CDPM2 UMAT Manual

Fortran implementation for implicit Abaqus/Standard

2026-11-09

Current material model, numerical update, inputs, state variables, execution and limitations. Research preview.

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Document edition: 2026-11-09. Test results, worked examples and change history are maintained in separate guides.

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1 CDPM2 origins and this project

CDPM2 is a concrete damage-plasticity constitutive model published in 2013 by Peter Grassl, Dimitrios Xenos, Ulrika Nyström, Rasmus Rempling and Kent Gylltoft[1]. It extends the 2006 damage-plasticity model of Grassl and Jirásek, called CDPM1 in the 2013 paper. CDPM2 separates tensile and compressive damage and extends the relationship between hardening and damage[1, 2].

Plasticity represents irreversible deformation; damage represents stiffness degradation. Their combination describes tension, compression, confinement effects, unloading and reloading.

1.1 What this project develops

This project implements the existing CDPM2 model in Fortran as an implicit UMAT for Abaqus/Standard. It does not propose a new CDPM2 constitutive model. The public OOFEM implementation is the reference for the port. This project supplies the Abaqus stress, strain, state-variable, rotation and tangent interface[3]. It is not an official OOFEM or SIMULIA UMAT.

- CDPM2 paper: the constitutive model defining the material response.
- OOFEM: the existing public reference implementation.
- This UMAT: the Fortran implementation for the implicit Abaqus/Standard solver. Viscous relaxation is an added extension.

The objective is a traceable constitutive implementation with practical convergence. No parameter fitting to experiments was performed for these comparisons.

2 Terminology and distinction from CDP

CDP Concrete Damaged Plasticity. In this report, CDP means the built-in Abaqus concrete model[5].

CDPM2 Concrete Damage Plasticity Model 2, the separate model of Grassl and coauthors. It is not version 2 of Abaqus CDP.

Plasticity Irreversible deformation remaining after unloading.

Damage An internal variable describing stiffness degradation; 0 denotes undamaged material and 1 complete damage.

Hardening and softening Increasing and decreasing resistance as deformation progresses.

Dilation Plastic volume expansion. The CDP dilation angle and the CDPM2 flow parameter are not directly interchangeable.

Confinement Compressive pressure applied laterally to the specimen.

Viscosity In this UMAT, an added time relaxation of plastic strain and damage. It can aid convergence but also changes the response.

UMAT and DDSDDE The user-material subroutine and the material tangent matrix supplied to the global Newton iteration.

Both models combine plasticity and damage, but their yield surfaces, hardening, flow rules and softening-damage relationships differ. CDPM2 has pressure-dependent plastic flow. Equal parameter or viscosity numbers do not imply equal responses.

3 CDPM2 material model

3.1 Stress, strain and damage

CDPM2 combines irreversible plastic deformation with damage-induced stiffness loss. The equations below follow Grassl et al., Sections 2–3 (preprint pp.3–17), and the adopted OOFEM implementation[1, 3]. Implementation extensions are identified explicitly. The topics follow the Abaqus CDP material description[5]; its constitutive equations are not used for CDPM2.

Tension is positive; $f_t, f_c > 0$ are positive strength magnitudes. For isotropic elasticity with Young's modulus E and Poisson's ratio ν,

$$\bar{\boldsymbol{\sigma}} = \mathbb{C}_e : (\boldsymbol{\varepsilon} - \boldsymbol{\varepsilon}^p), \tag{1}$$

$$\boldsymbol{\sigma} = (1 - d_t)\bar{\boldsymbol{\sigma}}^+ + (1 - d_c)\bar{\boldsymbol{\sigma}}^-. \tag{2}$$

$\bar{\boldsymbol{\sigma}}$ is effective undamaged stress, whereas $\boldsymbol{\sigma}$ is returned to Abaqus. The spectral splits replace each principal stress by $\max(\bar{\sigma}_i, 0)$ or $\min(\bar{\sigma}_i, 0)$ and transform back to the tensor. $d_t, d_c = 0$ denote undamaged material and 1 complete damage. Damage is not plastic strain or measured crack opening.

