Pretensioned Natural Stone for Low Carbon Construction

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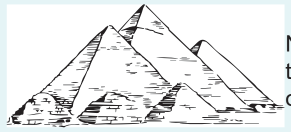
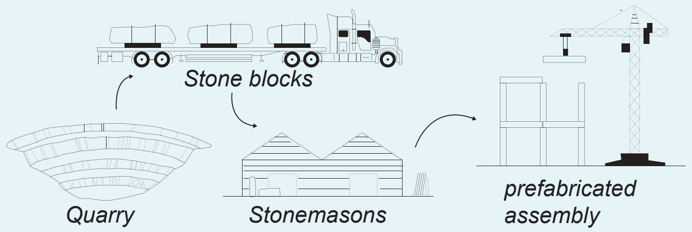
Green Stone



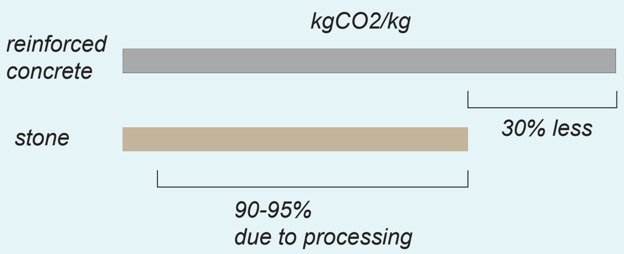
Natural stone is a durable material that lasts millenia. e.g. Pyramids of Giza 2570 BC.

At current rates of extraction there is an 850 million year reserve of natural stone. [ref]

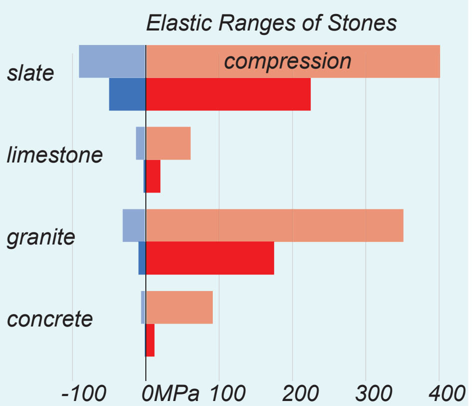
850 Ma. Cryogenian-Tonian period -A.K.A. "snowball earth"



Reinforced stone, in its application, is best compared to simple precast concrete structures



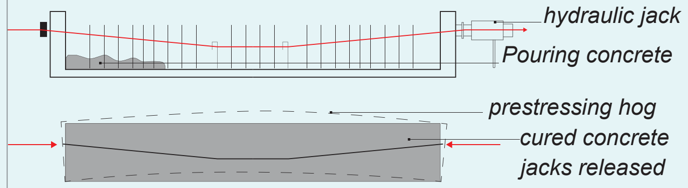
Producing concrete is an inherently carbon releasing process. The embodied carbon of stone can be significantly reduced by switching to renewably powered processing facilities. Transportation majorly affects embodied carbon, therefore green stone should be locally sourced.



Prestressing

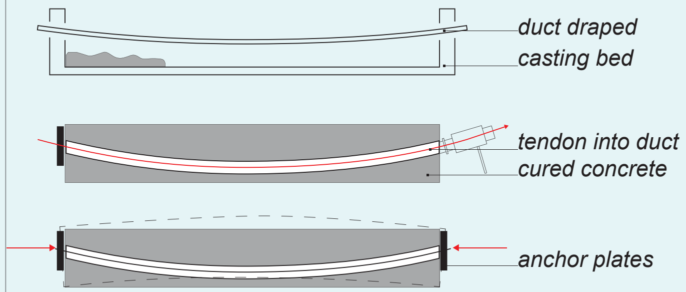
PRE-Tensioned Concrete

Concrete is poured into casting bed with exposed stressed cable. Concrete-to-strand connection forms. Stressing tools are removed, the cable transfers compression to the concrete through longitudinal shear.

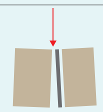


POST-Tensioned Concrete

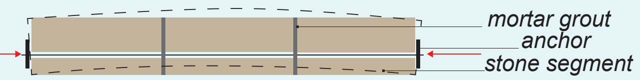
A duct is draped into the casting bed and the concrete cures around it. The cables are drawn through the duct, stressed and anchored at the beam ends.



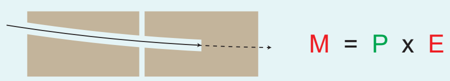
Segmental Stone

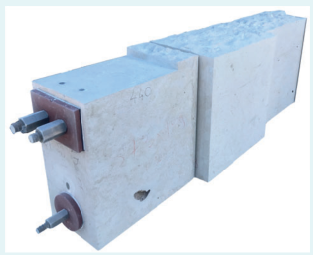


Long stone beams are segmental the mortar cannot support tension therefore clamping forces required



Approximating the variable prestressing moment in segmental stone by varying eccentricity requires drilling and aligning a curve through multiple segments. Curved profiles present friction losses in the beam and are practically tricky to fabricate.

