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ANALYSIS AND DESIGN OF PEDESTRIAN BRIDGE

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Abstract— National Highway -58 has an average hourly traffic of more than 2000 vehicles in front of College of Engineering Roorkee (COER), Roorkee where students and other people cross the road. With this high avg. Hourly traffic value, crossing by foot can not only be challenging, but can be dangerous. With this in mind, this paper aims to design and build a pedestrian bridge at the intersection of NH-58 and Kaliyar road in front of COER. This will eliminate traffic congestion and delay at the highway as well as eliminate conflicts between pedestrians and motor vehicles. In recent years, the interest in solar energy has risen due to environmental concern and also to support green building initiative of College, a solar power generation system also incorporates in the design.

Keywords- Arch bridge, Truss bridge structures, Solar system, Soil property, STAAD analysis.

I.INTRODUCTION

College of Engineering Roorkee (COER), an engineering and management institution of higher education located in Roorkee educates more than 4,500 undergraduate and graduate students and employs about 300 employees. The students and faculty population has experienced steady growth for many years. College is situated at the intersection of National Highway-58 and Kaliyar road. Both roads have high number of vehicular traffic about 2000 vehicles per hour and also high pedestrian traffic cross the highway more than 400 at peak hour which include college students, employees and other locals. Due to increasing pedestrian traffic to cross the road creates delay to vehicles and it is not also safe. To more effectively deal with this problem, our team propose a plan, which include new means to crossing the highway safely and without causing traffic delay. A solution to protect pedestrian's safety is to design and build a pedestrian bridge. This will eliminate traffic congestion and traffic delay at both roads, as well as prevent conflicts between pedestrians and motorists.

This paper explored alternative structural solutions for a pedestrian bridge to connect the two sides of National Highway-58 in front of COER Campus. Four basic bridge types, each consisting of steel members, were initially considered. Two alternatives, a steel truss and steel arch bridges were designed in detail. STAAD-PRO, v8i software was used to support the calculation process. To support green building initiative of College, a solar power generation system also incorporates in the design.

II. SOIL CONDITIONS

Soil conditions have a major impact on the design and construction process. Tests are performed on the soil of proposed location for the new pedestrian bridge. From the tests report it was easy to determine that the site soil conditions were very poor, with moist loose silty sand and wet soft clay.

To know the type and behavior of soil tests are performed and following are the results:

2.1. Specific Gravity of soil (by Picnometer Test),G = 2.5926

2.2. Unit weight of soil (by Core cutter test) = 14.5 kN/ m^3.
2.3 Liquid limit of soil: Water content at which soil behaves practically like a liquid, but has small shear strength. Its flow closes the groove in just 25 blows in Casagrande's liquid limit device. From the 'flow curve' (in the Appendix) as the liquid limit. WL = 25.25%
2.4 2.4. Plastic limit of soil: Plastic Limit, wp = 21.729 %
2.5 Plasticity Index**:** Ip : PI = LL – PL = 25.25 –21.729 = 3.52%
2.6 2.5. Shrinkage limit of soil = 21.5%
2.7 2.6. Grain size distribution (Sieve analysis): Graph is plotted between log sieve size v/s % finer (in the Appendix). The graph is known as grading curve. Corresponding to 10%, 30% and 60% finer, obtain diameters from graph are designated as D10, D30, D60.
2.8 Cu = D60 / D10 = 0.2 / 0.076 = 2.632
2.9 C_c = (D30)2 / D60D10 = (0.094)2 / (0.2 X 0.076) = 0.58
2.10Hence, soil is **poorly graded** mainly silt because Cc don't lie between 1 &3 and Cu is less than 6 (for sand).

III. PROPOSED BRIDGE DESIGN

After conducting multiple field visits to the proposed bridge location and obtaining all of the necessary background information for the site as well as the necessary clearance requirements for all of the design obstacles, the design team has come up with two potential design solutions. Each of the potential design solutions was designed in an effort to safely transport pedestrians across NH - 58 without causing an unnecessary delay to traffic.

