



AD FALCON API Manual

# Effective Stress Model – Ghorbani and Kodikara (2024)

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# 1 Effective Stress Model – Ghorbani and Kodikara (2024)

## 1.1 Syntax

Specify this model in % Materials using @EffectiveStress::

```
@EffectiveStress: GhorbaniKodikara Beta1 <Beta1> Beta2 <Beta2>
```

The effective stress in unsaturated soils is influenced by both pore water and pore air pressures. Ghorbani and Kodikara (2024) proposed a generalized formulation that introduces a saturation-dependent weighting function to interpolate between Terzaghi's effective stress (for saturated soils) and Bishop-type expressions (for unsaturated conditions).

The model is expressed as:

$$\sigma' = \sigma - \chi(S_w) p_w I - [1 - \chi(S_w)] p_a I \quad (1)$$

where:

- $\sigma'$ : effective stress tensor
- $\sigma$ : total stress tensor
- $p_w$ : pore water pressure
- $p_a$ : pore air pressure
- $S_w$ : degree of saturation
- $I$ : identity tensor
- $\chi(S_w)$ : effective stress weight function

The weighting function  $\chi(S_w)$  is defined by:

$$\chi(S_w) = S_w^{\left(\frac{\beta_1}{S_w^{\beta_2}}\right)} \quad (2)$$

with model parameters:

- $\beta_1$ : exponent controlling the saturation influence
- $\beta_2$ : scaling parameter for nonlinear saturation behavior

## 1.2 Special Cases

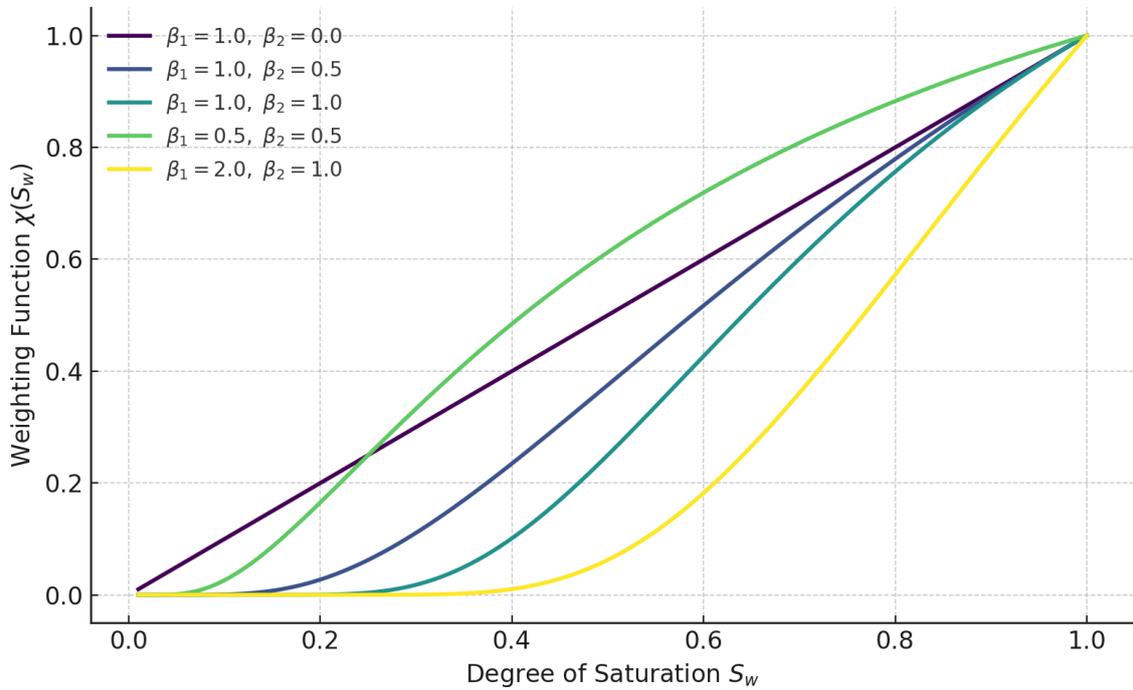
- If  $\beta_1 = 1$  and  $\beta_2 = 0$ , then  $\chi(S_w) = S_w$ , recovering the classical Bishop's model.
- If  $S_w = 1$ , the formulation reduces to Terzaghi's effective stress.

This model provides greater flexibility in capturing intermediate saturation effects and enables a smooth transition between saturated and dry states. It is particularly useful for coupling hydro-mechanical processes in unsaturated soils, especially when dealing with strong suction regimes or complex loading paths.

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**Influence of  $\beta_1$  and  $\beta_2$  on  $\chi(S_w)$** 


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Equations (1)-(2) follow the effective-stress formulation proposed by Ghorbani and Kodikara (2024).

### 1.3 References

- Ghorbani, J., & Kodikara, J. (2024). *Thermodynamically consistent effective stress formulation for unsaturated soils across a wide range of soil saturation*. *Computational Mechanics*, 73(5), 1077-1094.