

Load relaxation and anchor testing

By Mark Salmon, Independent Fixings Consultants

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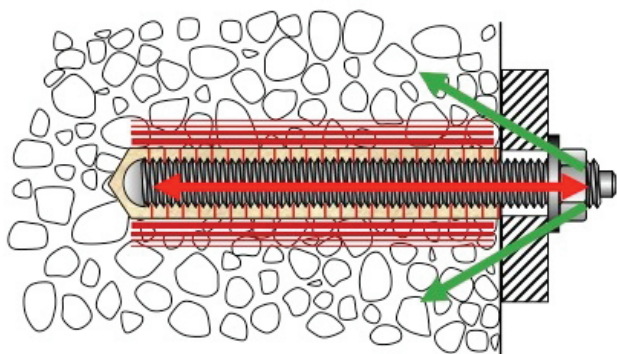
Load relaxation and anchor testing

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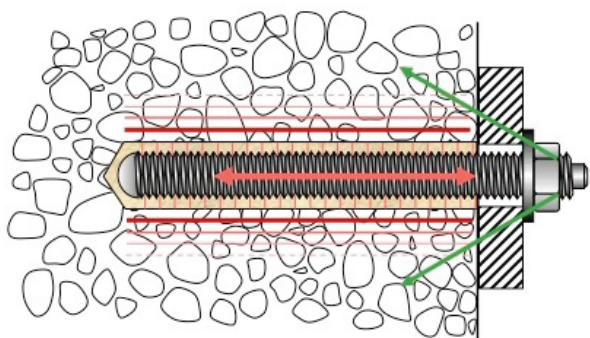


In the Technical Analysis paper entitled 'Tightening torques explained' (ref: FFM671101/66), Mark Salmon outlined the relationship between tightening torque and clamping force and introduced the idea of "Load relaxation". In this article he follows this up by explaining how this can affect anchor testing in general, why it's particularly significant when testing resin anchors and why it should be born in mind when selling them.

Load relaxation – for those of you who may have missed Issue 67 – is the phenomenon whereby stresses induced into the base material around the fixing gradually dissipate further into the material causing the tension in the anchor bolt, and hence the clamping force through the fixture, to relax. In Issue 67 I showed the stresses around the expansion point of an expansion anchor. The diagrams below are my attempt to show the stresses in the base material parallel with the bond of a resin anchor plus the stresses in the resin bond itself which also relax.



Immediately after tightening – high stress around the fixing and in the resin, high tension in bolt and clamping force through fixture



After relaxation – stresses dissipate into material and within resin, tension in bolt and clamping force through fixture both reduce

When we test fixings on site this may or may not be apparent. With fixings which have been tightened down we should experience no load relaxation until we have exceeded the clamping force introduced by tightening. Yes, the clamping force will be in the process of relaxing but until it relaxes to below the test load we won't notice it. But with fixings where we have not clamped down a fixture, or a test adaptor simulating a fixture, e.g. a resin stud with no fixture applied, we may see load relaxation because all the stresses in the base material and in the resin will have been introduced by the test load and will start to relax immediately they are applied. This relaxation is seen as a small drop off in the load reading. With most fixings all we need to do when this happens is to return the load to the original figure and the subsequent relaxation will usually then be hardly apparent. But it can cause doubt in the mind of some observers, the natural reaction being "The fixing must be failing." ***One recent development which emphasises this is the introduction of digital readouts on some testing equipment. We get to a load and instead of it holding steady the load is seen to be clicking back giving the appearance of a failure. Somehow with hydraulic gauges the slight reduction in load is more readily accepted.***

The problem we get with resin anchors in this regard is to do with the way they fail and to understand that we need to go back to the way they work.

Essentially what we do when we install a resin anchor is to drill a hole, usually using a hammer drilling machine, part fill that with resin so that once the anchor is inserted it will be fully encased in the resin which, when cured, is very hard indeed. This hard material forms very strong interlocks between the rough shapes of the anchor on one side and the surface of the hole on the other. We can see the "roughness" of the anchor as it will usually be either the thread of an anchor rod, the knurling of an internally threaded socket or the deformed shape of reinforcing bar. But the characteristics of the hole sides are harder to appreciate. There are two aspects to this. The first is easy – the roughness of the hole sides. This roughness is generated on an almost microscopic level by the hammering action of the drill bit. It may not feel rough but it is rough enough for the resin to form a very useful interlock.

