# Dafalias-Manzari 04 Model, v4.0
# for FLAC3D v9.0

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## Introduction

The Dafalias-Manzari model (Dafalias & Manzari, 2004) version 1.0 was implemented in 2012 for FLAC3D v5.0. The current version (**v4.0**) is compatible with **FLAC3D v9.0**.

This model is stress-ratio controlled and is compatible with critical state sand mechanics, accounting for changes in fabric under multiaxial loading. One of its key advantages is that a single set of material parameters can be used for a wide range of stresses and densities. The model's material parameters have been calibrated for Toyoura sand, with some parameters serving as default values for most types of sand and not requiring individual determination.

The background of the model is outlined in Dafalias & Manzari's (2004) paper, while Cheng et al's (2013) paper describes its original implementation in FLAC3D. The DLL file, along with attached examples containing FLAC3D and Python scripts for this model, is available for free use. However, if this DLL is being used as a user-defined model (UDM), it is recommended that both aforementioned papers be cited in any reports or publications.

## Model Properties/Parameters

| Name | Description | Calibrated values for Toyoura Sand (Dafalias & Manzari 2004) |
|---|---|---|
| **Input Material Properties:** | | |
| **G0** | Material constant to calculate the elastic moduli, $G_0$ | 125.0 |
| **Patm** | Reference pressure to normalize the current pressure in calculation of elastic moduli, the standard atmospheric pressure (~100 KPa) is recommended, $p_{at}$ | 100.0 (if in KPa) |
| **poisson** | Poisson's ratio, $v$ | 0.05 |
| **Mc** | Critical state ratio, $M$ | 1.25 |
| **c** | Ratio of the triaxial extensive strength to compressive strength, $c$ | 0.712 |
| **lambda** | Parameter to define the critical state line, $\lambda_c$ | 0.019 |
| **ec0** | Parameter to define the critical state line, $e_{c0}$ | 0.934 |
| **xi** | Parameter to define the critical state line, $\xi$ , | 0.7, the default value 0.7 may be |

| | | |
|---|---|---|
| | it is value is 0.7 for most sands | valid for most sands. |
| **mm** | Parameter to define the yield function, $m$, a value in the range of (0.01-0.05) | 0.01-0.05, the default value is 0.01. |
| **h0** | Parameter for the plastic modulus, $h_0$ | 7.05 |
| **ch** | Parameter for the plastic modulus, $c_h$ | 0.968 |
| **nb** | Parameter for the plastic modulus, $n^b$ | 1.25 (originally 1.1) |
| **A0** | Parameter for dilatancy, $A_0$ | 0.704 |
| **nd** | Parameter for dilatancy, $n^d$ | 2.1 (originally 3.5) |
| **zmax** | Parameter for fabric-dilatancy tensor, $z_{max}$ | 2.0 ~ 6.0, the default value is 2.0. |
| **cz** | Parameter for fabric-dilatancy tensor, $c_z$ | 600 |
| **Auxiliary Material Properties:** | | |
| **kcut** | Cut-off factor to deal with low pressures | 0.01 (default value, if not input) |
| **flag-ini** | If reset to zero, the property set will be re-initialized. | 0 by default, will become 1 once the property set has been initialized. |
| **flag-origin** | If equal to 1, the fabric tensor will be set to the origin position to avoid possible overshooting. | 0 by default. |
| **Input Initial Conditions:** | | |
| **evd0** | Initial void ratio, $e^0$ | • Must be input.<br>• Once input, the values is fixed. |
| **sxx-ini** | Initial effective stress, xx-component | • Must be input one or some.<br>• The default value is 0 if not input.<br>• Can be input through commands or a FISH function.<br>• Once input, the values is fixed. |
| **syy-ini** | Initial effective stress, yy-component | |
| **szz-ini** | Initial effective stress, zz-component | |
| **sxy-ini** | Initial effective stress, xy-component | |
| **syz-ini** | Initial effective stress, yz-component | |
| **sxz-ini** | Initial effective stress, xz-component | |
| **zxx** | Current fabric dilatancy tensor, xx-component | • The default value is 0.<br>• Most cases all components are initialized from 0.<br>• Can be evolved after initiation. |
| **zyy** | Current fabric dilatancy tensor, yy-component | |
| **zzz** | Current fabric dilatancy tensor, zz-component | |
| **zxy** | Current fabric dilatancy tensor, xy-component | |
| **zyz** | Current fabric dilatancy tensor, yz-component | |
| **zxz** | Current fabric dilatancy tensor, xz-component | |
| **Output Material Properties:** | | |
| **void** | Current void ratio | |
| **sp** | Current state parameter | |

