

1388855

PATENT SPECIFICATION

(11) 1388855

- (21) Application No. 7735/71 (22) Filed 24 March 1971
 (23) Complete Specification filed 26 June 1972
 (44) Complete Specification published 26 March 1975
 (51) INT CL² F16B 1/00//E01D 9/02
 (52) Index at acceptance
 F2M W2L
 E1G 90A 90E 90F
 E1K 2A 2B



(54) NOVEL CONNECTING MEMBERS IN AND FOR A STRUCTURE OR MACHINE

(71) We, ANIRUDHA SHIVPRASAD BHAGAT and SHAKUNTALA ANIRUDHA BHAGAT, both Indian Nationals, of c/o Messrs. Bhagat Engineering Co. Private Ltd., 68B, Woollen Mill Lane, Bombay 28, India, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to the connecting together of structural members or units like rails, beams, girders and gantries or any machine parts.

Conventional methods for connecting together two such members consist in riveting or welding the two ends together or connecting them by bolts and nuts so that the entire load is taken by the weld or bolts and nuts or the rivets. The disadvantages of these are that all of them develop eccentricity in local transfer of loads and to counteract the eccentricity cover plates have to be used on both sides of the end of member. Where rivets or bolt and nut assemblies are employed, marking and drilling of several holes, matching them in different and in cover plates and reamering thereof are necessary. In view of the pluralities of operations involved, the assembly of members on site is rendered difficult or cumbersome so that often assembled large sized members have to be transported to the final site and this needs heavy handling tackle or arrangements have to be made to carry out all or some of the operations at least, on site. Again, in cases in which rivets and bolt and nut assemblies are employed large quantities of additional materials are required with the result that the size of the joint becomes enlarged and out of all proportion to the job requirement in order to accommodate the minimum number of requisite rivets or bolts and nuts which have to be of manageable sizes and must have the requisite spacing between them. Besides, in the case of structural frames the spans are long and therefore the deviation and deflec-

tions remain unknown factors due to side slip or shift that takes place as a result of the clearance between the bolt or rivet and the hole. This necessitates the inclusion of additional members in the framework so as to compensate for such unknown factors, or the use of members of still heavier cross section at the joints to prevent failure due to eccentric movements.

Objects which were aimed at by the present invention can be summed up as follows:

- (A) building any structure, from the lightest to the heaviest, of any practicable span with permutations and combinations thereof, out of a few standardised, prefabricated, mass-produced components,
 (B) making prefabricated components in small sizes for ease of handling, storage, and erection,
 (C) assembly into any structure in situ by even semi-skilled personnel.
- The achievement of the above objects implies that the connecting device should further meet the following criteria:

- (i) Material consumption:
 There should be minimum difference in the material consumption if a given span is divided into several prefabricated small components jointed together. In other words, there should be a minimum of overlapping of jointed members.
- (ii) Side Shift:
 There should be no chance of side shift or slip in the joint, which is so common in bolted joints due to gap between the bolt hole and bolt shank.
- (iii) Smallness of joint
 The joint should be small enough efficiently to utilise the material but still develop no eccentricity in load transfer.
- (iv) Mass production
 The joint itself is a mass produced item, divided into several load carrying capacities, to effect economies of sale and to be utilised as per the loading conditions, types of structural members and magnitudes of loading.

(v) Identity of Parts

The parts of the joints are not male and female but are identical, so that any half joint can mate with any other half joint in the same capacity range. This factor not only reduces the inventory of joints by half, but also the prefabricated components.

(vi) Versatility of Application

All capacities of joints can be made which will be suitable for use with the standard rolled sections so that they can be adopted for any application and which are readily available.

(vii) Welding with Ordinary Skill

The joint will be capable of being welded to the sections of the structural members or units with ordinary skill and yet be of robust construction, safe from damage in transit and handling. It will have the life factor, wear and tear and corrosion considerations incorporated in its design.

(viii) The joint may be either an ideal pin joint or a rigid joint so that the basis of analysis properly met with.

(ix) It would be possible to manufacture the joint out of any material usable as structural or mechanical component, metallic or non-metallic.