3.2 Stress invariants and yield condition

Mean effective stress s, deviator $\bar{\boldsymbol{s}}$, deviatoric norm ρ and Lode angle θ are defined by

$$s = \tfrac{1}{3}\operatorname{tr}\bar{\boldsymbol{\sigma}}, \qquad \bar{\boldsymbol{s}} = \bar{\boldsymbol{\sigma}} - s\boldsymbol{I}, \tag{3}$$

$$J_2 = \tfrac{1}{2}\bar{\boldsymbol{s}} : \bar{\boldsymbol{s}}, \qquad J_3 = \det \bar{\boldsymbol{s}}, \tag{4}$$

$$\rho = \sqrt{2J_2}, \qquad \theta = \tfrac{1}{3}\arccos\left(\frac{3\sqrt{3}J_3}{2J_2^{3/2}}\right). \tag{5}$$

Pressure is $p = -s$; confinement makes s more negative. $0 \le \theta \le \pi/3$ on regular returns. Hydrostatic vertices ($\rho = 0$) use a dedicated return, not division by zero. With hardening functions $q_1(\kappa_p), q_2(\kappa_p)$,

$$B = \frac{s}{f_c} + \frac{\rho}{\sqrt{6}f_c}, \qquad A = (1 - q_1)B^2 + \sqrt{\tfrac{3}{2}}\frac{\rho}{f_c}, \tag{6}$$

$$F = A^2 + m_0 q_1^2 q_2 \left(\frac{s}{f_c} + \frac{\rho r(\cos\theta)}{\sqrt{6}f_c}\right) - q_1^2 q_2^2, \tag{7}$$

$$m_0 = \frac{3(f_c^2 - f_t^2)}{f_c f_t}\frac{e}{e+1}, \tag{8}$$

$$r(c) = \frac{4(1-e^2)c^2 + (2e-1)^2}{2(1-e^2)c + (2e-1)\sqrt{4(1-e^2)c^2 + 5e^2 - 4e}}. \tag{9}$$

e controls the deviatoric section; m_0 is calculated from strengths and e, not an input friction angle. Admissibility is $F \le 0$, $\dot{\lambda} \ge 0$, $\dot{\lambda}F = 0$. At $q_1 = q_2 = 1$, the surface becomes the Menetrey–Willam strength envelope. Confinement dependence is contained in the surface, not imposed by changing f_c.

3.3 Nonassociated flow and dilation

Plastic strain follows a potential g different from F:

$$\dot{\boldsymbol{\varepsilon}}^p = \dot{\lambda}\,\frac{\partial g}{\partial \bar{\boldsymbol{\sigma}}}, \qquad \frac{\partial g}{\partial \bar{\boldsymbol{\sigma}}} = \frac{g_s}{3}\boldsymbol{I} + g_\rho \frac{\bar{\boldsymbol{s}}}{\rho}. \tag{10}$$

A potential consistent with the distributed regular-branch gradient is

$$g = A^2 + q_1^2\left[\frac{m_0\rho}{\sqrt{6}f_c} + A_g B_g \exp\!\left(\frac{s-s_0}{B_g f_c}\right)\right], \tag{11}$$

$$s_0 = f_t q_1 q_2/3, \qquad A_g = 3f_t q_1 q_2/f_c + m_0 q_1^2/2, \tag{12}$$

$$B_g = \frac{q_1 q_2(1+f_t/f_c)}{3[\ln A_g + \ln(D_f+1) - \ln(2D_f-1) - \ln(3q_1q_2 + m_0 q_1^2/2)]}. \tag{13}$$

For $M = A_g \exp[(s-s_0)/(B_g f_c)]$, the gradients used in the code are

$$g_s = 4(1-q_1)AB/f_c + q_1^2 M/f_c, \tag{14}$$

$$g_\rho = \{A[4(1-q_1)B+6] + m_0 q_1^2\}/(\sqrt{6}f_c). \tag{15}$$

Unlike F, g does not depend on Lode angle. The q_1 factors follow the adopted OOFEM `computeDGDInv` generalization; at $q_1 = 1$ they reduce to the 2013 paper's Eqs.(22)–(29). The pre-peak generalization is not presented as a verbatim equation from the paper.