The first design option is of a steel through truss bridge with roofing. The second design option is of a steel arch bridge without roofing.

IV MODELLING IN STAAD-PRO

With the limitation of the space, the arch has to start below the bridge deck. The appropriate load combinations were applied to each member. The arches of the arch bridge were determined to be steel tubes. Although concrete is preferred in compression, steel ribs produce far less dead load forces. Furthermore, the steel arches allow for smaller cross-sections, which help with the clearance limitation of the bridge, and are popular in arch bridge design.

Once determining the coordinates for the top of the arch, the box for curve type, we selected "Parabolic Arch – 3rd Point Coordinates" to set the height. The arch was drawn into STAAD-PRO; however, due to the software's limitations, the curved member drawn was converted into 16 straight line members.
The connections for the 16 separate frame members also will serve as the joints where the cables would transfer the bridge deck loads to the arch. Cross members were added between the two arches to provide lateral support, as well as connectivity

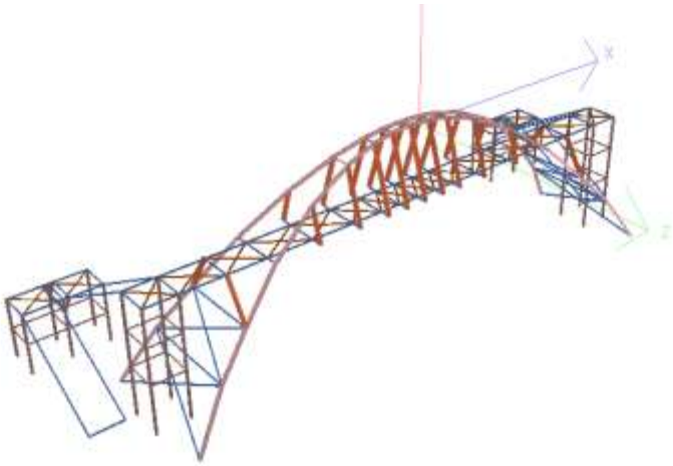

Figure1 : 3D view of Designed Arch Bridge**.**

Design Dimensions:
Clear Span = 22 m, Truss Depth = 3 m, Height of peak of arch from road = 8 m,
Clear Width = 1.5 m, Clear Height = 5.5 m, Roof Inclination angle = 30 degree
Design Loads: The Loads applied to bridge structures in STAAD-PRO are Dead Load (self-weight of members plus slab load, 3.5 kPa), Pedestrian Live load (4.5 kPa), Wind Load (according to basic wind speed, 39 m/sec in Roorkee) and Seismic Loads (based on seismic zone of Roorkee).

V STAAD-PRO, v8i ANALYSIS

After laying out the proposed arch bridge design in STAAD-PRO and inputting all joint loads and load combinations as previously described, a complete analysis was ran on the arch. Using the maximum axial forces in each member type, whichwere obtained from the STAAD-PRO analysis output, the various members of the arch bridge were sized accordingly.

Listed below are the selected member sizes and shapes for the bridge structures:

Arch bridge Beams	Member Section
Arch	TUB 1001005.0
Longitudinal beam	I80012B50012
Cross Beam	I80012B50012
Arch Bracing	PIP 337.0H
Roofing beam and column	PIP 213.0L
Cross Beam Bracing	ISA 40*40*5
Column	PIP 1016.0L

