

A Case Study on the Construction and Estimation of Materials Composites for Superstructure of a Railway Cross Overhead Bridge

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Abstract: The mechanical characteristics of steel girders dictate their response to external forces and loads. Tensile strength refers to the highest amount of stress that a material can endure without breaking when subjected to strain. Greater tensile strength shows increased resistance to tensile forces and is essential for maintaining the structural integrity of girders. The construction of the bridge is in the three phases; foundation, substructure and superstructure. This study is based on the superstructure construction and estimation of an overhead railway bridge. In this case, the study shows the superstructure construction procedure with the particular importance of all parts. The prestressing concrete beams are increasing the load-carrying capacity of the bridge. The geogrid installation increases the stability of the surface. After the construction procedure, calculate the estimation of the concrete and steel amount used in the superstructures. The last calculation shows a total of 2784.525 m³ of concrete used in the superstructure, and around 429.05 million tonnes of steel is utilised in the superstructure of the overhead railway bridge.

Keywords: Bridge; Construction; Mechanical Properties; Cost Estimation; Materials composites

1. INTRODUCTION

Steel girders are vital elements in many construction endeavours, providing crucial structural reinforcement and steadfastness to buildings, bridges, and other infrastructure. The chemical composition and mechanical qualities of steel girders are vital factors in determining their performance and appropriateness for various applications. Steel girders are principally composed of iron and carbon, with various quantities of additional alloying elements. Typical alloying elements include manganese, silicon, sulphur, phosphorus, and small amounts of other elements such as copper, nickel, chromium, and molybdenum. The specific composition of the steel girder relies on the desired characteristics and intended use of the structure. The carbon content of steel has a considerable impact on its strength and hardness. Increased carbon content leads to enhanced strength but reduced ductility, resulting in increased brittleness of the steel. Manganese (Mn) improves the strength, hardenability, toughness, and weldability of steel. Silicon

(Si) enhances the durability and toughness of steel, hence enhancing its ability to withstand corrosion. Sulphur (S) and Phosphorus (P): These elements are often regarded as contaminants and are maintained at low levels to guarantee favourable weldability and mechanical qualities. High levels of sulphur and phosphorus may lead to increased brittleness and decreased ductility in steel. Additional Alloying Elements: Elements like as nickel, chromium, and molybdenum are used in lesser amounts to provide particular characteristics such as enhanced resistance to corrosion, greater tensile strength, or better toughness.

The mechanical characteristics of steel girders dictate their response to external forces and loads. Tensile strength refers to the highest amount of stress that a material can endure without breaking when subjected to strain. Greater tensile strength shows increased resistance to tensile forces and is essential for maintaining the structural integrity of girders. Yield strength refers to the level of stress at which a material starts to undergo permanent deformation when

subjected to a load. It represents the moment when the material shifts from exhibiting elastic properties to displaying plastic properties. Elongation refers to the capacity of a material to undergo deformation prior to breaking. Greater elongation signifies increased ductility, a crucial characteristic for enduring dynamic loads and absorbing energy during impacts. The Modulus of Elasticity, sometimes referred to as Young's modulus, is a measure of the material's stiffness. A greater modulus of elasticity indicates that the material will experience less deformation when subjected to a given load, resulting in improved resistance to bending and deflection. Impact toughness refers to the capacity of a material to absorb energy when subjected to impact stress, without experiencing fracture. Structures that are exposed to abrupt impacts or dynamic forces, such as bridges and buildings located in regions prone to earthquakes, need special attention. Steel girders are meticulously designed with precise chemical composition and mechanical qualities to fulfil the individual needs of different building projects, guaranteeing safety, longevity, and structural soundness. Manufacturers conform to industry norms and criteria in

order to create girders that exhibit consistent quality and performance [1].