| | | |
|---|---|---|
| **cycles** | Current cycles | Variation could be ±0.25 cycles. |

**Note:** Before running the model, the initial void ratio and initial stress must be specified, or the initial stress must be derived from the previous calculation stage. Once the initial stresses are set or derived, the FISH function to assign initial effective stress can be implemented as follows:

```
fish operator ini_stress(modelname, zp)
  if zone.model(zp) = modelname
    local pp = zone.pp(zp)
    zone.prop(zp,'sxx-ini') = zone.stress.xx(zp) + pp
    zone.prop(zp,'syy-ini') = zone.stress.yy(zp) + pp
    zone.prop(zp,'szz-ini') = zone.stress.zz(zp) + pp
    zone.prop(zp,'sxy-ini') = zone.stress.xy(zp)
    zone.prop(zp,'sxz-ini') = zone.stress.xz(zp)
    zone.prop(zp,'syz-ini') = zone.stress.yz(zp)
  endif
end
[ini_stress('dm04', ::zone.list)]
```

## Included DLL file

| | |
|---|---|
| **Modedm04009.dll** | Dynamic Link Library (DLL) file of the Dafalias-Manzari model, compatible with FLAC3D Version 9.0 64-bit. |

**Note:** the DLL file can be loaded into FLAC3D by using the command "**ZONE CMODEL LOAD 'modeldm04009.dll'**". Alternatively, it is strongly recommended to place the DLL files in the "**[ C:\Program Files]\Itasca\ItascaSoftware900\exe64\plugins\cmodel**" folder. Once the DLL file is loaded, the model name "**dm04**" and its property names will be recognized by FLAC3D and its FISH functions that reference the model and its properties. If the **ZONE CMODEL LOAD** command is given for a model that is already loaded, an informative message will be displayed but nothing will be done. Before constitutive model plug-ins can be assigned to zones, the model must be configured for their use with the "**MODEL CONFIGURE PLUGIN**" command. Keep in mind that the model will not cycle unless your FLAC3D v9 license includes the C++ plug-in option.

## Demonstration Examples

| | |
|---|---|
| **Single Zone DSS simulation** | A cyclic loading example |
| **Drained Triaxial Simulation** | Example to validate the Toyoura Sand drained triaxial lab tests (Verdugo & Ishihara, 1996) |
| **Undrained Triaxial Simulation** | Example to validate the Toyoura Sand undrained triaxial lab tests (Verdugo & Ishihara, 1996) |

Some simulated results are illustrated Figure 1 to Figure 5.

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## Disclaimer

It is subjected to the Itasca UDM Liability: https://www.itascacg.com/software/udm-library.

## Referencies

Cheng, Z., Dafalias, Y.F. & Manzari, M.T. (2013). Application of SANISAND Dafalias-Manzari Model in *FLAC3D*. in *Continuum and Distinct Element Numerical Modeling in Geomechanics*. H. Zhu, C. Detournay, R. Hart, and M. Nelson, Eds. Minneapolis: Itasca International, Inc.

Dafalias, Y.F. & Manzari, M.T. (2004). Simple plasticity sand model accounting for fabric change effects. *Journal of Engineering Mechanics* 130(6): 622-634.

Verdugo, R. & Ishihara, K. (1996). The steady state of sand soils. *Soils and Foundation* 36(2): 81-92.