Table 1: Arch bridge beams and their member sections

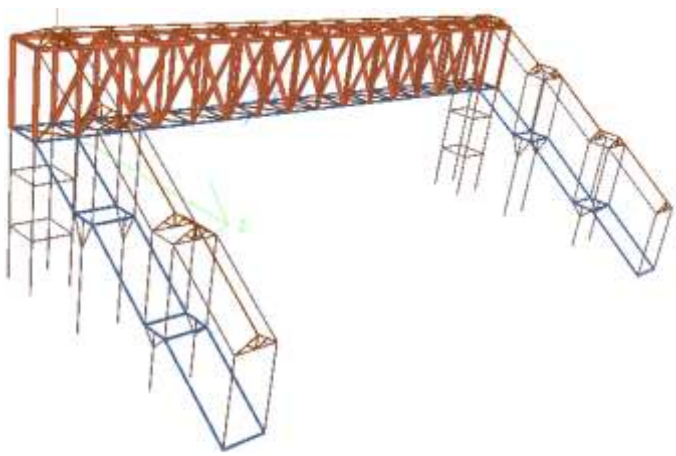

Figure 2: 3D view of Designed Truss Bridge**.**

Through Truss Beams	Member Sizes
Top Cord	ISMC 150
Bottom Cord	I80012B50012
Vertical	ISMC 150
Diagonal	ISMC 150
Roofing beam and column	PIP 213.0L
Cross Bracing	ISA 25*25*5
Column	PIP 269.0L

Table 1: Through truss beams and their member size

VI ARCH FOOTING DESIGN

The abutments were designed as retaining walls using the loads applied to the STAAD bridge model for an Arch. The supports for each of the two piers which will support the arch bridge are to be designed from concrete using a design compressive strength of 30 MPa. By using the reactions from the decking, and self-weight of the members, steps were taken into designing the abutments. The final recommended designs will have four concrete abutments with dimensions shown in Figures.

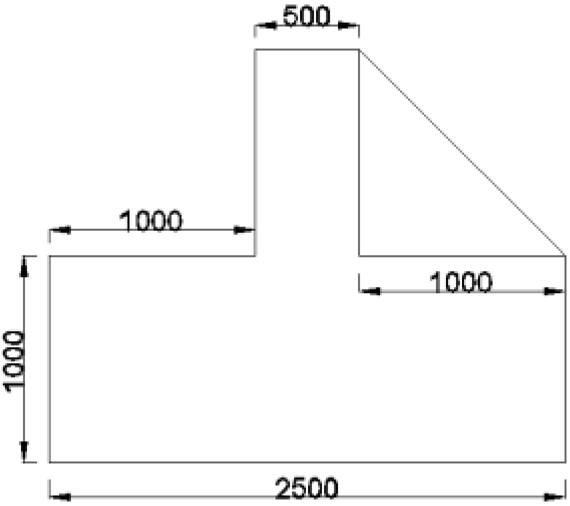

Figure 3: Plan of the designed foundation`

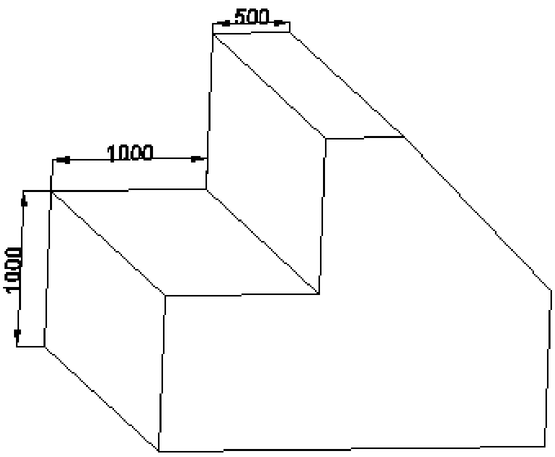

Figure 4: Plan of the designed foundation`

VII TRUSS BRIDGE FOUNDATION

The footing is designed using the vertical reactions of 100 kN, 100 kN, 200 kN, 200 kN respectively at the base of 4 columns for each side of bridge. These values are calculated by applying safety factor to the reactions obtained by STAAD-PRO analysis. The foundation for four columns is designed as combined footing which is designed with concrete of characteristic strength of 15 MPa and yield strength of the reinforcing steel of 250 MPa. By using the reactions from the decking, and self-weight of the truss design, steps taken into design are shown in Appendix. The final recommended design would be a concrete footing of 3m x 2.5m x 1m, with a base plate of 300mmx 300mm x 10mm, 6mm Fillet weld for connection of column to plate and 20 mm four bolts for the connection of plate to foundation. The concrete decking will rest on the four concrete piers at the ends of the parking garage.