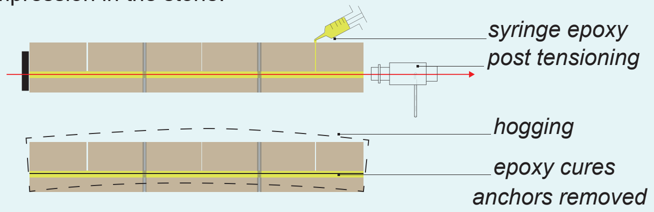




Pretensioned Stone

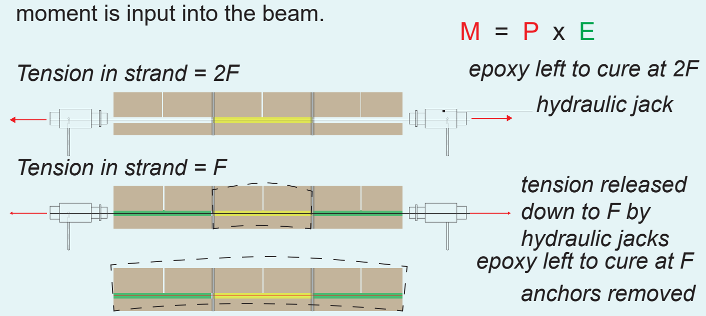
PRE-Tensioned Stone

A structural adhesive is syringed into the duct with the prestressing strand. Once the adhesive cures the anchors are removed. The tension from the cable is transferred into compression in the stone.

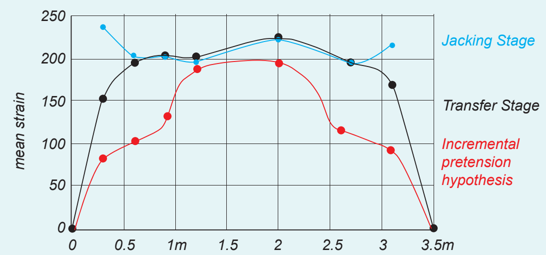


Decremental PRE-Tensioning

Decremental pretensioning is a sequence of stressing the cable, adhering the strand to the stone, and then partially releasing the tension. By doing this a variable prestressing moment is input into the beam.

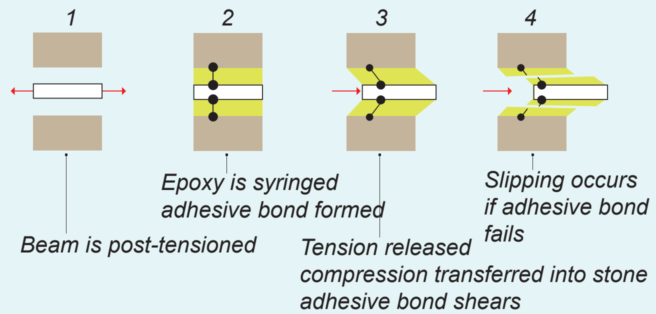


PRE-Tensioned Stone



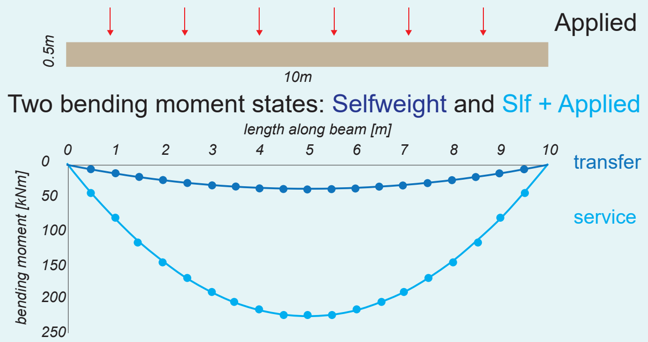
strain response of pretensioned single strand beam Sebastian and Webb

The efficacy of the pretensioning method relies on the strength of the longitudinal shear connector - the strength of the adhesive bond.

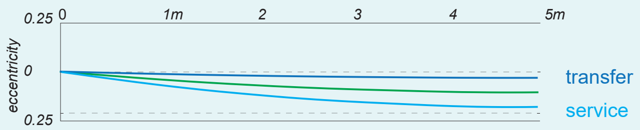


Design

Optimal Prestressing Moments



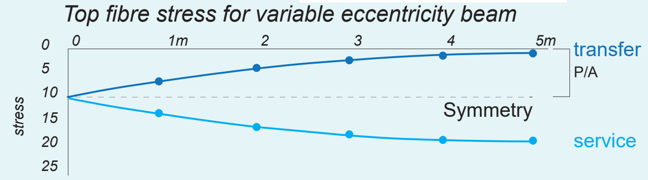
Tendon eccentricity profiles for the two applied moments A third profile, satisfying stress limits in both states, is found using C.R. Calladine's improved Magnel diagram



An optimal eccentricity profile using Calladine's diagram

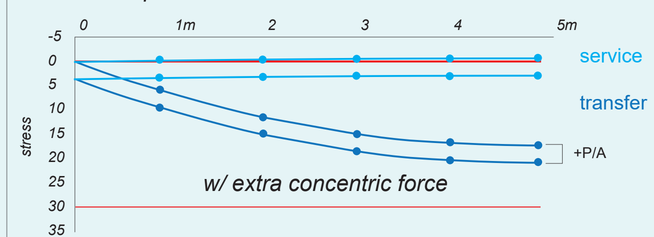
Prestressed beam stress eq. $f_b^t = -\frac{P}{A} \mp \frac{Mc_b^t}{I} \pm \frac{Pec_b^t}{I}$

Top fibre stress for variable eccentricity beam



Decremental Force Beam Stresses

Top fibre stress for variable force beams



As uniform stress varies with the prestress force.

$$f_b^t = -\frac{P}{A} \mp \frac{Mc_b^t}{I} \pm \frac{Pec_b^t}{I}$$

An extra concentric force may be necessary to prevent splitting

Conclusions

1. Decremental force pre-tensioned beam design could use a similar optimisation to draped tendon prestressing.
2. Further work needs to be done to accurately model the longitudinal shear behaviour of the tri-material bond. Experimental results of the prototype decremental beam will provide further insight for the design.