From one aspect, the present invention consists in a connecting member for connecting together two structural units, which is formed on one face with at least one ridge and one groove for interengaging with the ridge(s) and groove(s) of an identical connecting member with which its face is disposed in overlapping relation, said ridge(s) and groove(s) having tapered side surfaces which are so tapered as to produce a taper lock between interengaging ridges and grooves, and the or each groove having a width at its base less than the width of the or a corresponding ridge at its top so that only the tapered surfaces of the ridges and grooves are in contact when the two identical connecting members are interengaged, said connecting member also being adapted to be secured to the identical member by fixing means.

From another aspect, the invention consists in a connecting assembly for connecting together two structural units, comprising two identical connecting members having overlapping faces, each of which is formed with at least one ridge and one groove which are interengaged with the ridge(s) and groove(s) of the other member, said ridges and grooves having tapered side surfaces which are so tapered as to produce a taper lock between the interengaging ridges and grooves, each groove having a width at its base less than the width of the interengaging ridge so that only the tapered surfaces of the ridges and grooves are in contact, and additional fixing means for also securing said connecting members together.

The tapered surfaces of the ridges and grooves preferably have a taper angle of 12° or less.

To fasten or hold the two connecting members together in the exact desired position conventional fixing means such as a bolt and nut assembly, or a threaded stud, wedge, taper-pin, rivet or welding connection is used in a predetermined location or locations on the joined faces of connecting members. For the same strength in a solely welded joint, the welding quantity and area would easily be at least 100 times greater. However, due to forming the two connecting members in the manner stated, the load is not borne by the bolt or weld, but the portions of the connecting members, where the mating of ridges and grooves occurs, take the load by development of shear stresses in such locations. The main function of the bolt and nut (or taper pin) or weld is to hold the two half joints (connecting members) together. The bolt or other fixing system joining the two connecting members together is in direct tension. Thus, these connecting members may be formed in any size and configuration to enable a joint to be created that will develop the calculated stresses and take the desired load. It has been found that even after large number of repeated engaging and disengaging of the connecting members, the gap between the ends of the mating ridges and grooves still exists so that endurance and life of the device is immense.

In the present invention, since the load being transferred by the joints is taken by shear stresses developing in the material of the joints, the ends of the members according to this invention may be referred to as SHEAR CONNECTORS. Such shear connectors can be made integral with the structural units or members, as defined above, or separately made and joined to the ends of the structural members by welding. They may also be precast along with concrete beams.

Such shear connectors may be made from metal by casting and/or by machining methods or by forging or any other method of manufacture. They may be made of metal or other materials such as plastics or of fibre glass. Moulding methods can be used for fabrication from plastics or fibre glass.

The structures to be built up would utilize a series of above described shear connectors which effect a full force transfer connection of structural load carrying components, using just a single bolt and nut assembly (or taper pin) in exact predetermined location which makes it possible to maintain exact geometry of shape and alignment of even the largest and heavily loaded structures even though the same are assembled out of small components. This is possible because this joint does not give rise to any eccentricity in load transfer or to secondary moments. In other words,

it functions as a welded joint, but retains the advantages of a bolted or an ideal pin joint. The shear connectors enable easy erection of components, dismantling and rejoining as often as desired, as against the conventionally welded or rivetted joints which make it difficult. There is also considerable savings in materials since the joint also spans the distance at joints and the main members are shorter.

According to one embodiment of this invention the connecting members are made of circular section. The grooves and ridges in the connecting members or integral connecting members may be arcuate type, i.e. their elevation is in the form of a sector, or may radially extend from central portion of each said surface.

This invention also includes a structural unit adapted to be connected to another structural unit characterised in that a connecting member as described above is provided on at least one end of each such unit or is integrally formed at said end.

The structural unit to which connecting member(s) of this invention are attached or on which they are integrally formed may be a rolled section. Such rolled section may be a girder. The rolled section may comprise channel section girders connected back to back by welding, or otherwise, and the connecting member is adapted to be mounted at least at one end between the two with its face projecting therefrom.

It will be noticed that the connecting members of this invention are not "male" and "female" type but identical so that when one is brought opposite to the other from two different directions ridges in one correspond with grooves in the other. This is a great advantage as no selection or two storages are necessary. One can pick up any two connectors of the same type and capacity and effect the connection.

