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Technical Analysis

Tightening torques explained

By Mark Salmon, Independent Fixings Consultants

Mark Salmon, of Independent Fixing Consultants, is always banging on about the benefits of tightening a fixing to the manufacturer's recommended torque because this will "induce a clamping force greater than the recommended tensile load so the fixture won't move". But does this mean it can also be used to test fixings? Mark explains in detail how torque relates to the holding power of a fixing in order to understand when we can and cannot use this relationship.

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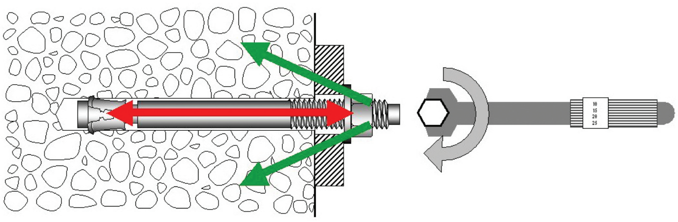
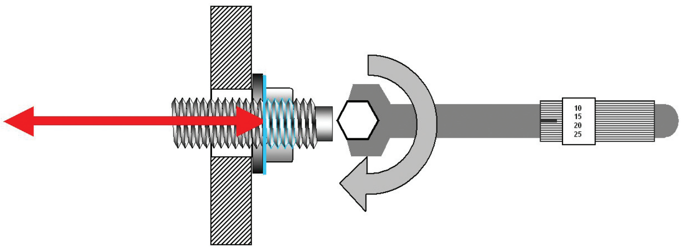
Before we start talking about torque we need to remember what we are trying to achieve. With most fixings, where we are fixing something to a base material, what we need to do is to generate a clamping force through the fixture. As long as that clamping force is greater than the applied load the fixture will not move. With fixings like the one shown below – a throughbolt, but it could be any fixing not just one that is set by tightening – as we tighten it up the two forces shown below develop together. The tensile force in the bolt itself, shown by the red arrow, and an equal and opposite force going from the nut through the washer and fixture and into the base material – the clamping force.

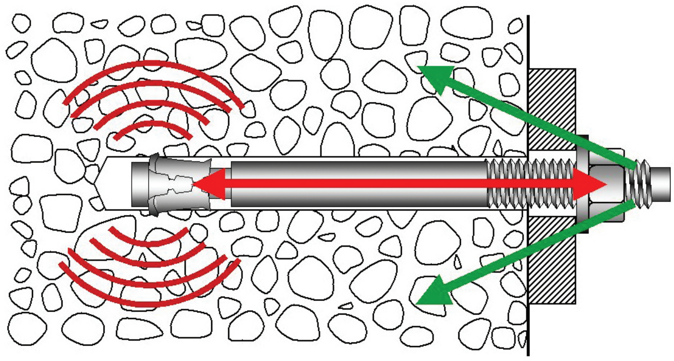


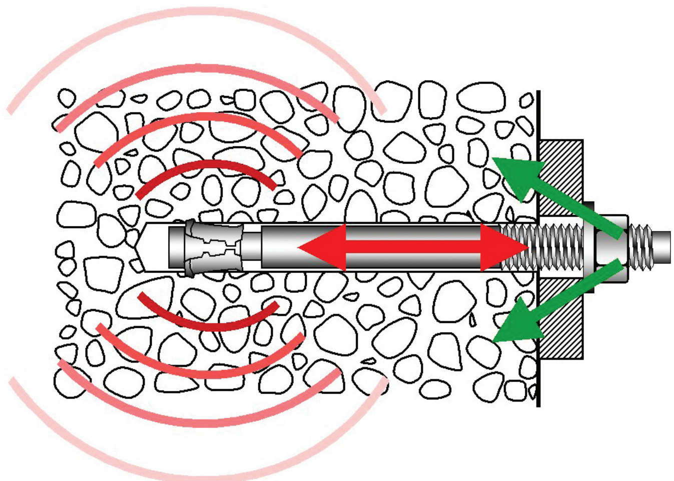
As these forces increase so does the friction between the nut and the washer and that between the threads of the nut and the bolt. This friction – this resistance to turning – is what the torque wrench is actually indicating.



So we have established that there is a direct relationship between the torque and the clamping force we are looking for. There is in fact a formula which can be used to work out the bolt tension and hence clamping force induced by a particular torque for a bolt of a particular diameter and finish (oiled, dry zinc plated, galvanised etc – stainless is a bit tricky) but this relationship is relatively approximate and depends very much on the actual condition of the mating surfaces being clean and undamaged and, in the case of anchors, free from any oil or grease. The fixings manufacturer will use such a formula, maybe backed up with practical tests, to determine the installation torque he wants to recommend.

