BUILDING DIGEST

CENTRAL BUILDING RESEARCH INSTITUTE INDIA

FRICTION GRIP JOINTS

Introduction

Friction grip joints using high strength bolts tensioned to 80% of the proof load show better characteristics in fatigue and provide better means of effecting site connections than site welding or riveting. The joint develops shear strength by virtue of the friction between the interfaces of the connecting members.

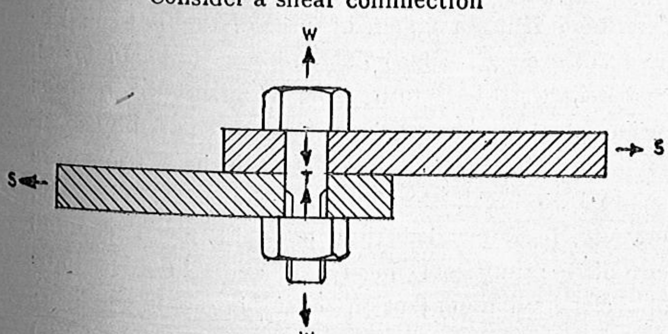
This method of jointing is very common in U.S.A. and Europe. In 1951, the American Society of Testing Materials issued a specification A—325; and in 1959, the British Standards Institution brought out specification BS—3139 for the manufacture of suitable bolts, nuts and washers. Canada, Germany and USA have codes of practice for the assembly of structural joints using high strength bolts.

This digest discusses the behaviour of friction grip joints and describes the design procedure and tightening methods. The object is to familiarize engineers with this method of jointing wherever it offers marked advantages.

General Principles

Friction grip joints between two or more structural members are made by clamping them together with the help of high strength bolts tightened to 80 per cent of their proof load. The tension in the bolt imparts frictional resistance to the contact faces of the structural members joined, when they are subjected to shear forces.

Consider a shear connection



Let T = Clamping force

μ = Coefficient of friction between the interfaces.

S = Shear Load.

It is obvious that

$$S = \mu T$$

It means that so long as the tension in the joint is less than μT, slip will not take place.

Behaviour in Shear

If the load is increased so as to cause slip, the joint will still carry the load by shear and bearing through the bolt like any other conventional riveted or bolted connection. The ultimate load of the joint will, however, be higher than that of riveted or plain bolted joints because the strength of bolts used is higher than ordinary bolts and nuts.

The stress relaxation due to the heavy stress concentration under the bolt head, occurs during the first hour and is of the order of 5% after which it is negligible. The stress relaxation is not substantially reduced by the use of hardened washers. When the slip takes place in ordinary bolted and riveted joints, there is a change of configuration of the bolts and rivets. This creates additional tensile forces, in bolts and rivets. Secondly, the ordinary bolts and rivets are subjected to high stress concentration where they bear against the hole in the plate as some amount of play in such joints is always present.

In friction grip joints there is no slip and no transfer of forces by bearing during working loads. So there is neither change of tensile forces nor presence of stress concentration due to bearing. Consequently the high strength bolts display good fatigue characteristics when used in friction grip joints.

Behaviour in tension across interfaces

When the friction grip joint is subjected to tension across the interfaces, the compressive force between them is reduced while the tension in the bolt is increased. The increased magnitude of tension will have to be checked so that it does not exceed the proof load. When the external tension equals the preload in the bolts, the compressive force between the interfaces is zero and the joint will fail to carry shear forces by friction.

ı grip joints can also be used for beam to
:tions where bending and shear is present.
int is subjected to bending the effective
e is reduced on the tension side of the
and increased on the compression side.
no total loss of friction grip of the bolts.

f friction grip joints

the foregoing discussion it can be noted
ad in high strength bolt remains practi-
d when it is subjected to varying external
t there is no stress concentration in the
aring against holes.

haracteristics provide high strength bolts
fatigue strength. Tests made by Munse,
Newmark[1] showed that in no case was
ue failure of high strength bolts in the
d there was no slip during the application
d that the tests of duplicate specimens
h rivets and bolts demonstrated that the
th of high strength bolted joint is 25%
that of similar riveted joints.

er, there is always present a compressive
n the threads of the bolt and the nut.
s loosening of the bolt when subjected to
ads obviating the need for the use of lock

properties of high strength bolts make
lly suitable where dynamic loads are encou-
bridges and machine foundations.