The invention will be now further described with reference to the accompanying drawings:

Figs. 1 and 2 show elevations from opposing directions of faces of two identical connecting members according to an embodiment of the invention;

Fig. 3 shows in section how the two connecting members of Figs. 1 and 2 are connected and held together;

Figs. 4 and 5 show elevations from opposing directions of faces of two identical connecting members according to another embodiment of the invention;

Fig. 5A is end view of what is shown in Figs. 4 or 5;

Fig. 6 shows in section a modification of what is shown in Fig. 3;

Fig. 7 shows in elevation the face of a connecting member according to the embodiment of Fig. 1 or 2 but having a plurality of fastening or holding means;

Fig. 8 shows a similar modification as in Fig. 7, but in respect of a connecting member as shown in Fig. 4 or 5;

Figs. 9(a) and (b) show top plan views of two embodiments of girders, rail sections, on a small bridge; using this invention;

Figs. 9 (c), (d), (e) and (f) are end elevations of four embodiments of the same;

Fig. 9(g) is side elevation of same according to one embodiment;

Fig. 9(h) shows on a larger scale than in Fig. 9(a) or 9(b) one of the structural units used herein;

Fig. 9(i) illustrates use of a connecting member of this invention in a concrete structural unit;

Fig. 9(j) illustrates use of this invention in building of cranes;

Fig. 9(k) illustrates one example of application of this invention to frame work (unit) for use in bridges requiring heavier structure; and

Fig. 9(l) is perspective view of part of a bridge built according to one embodiment of this invention.

In the drawings, Figs. 1 and 2 show mating surfaces 2 and 2' at one end of each of a pair of identical connecting members 1 and 1' (half joints) for forming the joint according to this invention. This is shown in assembled form in Fig. 3. The two connecting ends are mated together and held by a single central bolt 3 and a nut 5. (Head of bolt is marked 4.) The bolt 3 is passed through the holes 6 and 6' in the connecting ends.

The configuration of mating surface 2 is exactly identical to that in mating surface 2' and when the ends with the mating surfaces are brought together to bear on each other they engage or lock with each other.

In connecting member 1 mating surface 2 has arcuate ridges A and B, and arcuate grooves A₁ and B₁ and in connecting member 1' mating surface 2' has arcuate ridges A¹ and B¹ (identical to ridges A and B respectively) to correspond to arcuate grooves A₁ and B₁ in surface 2 with which they mate; while its arcuate grooves A₁' and B₁' (which are identical to grooves A₁ and B₁) correspond to and mate with arcuate ridges A and B in surface 2. (The elevation of the ridges and grooves is a sector). The mating surfaces 7A and 8A have gradual tapers (as seen in Figure 3 and ends of mating ridges and grooves leave a gap 11' (see Figure 3) on the two ends being connected.

The load borne by the joint formed by the two connecting ends is taken up by shear stress as developed in the areas A and B on section along PQ in member 1 and in the areas A' and B' on section along P'Q' in member 1'.

The ridges and grooves may each cover

as much as half of each surface, so that they may appear almost semi-circular.

As far as the above embodiment is concerned, it can allow slight relative arcuate movement for adjustments in the plane in which the two members lie.

Figs. 4 and 5 illustrate another embodiment of this invention in which the ridges A_2 and grooves B_2 have been provided radially around the central hole 6" in surface 2 of member 1 and grooves B_2' and ridges A_2' in the other connecting member 1. (Both are, however, identical.) The mating sides have matching gradual tapers as seen in Fig. 5A and mating ridges and grooves leave a gap as described above.

The connecting members, according to this embodiment, can be assembled at various angles to each other depending upon the angular pitch between said two consecutive radial projections or radial grooves. The smaller the said angular pitch, the finer the angular adjustment between the said ends is possible so that variety of relative angular disposition increases. The connecting members according to this embodiment are also formed at the ends of the structural members to be joined or are separately made and jointed by welding or like methods to the structural members to be connected together.

Unlike in the embodiment shown in Figs. 1, 2 and 3, this embodiment will have complete locking between two connecting members in all directions, permitting no relative arcuate movement about the central point of connection.

Fig. 6 shows a cross section of another embodiment of this invention in which there are provided more than two sets of ridges and grooves on each surface. (7 are grooves and 8 are ridges). By providing multiplicity of such sets the sectional area which resists the shear stresses can be increased thereby allowing increased loads to be transferred by the joints.