$D_f = -\dot{\varepsilon}^p_{\text{lateral}}/\dot{\varepsilon}^p_{\text{axial}}$ is the dimensionless ratio in uniaxial compression for $q_1 = 1$, not a dilation angle in degrees. At fixed hardening state, increasing confinement reduces M and the volumetric-flow contribution: high confinement suppresses dilation. The lateral/axial ratio is not constant on arbitrary multiaxial paths. Similarly, a constant CDP dilation-angle input does not imply a constant plastic strain ratio in every CDP stress state. The calibration gives zero lateral plastic strain in uniaxial tension for $q_1 = 1$; this does not mean zero total lateral strain. Nonassociated flow generally gives an unsymmetric tangent; the examples request `UNSYMM`.

3.4 Hardening and pressure-dependent ductility

The accumulated variable κ_p controls surface shape and size:

$$q_1 = \begin{cases} q_{h0} + (1-q_{h0})(\kappa_p^3 - 3\kappa_p^2 + 3\kappa_p) - H_p(\kappa_p^3 - 3\kappa_p^2 + 2\kappa_p), & 0 \le \kappa_p < 1, \\ 1, & \kappa_p \ge 1, \end{cases} \tag{16}$$

$$q_2 = \begin{cases} 1, & \kappa_p < 1, \\ 1 + H_p(\kappa_p - 1), & \kappa_p \ge 1. \end{cases} \tag{17}$$

q_{h0} defines the initial surface and H_p continued effective-stress hardening. Nominal stress may soften while q_2 grows, because damage increases; plastic hardening is not stopped by nominal softening.

3.5 Evolution of hardening and damage histories

On regular returns,

$$\dot{\kappa}_p = \frac{\|\dot{\boldsymbol{\varepsilon}}^p\|}{x_h(s)}(2\cos\theta)^2, \qquad R_h = -s/f_c - 1/3, \tag{18}$$

$$x_h = \begin{cases} A_h - (A_h - B_h)\exp(-R_h/C_h), & R_h \geq 0, \\ E_h \exp(R_h/F_h) + D_h, & R_h < 0, \end{cases} \tag{19}$$

$$E_h = B_h - D_h, \qquad F_h = (B_h - D_h)C_h/(A_h - B_h). \tag{20}$$

A_h, B_h, C_h, D_h control plastic ductility, not damage. The norm is the tensor Frobenius norm: $\|\boldsymbol{\varepsilon}^p\|^2 = \sum_i (\varepsilon^p_{ii})^2 + [(\gamma^p_{12})^2 + (\gamma^p_{13})^2 + (\gamma^p_{23})^2]/2$ in engineering-shear storage. Hydrostatic returns use the reference vertex convention; the regular formula alone does not prescribe the $\rho = 0$ branch.

Let $\varepsilon_0 = f_t/E$ and $Y = s/f_c + \rho r(\cos\theta)/(\sqrt{6}f_c)$. Equivalent strain is

$$\widetilde{\varepsilon} = \varepsilon_0 \left[\frac{m_0 Y}{2} + \sqrt{\frac{m_0^2 Y^2}{4} + \frac{3\rho^2}{2f_c^2}} \right]. \tag{21}$$

It equals $\bar{\sigma}_t/E$ in uniaxial tension and $f_t|\bar{\sigma}_c|/(Ef_c)$ in uniaxial compression. Both reach ε_0 at their reference strengths. This normalization does not replace compressive strength by f_t. For nonzero effective stress, define

$$\alpha_c = \frac{\sum_i \min(\bar{\sigma}_i, 0)^2}{\sum_i \bar{\sigma}_i^2}. \tag{22}$$

Pure tension gives 0 and pure compression 1. Accumulated measures evolve as $\dot{z}_t = \dot{\widetilde{\varepsilon}}$ and $\dot{z}_c = \alpha_c \dot{\widetilde{\varepsilon}}$; their maximum histories are κ_t, κ_c. Damage starts at the corresponding history threshold ε_0. The increment implementation includes reversal handling and a small reference activation tolerance; damage is irreversible.