he high strength bolts

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contact surfaces have to be free of paint,
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h the development and sustenance of fric-
ı them.

al methods of tightening the bolts to induce
tension are available. The "torque coeffi-
od and the "part torque part turn" method
in U.K. In U.S.A. the practice is to rely
f nut" method. Techniques such as the
lloy ring in between hardened washers and
nethods to determine the clamping force,
ned in favour of new and simpler techni-
could be relied upon for site work. Self
rshear and load indicating bolts are now
ıfactured. The latter two types of bolts
require very little supervision and a ready indication
of the bolt having reached a specified tension is available
as the bolt is being tightened.

Torque coefficient method

This technique is based on the fact that the load in the bolt varies linearly with the torque. The relationship between torque and clamping force may be expressed as :

$$M = K.T.d$$

where, M = Torque applied,
T = Bolt tension,
d = Nominal dia. of bolt
and K = a nondimensional torque coefficient.

Value of the torque coefficient K ranges between 0.15 and 0.20. The condition of the threads affecting friction like dry, rusty, lubricated etc., the form and the method of manufacture have a marked effect on the value of torque coefficient. As there are some uncertain conditions in determining the torque coefficient, a variation of the order of $\pm$ 15% would exist. The torque coefficient method of tightening is implemented by the hand operated torque limiting spanners. Impact type of pneumatic wrenches can also be used. In both cases calibration of spanner is necessary. At present the C.B.R.I. is developing a torque limiting spanner which can be manufactured by small scale industries.

This method was found to be unreliable as there was no direct measure of the tension in the bolt. Factors like friction between the threads, the fluctuation in air pressure in case of pneumatic torque wrenches caused an unacceptable scatter in the desired amount of tension. Moreover, the method is impracticable for joints requiring bolts of different sizes as calibration can be done only for one bolt at a time. This led to the methods wherein the deformation of the bolt as indicated by the rotation of the nut is taken as a measure of tension in the bolt.

Ruble[1] conducted a large number of tests to determine if the number of turns of the nut could be used as the criterion for bolt tension. He found for all diameters that half turn from a fingertight position produced the minimum bolt tension required by specifications. He also found that two to three turns were required to break the bolt or strip the threads. He, however, recommended that bolts be given one full turn of the nut from fingertight state in order to be above the minimum tension required.

This procedure, as it is, depends upon the initial state of fingertightness which inherently has a wide scatter of results. Consequently part torque-part turn and turn-of-the-nut methods have been evolved to establish a definite initial state.

Part Torque-Part Turn Method

In this method the bolts are initially tightened by any amount between one quarter and three quarters of the nominal torque (calculated according to the torque coefficient method). This is followed by a further turning of the nut given by :

$$\text{degrees of turn} = (180^\circ + x)\ \frac{TPI}{10}$$

where, x=0 for grip length 0 to 6 inches
and 90° for grip length greater than 6 inches
and TPI=threads per inch.

Thus a $\frac{3}{4}''$ dia bolt which has a grip length less than 6", with an initial half turn of nut, would, after an additional half turn, be tensioned beyond 90% of the proof load. This technique offers many advantages over the torque coefficient method. It simplifies site supervision and eliminates the need for calibrating devices. Hand or impact type of pneumatic wrenches are used to tighten the bolts initially.

Turn of nut method

In this method instead of giving one full turn after the fingertight position $\frac{1}{2}$ to $\frac{3}{4}$ turn depending upon the bolt diameter and grip length[5] is given after all the bolts in the assembly of the joint are brought to the snug-tight condition.

The snug-tight condition is produced by a few blows of pneumatic or hand torque spanner.

Bolt diameter in inches.	From snug tight rotate nut	
	$\frac{1}{2}$ turn for grips	$\frac{3}{4}$ turn for grips
$\frac{3}{4}$	upto 5 inches	above 5 inches
$\frac{7}{8}$	,, 5 ,,	,, 5 ,,
1	,, 8 ,,	,, 8 ,,
$1\frac{1}{8}$	,, 8 ,,	,, 8 ,,
$1\frac{1}{4}$	,, 8 ,,	,, 8 ,,
Permissible tolerance + $\frac{1}{2}$ turn		

In the above methods the bolt has to be held in position while it is being tightened. To overcome the need for a separate reaction fitting, bolt with a splined extension was introduced in U.K. It has a spline which is held in position by a specially designed torque multiplying and limiting spanner. Increased length of bolts and depth of spanner restrict the use of this type of bolt.

