COMPOSITE STRUCTURAL MEMBER WITH LONGITUDINAL STRUCTURAL HAUNCH

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ABSTRACT
A composite structural member with a longitudinally extending structural haunch. The composite structural member comprises a plurality of longitudinally extending girders with molded sections disposed thereon. The molded section comprises a molded deck portion having a plurality of longitudinally extending structural haunches extending downwardly therefrom. Each haunch is disposed on a corresponding girder. The haunches are molded around shear connectors attached to the girders. The resulting structure has greater strength properties than a corresponding prior art structure having no haunch, the same deck thickness and substantially the same overall height and girder weight.
COMPOSITE STRUCTURAL MEMBER WITH LONGITUDINAL STRUCTURAL HAUNCH

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] This invention relates to structural members, and more particularly, to a composite structural member having a concrete deck section with a longitudinal concrete structural haunch molded thereto which is attached to a steel structural member.

[0003] 2. Description of the Prior Art

[0004] In the prior art there are a wide variety of structural members, both prefabricated and fabricated in place. These structural members include single element members, such as steel or concrete beams, and composite structural members with molded materials reinforced with, or supported by, metal bars or structural beams, girders or other elements. A typical molded material for the deck portions of these structures is concrete. To compensate for the deflection of the beams caused by their self-weight and the weight of the moldable material, a varying depth, longitudinal corrective haunch is used.

[0005] In forming structural members for spanning between two supports, it has often been found desirable to utilize a steel or wooden form beneath a molded concrete deck surface. First, the steel supports, such as wide flange girders, are erected. Then the forms are disposed around, and supported by, the girder or girders. The girder top elevations are then measured, and the varying depths for the longitudinal corrective haunch are computed and the necessary formwork built. Next, the concrete is poured into the mold such that the concrete fills the mold and extends over the girder. When the concrete is hardened, the forms are disassembled from around the girders, and the concrete then rests on the girders. In most instances, these wide flange girder-supported concrete structural members are formed in place. This is usually advantageous so the concrete surface can better fit into the finished structure because of the longitudinal corrective haunch. The concrete deck portion is attached to the beams by shear connectors which are molded into the concrete.

[0006] In such composite structures, the concrete deck portion must be sufficiently thick to support the load applied thereto. Such loads include the weight of the concrete itself and any external loads which are applied, such as traffic on a bridge.

[0007] The present invention utilizes a longitudinally extending structural haunch beneath a concrete deck portion, and a steel member is connected to the haunch. Preferably, the haunch has a substantially constant depth or height. The intent of the structural haunch is to increase the structural properties of the composite member, and more importantly, to reduce the steel beam weight required for a specified total structural depth or height, whereas in the prior art, the varied depth corrective haunch served only to compensate vertically for dead load deflections. As a result, for a structure having a given total depth or height and deck thickness, the steel beam weight in the present invention will be reduced as the haunch depth increases, or for a constant steel weight, the section properties increase as the haunch depth increases.

[0008] The present invention can be built in place or off-site with continuous shoring but includes an embodiment utilizing end supports and a single temporary support at or near the centerline of the span as disclosed in U.S. Pat. No. 5,144,710. In either case, the beam or beams can be elevated at the temporary supports during the casting process to compensate vertically for dead load deflections and do not require a variable depth haunch.

SUMMARY OF THE INVENTION

[0009] The present invention is a composite structural member with a molded longitudinal structural haunch. The invention is particularly well adapted for bridge structures, but is not intended to be so limited.

[0010] Generally, the invention can be described as a structural apparatus comprising a plurality of girders extending in a longitudinal direction and a molded deck portion disposed above the girders. The girders are spaced from one another in a transverse direction with respect to the girders. The molded section comprises a deck portion disposed at least partially above the girders and a plurality of longitudinally extending structural haunches extending downwardly from the deck portion. Each haunch is attached to a corresponding girder. The haunches preferably have a substantially constant depth or height.