Two auxiliary histories per mode combine plastic and damaged deformation. On active history branches,

$$\dot{\kappa}_{t1} = \|\dot{\boldsymbol{\varepsilon}}^p\|/x_s, \qquad \dot{\kappa}_{t2} = \dot{\kappa}_t/x_s, \tag{23}$$

$$\dot{\kappa}_{c1} = \alpha_c \beta_c \|\dot{\boldsymbol{\varepsilon}}^p\|/x_s, \qquad \dot{\kappa}_{c2} = \dot{\kappa}_c/x_s, \tag{24}$$

$$\beta_c = \frac{f_t q_2 \sqrt{2/3}}{\rho\sqrt{1 + 2D_f^2}}, \qquad x_s = 1 + (A_s - 1)R_s^{B_s}, \tag{25}$$

$$R_s = \begin{cases} -\sqrt{6}s/\rho, & s < 0, \\ 0, & s \geq 0. \end{cases} \tag{26}$$

The plastic contribution starts after activation; crossing increments use only the post-activation portion. These histories are distinct from κ_p. A_s controls compressive softening ductility. $B_s = 1$ recovers the paper's Eq.(56); B_s is an OOFEM extension. Near $\rho = 0$ the code uses its reference small-denominator convention, not these expressions at zero. In uniaxial interpretation, inelastic strain is $\varepsilon^i = \varepsilon^p + d(\varepsilon - \varepsilon^p)$, not plastic strain alone.

3.6 Tensile softening, fracture energy and characteristic length

A bilinear traction–inelastic-opening law is specified by f_t, knee stress f_{t1}, knee opening w_{f1} and final opening w_f:

$$T(w) = \begin{cases} f_t - (f_t - f_{t1})w/w_{f1}, & 0 \le w \le w_{f1}, \\ f_{t1}(w_f - w)/(w_f - w_{f1}), & w_{f1} < w \le w_f, \\ 0, & w > w_f. \end{cases} \tag{27}$$

Tensile damage is the admissible intersection

$$(1 - d_t)E\kappa_t = T(l_e[\kappa_{t1} + d_t\kappa_{t2}]), \tag{28}$$

$$G_f = \int_0^{w_f} T(w)\, dw = \tfrac{1}{2}(f_t w_{f1} + f_{t1} w_f). \tag{29}$$

l_e converts inelastic strain to equivalent opening. Automatic selection projects initial node coordinates along the maximum-principal-strain direction $\boldsymbol{n}$ at activation: $l_e = \max_a(\boldsymbol{x}_a \cdot \boldsymbol{n}) - \min_a(\boldsymbol{x}_a \cdot \boldsymbol{n})$. The selected length is fixed thereafter. This smeared crack-band regularization reduces tensile mesh-size sensitivity; it is not discrete crack creation or a guarantee of mesh-independent structural results. The code consistently applies the reference activation tolerance to initial traction; the equation above shows the intended softening envelope.

3.7 Compressive softening and unloading/reloading

Compressive damage uses an exponential law in normalized equivalent-strain space, not the tensile opening law:

$$(1 - d_c)E\kappa_c = f_t \exp[-(\kappa_{c1} + d_c\kappa_{c2})/\varepsilon_{fc}]. \tag{30}$$

ε_{fc} is a dimensionless softening scale. The f_t factor is due to normalization. On an active monotonic uniaxial compression branch, the actual compressive stress magnitude is f_c/f_t times this normalized damaged-stress measure, not a compressive strength of f_t. x_s adjusts history growth under confinement. Compression is not regularized by l_e and may retain localization-related mesh sensitivity.

Damage does not heal. For fixed plastic strain and damage, uniaxial unloading slopes are $(1 - d_t)E$ in tension and $(1 - d_c)E$ in compression. Plastic strain shifts the zero-stress intercept. Reversing from tension to compression uses d_c; if $d_c = 0$, compressive stiffness is recovered despite $d_t > 0$. There are no separate CDP-style stiffness-recovery coefficients. Reloading inside the yield domain need not create plastic strain. Damage fields visualize distributed degradation, not discrete crack paths.

3.8 Inputs, viscosity and scope

Use consistent stress, length and time units: E, f_t, f_c, f_{t1} are stresses; w_{f1}, w_f, l_e are lengths; G_f is stress times length. Strains and hardening/dilation/ductility parameters are dimensionless. Optional relaxation time μ is this UMAT's extension, not part of the rate-independent CDPM2 equations; it relaxes plastic strain and damage. It is neither a calibrated strain-rate strength law nor identical to CDP viscosity. The distributed formulation is 3D and isotropic, for the documented Standard cases. Temperature dependence, rate-strength enhancement, rebar bond laws and automatic element deletion are not included.