Recently, to avoid torque coefficient and turn-of the-nut method, bolts which would indicate the tension in them have been designed. They are torshear and load indicating bolts.

Torshear bolt.

This bolt has a splined extension which does away with the separate reaction fitting. In addition the extension breakes off through failure in torsion at a machined groove, when the load in the bolt reaches the required tension. The inspection of the work using such bolts is easy because the broken off ends will provide the necessary information.

Load indicating bolts

G.K.N. group research laboratory has designed and developed the load indicating bolt. The bolt head is so shaped that before complete tightening it makes contacts with the washer with its four corners only. A gap of 0.063" is provided between the washer and the middle of each side of the bolt head. These gaps slowly close as the bolt tension increases. By the time the gaps have been reduced from 0.063" to about 0.04", the specified minimum tension is reached. It is only necessary to check the gaps by a feeler gauge. It gives a reliable and easily inspected indication that a specified tension has been achieved during tightening.

Practical advantages

After examining the methods of using high strength bolts it will be seen that :

1. No elaborate equipment as required for site welding or riveting is necessary.
2. Power supply need not be available.
3. Once the spanners are calibrated, no more control over the skill of operators is necessary.
4. The skill required is very little and, therefore, the operators can be trained quickly to do an efficient job.

Thus, high strength bolts have many advantages especially for site connections.

Design Considerations

No Indian standard exists for the design of friction grip joints. It will be upto the engineers to decide upon the right method.

In America, the practice is to design joints as friction-type and bearing-type connections. In friction type joints the contact surfaces are made free of oil, paint, lacquer or galvanising. The strength of such a bolt is the same as that of the hot driven rivet of the same nominal diameter. There is no need to consider bearing stresses and bending of the bolts in Friction type joints.

The bearing type joints are designed as if they are ordinary riveted joints. This procedure which does not take into consideration the frictional strength of the joint is tolerable upto 33 tons/in^2 when the difference in cost between the bearing type and friction type is small. In U.K., bolts which can take a preload of 60 tons/in^2 are available giving a high frictional strength. Therefore, the trend, there, is to design these joints allowing for the frictional force.

The design based on frictional strength uses the formula

$$S_p = \frac{\mu . T}{\text{Foctor of safety}}$$

Where S_p=Permissible shear load.

μ=0. 45, if the contact surfaces are flame cleaned or sand blasted five hours before jointing and 0. 30 in case of plain mill scale surface.

The factor of safety is 1.5,

and T=80% of the proof lood which is the clamping force.

Very few tests have been done on the friction grip joints subjected to tension. It is suggested that a factor of safety of 2 against the separation of contact surfaces be used in such cases which means that the externally applied tension does not exceed half of the preload.

Therefore, $W_p = \frac{T}{2}$

Where W_p = permissible tension.

T = clamping force

With the above considerations, a general formula is suggested: $\frac{S}{S_p} + \frac{W}{W_p} \ngtr 1$

By readjustment a formula

$$\frac{1.5S}{\mu} + 2W = T .$$

will be of more use in design offices where it is necessary to find the clamping force for a given shear and tension across the joint. In this formula

S = actual shear load

W = actual tension

Such a joint designed with ordinary plate tensile stresses of 8 tons/in^2 would have an endurance limit of 2×10^6 cycles with full reversal between tension and compression.

Conclusions

1. The friction grip joints are more rigid and have a better stress pattern than ordinary riveted and bolted connections.

2. The fatigue strength is higher and the nut is secured against loosening. Therefore, they perform better under repeated loads, vibration and impact.

(3) The field equipment is very simple and skill demanded is elementary. This makes the field connnections very much easier than field welding or rivetting.

So far, the high strength bolts and nuts are not available in our country mainly because the users are not aware of their advantages. Efforts are being made to initiate the manufacture of these bolts and make the technique welknown among users.

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There is a demand for short notes, summarising available information on selected building topics for the use of Engineers and Architects in India. To meet the need this Institute is bringing out a series of Building Digests from time to time and the present one is the twenty seventh in the series.

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