[0011] Preferably, the deck portion and haunches are integrally molded and made of concrete.

[0012] Also, the girders are preferably supported at their ends and by a single temporary support at or near the centerline of the span or by multiple shores along the length of the girders.

[0013] The structure may further comprise a shear connector attached to each of the girders with the haunches molded around the shear connectors. If the haunches are greater than about 4 inches deep, a hat bar is preferably added adjacent to the shear connectors. An upper portion of the hat bars extends into, and is molded in, the deck portion.

[0014] The configuration of the present invention allows for the thickness of the deck portion and the total height of a haunch having a measurable height plus the girder height to be selected along with a girder weight, and that structure will have an increasing ultimate resisting moment as the haunch depth or height increases and the beam depth decreases the same amount. If the ultimate resisting moment is constant, then the girder weight will drop as the haunch depth increases and the beam depth decreases the same amount.

[0015] Numerous objects and advantages of the invention will become apparent as the following detailed description of the preferred embodiment is read in conjunction with the drawings which illustrate such embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1 shows a side elevation view of a prior art composite structural member having a molded deck portion, a variable depth corrective haunch and a steel supporting member.

[0017] FIG. 2 is a transverse cross section of the prior art structure taken along lines 2-2 in FIG. 1.
FIG. 3 is a side elevational view of a first embodiment of the composite structural member with longitudinally extending structural haunch of the present invention. FIG. 4 is a transverse cross section taken along lines 4-4 in FIG. 3. FIG. 5 shows a specific example of the prior art structure. FIG. 6 shows a corresponding example of the first embodiment of the structural member of the present invention. FIG. 7 is a transverse cross section of a second embodiment of the invention. FIG. 8 shows an example of the second embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1 and 2, a prior art composite structure is generally designated by the numeral 10. In the embodiment shown, prior art member 10 is a bridge structure adapted for extending between a pair of abutments or supports 12 and 14 disposed on opposite sides of whatever is to be bridged, such as a river (not shown).

Member 10 comprises a plurality of longitudinally extending girders 16 which generally have an I-beam configuration. A pair of girders 16 are shown, but more may be used. Girders 16 are positioned and supported on abutments 12 and 14 adjacent to longitudinally opposite ends 18 of the girders. As best seen in FIG. 2, each girder 16 has a vertically extending central portion 20 with horizontal upper and lower flange portions 22 and 24.

Disposed above girders 16 is a molded deck portion 26 which is made of a moldable material such as concrete. Deck portion 26 has an upper surface 28. A lower surface 30 of deck portion 26 is spaced above upper flange 22 of girder 16 by a downward extending variable depth corrective haunch 32. Haunch 32 is an integral part of deck portion 26 and varies in thickness from a thinnest portion adjacent to ends 18 tapering to a thickest portion at the longitudinal center of girder 16. Haunch 32 is a "variable depth corrective" haunch which is used to compensate for the downward deflection of girders 16 as a result of their own weight and the weight of deck portion 26. The object of these corrective haunches is simply to keep upper surface 28 for the structure substantially close to the required grade line of the roadway even though girders 16 deflect somewhat.

Extending upwardly from the top of girders 16 are a plurality of shear connectors 34. Shear connectors 34 are fixedly attached to the top of upper flanges 22 of girders 16. Each shear connector 34 preferably has a Shank portion 36 with an enlarged head portion 38 at the outer end thereof. Other kinds of connectors are also generally known. Deck portion 26 is formed and placed on girders 16 such that the molded material forming the deck portion is molded around shear connectors 34 thus forming a locking attachment between deck portion 26 and girders 16. Once the molded material has hardened, a composite structure is formed.

Referring now to FIGS. 3 and 4, a first embodiment of the composite structural member with longitudinally extending structural haunch of the present invention is shown and generally designated by the numeral 50. The illustrated embodiment shows structural member 50 as a bridge. Structural member 50 which may also be referred to as a structural apparatus 50 is also positioned on a pair of known supports or abutments 52 and 54 which are of conventional type. During construction of structural member 50, a single temporary support 53 with a jack 55 on it is used at the center of the span which allows for vertical adjustment for girder 56. Alternatively, several temporary supports 53 may be used along the length of girder 56 to continuously shore and adjust the girder 56.

