University of Minnesota UROP Project:
Assessing the Merit of F14T Super High Strength Structural Bolts

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Introduction

Steel buildings and bridge structures across the United States currently utilize two main types of high strength structural bolts to transfer the forces developed in the connections between structural members. These bolts are designated by the *American Society for Testing and Materials* (ASTM) as A325 and A490, which can hold up to 120ksi and 150ksi respectively. Several countries across the globe have recently introduced new grades of high strength bolts to cope with increasing material strength and to enhance design options. The recently developed *Japanese Industrial Standard* (JIS) F14T bolt has an ultimate tensile strength of roughly 200ksi, 33% stronger than the A490, the strongest ASTM bolt.

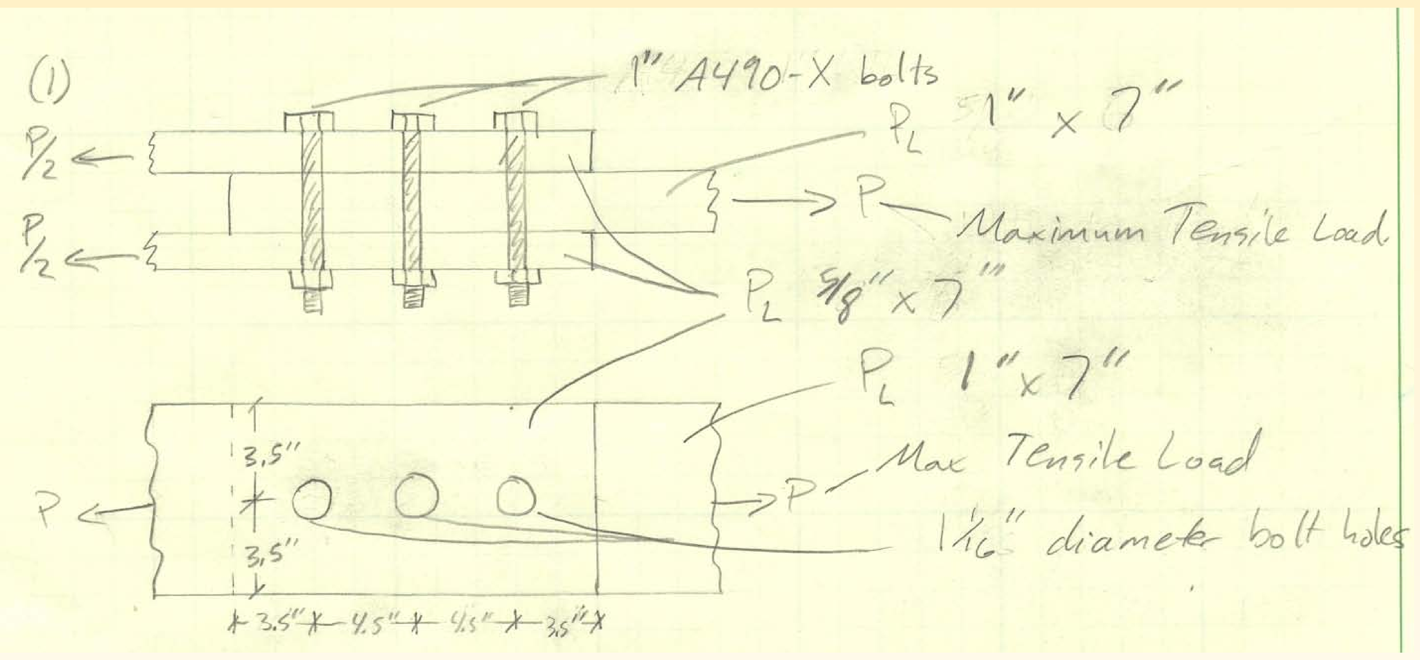
Although the F14T is considerably stronger than the A490, that does not necessarily mean the connection will be stronger. There are many ways a connection can fail besides bolt failure. The type of failure depends on many factors such as what kind of connection it is, what types of loads are being applied to the connection, and the material properties of all connection members. To determine the potential benefit of the F14T over the A325 and A490, all connection limit states must be investigated and calculated using the different bolts. Also, before this is done the standards and practices of each standardizing company (ASTM and JIS) must be researched to determine if the bolts can be directly compared or if some values must be changed for a fair representation of their differences.

Method

Before any calculations could be done, research on the differences in bolt properties and testing procedures needed to be collected. The F14T bolt achieves its extra strength from the steel's unique chemical alterations as well as from its more rounded thread design rather than sharp thread design. The rounded threads give the bolt a larger cross sectional area in the threaded (weakest, and therefore limiting) section of the bolt. This difference means that the ASTM reduction factor of 0.75 for cross sectional area in the threaded section of the bolts is not the correct factor for the F14T. After extensive research to find the correct reduction I found no official document with the value and it may very well be that it does not officially exist yet as this bolt type is very new. To keep the study and the calculations conservative, I did not change the 0.75 factor for the F14T and later made other conservative assumptions to account for the increased area.

The second part of the research was to find the differences between ASTM and JIS testing procedures and then how each company determined what the bolt's tensile strength values were. I found that there are many accurate methods of testing bolt strength, and that both ASTM and JIS use several of these same standard methods. How the data scatter from theses tests is then analyzed to designate a specific strength for the bolt type could very well be different for each company however. Neither Dr. Okazaki nor I found results on how the scatter is interpreted by each company or what percentage of the test results were cut off as a failure qualification during our research on the subject. However it can be reasonably assumed that the standards for both ASTM and JIS are very similar as both use the same strength equations and have very comparable standards in other areas. For the purpose of continuing the study I once again assumed JIS standards to be the same as ASTM.

Once the background research was done, I designed a simple splice connection that is very common in steel structural design to test the different bolts. A diagram of the connection is shown below. I did not have time to test all types of connections and loadings, as there are very many variations that can change strength values, so I only tested this connection. The results from this connection will be very similar and representative of many other connections though. There are six limit state calculations that need to be done to determine the overall connection design strength and I conducted all of these for this connection using all three bolts. Depending upon if the connection is designed as a slip critical or bearing type connection, the connection tensile forces the bolts can hold without failing changes so both of these calculations, and therefore connection types, were compared as well.



Results

The results of my limit state calculations showed that in slip critical connections the tension members in the connection may be made up to 65% stronger or thicker from the A490 bolted connection to the F14T connection. In bearing type connections, I calculated that the increase in connection design strength, and therefore the increase in tension member strength or thickness, was proportional to the increase in tensile strength from A490 to F14T, which is 35%.

Conclusions

The F14T is an extremely strong structural connector. It is very effective in reducing the amount of bolts in a connection or increasing the bolt strength of a connection, in some cases even more than just the increase in listed bolt tensile strength. Not every structural connection should use super high strength bolts but if extra strength is needed without having to use a lot of bolts the F14T or a similar bolt is definitely capable of the task. As buildings, bridges, and other steel structures continue to get larger, so must the strengths of the materials they are made out of. I recommend that ASTM design a similar super high strength bolt to add to its current lineup or else future designs in the U.S. will be limited by connection strength.

References

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