The superstructure of the overhead railway bridge consists of the component that spans the obstacle the bridge is intended to cross and includes the following; deck slab, structural members, parapets (bridge railings), handrail, sidewalk, lighting and drainage features. The bridge's total length is 658.50 metres whereas the length of the main railway overhead is 32.835 meters. Table 1 describes the brief details of the flyover railway overhead bridge. Any bridge has three faces of construction: the foundation, the second one is the substructure, and the last one is the superstructure. The foundation also called footing contains the pile and pile cap under the ground, the substructure contains the pier and pier cap while as superstructure contains the beams of all types, deck slab, crash barriers and other miscellaneous concrete structures. The project is constructed as a railway overhead bridge to pass the traffic without delay. It is a direction flyover in which above the railway crossing steel girder is used as a beam below the deck slab whereas the beam is constructed by the RCC with the design between the pier cap. The bridge clearance at the railway line is 6.5 metres, and another

side varies. Figure 1 describes the whole site detail plan on the map, whereas Figure 2 describes the construction structure's front view side view. Pile type of foundation used in the construction practice for the bridge [2], [3].

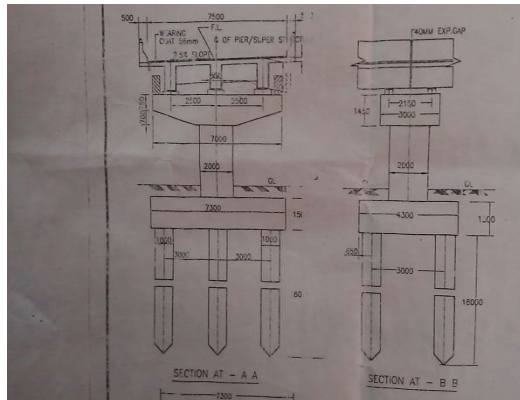


Figure 1 Whole Site plan.

The pile has a diameter of one metre, a length of 18 metres and 6 number of piles constructed at the one foundation all 6 piles are joined by a pile cap above the pile of dimensions 7.3 metres, 4.3 metres and 1.5 metres are length, width and depth respectively. The entire 20-metre structure was constructed below the ground level. The pile cap connected with the pier of a diameter of 2 meters and the pier length varies according to the deck level construction. The pier cap of the trapezoidal

shape of cross-section 7 meters, 3 meters and 1.45 meters are length, width and depth respectively constructive above the pier [4], [5]. The main portion of the bridge above the railway line of 32.835 meters used an iron girder as a beam above the pier cap and a deck slab constructed above that beam.

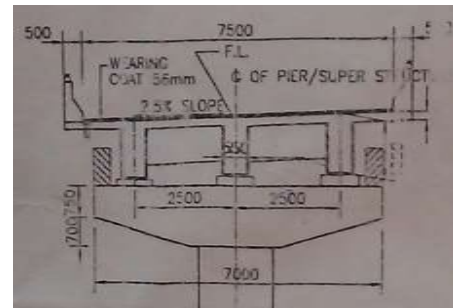


Figure 1 Side view of the project plan.



Figure 2 Girder for the railway overhead beam.

Table 1 Brief Project detail.

S. No.	Items	Particulars
1	Name of the bridge	Railway overhead bridge on level crossing no. 2 C Ghaziabad – Saharanpur section on Nehru Nagar-Kavi Nagar Road in Ghaziabad city
2	Estimated cost	Rs. 4459.54 Lacs
3	Vertical clearance	6.50 M
4	Foundation	Pile foundation in the viaduct
5	Substructure	2.0 M dia circular pier
6	Superstructure	3 nos. prestressed beams with RCC deck slab
7	Span arrangement	1*30.55+1*23.66+7*24+2*23.325+1*19.74
8	Length of the main bridge (railway portion)	32.835 M
9	Length of RE wall	133.625+143.44=277.065M
10	Length of RCC wall (retaining wall)	30.00 M on each side
11	The total length of the bridge	658.50 M
12	Bearing	Rubber-bearing
13	Roadway	7.5 M clear roadway without a footpath
14	Loading	Safe for class “A” two-lane or 70 R one-lane
15	Wearing coat	30 mm BC & 25 mm thick mastic asphaltic
16	Expansion joint	Strip seal type
17	Railing & the crash barrier	The RCC crash barrier & MS pipe railing
18	Crust detail main flyover ramp	GSB -250 mm thick in two-layer WMM -250 mm thick in two-layer DBM -165 mm thick in two-layer BC -50 mm thick in one layer

