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## MODELLING ICE RUBBLE WITH PSEUDO-DISCRETE CONTINUUM MODEL. DIRECT SHEAR TEST

The idea of pseudo-discrete continuum model of the ice rubble will be presented in this paper. This model conducted study the behaviour of ice rubble in the primary failure mode that is associated with the initial breakage of the rubble skeleton. The model is a combination of the discrete particle assembly generation (i.e. ice rubble accumulation) and the FE analysis of this assembly. It provides a possibility to simulate the contacts between the ice blocks and their local failure.

The modelling procedure consists of two basic steps. First, the assembly of blocks is generated. The block generator tool was developed to fulfill this task. In the second step, the generated assembly is used as a geometrical input for the FE analysis to study its behaviour under loading at the different boundary conditions.

### *Generation of discrete block assembly*

Generation of the discrete block assembly was conducted in the custom-developed computer program called the block generator. This program fills the closed contour with blocks of rectangular shape. The blocks themselves are considered as solid bodies. Geometry of each block is defined by its centre of gravity  $x_c, y_c$  and four vertices.

### *Finite element model*

The generated assembly of ice blocks was used as a geometrical input for the FE analysis. It was suggested to use the Plaxis FE code for the simulations.

The quasi-static approach was used in the simulations. The ice rubble was modelled as a weightless material, i.e. initially the rubble was unloaded. Iterative calculations were carried out until the overall stiffness of the material approached zero. This was an indication of complete breakage of the initial rubble skeleton.

The model consists of:

- *The ice blocks.* They were assigned an elastic-perfectly plastic Mohr-Coulomb material model.
- *The voids between the blocks.* They were modelled using elastic material with a negligible stiffness. This was done to avoid mesh problems – use of elastic material instead of leaving voids “empty”.
- *The contacts between the blocks.* They were modelled using the interface elements. Fig. 1 shows the close-up of contacts between ice blocks in the rubble (with the mesh on). The strength properties of the interfaces are linked to the strength properties of the ice blocks via the strength reduction factor for interfaces  $R_i$  as follows:

$$c_i = R_i \cdot c \text{ and } \tan \varphi_i = R_i \cdot \tan \varphi \quad (1)$$

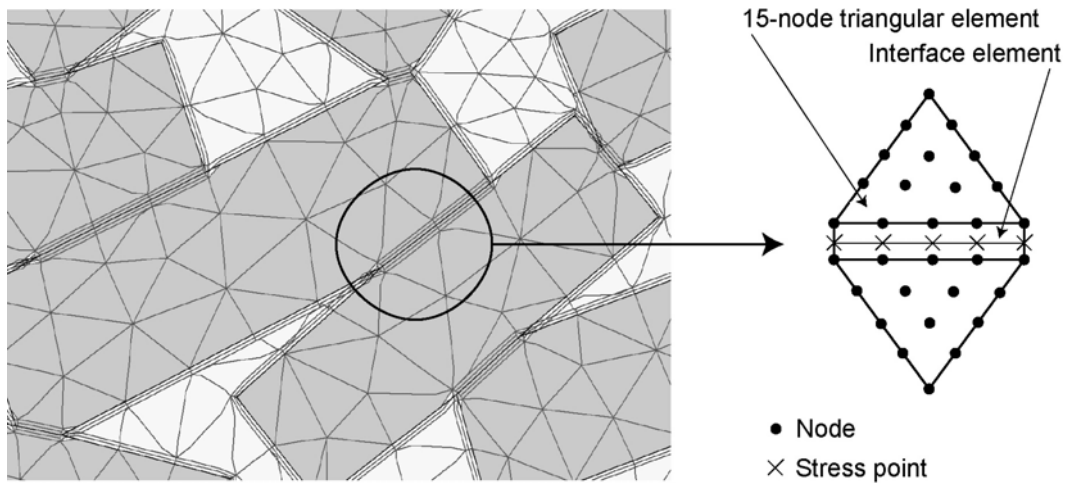


Fig. 1. Ice blocks in contact.

### Direct shear test

A series of numerical tests with the direct shear box were done so far. The apparatus simulated in this set of numerical experiments is the two-dimensional direct shear box that is shown in Fig. 2. The inner length of the shear box is 6 m and the depth is 3 m. This box were filled by ice blocks with average dimensions 0,3×1,0 m.

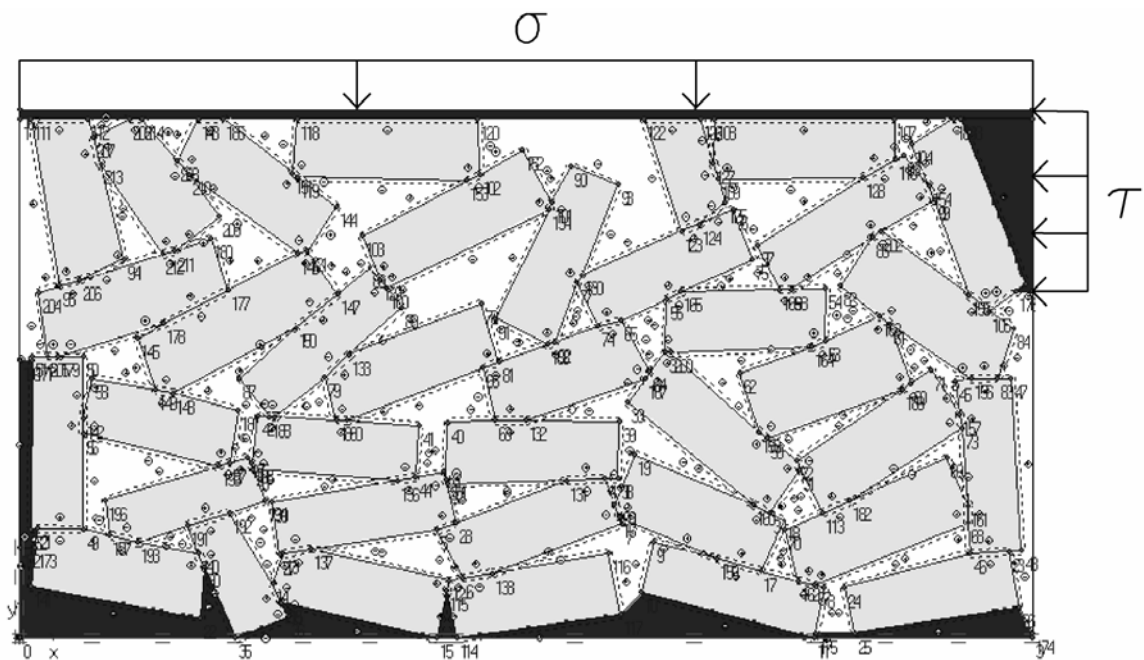


Fig. 2. The direct shear box.

The following conclusions could be made so far:

- Failure of ice rubble in primary failure mode was associated mainly with breakage of contacts between the blocks, but some local breakage of individual blocks was also observed during the simulations.
- The freeze-bond properties and their relation to the properties of parent ice are important for the overall strength of the rubble skeleton.
- The shear strength of rubble increased more or less linearly with increasing strength of the freeze bonds between the blocks.

- The shear strength increased non-linearly with increase of confining pressure. As a result change of failures mechanism from tensile to shear was observed as confinement increased.