Member 50 comprises a plurality of longitudinally extending girders 56 which are supported on abutments 52 and 54 adjacent to longitudinal ends 58 of the girders. Each girder 56 has a vertically extending central portion 60 with upper and lower horizontal flange portions 62 and 64 on opposite sides thereof.

Structural member 50 also comprises a molded section 66 made of a moldable material, such as concrete. Molded section 66 comprises an upper deck portion 68 with a plurality of longitudinally extending haunches 70 positioned on a corresponding upper flange 62 of each girder 56.

Haunches 70 may be attached to girders 56 by a plurality of shear connectors 74 extending from upper flanges 62 in a manner similar to prior art shear connectors 32 previously described. An inverted hat bar 72 is preferably added at about the same spacing as the shear connectors 74 for depths or heights of haunches 70 greater than about 4 inches. Each hat bar 72 is molded in a corresponding haunch 70. Upper, outwardly extending leg 76 on hat bars 72 extend into deck portion 68. Thus a composite structure is formed.

Deck portion 68 of molded section 66 of structural member 50 is substantially the same thickness as deck portion 26 in corresponding prior art structural member 10 designed for the same application. Also, the overall height of structural member 50 from the top of deck 66 to the bottom of beams 56 is the same for the corresponding prior art structural member 10.

Because of haunch 70, it will be seen that the height of girder 56 is significantly smaller than girder 16 in prior art structural member 10. The key aspect of the present invention is that structural member 50 is a composite unit which, for the same weight of girder, has a higher ultimate resisting moment than the corresponding prior structural member 10, or, if structural members 50 and 10 have the same ultimate resisting moment, beam 56 will be lighter than beam 16. Haunch 70 is a structural haunch which adds significant strength and other material properties to the entire structure unlike the corrective haunches used in the prior art. The latter, since their depth varies and depends on the existing camber of the girders does not operate as a structural haunch. The advantage of the present invention is that it allows the use of a smaller girder 56 than prior art girder 16 in a structure designed for the same application and which will fit in the same space and location. The cost of constant depth, molded haunches 70 is considerably less than variable depth haunch 32. Therefore, with the girder savings, there is a sizable savings using structural member 50 instead of prior art member 10. Thus, the need for a strong, but less expensive structure, is met.
EXAMPLE 1

[0034] Referring to FIGS. 5 and 6, examples of a prior art structure and a corresponding example of the first embodiment of the present invention are shown. Prior art structural member 10, as seen in FIGS. 1 and 2, has a thickness of 8 inches for deck portion 26 with girder 16 being a W30x124 I-beam (30-inch height, 124 pounds per foot) giving an overall height of 38.17 inches compared to structural member 50 of the present invention having a deck portion 66 thickness of 8 inches with a 6.11 inch haunch 70 mounted on a girder 56 which is a W24x104 I-beam, giving an overall height of 38.17 inches as well. This example confirms that for a constant total depth or height, deck thickness and required ultimate resisting moment, as the haunch depth or height increases the required beam weight decreases. Likewise, it confirms by logic, that if the beam weight is constant, the ultimate resisting moment increases as the haunch depth increases.