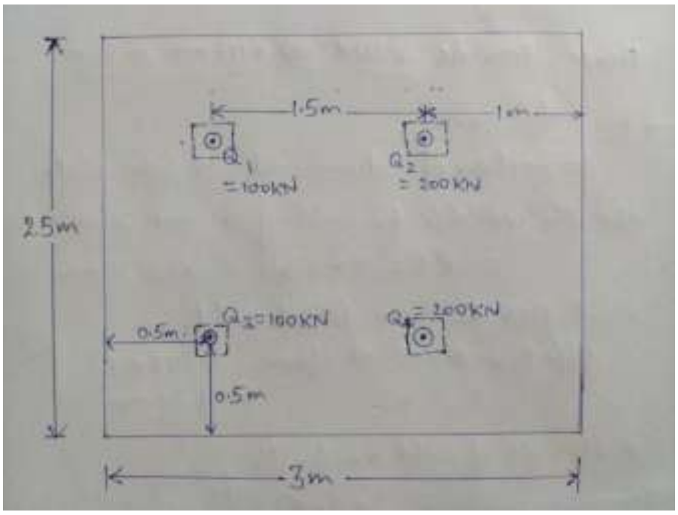

Figure 5: Plan of the designed foundation`

VIII. SOLAR PANEL SYSTEM DESIGN

In an effort to create a sustainable structure and to compliment the green building initiatives, the structural steel through truss portion of the bridge has been designed to have solar panels mounted along the south side of the roof. The optimal angle to mount solar panels is equal to the angle of latitude at the proposed location, which is 29.8926 N degree for our location. This mounting angle can however be within 15 degree either direction of the optimal angle without losing much power or efficiency from the solar panels, with lower angles being better for summer months and higher angles being better for winter months. The proposed roof design gives a mounting angle for the solar panels of 30 degree, which is well within the 15 degree allowable range without losing much power or efficiency from the solar panels. To increase the top surface area of roof we can made sloping roof at an angle of 20 degree. The solar system will consist of 24 solar panels (of dimension 1m*1.6m), each with a peak power output of 250 watts, which will be tied into the main electric grid or direct supplied to College campus. The credit that College will receive for the electrical power generated by the solar system will work towards powering the lighting for the bridge in addition to other electrical power used by the College.

The cost of solar panel is 50 Rs per watt. So, total cost of solar panels will be 3L Rs. The cost of electric inverter is about 2.5 L. additional cost of the wires, installation charges will be maximum of 50,000 Rs. Therefore, total cost of solar power system will be about 6 L Rs. Using a conservative year round average estimate of 4-5 hours of peak sunlight per day for solar power generating purposes, the proposed system will generate approximately 9,000 kilowatt hours (units) of electricity per year (we take only 300 days for calculation in a year). Furthermore, commercial price of electricity in Roorkee is 5 Rs. per kilowatt hour, the system will save the College approximately 45,000 Rs. per year in energy costs.The solar panels have life of at least 25 years. So, total electricity generation in this time period will be 2, 25,000 kWh (units) of worth 11, 25,000 Rs.

IX. CONCLUSIONS

This paper has given our group a greater understanding of the effort, time and diligence required during a major design process. Our team took the time to meet with a key administrator to gain a better understand of why a bridge was necessary. The bridge will become a main gateway at NH-58 and become part of the future promenade in that location.

Once the need for the bridge was addressed, research on multiple bridge styles and materials to give ourselves a number of options to choose from was performed. After brief analysis and design considerations of these options, two alternatives were selected for detailed design. These two alternatives would be an arch-cable bridge and a truss bridge.
Once the comprehensive design of each bridge was completed, and in depth schedule and cost estimate could be produced for each alternative. Based on our analysis, each bridge would have similar costs and times required for construction. Due to this, a final decision would likely be made based on constructability, aesthetics, and the overall favouritism of the Board of Trustee at College Of Engineering Roorkee. Exploring the social and technical aspects of this project has broadened our views of the construction process. Understanding that we need not only design the bridge, but also design a bridge that will actually get built has been a challenge.

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