4 Implicit UMAT update and viscosity

The material equations are described in Section 3. When viscosity is enabled, the final stress uses relaxed plastic strain and damage.

1. Preserve the committed state and check inputs and rotation.
2. Solve the increment endpoint using an elastic predictor and local Newton return mapping.
3. Update damage histories from the plastic history.
4. Apply optional viscous relaxation and calculate stress and DDSDDE.
5. Commit only accepted updates. On failure, retain old stress and state and request an external increment reduction.

The method does not force substepping of every increment. The tangent combines analytical sensitivities with numerical differences at difficult local branches.

$$z^{v}_{n+1} = \frac{\mu z^{v}_{n} + \Delta t\, z^{\mathrm{target}}_{n+1}}{\mu + \Delta t}.$$

μ has the analysis time unit; $\mu = 0$ recovers the non-viscous update. Different relaxed variables mean this extension is not identical to Abaqus CDP viscosity. No artificial damage cap at 0.99, hardening freeze or forced residual-strength plateau is added.

4.1 Numerical stability and tangent checks

The local 4-by-4 linear system is equilibrated by columns and rows before partial pivoting. A componentwise backward-error check precedes unscaling. The same equations are solved; genuinely singular or nonfinite systems remain rejected. No constitutive equation or material parameter is altered. For numerical checks of DDSDDE, compare against the Abaqus tangent definition, not a plain difference of Cauchy stress. In a fixed corotated material-point check this includes the derivative of Kirchhoff stress divided by the volume ratio. Perturbations crossing an activation branch need separate interpretation; a branch crossing is not a smooth derivative test.

4.2 Normalized flow and tangent

Exponential terms are evaluated in the logarithmic domain. The flow direction is normalized and the plastic multiplier transformed to evaluate the local equations without directly forming very large flow components. Material constants, viscosity and acceptance tolerances are not relaxed. When ordinary initial guesses fail, algebraic continuation supplies additional guesses. This is not constitutive substepping. Converged roots from different paths are compared and multiple-root protection is applied. The tangent includes direction sensitivity at first activation of characteristic length. The selected length remains fixed in subsequent history. Positive/negative stress splitting uses spectral divided differences. A slope of one half at roundoff-zero is a generalized convention, not a unique classical derivative.

5 Installation and execution

Scope: Abaqus/Standard, three-dimensional non-perturbation analysis, NDI=3, NSHR=3, NTENS=6. Basic inputs use DEPVAR=89, 24 constants and UNSYMM. The verification guide defines current-source small C3D8/C3D6, requested two-thread and static-restart checks. MPI, shells, plane stress, axisymmetry, hybrid elements, Explicit, dynamics, thermal coupling and material ORIENTATION are outside this edition's tested scope.

5.1 Build and minimal example

Supply licensed Abaqus and a compatible Fortran compiler. Copy src/cdpm2.f90 and examples/shear.inp into an empty work directory and configure free-form Fortran. Do not reuse a directory containing results.

```
abaqus job=shear user=cdpm2.f90 cpus=1 datacheck interactive
abaqus job=shear user=cdpm2.f90 cpus=1 continue interactive
```

Execute the second command only after successful datacheck, the DAT completion marker and no errors. Clear unrelated CDPM2_FIL_FILE and CDPM2_GEOMETRY_TABLE overrides. Match supplied example decks with the verification guide. Model-specific commands are documented in the analysis examples guide.

5.2 Mesh geometry from the results file

At the start of the first increment, UEXTERNALDB reads initial global node coordinates (record 1901) and element connectivity (record 1900) from jobname.fil in the output directory. Abaqus resolves mesh generators, includes, node coordinate systems and instance placement; the UMAT no longer parses the input language. The initial geometry is retained in memory and the selected characteristic length is fixed at damage onset.

