# A Conceptual empirical approach for the overall strength of unwelded bimrocks

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ABSTRACT: Design and engineering facilities are often constructed in complex geological mixtures or fragmented rocks such as mélanges, fault rocks, coarse pyroclastic rocks, breccias and sheared serpentines. These types of geological materials are generally chaotic and mechanically and/or spatially heterogeneous rock masses, which are composed of relatively strong rock inclusions, surrounded by weaker matrix, and may be considered as bimrocks (block-in-matrix-rocks; Medley, 1994). The preparation of standard and representative cores from these types of rock masses for conventional laboratory experiments is almost impossible. In the literature, there are a few attempts to overcome this difficulty by developing empirical approaches based on case histories and laboratory studies on bimrocks. However, despite these attempts, there is no widely accepted empirical approach in the rock mechanics community. In this study, some conceptual equations, which are open to improvement, were generated by considering literature findings to predict strength of unwelded bimrocks.

## 1 INTRODUCTION

In literature, bimrocks is divided into two groups, namely, welded and unwelded bimrocks. The bimrocks, which were formed under high pressure and temperature conditions, are evaluated as welded bimrocks, the best-known current example being agglomerate (Sonmez et al., 2004[a], 2004[b] and 2006). The strength of the contact boundary between matrix and blocks is accepted as approximately equal to the strength of matrix for welded bimrocks. Based on the strength behavior of the boundary, the uniaxial compressive strength (UCS) will increase when the volumetric block proportion (VBP) increases (Sonmez et al. 2004[b] and 2006). On the other hand, the overall strength behaviors of unwelded bimrocks such as mélanges, which are globally geological mixtures, are completely different from welded bimrocks. As shown the data given in Figure 1, when VBP increases, the internal friction angle ($\phi$) increases, whereas the cohesion and UCS decrease (Lindquist 1994, Lindquist & Goodman 1994) Similar results were also obtained from the experimental studies performed on the artificial bimrock models by Altınsoy (2006).

In this study, a conceptual empirical approach was drawn for predicting of overall strength of bimrocks considering the boundary conditions for unwelded bimrocks discussed in literature.

## 2 GENERATION OF CONCEPTUAL APPROACH

Lindquist & Goodman (1994) employed triaxial tests on model cores including oriented blocks having various ratios of block to matrix. The tests results reveal that the cohesion of model bimrock decreases when the volumetric block proportion increases. In contrary to this, the internal friction angle increases for higher volumetric block proportions (Fig. 1).

Lindquist (1994) indicated that the increment of the internal friction angle of bimrocks was about 15 degrees for VBP=75%. Scott dam mélange data have greater increment than the model tests data, however no requirement was given for this difference (Fig. 2).

The boundary conditions underlined in related literature can be summarized as follows:

i. The internal friction angle of bimrocks ($\phi_{bimrock}$) starts from the internal friction angle of matrix for VBP=0%, and it increases with low increment up to VBP=25%; higher increment is observed between VBP=25% and VBP=75%, and almost no increment for VBP>75%.

ii. $\phi_{bimrock}$ is almost equal to the angle of repose of block ($\alpha$) for VBP>75%

iii. The $UCS_{bimrock}$ decreases from the $UCS_{matrix}$ to zero between VBP=0% and VBP=100%.

By considering boundary conditions discussed in literature, schematic illustration of the strength behaviour of unwelded bimrocks were drawn from VBP=0% to VBP=%100 (Fig. 3).