2. CONSTRUCTION OF THE SUPERSTRUCTURE OF THE BRIDGE

2.1. Bearings

Bearings are a structural device that transmits loads while facilitating translation and rotation from the superstructure to the substructure of the bridge. The rubber bearings used in the project for bearing. Natural Rubber bearing generally consists of interleaving layers of rubber bonded sandwich fashion to steel plates. The whole unit is covered with rubber to afford weather protection [9], [10].

2.2. Prestressing Beams

Prestressed Bars are steel in prestressed applications that have to be of good quality. It requires the following attributes: high strength, adequate ductility, Bend ability, which is required at the harping points and near the anchorage, High bond strength required for pre-tensioned members, and low relaxation to reduce losses and Minimum corrosion. Tendons are a group of strands or wires that are placed together to form a prestressing tendon. The tendons are used in post-tensioned members[11]. The strands are placed in a duct which may be filled with grout after the post-tensioning operation is completed. In prestressing the

beam, High-strength steel tendons are stressed while the beam is cast over them when concrete is cured, the tendons are slowly released, and the beam is immediately under axial load. This eccentric loading creates an internal moment and in turn, increases the moment carrying capacity of the beam [12], [13].

In general casting, the beam is done, and high-strength steel is placed via a duct so that it can be tensed after the curing. After tension, the empty spaces of ducts are filled with *grouting*. Grouting is a mixture of cement and water. After ducts are filled, and grouts are cured, the tension is released, and excess steels are cut. In every span, two or more beams are provided depending upon the width of the deck slab, and since spans of the bridges are long, the cross beam is provided for shortening the design span for the deck slab [14]–[16].

Figure 3 shows the prestressing cable layout beam in the longitudinal structure for PSC. The cable layout in beams is always in the shape of the boat. So the chances of failure of the structure become low.



Figure 4 shows the picture of cables before the prestressing, whereas Figure 5 shows the setup of the prestressing of cables before the load on the cables or tendons. The cables or tendons are stressed by the hydraulic jack fitted on both sides of the beam tendons. When cables or tendons are stressed by the hydraulic jack it lifts the beam section of the bridge. Figure 6 shows the rising condition of the beam after the stressing of the tendons. After the prestressing, grouting is done of the tendons space cylinder area for fixing the condition in which use the paste of cement and water with some additives like cebex for crack-free cement after the hardening. Figure 7 shows the picture after prestressing and grouting hardening. The tendons harden or are fixed through the grouting for practical use. The prestressed portion of the beam is covered by the section. Figure 8 shows the

cover section of the prestressed beam [17]–[19].



Figure 3 Prestressing cable layouts



Figure 4 before the prestressing of cable.



Figure 5 Setup for the prestressing of the beam.

Figure 6 Rise of the beam due to the Prestressing.

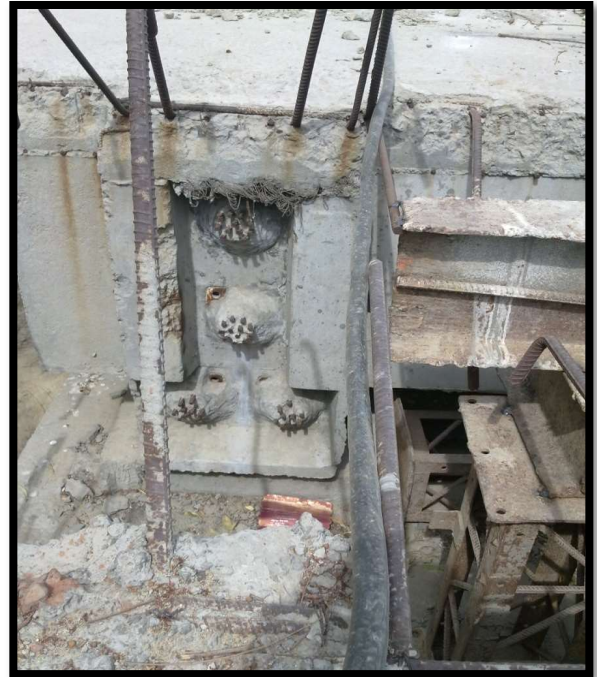


Figure 7 after the prestressing and grouting.