For your own model, add the settings below to the input file. Place `*FILE FORMAT, ASCII` before the first `*STEP`, outside the descriptive text of `*HEADING`. Place `*NODE FILE` and `*EL FILE` inside every step, without restricting them to a node or element set. The supplied examples already contain these settings. A large output frequency avoids writing results at every increment while retaining the initial mesh information needed before the first material calculation.

```
*FILE FORMAT, ASCII
** Inside each *STEP:
*NODE FILE, FREQUENCY=999999
U
*EL FILE, FREQUENCY=999999
S
```

Supported element types for mesh reading are C3D8, C3D8R, C3D8I and C3D6. The settings above make Abaqus write a text-readable ASCII `.fil` file. The subroutine reads node coordinates and element connectivity from that file; binary `.fil` files are not supported. If the required information cannot be read, an error is written to the log and the material calculation is not performed. Missing geometry is never guessed.

Normally, `jobname.fil` in the current job's output directory is selected automatically, so no file path is needed. Only for a different location, set the environment variable CDPM2_FIL_FILE to an absolute path.

With DEPVAR=89, initial geometry is saved in STATEV63–89 and restored by Abaqus restart. No original FIL or external geometry table is required at restart. Legacy DEPVAR=62 still runs, but its restart requires the original explicit geometry table; an old 62-variable restart cannot be converted by changing DEPVAR in a restart deck. Material ORIENTATION and general MPI remain unverified.

5.3 Restart

Run the 89-variable shear example, which writes restart data every five increments. From the same folder:

```
abaqus job=shear cpus=1 mp_mode=threads interactive
abaqus job=restart_shear oldjob=shear cpus=1 mp_mode=threads interactive
```

The second command uses examples/restart_shear.inp and the same built UMAT. This restart input includes the later steps explicitly: RESTART READ alone resumes the saved step, not every subsequent step of the original input. Follow Abaqus requirements when transferring the normal restart files to a different folder. Added reference geometry is part of the saved STATEV, so a changed job name or directory does not require a geometry-table tool. An explicit *RESTART, WRITE request is still required. Static restart has been tested; automatic restart for Riks is not claimed. Same-source 89-entry restart was tested, but its initial-frame reaction difference exceeds the comparison criterion; all-field equivalence is not established. See the verification guide for measured differences. Restart across different source versions is not guaranteed.

5.4 Contact stiffness multipliers

*CONTACT CONTROLS, STIFFNESS SCALE FACTOR is an additional multiplier on the scale in *SURFACE BEHAVIOR. For example, 0.1 in each location gives a combined factor of 0.01, not 0.1. Apply a requested factor once, or state the product explicitly. Linear and nonlinear penalty laws with the same factor are not equivalent. Check physical overclosure (negative COPEN), not only the iteration contact-error message. No pullout contact factor is recommended by this manual.

6 Material inputs and state variables

24 material inputs and 89 state variables (62 material/work variables plus 27 immutable geometry values). The example is not a recommended calibration for arbitrary concrete. Example units: N, mm, s; stress MPa. Tension is positive, compression negative; strengths are positive magnitudes. Component order is 11,22,33,12,13,23. Strain/plastic-strain shear is engineering shear; stress shear is tensor shear. Engineering plastic shear squares have weight 0.5 in the norm.

6.1 Material constants

PROPS	Meaning	Example	Unit
1	Young modulus	35892.339	MPa
2	Poisson ratio	0.2	1
3	Compression strength (positive magnitude)	35.892339	MPa
4	Tension strength (positive magnitude)	2.71644205	MPa
5	Yield-surface eccentricity	0.525	1
6	Initial hardening coefficient	0.3	1
7	Hardening coefficient	0.5	1
8	Non-associated flow dilation parameter (not an angle)	0.85	1
9	Plastic ductility ah	0.08	1
10	Plastic ductility bh	0.003	1
11	Plastic ductility ch	2	1
12	Plastic ductility dh	1e-6	1
13	Input characteristic length (distinct from selected length)	20	mm
14	Tensile softening breakpoint stress	0.814932615	MPa
15	Tensile softening breakpoint opening	0.021974493916716565	mm
16	Final tensile softening opening	0.14649662611144376	mm
17	Compressive softening strain scale	1e-4	strain
18	Damage ductility coefficient	15	1
19	Damage ductility exponent	1	1
20	Damage-onset tolerance (not global FE tolerance)	1e-5	1
21	Legacy internal strain cap (compatibility check only)	1e-6	strain
22	Local difference strain scale	1e-9	strain
23	Legacy trial budget (compatibility check only)	20000	count
24	Viscous relaxation time	1e-3	s

PROPS23 does not force 20000 subdivisions. Tensile softening is bilinear traction-opening; compression uses damage history and efc with exponential softening. These are not direct uniaxial total-strain curve inputs. No artificial 0.99 damage cap, hardening freeze or forced residual plateau is added. Distinguish constitutive parameters, numerical controls and user-selected viscosity.