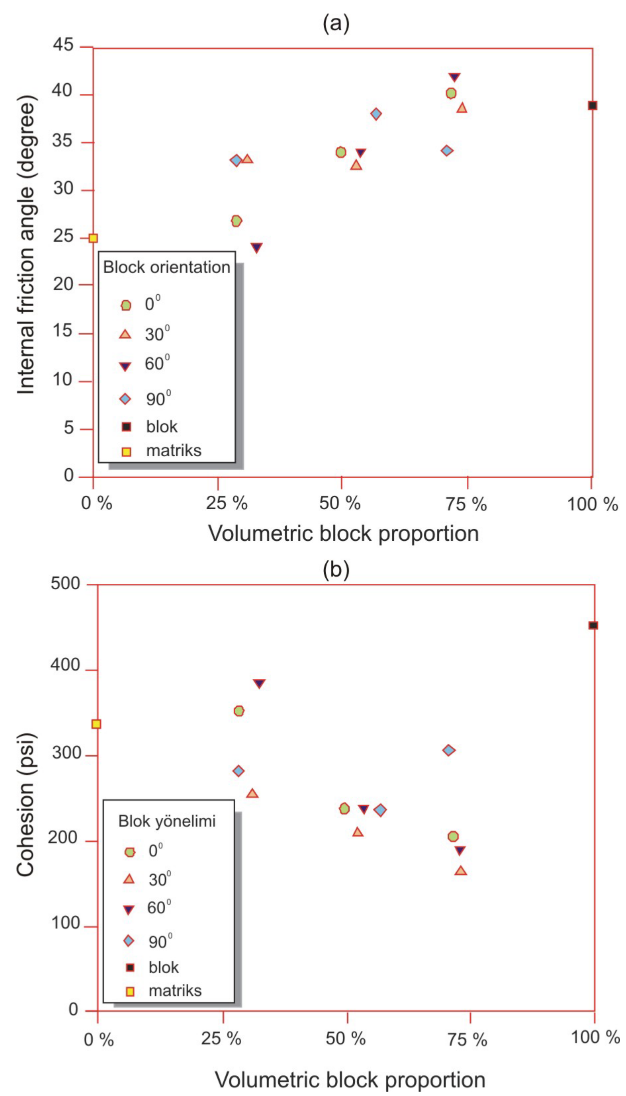


Figure 1. (a) Cohesion versus VBP, (b) internal friction angle versus VBP graphs (Lindquist, 1994).

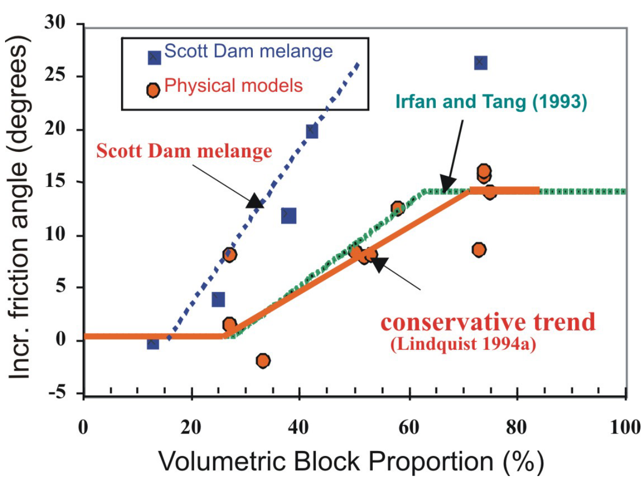


Figure 2. Incremental internal friction angle versus VBP graph (Lindquist, 1994).

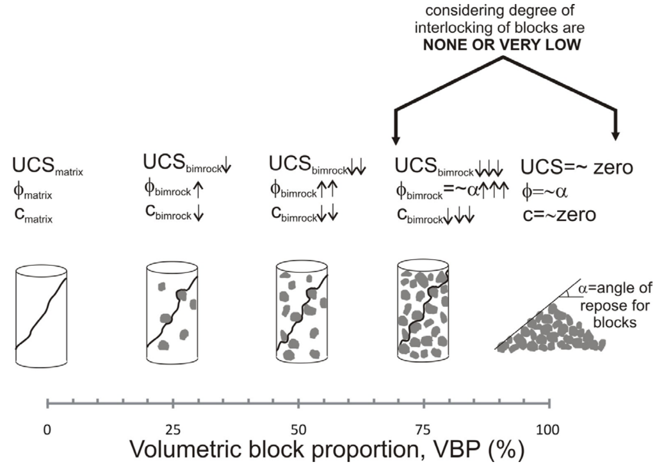


Figure 3. Schematic illustration of the strength behaviour of unwelded bimrocks depending on full ranges of VBP (from zero % to 100%)..

The items ii. and iii. are just valid for no or low degree of interlocking of blocks. By considering boundary conditions given above the conceptual empirical equations (curves) were generated by a trial and error method (Eqs. 1a-c and Fig. 4).

Data collected from the studies performed by Lindquist (1994) and Altınsoy (2006) were considered for just comparison with the conceptual empirical approach. For the artificial bimrock models prepared by Altınsoy (2006); while the angle of repose of blocks ($\alpha$) varies between $33^0$ and $36^0$, the internal friction angle of the matrix ($\phi_{matrix}$) varies between $24.8^0$ and $26^0$. The artificial bimrocks prepared by Lindquist (1994) included oriented blocks, in order that the anisotropic strength behavior of the bimrocks could be evaluated. Although $\phi_{matrix}$ was about $24.7^0$, the angle of repose of the blocks was not measured by Lindquist (1994). Therefore, in the present study, the data collected from both Altınsoy (2006) and Lindquist (1994) were plotted on the graphs for just comparison with the conceptual empirical approach (Fig. 4).

As can be seen from Figure 4a, the upper value of internal friction angle of bimrock is restricted by the ratio of tan($\alpha$) to tan($\phi_{matrix}$), where $\alpha$ is the angle of repose blocks. However, the curves between volumetric block proportion and UCS were controlled by the constant A (Fig. 4b). When the value of A is equal to zero conservative trend was obtained. On the other hand, the value of A increases for the higher adhesion (cohesion) on the boundary between block and matrix. For the selection of constant A, Table 1 is introduced for practical purposes. It should be remembered that, the conceptual approach proposed in this study is open to improvement depending on the cases and additional laboratory test results. Therefore, the conceptual approach generated in this study should not be used for design purpose alone. It can be used for selection of strength parameters in pre-design stage.