Figure 8 Closing section after prestressing of the beam.



Figure 9 casting of the deck slab of the bridge.

2.3. Deck Slab Construction

The deck slab is a slab constructed over the beam section of the bridge. The deck slab is the portion of the superstructure of the bridge which absorbs the traffic load. Figure 9 shows the deck slab casting at the site of the bridge construction. The ready-mix concrete is used for the casting of M40-grade [20].

2.4. Expansion joints

An expansion joint or movement joint is an assembly designed to safely absorb

the heat-induced expansion and contraction of construction materials, absorb vibration, hold parts together, or allow movement due to ground settlement or earthquakes. They are mostly found in the structural part between buildings, bridges, sidewalks, railway tracks, piping systems, ships, and other structures [5]. Figure 10 shows the expansion joint setup before the casting of the deck slab.



Figure 10 Expansion joint setup

2.5. GEO GRID

A geogrid is a geosynthetic material used to reinforce soils and similar materials. Geogrids are commonly used to reinforce retaining walls and subbases or subsoils below roads or structures. Soils pull apart under tension. Compared to the soil, geogrids are strong in tension. This fact allows them to transfer forces to a larger soil area than would otherwise be the case.

2.5.1. Installation of geo-grid in ramp portion

Before unrolling the geo-grid, verify the roll identification length, installation orientation, and installation location with the construction drawings while unrolling the geo-grid, inspect it for damage or defects damaged or defective geo-grid shall not be installed [21]. The geo-grid shall be laid at the proper elevation and orientation as per the construction drawings or as directed by the engineer. Correct orientation of the geo-grid is of extreme importance and shall be verified by the engineer. No lapping is permitted in the machine's direction. The geo-grid shall be cut to length as shown on the construction drawings using a razor, sharp knife, scissors or an equivalent. After the geo-grid has been laid in place, it shall be tensioned by hand until free of wrinkles and lying flat using pins or pegs at regular intervals as per the sketch. Figure 11 shows the picture of the tie-up of the two sections of the geogrid at the site. Figure 12 shows the spreading of the materials over the geogrid ramp portion at the site. Geogrid stable the materials or soil after the uneven load is applied on the ramp [22]–[25].



Figure 11 Tie-up of the geogrids.



Figure 12 Base course material

3. THE ESTIMATE OF CONCRETE & STEEL IN THE SUPERSTRUCTURE

The estimation and costing of the project structure are an essential part of the construction. The construction project's cost is very high, so a very accurate estimation of the project is required for approval.

3.1. Measurement of concrete in the superstructure

The calculation of concrete used in the construction of the project is essential for estimating the project. Concrete is the primary material to use for the construction of the bridge with different grades of concrete. A bridge contains three parts; the first one is foundation or footing, the second one is substructure, and the third is the

Table 2 describes the calculation of concrete of the whole superstructure of the bridge [26]–[28]. The calculation of the concrete is based on the cross-section of the structures.

3.2. Measurement of Steel in Super Structure

Steel is the second most essential material in the construction industry. Steel is used with the concrete to increase the

Table 3 describes the calculation of the steel used in the superstructures of the bridge. The consumption of the steel in the structure section as per the requirement of the section for strength [29]–[32].

superstructure. The bridge's superstructure contains prestressing beams, crossbeams, deck slabs, approach slabs, a central verge, a crash barrier, and miscellaneous concrete structures. The M40 grade of concrete is used to construct prestressed beams, cross beams and deck slab, whereas the M35 grade is used in the approach slab, central verge and crash barriers. M20 is used in the other miscellaneous concrete structures.

flexural or tensile strength of that section. Concrete has higher compressive strength but is weak in the tensile strength. So, the steel is used to increase tensile strength.

