**Finite element modelling details**

A cohesive-like separation law is implemented between the layers allowing failure of the interface and thus simulating the delamination. The interface will fail when the following condition is satisfied:

|  |  |  |
| --- | --- | --- |
|  | $$\left(\frac{σ}{σ\_{lim}}\right)^{2}+\left(\frac{τ}{τ\_{lim}}\right)^{2}\geq 1$$ | (S1) |

with $σ\_{lim}$ and $τ\_{lim}$ being the interface normal and shear limit strengths respectively. When failure occurs and the surfaces separate, the interaction automatically switches to a classical penalty based contact (static and dynamic coefficient of friction conventionally assumed 0.2. and 0.1). According to the Tresca criterion we have assumed $τ\_{lim}=\frac{1}{2}σ\_{lim}$ and estimated the stresses, $σ\_{lim}=11$ MPa and $τ\_{lim}=5.5$ MPa. This value was obtained by targeting the experiments bending modulus strength and strain given the material properties (Supplementary Figure S4). As the trabecular structures were observed to be formed by an extension of middle layer, the nodes surrounding trabecular top faces are welded together in order to simulate the degree of restrain between the two substructures (Supplementary Figure S3). Material failure is treated using erosion algorithm with failure that occurs when either one between the principal stress or strain reaches its limit, which corresponds to the average strength *σf* and strain εf = σf/*E* measured from tensile tests (Supplementary Table S1). Failure of one element occurs when one integration point reaches the failure limit. Since the simulation is under control of the loading bar displacement, the external loading force *F* is measured indirectly from the normal contact force between loading bar and the layer in contact (that for equilibrium is equal to the one recorded at the two support bars).

**Table S1.** Characteristics and material properties of the layers used in the FEM model, taken as averages of the experimental results. εf is derived indirectly by σf/*E* assuming a linear elastic constitutive response for all layers.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Layer** | **Thickness [μm]** | ***E* [GPa]** | **σf [MPa]** | **εf** |
| Epicuticle | 45 | 3.23 | 93 | 0.029 |
| Endocuticle | 67 | 2.70 | 132 | 0.049 |
| Void | 39 | - | - | - |
| Trabecular struct. | 39 | 2.70 | 132 | 0.049 |
| Lower lamination | 8 | 2.29 | 156 | 0.068 |