DETAILED EXPLANATION OF COLLAPSED TREE DUE TO WRONG DESIGN OF SUPPORT STRUCTURE

Around 2009 it was decided to make a support structure for the Anne Frank's chestnut tree to protect it against blowing over. This was necessary because an inspection showed that rot was present at the bottom of this tree. This rotten spot weakened the tree. Therefore a steel structure was designed to ensure that the tree would not blow over during wind gusts. The tree was important for a lot of people due to the second world war. When I saw the news and pictures of the tripod structure and the broken tree I was shocked. The top ring is much too low around the tree. The rotten place in the tree was positioned above the lowest ring. At high winds this position of the ring will cause high shear forces at the rotten position of the tree. The lowest ring should be positioned above this rotten spot.

If the design of the support structure is too stiff, you lose the benefit of the flexibility of the tree. This flexibility actually means that the tree can absorb wind gusts on. If the steel structure is too stiff, the tree will break above this rotten spot. A jump in stiffness is always fatal for a construction particularly for a tree. The construction should move along with the tree. The movement and flexibility of a tree makes it possible for the tree to overcome wind gusts. If the construction is too stiff you overcome the natural surviving technique of the tree to take wind gusts. You can for example build in flexibility by making the tripod out of not straight pipes. Due to this curvature in the support structure, this structure becomes less stiff. Good contact between the rings and the tree is very important. If the tree would be able to bend away a little and then at once feel the help of the support structure the tree would also break. That is why chocks are used to stiffly connect the rings with the tree. Also the footplates to connect the pipes hammered into the ground with the tripod are not designed properly. For placing flexibility the designers choose to weld a footplate on the pipes hammered into the ground. Also the three legs of the support structure were produced with footplates. Both footplates welded on the pipes into the ground and welded on the tripod were welded together. Due to wind loads one pair of footplates welded on each other are pulled away from each other. Due to this high bending forces arise in the welds. Also the footplates tend to be pulled in a curvature. This makes that the welds feel bending moments. Welds are only strong when the welds are under shear stresses. Bending stresses are very unfavourable for the welds. To connect the ground based construction with the tripod no footplates should be allowed. A much better design is to place two strips of metal along the ground based piles and also along the legs of the tripod. Then we weld these steel plates on the piles hammered into the ground and on the tripod legs. For flexibility for positioning the tripod above the pipes hammered into the ground, two connections can be made with footplates. The two legs of the tripod that are under compression (due to wind loads) can be made with footplates. For the leg that is under tension no footplates but steel strips should be used. You now keep the flexibility for positioning but no welds will be under bending forces. If we can look at the crashed support structure we can see what was the cause of the failure.

There can also be another cause of failure. When we trie to move the upper ring to the right only tension and compression forces occur in the three legs of the tripod. When we move the lower ring horizontally, also bending forces occur in the legs of the tripod. When a steel bar is under tension the elastic movement is low. A bar under bending will generate much higher elastic deformations. So at the same horizontal force the lower ring will move much more in horizontal direction compared to the upper ring. Due to this effect the tree has to deform more near the ground. At that spot the tree was rotten. Due to much flexiblity of the tripod near the lower ring the tree could also break. The shear force in the tree got too high at the rotten part of the tree. The tripod breaks down the natural surviving technique of the tree. The tree should be able to bend away at high winds. The tripod made this impossible. So if the welds in the footplate did not break this phenomena of wrong flexibility caused the tree to break down. To explain a little bit; if you hang a wooden plank on the ceiling and you hang on it you will not feel any deformation. When you take the same plank and lay him over a ditch and you go and stand on it the deformation is much greater. With this simple explanation you can see that deformation due to bending is 10 until 1000 times bigger compared to deformation due to tension. The wrong thing in the design is that the lower ring should h and that this ring should be placed higher above the rotten place of the tree.

So three design errors are made;

1: The lower ring should be positioned above the rotten place in the tree. Due to this position of the ring the rotten place had to overcome high shear forces.

1: The lower ring can move horizontally much easier compared to the upper ring. This kills the natural surviving technique of a tree. A tree should be able to bend away at wind gusts. The lower ring should have its own tripod.

2: Welding details are designed wrong. In this design the welds of the footplates are under bending and not under shear. A weld that is under bending or pulling is much weaker compared to welds under shear. Just by forgetting the footplates and welding two strips of steel along the hammered pipes and along the legs of the tripod will make this connection at least 10 times as strong and durable.

After an investigation it was pointed out that the welds were not strong enough. The brand in of the welds was too low because a 220 Volt welding machine was used. Off course when you change from footplates to strips for connecting the hammered piles with the tripod forces in welds would be much lower. Also because the welds will now be under shear and not under bending the welds would hold.

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