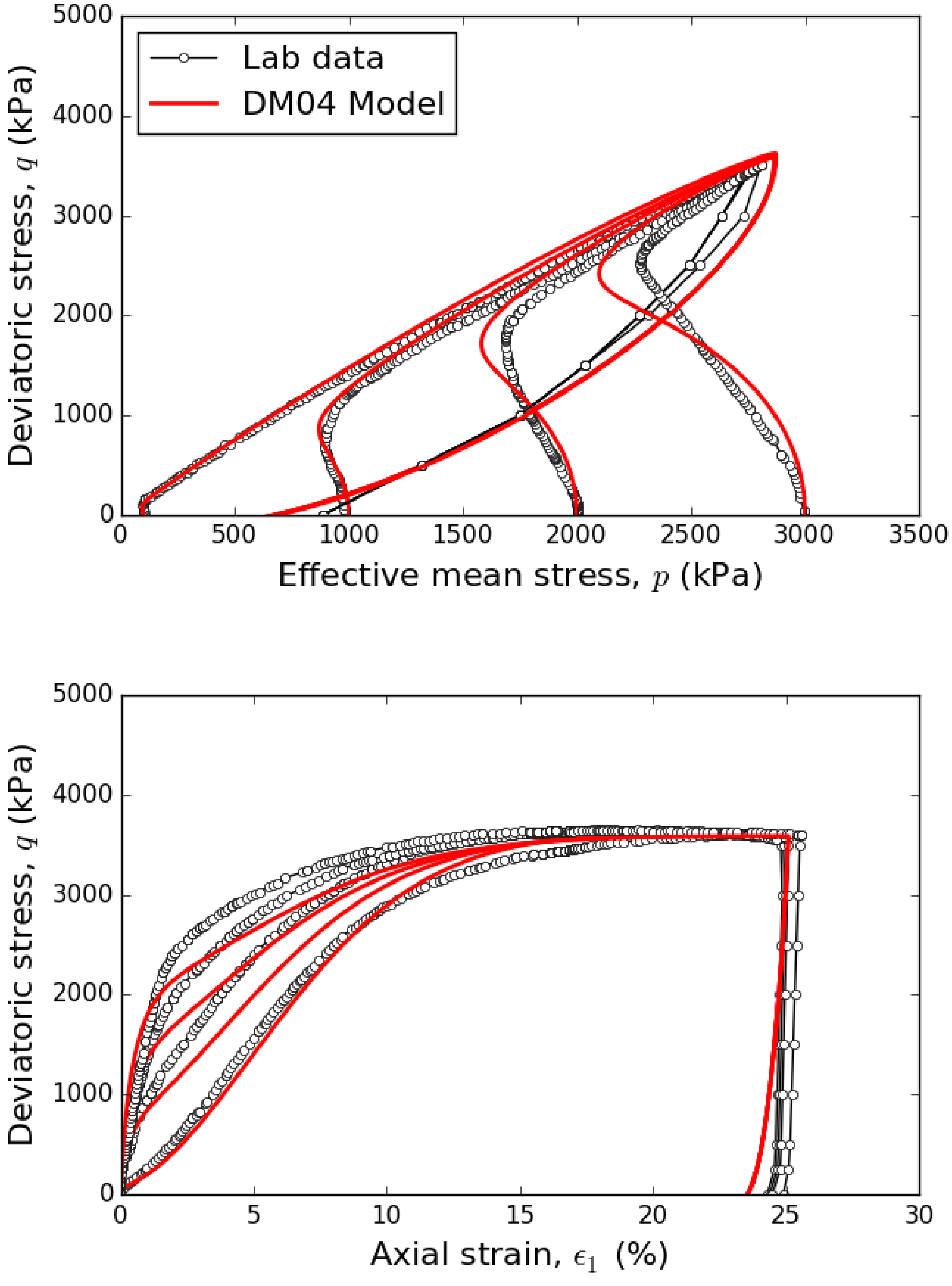


*Figure 1: Simulated versus experiment in undrained trial compression tests $e_0$ = 0.735.*

