Abstract: Röthlisberger Channel Model with Anti-Plane Shear Loading Superposed on In-Plane Compression

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The Röthlisberger channel (R channel) is a commonly adopted model that balances creep closure by Nye 2D in-plane straining, driven by the ice overburden pressure, against the melt rate from viscous energy dissipation in turbulent flow within the channel. Perol and Rice (AGU abstr. C11B-0677, 2011; JGR 2014 in review) and Suckale et al. (JGR F003008, 2014) have conjectured that these R-Channels may exist at the beds of rapidly straining West Antarctic Ice Stream shear margins. That is expected as a result of melt generation and drainage from forming temperate ice, and the channels may interact through the bed hydrology to partially stabilize the shear margin against lateral expansion. However, at those locations the overburden stresses, driving in-plane flow, are supplemented by substantial anti- - plane shear stresses. Similarly, R-channels in mountain glaciers are also subject to both in-plane and anti-plane stresses. These channels usually form in the downstream direction, where anti-plane shear effects arise horizontally from drag at lateral moraines and vertically from the downslope gravity component. Here we examine how superposed anti-plane loading can alter results of the Nye solution for a 2D R channel. We use a combination of perturbation analyses and finite element methods, varying the amount of applied anti-plane stress. A closed-form solution is derived for imposing a small anti-plane perturbation, which has no effect at linear order on the Nye closure rate. Such effects become strong at more substantial perturbations, and the in plane stress and strain fields are then significantly altered from the Nye solution. We further extend our model to compute channel size in terms of the external stressing and flow rate. Understanding the effect of the ice flow on channel size and formation is important to subglacial hydrology, as well as a potentially vital component for our understanding of the formation and motion of ice-streams found in West Antarctica.