Table 2 Calculation of concrete used in the superstructures.

S. No.	Item	Grade	Cross-section (m ³)	Number of items	The volume of concrete (m ³)
1.	PSC Beam	M40	23.05*0.55*1.15	54	787.27
2.	PSC Beam	M40	29.05*0.62*0.25	6	27.02
3.	PSC Beam	M40	29.05*0.465*0.15	6	12.16
4.	PSC Beam	M40	29.05*0.31*0.1	6	5.40
5.	PSC Beam	M40	29.05*0.565*0.1	6	9.85
6.	PSC Beam	M40	29.05*0.82*0.1	6	14.29
7.	PSC Beam	M40	22.16*0.62*0.25	6	20.61
8.	PSC Beam	M40	22.16*0.465*0.15	6	9.27
9.	PSC Beam	M40	22.16*0.31*0.1	6	4.12
10.	PSC Beam	M40	22.16*0.565*0.1	6	7.51
11.	PSC Beam	M40	22.16*0.82*0.1	6	10.90
12.	PSC Beam	M40	18.24*0.62*0.25	6	16.96
13.	PSC Beam	M40	18.24*0.465*0.15	6	7.63
14.	PSC Beam	M40	18.24*0.31*0.1	6	3.39
15.	PSC Beam	M40	18.24*0.565*0.1	6	6.18
16.	PSC Beam	M40	18.24*0.82*0.1	6	8.97
17.	Deck Slab	M40	24*8.5*0.25	18	725.76
18.	Deck Slab	M40	30.55*8.5*0.25	2	129.84
19.	Deck Slab	M40	23.66*8.5*0.25	2	100.56
20.	Deck Slab	M40	19.74*8.5*.0.25	2	83.895
21.	Cross Beam	M40	1.2*0.8*0.55	180	95.04
22.	Cross Beam	M40	1.78*1.55*0.3	36	29.80
23.	Approach	M35	2.75*7.5*0.3	4	24.75

	Slab				
24.	Central Verge	M35	24*1.2*0.3	5	43.2
25.	Crash Barrier	M35	2*24*5	0.297	254.26
26.	Crash Barrier	M35	2*24*4	0.297	57.02
27.	Crash Barrier	M35	2*24*4	0.297	57.02
28.	Crash Barrier	M35	2*30.55*2	0.297	36.29
29.	Crash Barrier	M35	2*23.66*2	0.297	28.11
30.	Crash Barrier	M35	2*19.74*2	0.297	23.45
31.	Misc. Concrete	M20	1*1*0.6	240	144
			Total		2784.525

Table 3 Calculation of the steel used in the superstructure of the bridge.

S. No.	Item	Concrete (in m ³)	Consumption of steel (in kg/m ³)	Quantity of steel (in MT)
1	PSC Beam	1158.29	100	115.83
2	Deck Slab	1040.05	200	208.01
3	Cross Beam	124.92	200	24.98
4	Crash Barrier	273.18	150	40.98
5	Approach Slab	24.75	150	3.72
6	Misc. Concrete	144	15	2.16
7	Central Verge	43.20	80	3.46

	TOTAL	2784.525		399.14
	Add 10 % for overlap			39.91
	GRAND TOTAL			439.05

4. CONCLUSION

The paper is written based on the case study of railway overhead bridge construction. The construction important technical parts of the construction are concluded here. The study is mostly based on the superstructure part construction of the bridge. Then the following concluded:

- Prestressing of the beams plays an essential role in the load-carrying capacity of the structure. The load-carrying capacity of the beam increases without increasing the section.
- When the beam's construction is complicated, then use the steel girder as the beam section of the bridge directly putting between two pier caps.
- Additives like cebex play an essential role in cement water paste and reduce the cement's cracking properties.

- Geogrid is an essential part of the ramp portion. It increases the stability of the soil after applying the uneven load on the roads or pavements.
- The calculation of the concrete directly calculates with the cross-section parts of the superstructures. Steels are calculated by the content of the percentage used in that section of the superstructures.

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