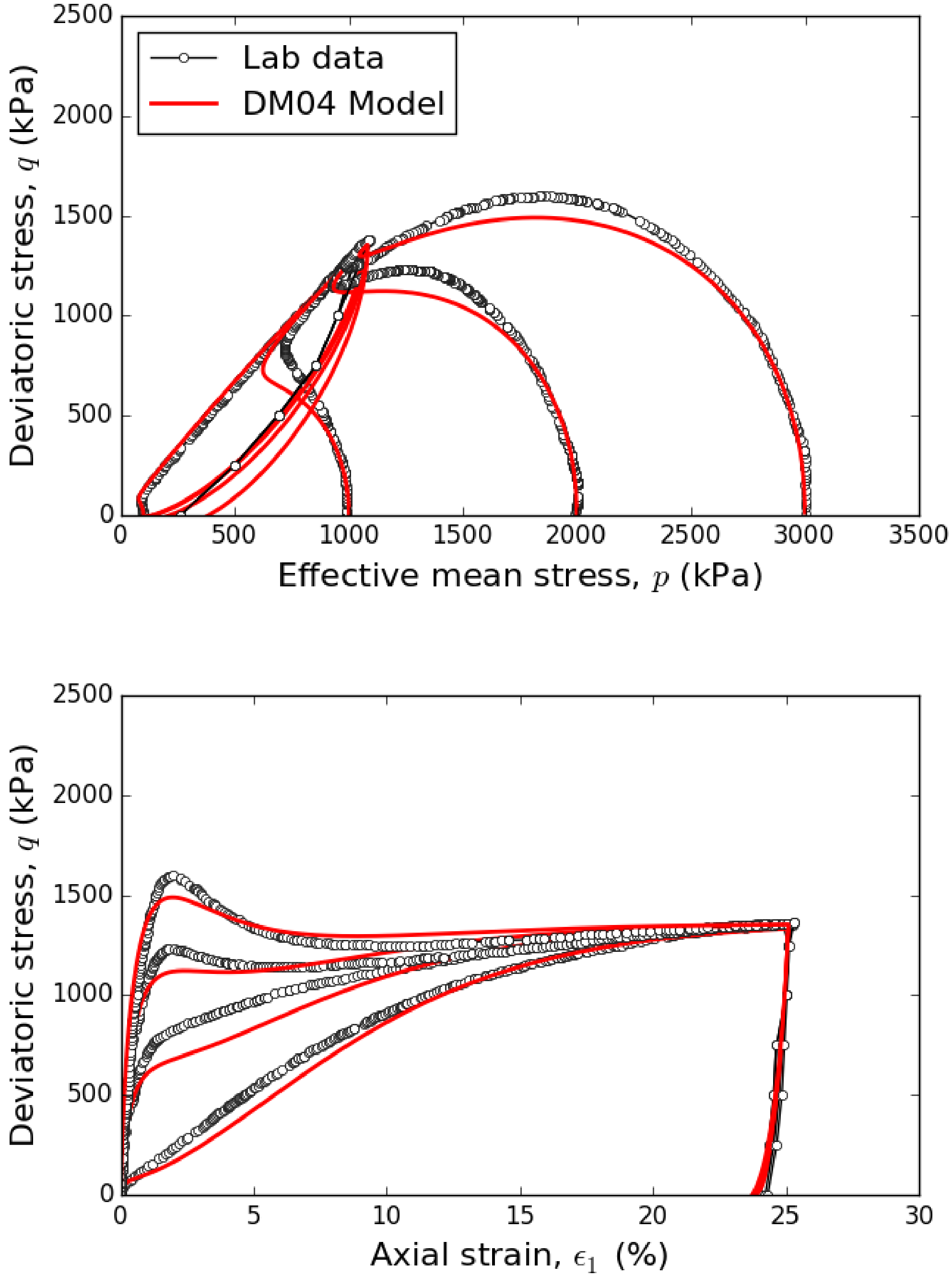


*Figure 2: Simulated versus experiment in undrained trial compression tests $e_0$ = 0.833.*