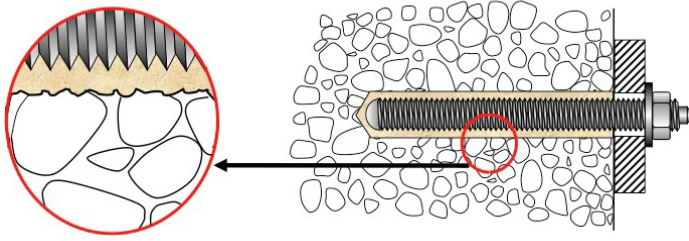
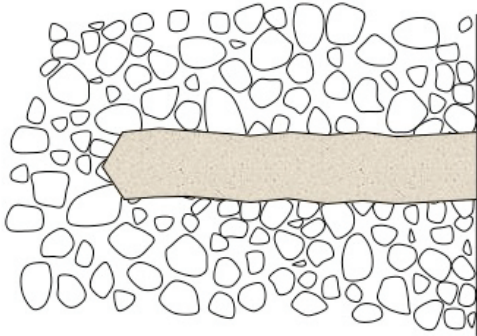


Figure X Surface roughness from hammer drilling is the "Key" to resin anchor strength

The second feature plays an important role and that is its meandering shape. When we drill into concrete the drill bit is deflected first to one side and then the other by the aggregate the drill tip meets on its journey. And in materials without aggregates, like brick or stone, it's us that causes the drill bit to wander simply because we can't hold the drill straight.

So we have a rough surface in a meandering hole. When we load the fixing we increase the stress in the bonds between the resin and the hole sides and between the resin and the anchor. If we keep increasing that load eventually the bond between the resin and the hole sides will break and, if we're testing a fixing when this happens, we will only see a slight reduction in the load.



The meandering hole – even after the bond is broken pulling an anchor out of this shape takes a high force

This failure of the resin bond happens at the level of the surface roughness of the base material but once the bond is broken then pulling the awkwardly shaped plug of hard resin from the awkwardly shaped hole can take virtually as much force as the initial failure load as gradually more of the resin and base material are sheared off. This can be regarded as a safe mode of failure, as the anchor does not just pop out of the hole, but a slightly misleading one.

The time when this can be confused with load relaxation is when we are proof testing anchors to check the quality of installation and when there happens to be a problem with the installation such that the anchor fails at a load close to the proof load. In the years that I spent site testing over thirteen thousand anchors of all sorts – many of them resin anchors – I actually came across this more times than you might imagine, in both concrete and masonry.

From the tester's point of view what may happen is this. Let's say we're testing an M12 anchor with a recommended load of 8kN to a proof load of 1.5 times that i.e. 12kN. We load the anchor carefully to 12kN and leave it to settle. After a minute or so we notice a slight loss of load to say 11.9kN.

Is it just load relaxation? Or has the anchor failed? We increase the load back to 12kN. If the anchor is well founded the initial loss of load was just relaxation and further relaxation will be hardly noticeable. If, on the other hand, the bond has broken then when we reapply the 12kN load again it will reduce again and we will eventually be aware that the anchor is pulling from the substrate. In fact the bond probably started to fail at a

load less than 12kN we just didn't notice it. The trouble is that each time we reapply the load we need to give it some time, say a minute or so, to see if it is relaxing or not. We just have to be patient. But of course there would need to be something wrong for the anchor to fail at a proof load. Maybe the installer had not cleaned the hole as thoroughly as he should have. Maybe he had not pumped any resin to waste before pumping into the hole. Maybe the anchor had been tightened before the resin had cured properly and the bond had inadvertently been broken in the process. Sadly this happens far more frequently than it should as many installers who I meet openly tell me: "You don't need to allow the full curing time, the resin cures in ten minutes." when the manufacturer's instructions talk about three or four times that. And the problem with tightening before the anchor is cured is that we can induce a pretty high load in the anchor when we tighten it (too high if we don't use a torque wrench) and the overload we then cause only breaks the resin bond locally but we don't realise it as the anchor doesn't just pop out of the hole. **Even testing an anchor at the manufacturer's recommended curing time will show more relaxation, due to creep of the resin, than if left much longer.**

So there are a few conclusions we can draw from this:

1. A reduction in load during a test may not mean failure – it may just be load relaxation.
2. Re-applying the proof load with no movement of the anchor shows it was just load relaxation.
3. When proof testing resin anchors we need to take time to differentiate between relaxation and failure.
4. If we're selling resin anchors to installers we should take the opportunity of reminding them about correct installation especially thorough hole cleaning (sell them a brush), pumping the first resin to waste, allowing the full curing time and not over tightening. ■