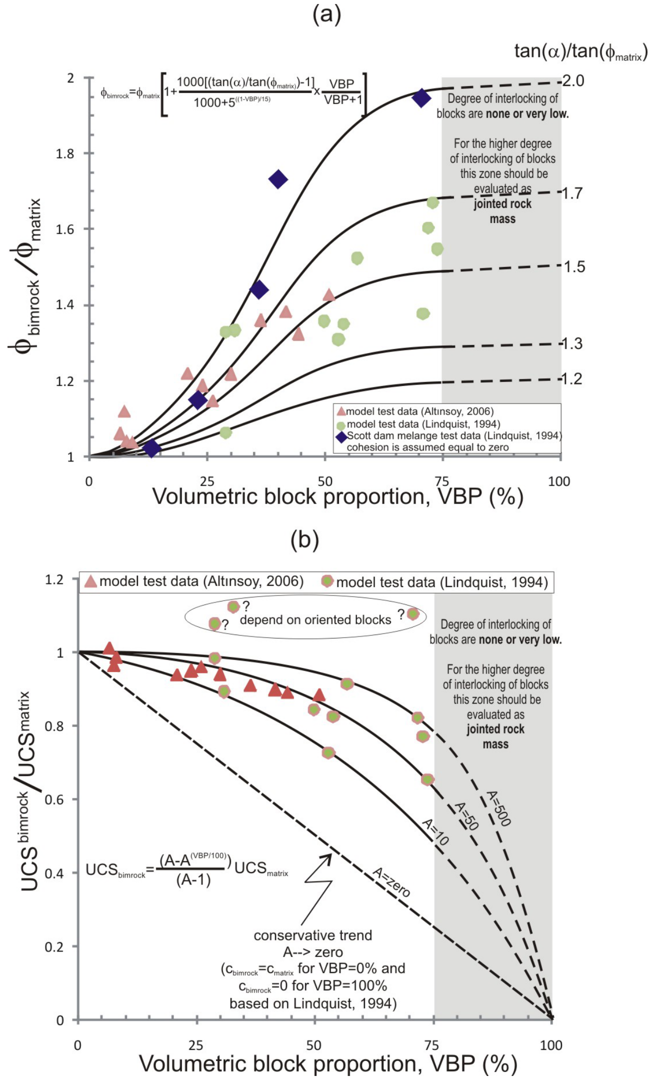


Figure 4. The graphical presentation of the empirical approach for (a) $\phi_{bimrock}$ (b) $UCS_{bimrock}$.

$$\phi_{bimrock} = \phi_{matrix}\left[1 + \frac{1000[(\tan(\alpha)/\tan(\phi_{matrix}))-1]}{1000+5^{((1-VBP)/15)}} x \frac{VBP}{VBP+1}\right] \quad (1a)$$

$$UCS_{bimrock} = \frac{(A - A^{(VBP/100)})}{(A-1)} UCS_{matrix} \qquad zero >= A <= 500 \quad (1b)$$

$$c_{bimrock} = \frac{UCS_{bimrock} x (1-\sin(\phi_{bimrock}))}{2\cos(\phi_{bimrock})} \quad (1c)$$

Table 1. The value of A depending on the boundary properties between block and matrix.

| Decription | The value of A |
|---|---|
| Almost no adhesion (cohesion) between block and matrix with rounded blocks. | 0 |
| Weak adhesion (cohesion) between block and matrix with semi-rounded blocks. | 10 |
| Moderate adhesion (cohesion) between block and matrix with semi-angular blocks. | 50 |
| Strong adhesion (but less than cohesion of matrix) between block and matrix with angular blocks. | 500 |

## 3 RESULTS AND CONSLUSIONS

The results obtained from this study, and some conclusion depending on the study can be summarized as follows.

As underlined in Figure 3, for higher VBP values, the strength parameters obtained from the empirical equation proposed in this study can only be used for degrees of interlocking of blocks that are zero or very low. For higher VBP values (particularly greater than 75%) the strength parameters will be increase when the degree of interlocking of the blocks increases. The values obtained from the proposed empirical equations may be evaluated for the lower bound for blocky geological mixtures having VBP greater than 75%. Therefore, blocky geological mixtures having VBP>%75 should be evaluated as jointed rock masses, by considering the rock mass quality with the degree of interlocking as well as other properties of the joints.

There isn’t sufficient data for evaluation of the strength behavior of the blocky geological mixtures having VBP>75% considering degree of interlocking of blocks. Therefore more effort should be spend to clarify this point. This study is a part of an ongoing project supported by TUBITAK (Project No. 108Y002). The equations generated in this study are based on just conceptual assumptions; therefore they are open to discussion and improvement by additional data that will be obtained during the project.

The conceptual approach generated in this study should not be used for design purpose alone. It can be used for selection of strength parameters in predesign stage. Some additional methods such as field test should be considered for safety of engineering projects to be constructed in/on birmcoks.

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