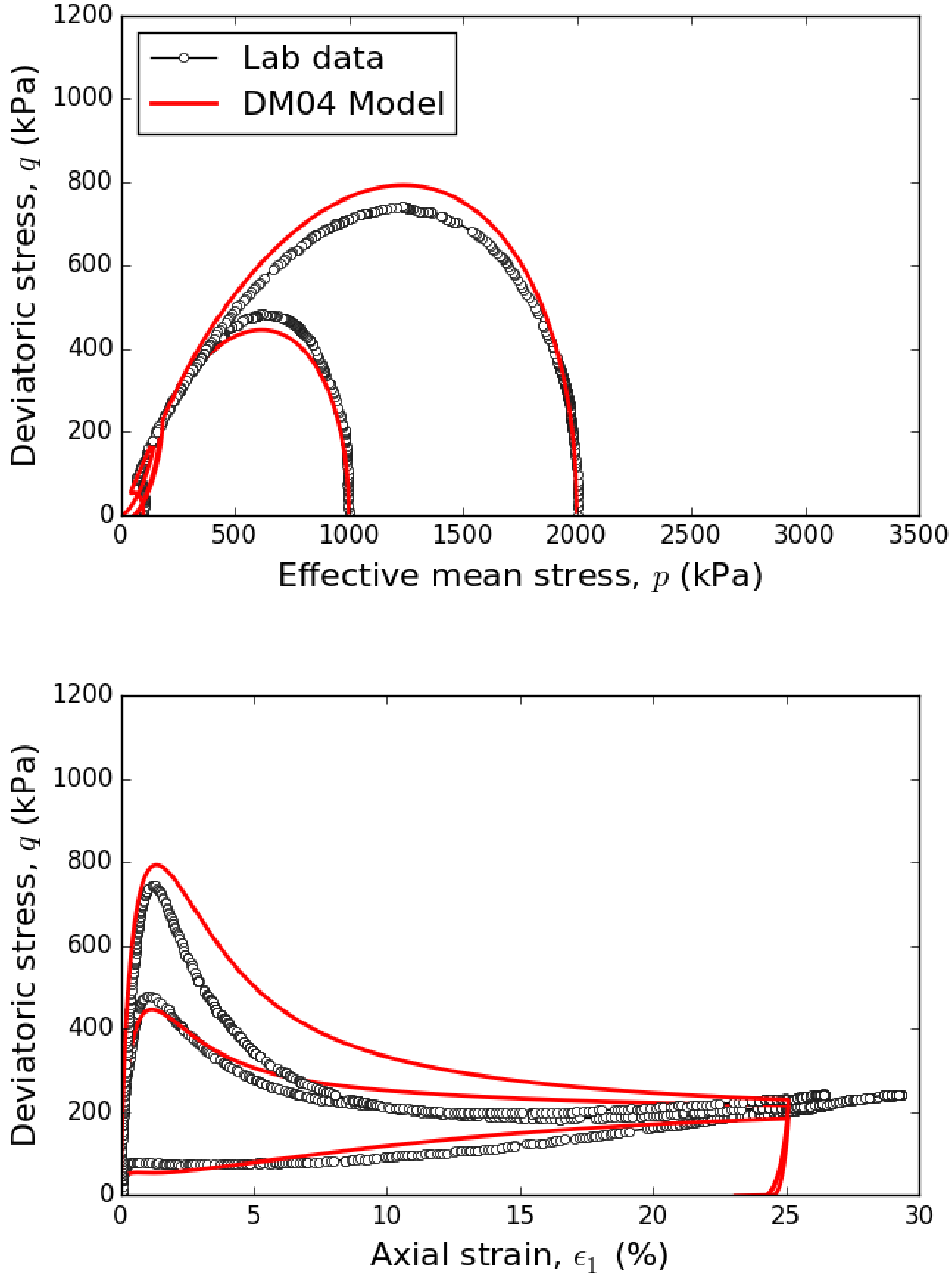


*Figure 3: Simulated versus experiment in undrained trial compression tests $e_0 = 0.907$.*

