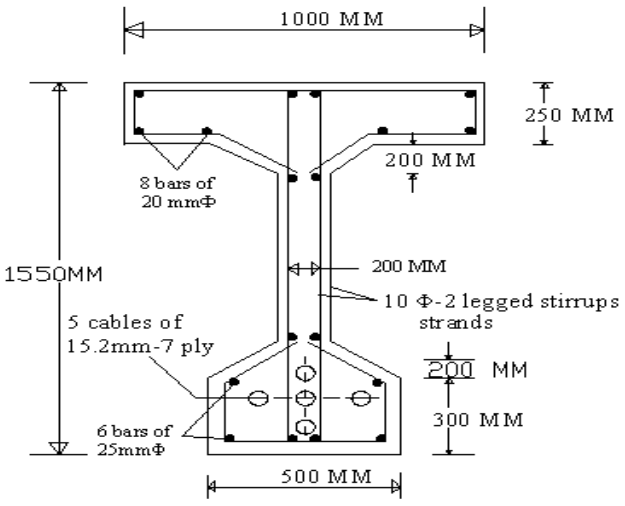
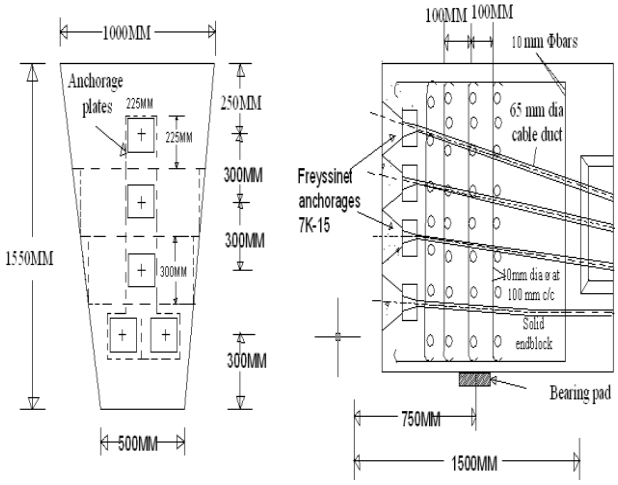


Figure 1 : Details of welded plate girder of span 24 M



Reinforcement Details at Centre-of-Span of 24 M



Reinforcement Details at Support of span 24 M

Figure 2 : Details of prestressed concrete girder of span 24 M

IV. RESULTS AND DISCUSSION

Table I below gives the cost in rupees for various spans for both prestressed concrete girder & plate girder. Figure 1.1 below depicts the same statistics with the help of bar charts.

Figure 3 below is a short form of Figure 4 where prestressed concrete girder is compared with plate girder with different span.

Figure 5 below gives the depth for various spans for both prestressed concrete girder & plate girder.

Pre-stressing requires skilled workmanship & need for superior quality control. But we must not forget that along with these minor inconveniences pre-stressing delivers a structure that is better from limit state of serviceability & durability point of view.

TABLE I

Cost Comparison of Prestressed Concrete Girder and Plate girder

Sr. No.	Span (m)	Estimated Cost of Prestressed Concrete Girder (Rupees)	Estimated Cost of Plate Girder (Rupees)	Difference
1	12	1,23,421.56	1,63,090.20	24 %
2	18	2,59,385.41	3,79,498.35	32 %
3	24	4,46,533.71	7,05,246.15	37 %
4	30	7,12,229.06	12,05,331.75	41 %
5	36	10,23,006.48	19,08,847.5	46 %

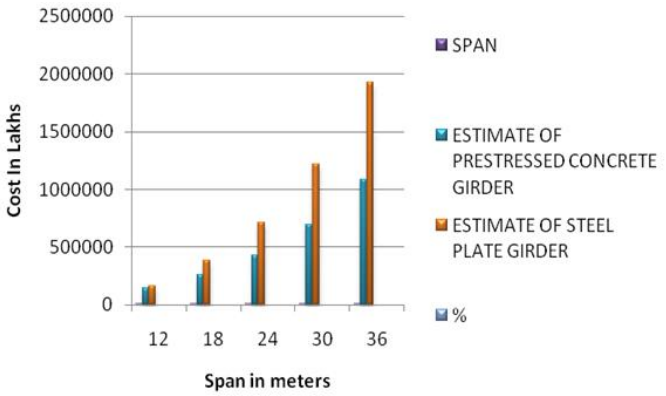


Figure 3: Variation of Cost with Span of Girder

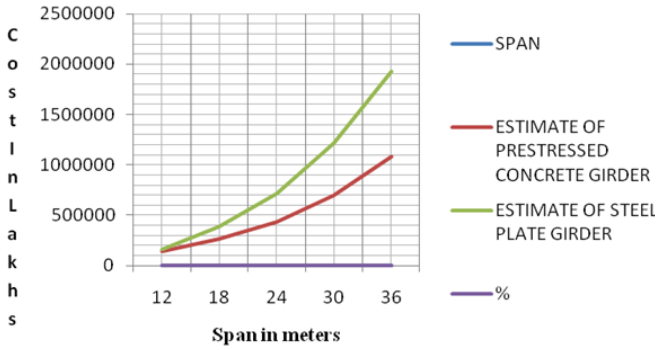


Figure 4: Variation of cost with span of girder

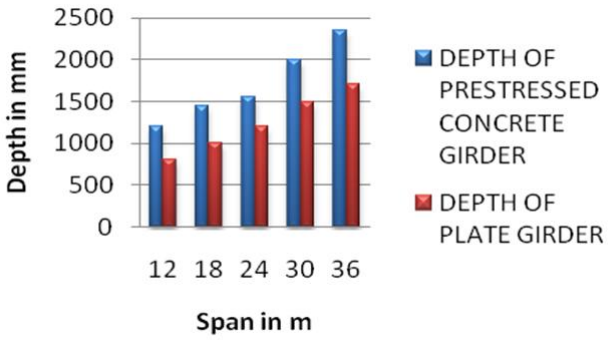


Figure 5: Variation of depth with span of girder

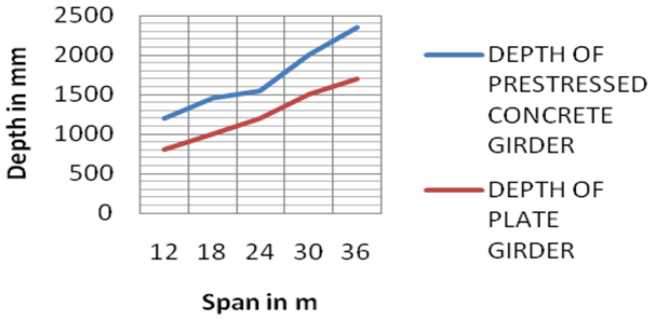


Figure 6: Variation of depth with span of girder

V. CONCLUSION

Based on the study conducted, it could be concluded that prestressed concrete girder are economical than plate girder. As the span length increases the cost goes on increasing. Durability of prestressed concrete girder is more than steel plate girder.

In a nut shell, for spans up to 15m, Steel plate girders are preferable. For spans between 15 to 36m, the decision should be based on other factors like the size & location of the project. For spans beyond 24m, prestressed concrete girders are decidedly superior as compared to steel plate girders. In fact for spans beyond 25m, conventional steel plate girders become costlier more than 37% &cease to remain an option.

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