Why aren't composite tensile specimens dog bones?

The tensile strength and modulus of materials are crucial characteristics that engineers use for component design. This information is determined by means of a simple tensile test. For most materials, a dog bone shape is used in order to promote a failure within the gauge length of the extensometer and prevent grip end failures, but not for composites. Why?

With a metal or a polymer, the material is isotropic, meaning that the material exhibits the same behaviour in all directions. Composites however are not. The strength of a composite material exists in the orientation of the fibres within. The removal of material within the gauge length leads to discontinuous fibres in the dog ears. The problem with this arises due to the fact that the shear stresses exerted during a tensile test and greater than the shear strength of the matrix. In practise, this results in the dog ears shearing off the specimen and leaving, what is essentially a straight sided specimen. As the force exerted within the grips (assuming wedge grips are used) is typically 20% higher than the applied force, this will result in grip breaks. This is undesirable as it gives an artificially low failure load. It has been calculated that in order to prevent the shear stresses overcoming the shear strength of the matrix, the radius of the dog ears would have to be 1m. Obviously, this would make gripping of the specimen impractical.

Dog ears shearing off a carbon fibre dog bon specimen, leading to failure in the grips

So as a composites test lab, how do we overcome this issue? The answer in short is end tabbing. End tabbing involves bonding glass fibre, sometimes carbon fibre, to the specimen using an adhesive that has a shear strength greater than the exerted shear stress. Glass fibre is preferable because it is soft enough to enable the grips to bite into the material surface and of course, is cheaper than a carbon fibre alternative. By end tabbing, the thickness, rather than the width of the material in the grip regions is increased, resulting in a failure in the gauge length.

An additional consideration that can be introduced is the tab termination angle. A tapered tab angle is recommended in order to minimise the stress concentration in the tab termination region and as such prevent failures in the tab termination region. Despite this, theoretically a perfect composite should fail at the tab termination angle as ultimately this will be the area of highest stress. In practise however, specimens contain flaws within the gauge length and as such, this is where failure will occur.

Whilst this can all seem a little bit theoretical, in practise, it makes a huge difference to measuring accurate and reliable results.