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Economic Design of Steel Concrete Composite Bridges

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ABSTRACT:

A new class of high strength steel with excellent toughness, ductility, and good weldability is emerging world-wide, named as High Performance Steel (HPS). HPS can be designed as having an optimized balance of these properties to give maximum performance in bridge structures while remaining cost-effective. A study is performed to compare the cost differences between bridge designs using conventional mild steel Fe 410 and high tensile steel Fe 590. Two cases of span supported and un-supported during construction are considered for comparison. Maximum flexural stresses, maximum deflection, weight and cost are compared for 40m span steel-concrete composite bridge for both the unsupported and supported conditions of the bridge span during construction. HPS steel is found to be most beneficial and economical in bridge design as compare to MS. However, the maximum deflection is found to increase more than two times the permissible deflection of L/600 for total dead and live load, for HPS girder in comparison to the mild steel girder case.

INTRODUCTION

The application of high strength steel [1] makes it possible to design not only lightweight structures, but also simple structures with simple weld details. As the spans of bridges are getting longer and longer, there is strong demand for steel with regard to the increased strength. However, careful attention must be paid for the fabrication of structural members using high strength steel due to their inherent poor weldability. The fatigue performance [2] of structural welded members of high strength steel indicates the inverse material dependence. The biggest problem in high strength steel is to achieve a balance between tensile strength and fatigue performance without loosing good weldability. Another important problem is to

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overcome corrosion which is a drawback of steel bridges. Steel processing has undergone significant development in the past ten years. In addition to the traditional hot rolling, controlled rolling, normalizing, and quenching and tempering, various combinations of rolling practices and cooling rates have opened new opportunities to develop high strength with very attractive properties. The word "High Performance Steel (HPS)" has been used as the steel having higher ductility, better fracture toughness, better weldability, better cold formability, and better corrosion resistance besides higher strength [3]. When HPS, first became available for use [4], it was attractive steel to bridge engineers because of its superior weldability, fracture toughness and weathering characteristics. Since its first introduction to the market, HPS has been implemented in bridge design and construction in several states. However, though HPS offers the above positive attributes, it does have higher material costs [5]. Therefore, it is important to develop an understanding of how this material may most economically be incorporated in the design of composite I-girder bridges. A few studies have been performed to explore this issue and the benefits realized by weight savings and reduced fabrication costs, which may offset the increased material costs. For deflection control, the structural designer [6] should select maximum deflection limits that are appropriate to the structure and its intended use. The calculated deflection (or camber) must not exceed these limits. Codes [7] of practice give general guidance for both the selection of the maximum deflection limits and the calculation of deflection. Again, the existing code [8] procedures do not provide real guidance on how to adequately model the time-dependent effects of creep and shrinkage in deflection calculations [9-12]. HPS design follows the same design criteria and good practice as provided in Section-6 of Steel Structures of the AASHTO LRFD Bridge Design Specifications [13]. Use of HPS generally results in smaller members and lighter structures. The designers should pay attention to deformations, global buckling of members, and local buckling of components. For HPS, the live load deflection criteria are considered optional as stated.

COMPOSITE CONSTRUCTION:

Composite construction is a generic term to describe any building construction involving multiple dissimilar materials. Composite construction is often used in building

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aircraft, watercraft, and building construction. There are several reasons to use composite materials including increased strength, aesthetics, and environmental sustainability. In structural engineering, composite construction exists when two different materials are bound together so strongly that they act together as a single unit from a structural point of view. When this occurs, it is called composite action. One common example involves steel beams supporting concrete floor slabs.If the beam is not connected firmly to the slab, then the slab transfers all of its weight to the beam and the slab contributes nothing to the load carrying capability of the beam. However, if the slab is connected positively to the beam with studs, then a portion of the slab can be assumed to act compositely with the beam. In effect, this composite creates a larger and stronger beam than would be provided by the steel beam alone. The structural engineer may calculate a transformed section as one step in analyzing the load carry capability of the composite beam.

House building

A flitch beam is a simple form of composite construction sometimes used in North American light frame construction.[2] This occurs when a steel plate is sandwiched between two wood joists and bolted together. A flitch beam can typically support heavier loads over a longer span than an all-wood beam of the same cross section.