But before he determines the clamping force on which to base this torque he will (or should, if he knows what he's doing) take into account a phenomenon that affects all fixings. This phenomenon is called "Load Relaxation".





High local stress induced at the time of installation will dissipate with time, relaxing the bolt load and clamping force in the process.

When any fixing is tightened stresses are induced in the base material. In the case of an expansion anchor, like the one shown above, these stresses emanate from the point of expansion. Even in a resin anchor stresses are developed in the base material, in that case parallel with the resin bond. These stresses gradually dissipate into the surrounding material and as they dissipate the tension in the bolt declines proportionately and along with it the clamping force. This effect starts quite quickly when the stresses are at their highest and, as they decline, so it slows down – as you would imagine. If we consider the life expectancy of a safety critical fixing in a building to be 50 years then over this period the clamping force will have declined, due to this effect, by something in the order of 50 to 60 percent. To take this into account the manufacturer will need to set the original clamping force at around twice the recommended tensile load. Before confirming this clamping force the manufacturer will check that this level of induced load will not take the bolt material near to yield and, in the case of a resin anchor, that it will not over stress the resin bond. This means that a carefully chosen tightening torque will do two things for us – it will ensure the clamping force for the life of the fixture and protect the fixing from being overloaded.

So I hope you can understand why manufacturers place so much emphasis on anchors being correctly torqued. For the switched on fixings distributor this represents not so much a problem as an opportunity – an opportunity to sell torque wrenches!

But let's move on the to idea of using this feature of fixings to test them.

For a start we cannot use torque checks to determine allowable loads on fixings where we have no recommended load data, this can only be done using a calibrated piece of test equipment.

There are, however, some instances when an engineer will want reassurance that anchors have been correctly installed. Of course if the fixings being used have an ETA and are installed by a trained operator working under supervision then there should be no more reassurance required. But if he or she insists on some checks being carried out then maybe torque checking will provide a cheaper alternative to load testing? After all it's easier to carry out, anyone can do it, the equipment is much cheaper and sometimes there is insufficient access for test equipment anyway. Or the fixing may not lend itself to being tested without being disturbed e.g. anchors with hexagon bolt heads. So what are the drawbacks? Well the first problem is just the inaccuracy. As I stated above the relationship between the torque and the clamping force is not a very accurate one, there can be a large discrepancy, so if we want accurate checks then a calibrated piece of test equipment is required. This inaccuracy will only be worsened by the passage of time with the possible ingress of dirt or dust (or – heaven forbid – rust!) between the mating surfaces. The next problem is this wretched load relaxation business. If we install a fixing today using the recommended torque of, say 100Nm, within a week it may be down to 80Nm, and within a month around 70Nm; 60Nm after a year; 50Nm after 10 and as little as 40Nm after 50 years. This is a very rough approximation of the phenomenon but you get the idea. What it means is that if we check the torque after a few days we cannot expect to see the original installation torque. If we do then it will suggest that the fixing was originally over tightened. But we should at least be able to recover the original torque within less than a turn. An engineer carrying out load tests with calibrated equipment may well find a quick check of the residual torque quite illuminating before carrying out the actual test. A dial indicating torque wrench will be needed for this – see below.

In conclusion we can say:

Torque checking cannot replace a test meter for accurate load testing and determining allowable loads.

It may be useful for giving a rough indication of installation quality if access is poor or the fixing has a hexagon bolt head as long as we bear in mind the inherent inaccuracy and are mindful of load relaxation.

Types of torque wrench

If you're very posh, like me, and you've got a thing about tightening torque, you might have a torque wrench with a dial on it, which actually shows the torque as it increases. These are very useful for investigating the condition of anchors before load testing but are pretty expensive and not what one would use for every day work on a construction site where the traditional "break back" type, which clicks on reaching the set torque, is more appropriate.

Typical "break back" torque wrench – photo courtesy of Norbar Torque Tools Ltd

Typical dial indicating torque wrench – photo courtesy of MHH Engineering Ltd

A couple of points to watch

Although all fixing manufacturers quote tightening torques in Nm most torque wrenches still carry calibration in lbf. ft as well. If the wrench is set to X lbf. ft instead of X Nm the fixing will be over tightened by about a third so encourage your customers to check the scale before setting the torque. When a "break back" wrench clicks it simply indicates that the required torque has been reached, it does not prevent a higher torque being applied if the user keeps pulling on the wrench.

For fixings with projecting studs always use a deep reach socket as a standard socket may not reach the nut. Torque wrenches, like most measuring equipment, need careful use and calibrating once a year. ■