[0035] Ultimate Resisting Moment Calculation—Prior Art

\[ C = T = \frac{A_{p}E_{f}}{\varphi} \]

\[ a = \frac{C - a_{e} \cdot F_{y}}{a \cdot f'_{c} \cdot W_{s}} \]

\[ a = \frac{[3,660 - 9(0.2)60] }{0.85(9)11.5(12)} = 7.570 \text{ inches} \]

\[ MA = d - \frac{a}{2} \]

\[ MA = 38.17 - \frac{30.17}{2} = 7.57 \text{ inches} = 19.30 \text{ inches} = 1.608 \text{ feet} \]

\[ M_{u} = C \cdot MA \]

\[ M_{u} = 3.660(1.608) = 5,886.5 \text{ ft-lb/in}^2 \]

[0036] Ultimate Resisting Moment Calculation—Present Invention, First Embodiment

\[ C = T = \frac{30.90(2)50}{3.090 \varphi} \]

\[ a = \frac{C - a_{e} \cdot F_{y}}{a \cdot f'_{c} \cdot W_{s}} \]

\[ a = \frac{[3,090 - 9(0.2)60] }{0.85(9)11.5(12)} = 6.355 \text{ inches} \]

\[ MA = d - \frac{a}{2} \]

\[ MA = 38.17 - \frac{24.06}{2} = 22.925 \text{ inches} = 1.914 \text{ feet} \]

\[ M_{u} = C \cdot MA \]

\[ M_{u} = 3.090(1.914) = 5,912.8 \text{ ft-lb/in}^2 \]

[0038] Where:

[0039] \( M_{u} = \) Ultimate Resisting Moment

[0040] \( C = \) Compression Force part of Moment Couple

[0041] \( T = \) Tension Force part of Moment Couple

[0042] \( F_{y} = \) Steel Yield Stress (50 ksi for structural steel and 60 ksi for reinforcing steel)

[0043] \( MA = \) Moment Arm

[0044] \( a = \) Depth of Compression Block

[0045] \( d = \) Distance from bottom of beam to top of slab

[0046] \( A_{p} = \) Area of beam

[0047] \( A_{s} = \) Area of reinforcing steel in concrete slab

[0048] \( W_{s} = \) Width of concrete slab

[0049] \( \varphi = \) Strength Reduction Factor

[0050] \( f'_{c} = \) 28 Day Breaking Strength of Concrete

[0051] \( y_{p} = \) Distance from bottom of flange to centroid of beam (for W beams)

[0052] for W beams)

[0053] Referring now to FIG. 7, a second embodiment of the present invention is shown and generally designated by the numeral 80. Structural member 80 which may also be referred to as a structural apparatus 80 is also positioned on a pair of known supports or abutments of conventional type in a manner similar to first embodiment apparatus 50.

[0054] Member 80 comprises a plurality of longitudinally extending T-shaped beams or girders 82. Each girder 82 has a vertical central web portion 84 extending upwardly from a horizontal flange portion 86.

[0055] Structural member 80 also comprises a molded section 88 made of a moldable material, such as concrete. Molded section 88 comprises an upper deck portion 90 with a plurality of longitudinally extending haunches 92 positioned on flange portion 86 of a corresponding girder 82 such that web portion 84 thereof is molded in the haunch. A plurality of shear connectors 94 may be attached to each web portion 84 and also molded in haunch 92.

[0056] A hat bar 96 is preferably added at about the same spacing as shear connectors 94 such that it straddles central web portion 84 of girder 82. Such a hat bar 96 is preferably used for depths or heights of haunches 92 greater than about 4 inches. Each hat bar 96 is attached to a pair of longitudinal bars 98 by any means known in the art, such as welding or tying. Longitudinal bars 98 are disposed on opposite sides of the corresponding central web portion 84 of girder 82. Bars 98 may be made of, for example, a section of conventional reinforcing rod, but the invention is not intended to be so limited.

[0057] Deck portion 90 of second embodiment structural member 80 is substantially the same thickness as deck portion 66 of the first embodiment member 50. Also, the overall height of structural member 80 is substantially the same as first embodiment 50.

[0058] As with first embodiment member 50, the key aspect of second embodiment structural member 80 is that it is a composite unit which has a higher ultimate resisting moment than the corresponding prior structural member 10.
Haunch 92 is a structural haunch which adds significant strength and other material properties to the entire structure in a manner similar to haunch 70 in the first embodiment. The advantage of the second embodiment is that it allows the use of an even smaller and lighter girder which has significant cost savings associated with it.