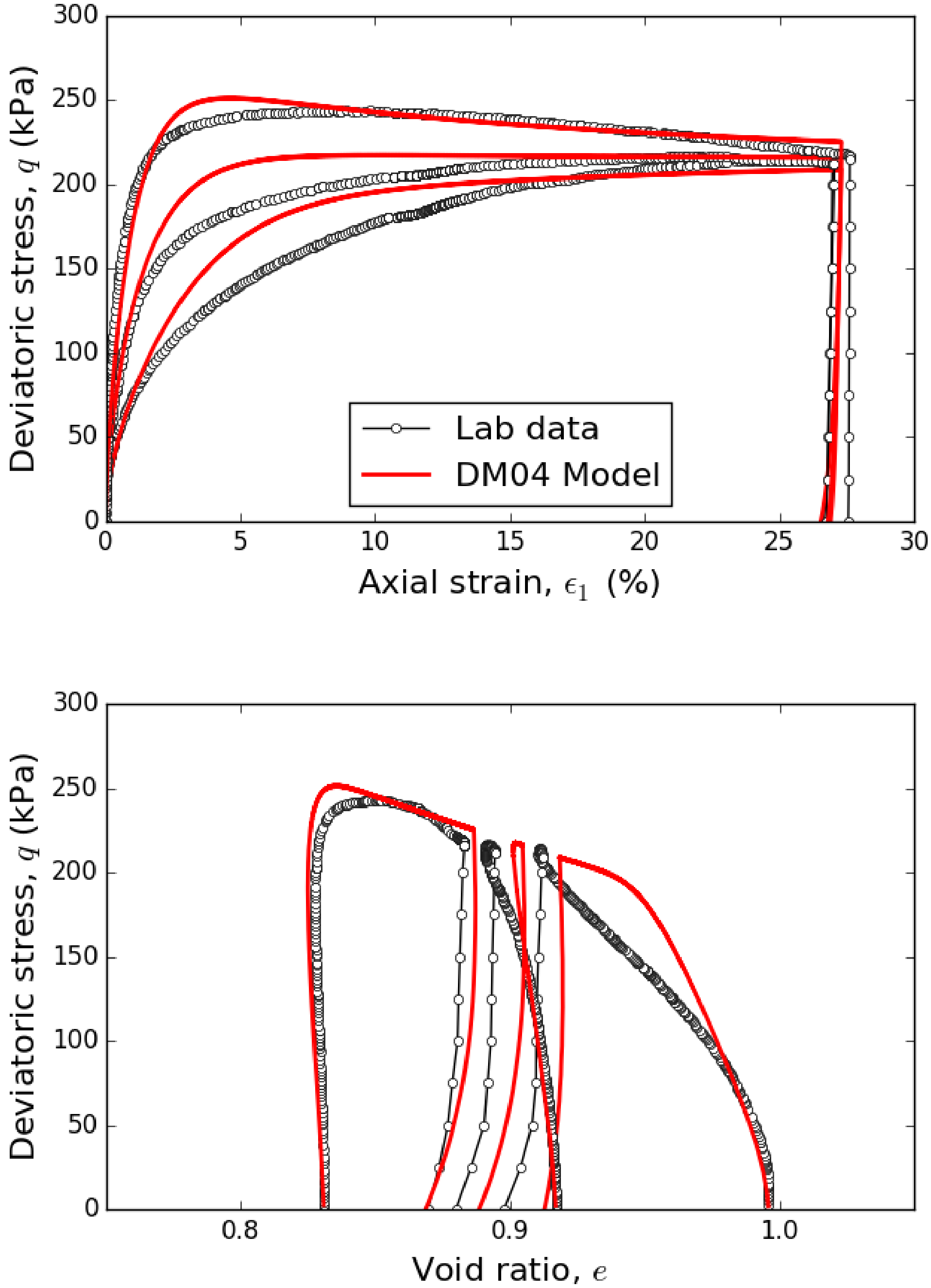


*Figure 4: Simulated versus experiment in drained trial compression tests $p_0$ = 100 kPa.*