Fig. 7 shows the view of one connecting member according to another variation of the type shown in Fig. 1 or 2 in which a plurality of fastening means can be employed. The connecting member has two slots 9 and 9' and two holes 10 and 10', said slots and holes being also provided in the opposite mating connecting member forming the joint. Each of the pair of slots and holes receives a fastening device (not shown) such as a bolt secured by a nut or a stud screwed into a tapered hole. Of course either the set 9, 9' (as shown in Fig. 8) or 10, 10' may be provided. Or, more than two such sets may be provided.

The frame work constituting a bridge (Figure 9a to 9k) comprises a series of rolled sections 11 and 11A connected together by members forming joints 12 by

mating and jointing connecting members 12A of one rolled section to that in the other.

If a single frame work is used the top plan of the bridge would be as seen at Fig. 9(a) and the end view as seen at Fig. 9(c). 14 (Fig. 9c to 9f) is a foundation for securing an end of the bridge frame work on the bank. For a double frame work the top plan will be as seen in Fig. 9(b) and the end view may be as seen in Fig. 9(d) or 9(e). Two parallelly disposed rolled sections constituting one unit in each framework may be reinforced by cross members 13 as seen in Fig. 9(b). Upper and lower rail sections in the same structural unit may also be reinforced by cross members as 13A, 13B or 13C as seen in Fig. 9(g) and Fig. 9(k). Such reinforcement will be dictated by the design.

In Fig. 9(f) and in Fig. 9(k) multi-tiered frameworks are shown, depending on the requirement or use to which they are to be put. Upper and lower structural units are connected together by the connecting members forming joints as seen at 12B in Fig. 9(f) while in Fig. 9(k) upper, intermediate and lower structure units are connected together by joints 17 and 21. The joint 17 is formed by connecting member 16 in the upper unit and member 16A in intermediate unit, while joint 21 is formed by connecting member 20 in intermediate unit and member 20A in lower unit. Size, shape and nature of the units and the nature of their combination is determined by the design requirements. Member 18, 19, 22 and 23 are adapted to be connected to other units on either side of the respective frame works. If necessary a similar arrangement can be made in respect of members 27, 28 of the intermediate unit if the design requirements so demand.

In Fig. 9(j) one apex of a crane is shown. Connecting member 12A is provided on rolled sections constituting the base frame of the crane. Connecting members are also provided, marked 12A' on structural members 24 and 25 on horizontal tie member 26 and on shear leg 26A respectively of the crane and are mated with corresponding members 12A to form the joints 12. If structural members 24 and 25 are relatively long, then joints may be formed at intermediate points as well.

For use in concrete structured units marked 11B, Fig. 9(i), reinforcing members 15 are provided on each connecting member 12A for embedding in concrete of member 11B. The structural units so obtained are then connected together by mating to form the joint 12.

The following is the list of structures in which preformed or integral connecting members as developed herein can be used. In all critical applications, the designs can be checked through computer analysis:

1) Universal launching girders for constructing road and railway bridges.

- 2) Temporary bridges to replace damaged bridges.
3) Light-weight bridges for the army, especially in mountainous terrain.
5 4) Floating bridges of larger spans, especially for sites, where foundations become expensive due to depth of water and unsuitable soil conditions.
5) Fly-over bridges.
10 6) Structures for off-shore drilling rigs for oil exploration.
7) Piling rigs, also floating type for off-shore drilling.
15 8) Structures for all types of Tower, Derrick, Goliath and E.O.T. Cranes, etc.
9) Structures and stagings for elevated water storage tanks which can be erected in matter of hours.
10) Structures for television or communication antennas.
20 11) Scaffoldings for heavy duty ship construction by prefab-methods.
12) Centering trusses for in-situ concrete construction.
25 13) Heavy road trailers.
14) Industrial heavily loaded structures.
15) Portable jetties, cantilevering type as well as floating type.

30 There are several other usages for this system which will be apparent to a structural engineer and designer which are expected to revolutionise structural engineering and make even a cumbersome structural process a simple one.