**EXAMPLE 2**

[0059] Referring to FIG. 8, an example of the second embodiment of the present invention is shown. In this example, structural member 80 of the present invention has a deck portion 90 thickness of 8 inches with a 23.31 inch haunch 92 mounted on a girder 82 which is a WT6×76 T-shaped beam, giving an overall height of 38.17 inches. This second embodiment structure has an even higher ultimate resisting moment than the first embodiment shown in Example 1.

[0060] Ultimate Resisting Moment Calculation—Present Invention, Second Embodiment

\[ C = \frac{A_c \cdot F_c}{2} \]

\[ C = \frac{(22.35)(2)(80)}{2} = 2,235 \text{ k} \]

\[ a = \frac{C - A_c \cdot F_c}{T \cdot W_b} \]

\[ a = \frac{(2,235 - 90.2)(60)}{0.85(4)(11.5)(12)} = 4.533 \text{ inches} \]

\[ MA = d - \frac{a}{2} \]

\[ MA = 38.17 - 4.3 - \frac{4.533}{2} = 34.4735 \text{ inches} = 2.873 \text{ feet} \]

\[ M_{u} = C \cdot MA \]

\[ M_{u} = 2,235(2.873) = 6,420 \text{ ft-lb/in} \]

[0061] Where:

- \( C \) = Ultimate Resisting Moment
- \( A_c \) = Compression Force part of Moment Couple
- \( T \) = Tension Force part of Moment Couple
- \( F_c \) = Steel Yield Stress (50 ksi for structural steel and 60 ksi for reinforcing steel)
- \( MA \) = Moment Arm
- \( a \) = Depth of Compression Block
- \( d \) = Distance from bottom of beam to top of slab
- \( A_b \) = Area of beam
- \( A_r \) = Area of reinforcing steel in concrete slab
- \( W_b \) = Width of concrete slab
- \( \phi \) = Strength Reduction Factor
- \( f'_{c} \) = 28 Day Breaking Strength of Concrete
- \( y_b \) = Distance from bottom of flange to centroid of beam

[0075] for W beams

[0076] It will be seen, therefore, that the composite structure with longitudinal structural haunch of the present invention is well adapted to carry out the ends and advantages mentioned as well as those inherent therein. While presently preferred embodiments of the apparatus have been described for the purposes of this disclosure, numerous changes in the arrangement and construction of parts may be made by those skilled in the art. All such changes are encompassed within the scope and spirit of the appended claims.

What is claimed is:

1. A structural apparatus comprising:
   a plurality of girders extending in a longitudinal direction, said girders being spaced from one another in a transverse direction with respect to said girders;
   a molded section disposed above said girders, said molded section comprising:
   a deck portion disposed at least partially above said girders; and
   a plurality of longitudinally extending, structural haunches extending downwardly from said deck portion, each haunch being attached to a corresponding girder.
2. The apparatus of claim 1 wherein said deck portion is made of concrete.
3. The apparatus of claim 1 wherein said deck portion and said haunches are integrally molded.
4. The apparatus of claim 3 wherein said deck portion and said haunches are made of concrete.
5. The apparatus of claim 1 further comprising a shear connector attached to each of said girders; wherein, said haunches are molded around corresponding shear connectors.
6. The apparatus of claim 5 further comprising a plurality of hat bars adjacent to said shear connectors.
7. The apparatus of claim 6 wherein each of said hat bars has an upper portion which extends into, and is molded in, said deck portion.
8. The apparatus of claim 6 wherein a depth of said haunches is greater than about 4 inches.
9. The apparatus of claim 1 wherein said haunches have a substantially constant depth.
10. The apparatus of claim 1 wherein said girders are T-beams.
11. The apparatus of claim 1 wherein said girders are T-beams.
12. The apparatus of claim 11 further comprising a shear connector attached to a web portion of said T-beams; wherein, said haunches are molded around corresponding shear connectors.
13. The apparatus of claim 1 further comprising a hat bar molded in at least one of said haunches.
14. The apparatus of claim 13 further comprising a longitudinally extending bar attached to said hat bar.
15. The apparatus of claim 14 wherein:
said girders are T-beams; and
one of said rods is disposed on each side of a central web portion of said T-beams.
16. A structural apparatus comprising:
a plurality of substantially parallel, spaced girders extending in a longitudinal direction;
a shear connector attached to each of said girders;
a molded section disposed above said girders, each molded section comprising:
a deck portion forming an upper surface of the apparatus; and
a plurality of substantially constant depth haunches disposed below said deck portion, each haunch corresponding to one of said girders and molded around said shear connectors attached to each corresponding girder.
17. The apparatus of claim 16 wherein said deck portion and haunch are integrally formed of a moldable material.
18. The apparatus of claim 17 wherein said moldable material is concrete.
19. The apparatus of claim 16 further comprising hat bars adjacent to said shear connectors.
20. The apparatus of claim 19 wherein said hat bars have an upper portion which extend at least partially into, and are at least partially molded into, said deck portion.
21. The apparatus of claim 19 wherein a depth of said haunches is greater than about 4 inches.
22. The apparatus of claim 19 wherein said girders are I-beams.
23. The apparatus of claim 22 wherein said shear connectors are attached to flanges of said I-beams.
24. The apparatus of claim 16 wherein said girders are T-beams.
25. The apparatus of claim 24 wherein said shear connectors are attached to a central web portion of said T-beams.
26. The apparatus of claim 25 further comprising a hat bar straddling said central web portion.
27. The apparatus of claim 26 further comprising a longitudinally extending bar attached to said hat bar.
28. The apparatus of claim 27 wherein there is one of said longitudinally extending bars disposed on opposite sides of said central web portion.
29. The apparatus of claim 16 further comprising a hat bar disposed in at least one of said haunches.
30. A structural apparatus comprising:
a plurality of girders extending in a longitudinal direction, said girders being spaced from one another in a transverse direction with respect to said girders;
a molded section disposed above said girders, said molded section comprising:
a deck portion disposed at least partially above said girders; and
a plurality of longitudinally extending haunches extending downwardly from said deck portion, each haunch being attached to a corresponding girder;
wherein, a thickness of said deck portion, a height of said haunch and a height and weight of said girders are selected such that the structure has an ultimate resisting moment greater than an ultimate resisting moment of a structure having a deck portion with substantially the same thickness, no haunch and substantially the same overall height.
31. The apparatus of claim 30 wherein said deck portion is made of concrete.
32. The apparatus of claim 30 wherein said deck portion and said haunches are integrally molded.
33. The apparatus of claim 32 wherein said deck portion and said haunches are made of concrete.
34. The apparatus of claim 30 further comprising a shear connector attached to each of said girders;
wherein, at least said haunches molded around said shear connector.
35. The apparatus of claim 34 further comprising a plurality of hat bars adjacent to said shear connectors.
36. The apparatus of claim 35 wherein each of said hat bars has an upper portion which extends into, and is molded in, said deck portion.
37. The apparatus of claim 35 wherein a depth of said haunches is greater than about 4 inches.
38. The apparatus of claim 34 wherein:
said girders are I-beams; and
said shear connectors are attached to flanges of said I-beams.
39. The apparatus of claim 34 wherein:
said girders are T-beams; and
said shear connectors are attached to a web portion of said T-beams.
40. The apparatus of claim 30 wherein said haunches have a substantially constant height.
41. The apparatus of claim 30 further comprising a hat bar disposed in at least one of said haunches.
42. The apparatus of claim 41 further comprising a longitudinally extending bar attached to said hat bar.
43. The apparatus of claim 42 wherein:
said girders are T-beams; and
one of said longitudinally extending bars is disposed on each side of a central web portion of said T-beams.
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