6.2 State variables

STATEV	Meaning
1	State schema identifier 2
2-7	Total strain, engineering shear
8-13	Non-viscous plastic strain, engineering shear
14	Plastic hardening kappa
15-20	Non-viscous effective stress
21-26	Non-viscous damaged stress, distinct from final STRESS
27	Equivalent strain
28	Compression weight alpha
29-30	Accumulated tension/compression histories
31-32	Tension/compression thresholds
33-34	Tension/compression kappaOne
35-36	Tension/compression kappaTwo
37-38	Non-viscous tensile/compressive damage
39	Selected characteristic length, mm
40	Frame identifier 386
41-49	Accumulated rotation matrix, Fortran column-major
50	Accumulated trapezoidal stress work: dot((S_old+S_new)/2,DSTRAN)
51	Diagnostic dot(S_new,total_strain-viscous_plastic)/2
52	SDV50-SDV51, not validated plastic/damage dissipation
53-58	Viscous plastic strain, engineering shear
59-60	Viscous tensile/compressive damage
61	Viscous schema identifier 1049
62	mu; saved/input consistency checked
63–65	Geometry schema 2, node count (6 or 8), reserved zero
66–89	Initial corner-node coordinates, global reference frame; unused wedge coordinates are zero

6.3 Numerical acceptance controls

The accepted damage increase per increment is limited to 0.25: non-viscous damage for mu=0, or the actual relaxed damage entering stress when mu>0. This is an increment-control limit, not a final damage cap. The normalized difference between two converged Newton solutions is limited to 0.001. Rejection preserves stress and STATEV and requests PNEWDT=0.5. Stress and hardening-normalized yield residual tolerances remain 1e-12. The kappa residual uses the larger of 1e-12, 1e-8 times the absolute kappa increment, and eight floating-point spacings at the current/old kappa magnitude. Thus large accumulated kappa does not impose an unattainable absolute precision. Tensile damage STATEV37/59 displays a damage distribution, not discrete crack directions. Do not use UMAT PE/PEEQ as substitutes for implemented plastic state variables.

7 Application limits and distribution

7.1 Tangent and energy limitations

For zero-strain-increment queries, an internal-variable-fixed approximate tangent has known differences from full differences including time relaxation. First-activation characteristic-length direction sensitivity is included; the selected length is subsequently fixed. Full tangent consistency across every branch is not claimed. SSE denotes elastic strain energy, SPD plastic dissipation and SCD creep dissipation[4]. This UMAT does not update these standard energy outputs. They cannot be used to evaluate an energy balance or energy consumed by fracture. STATEV50–52 are diagnostics, not a validated dissipation decomposition. Missing energy outputs do not mean the stress update is absent.

7.2 Contribution and distribution

Share small reproducible examples, environment, material values/units, loading history, viscosity and logs; omit confidential models and license credentials. Source, added tools and explanations are LGPL-2.1-or-later, without warranty. Preserve LICENSE and THIRD_PARTY_NOTICES.md on redistribution. No OOFEM or SIMULIA endorsement is implied. Third-party papers and experimental plots retain their owners' rights. Comparison plots are independently generated from simulation results and numerical values read from published plots; original third-party images and measured datasets are not distributed.

References

[1] P. Grassl, D. Xenos, U. Nyström, R. Rempling, K. Gylltoft (2013). CDPM2: A damage-plasticity approach to modelling the failure of concrete. International Journal of Solids and Structures 50, 3805–3816. https://arxiv.org/abs/1307.6998. Figures 11 and 12: PDF p.22. The corrigendum is also considered.

[2] P. Grassl, M. Jirásek (2006). Damage-plastic model for concrete failure. International Journal of Solids and Structures 43, 7166–7196.

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