35 **WHAT WE CLAIM IS:—**

1. A connecting member for connecting together two structural units, which is formed on one face with at least one ridge and one groove for interengaging with the ridge(s) and groove(s) of an identical connecting member with which its face is disposed in overlapping relation, said ridge(s) and groove(s) having tapered side surfaces which are so tapered as to produce a taper lock between interengaging ridges and grooves, and the or each groove having a width at its base less than the width of the or a corresponding ridge at its top so that only the tapered surfaces of the ridges and grooves are in contact when the two identical connecting members are interengaged said connecting member also being adapted to be secured to the identical member by fixing means.
50 2. A connecting assembly for connecting

together two structural units, comprising two identical connecting members having overlapping faces, each of which is formed with at least one ridge and one groove which are interengaged with the ridge(s) and groove(s) of the other member, said ridges and grooves having tapered side surfaces which are so tapered as to produce a taper lock between the interengaging ridges and grooves, each groove having a width at its base less than the width of the interengaging ridge so that only the tapered surfaces of the ridges and grooves are in contact, and additional fixing means for also securing said connecting members together.
60 65 70

3. A connecting member or assembly as claimed in claim 1 or 2, in which the tapered surfaces of the ridge(s) and groove(s) have a taper angle of 12° or less.

4. A connecting member or assembly as claimed in claim 1, 2 or 3, in which the ridge(s) and groove(s) are of arcuate shape in plan.
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5. A connecting member or assembly as claimed in claim 1, 2 or 3, in which the ridge(s) and groove(s) extend radially from a central portion of the face of the or each connecting member.
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6. A connecting member or assembly as claimed in any one of the preceding claims, in which said fixing means comprises a nut and bolt, threaded stud, wedge, taper pin, rivet or welding connection.
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7. A connecting member or assembly as claimed in any one of the preceding claims, in which the connecting members are intended to be embedded in concrete and, for this purpose, are provided with reinforcing members.
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8. A connecting member or assembly as claimed in any one of the preceding claims 1 to 6, in which the or each connecting member is integral with a structural unit.
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9. A connecting member or assembly for connecting together two structural units, substantially as hereinbefore described with reference to Figures 1, 2 and 3, or Figures 4, 5 and 5a, or Figures 6, 7 or 8, or Figures 9a to 9h, or Figures 9j to 9l, or Figure 9i of the accompanying drawings.
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- 2) Temporary bridges to replace damaged bridges.
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- 5) Fly-over bridges.
- 10 6) Structures for off-shore drilling rigs for oil exploration.
- 7) Piling rigs, also floating type for off-shore drilling.
- 8) Structures for all types of Tower, Derrick, Goliath and E.O.T. Cranes, etc.
- 15 9) Structures and stagings for elevated water storage tanks which can be erected in matter of hours.
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- 20 11) Scaffoldings for heavy duty ship construction by prefab-methods.
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2. A connecting assembly for connecting

together two structural units, comprising two identical connecting members having overlapping faces, each of which is formed with at least one ridge and one groove which are interengaged with the ridge(s) and groove(s) of the other member, said ridges and grooves having tapered side surfaces which are so tapered as to produce a taper lock between the interengaging ridges and grooves, each groove having a width at its base less than the width of the interengaging ridge so that only the tapered surfaces of the ridges and grooves are in contact, and additional fixing means for also securing said connecting members together.

3. A connecting member or assembly as claimed in claim 1 or 2, in which the tapered surfaces of the ridge(s) and groove(s) have a taper angle of 12° or less.

4. A connecting member or assembly as claimed in claim 1, 2 or 3, in which the ridge(s) and groove(s) are of arcuate shape in plan.

5. A connecting member or assembly as claimed in claim 1, 2 or 3, in which the ridge(s) and groove(s) extend radially from a central portion of the face of the or each connecting member.

6. A connecting member or assembly as claimed in any one of the preceding claims, in which said fixing means comprises a nut and bolt, threaded stud, wedge, taper pin, rivet or welding connection.

7. A connecting member or assembly as claimed in any one of the preceding claims, in which the connecting members are intended to be embedded in concrete and, for this purpose, are provided with reinforcing members.

8. A connecting member or assembly as claimed in any one of the preceding claims 1 to 6, in which the or each connecting member is integral with a structural unit.

9. A connecting member or assembly for connecting together two structural units, substantially as hereinbefore described with reference to Figures 1, 2 and 3, or Figures 4, 5 and 5a, or Figures 6, 7 or 8, or Figures 9a to 9h, or Figures 9j to 9l, or Figure 9i of the accompanying drawings.

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