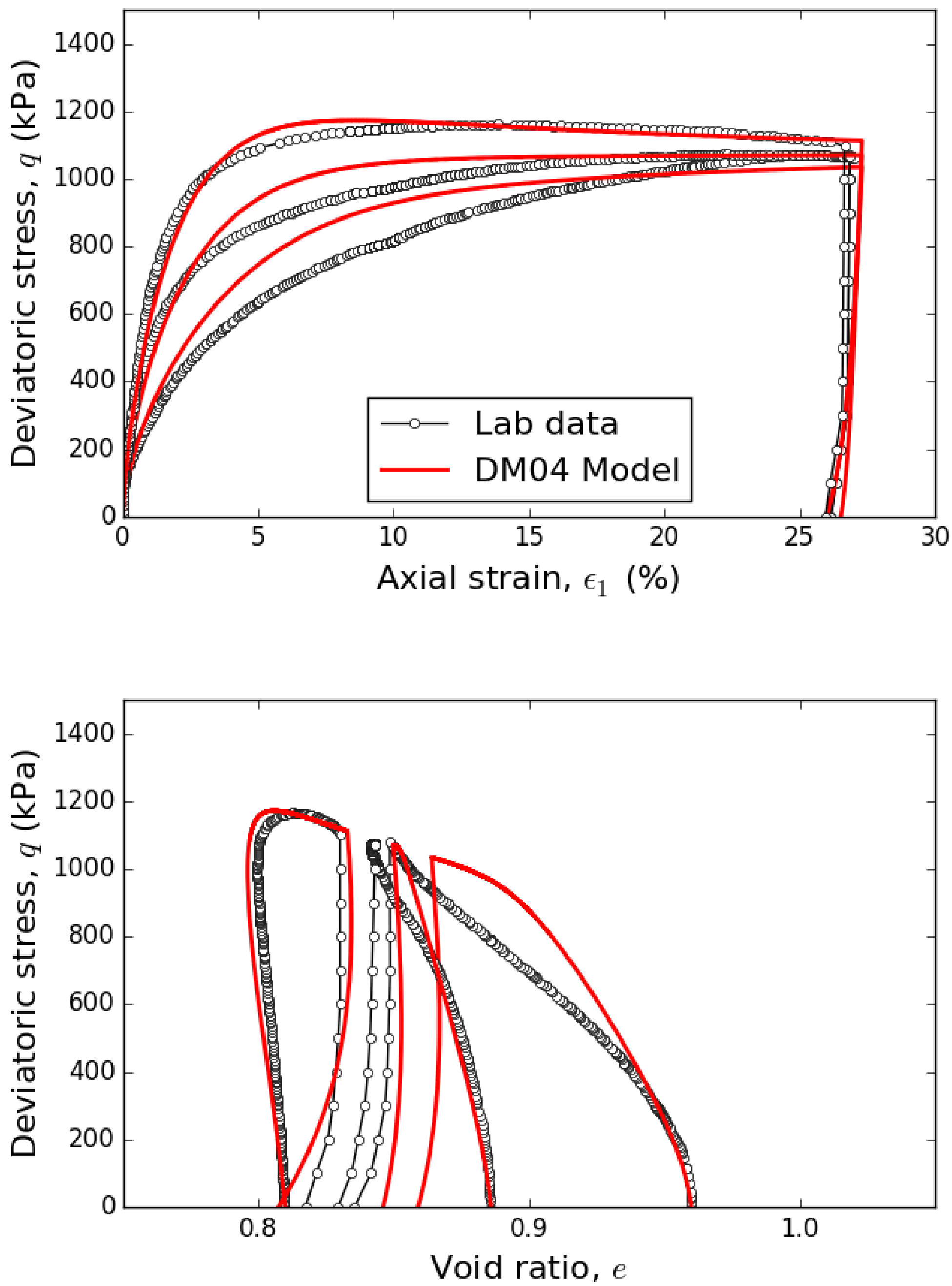


*Figure 5: Simulated versus experiment in drained trial compression tests $p_0$ = 500 kPa.*