Deck Construction

Composite Wood Decking

The traditional decking material is pressure treated wood. The current material many contractors choose to use is composite decking. This material is typically made from wood-plastic composite or Fiberglass Reinforced Plastic (FRP). Such materials do not warp, crack, or split and are as versatile as traditional pressure treated wood. Composite decking is made through several different processes, and there are a multitude of sizes, shapes, and strengths available. Depending on the type of composite selected the decking materials can be used for a number of other construction projects including fences and sheds.[3][4]

Composite Steel Deck

In a composite steel deck, the dissimilar materials in question are steel and concrete. A composite steel deck combines the tensile strength of steel with the compressive strength of concrete to improve design efficiency and reduce the material necessary to cover a given area. Additionally, composite steel decks supported by composite steel joists can span greater distances between supporting elements and have reduced live load deflection in comparison to previous construction methods.[5][6][7]

Cement-Polymer Composites

Cement-polymer composites are being developed and tested as a replacement for traditional cement. The traditional cement used as stucco rapidly deteriorates. The deterioration causes the material to easily crack due to thermo-processes becoming permeable to water and no longer structurally sound. The United States Environmental Protection Agency in conjunction with Materials and Electrochemical Research Corporation tested a cement-polymer composite material consisting of crumb rubber made from recycled rubber tires and cement. It was found that 20% crumb rubber can be added to the cement mixture without affecting the appearance of the cement. This new material was tested for strength and durability using American Society for Testing and Materials (ASTM International) standards.[8]

High Performance Composites

A newer but growing sector in the composite construction sector is the high performance decking that comes from companies like Trex Decking and Fiberon. High performance composite decking has emerged in recent years to combat earlier generations of composite decking like wood plastic composite (WPCs) that were struggling to maintain credibility in the marketplace.[9] Research is showing now, however, that consumers are choosing composite decking products over wood 11 times to 1. Initial concerns regarding moisture intrusion in composite decks has led to the rise of high performance decking products with protective shells, often referred to as “capped composite decking.”[10]

Capped composite decks have a high performance finish with the addition of the shell that is often called a “cap-stock.” This shell covers either all four sides of the composite board or just the top and sides, depending on the brand. Manufacturers apply the cap to the board using a process called co-extrusion. Most capped composite decking comes with some kind of warranty against stains and fading

Bridges

Steel is widely used around the world for the construction of bridges from the very large to the very small. It is a versatile and effective material that provides efficient and sustainable solutions. Steel has long been recognised as the economic option for a range of bridges. It dominates the markets for long span bridges, railway bridges, footbridges, and medium span highway bridges. It is now increasingly the choice for shorter span highway structures as well.

Society gains in many ways from the benefits delivered by steel bridge solutions. Landmark steel bridges embody good design, they are fast to build, and have stimulated the regeneration of many former industrial, dock and canalside areas.

Steel bridges are an essential feature of a country's infrastructure and landscape. Few man-made structures combine the technical with the aesthetics in such an evocative way. Look closely at the next 'landmark' bridge you see; the chances are that it is made of steel. Modern steel bridges taking advantage of the latest advances in automated fabrication and construction techniques

are able to provide economic solutions to the demands of safety, rapid construction, aesthetics, shallow construction depth, minimal maintenance and flexibility in future use. Steel also scores well on all the sustainability measures, and offers a broad range of benefits addressing the economic, environmental, and social priorities of the 'triple bottom line' of sustainability. The high strength-to-weight ratio of steel minimises the structural weight of superstructures and thus minimises the substructure costs, which is particularly beneficial in poor ground conditions. Minimum self-weight is also an important factor in the cost of transporting and handling components. Use of steel facilitates shallow construction depths, which overcomes problems with headroom and flood clearances, and minimises the length and cost of approach embankments. Steel is the most recycled construction material and choosing it for bridges represents a sustainable management of natural resources. When a steel bridge reaches the end of its useful life, the girders can be cut into manageable sizes to facilitate demolition, and returned to steelworks for recycling. Some 99% of structural steel either finds its way back into the steelmaking process where it is used to create new steel products or is reused. There is no degradation in the performance of recycled steel. Alternatively, component parts of steel bridges can be reused in other structures; entire bridges have been relocated and bridges can be designed with ease of future relocation in mind. Steel has broad architectural possibilities. Steel bridges can be made to look light or reassuringly solid, and can be sculptured to any shape or form. The high surface quality of steel creates clean sharp lines and allows attention to detail. Modern fabrication methods can easily provide curvature in plan and elevation.

CONCLUSION This study has presented the comparison between mild steel and HPSgirder. HPS steel is found to be most beneficial and economical in bridge design as compare to MS. Several trends can be observed from the comparison of the data. Main conclusions drawn from the study are:
(1) In all cases, the HPS girder bridge resulted in the lightest than the MS girderbridge design. (2) For all the cases, the deflection in HPS girders design is more than that of MS girders design. With all the advantages of HPS, its main disadvantage is that the deflection is more than the permissible deflection limit. This has further adverse effects of increased flexural stresses in the deck slab, and its deterioration underincreased fatigue loading.

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