# Winfrith Concrete Model – Extra History Variables
# Graphical and Text Crack Files

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Based on the notes from
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and
Jim Day of LSTC
http://ftp.lstc.com/anonymous/outgoing/jday/concrete/mat84_winfrith

| Extra Variable | Description | | Notes |
|---|---|---|---|
| 1 | Crack Indicators | crakmax | Crack Flag (0=uncracked; 1,2, or 3=cracked) |
| 2 | | dameng | Crack opening damage variable (mat 84 only) |
| 3 | | cd1 | Crack opening strain in direction 1 (mat 84 only) |
| 4 | | cd2 | Crack opening strain in direction 2 (mat 84 only) |
| 5 | | cd3 | Crack opening strain in direction 3 (mat 84 only) |
| 6 | Concrete stresses | $\sigma_x$ | |
| 7 | | $\sigma_y$ | |
| 8 | | $\sigma_z$ | |
| 9 | | $\tau_{xy}$ | |
| 10 | | $\tau_{yz}$ | |
| 11 | | $\tau_{zx}$ | |
| 12 | Reinforcement stresses | $\sigma_x$ / $\sigma_A$ | x, y and z are global directions, if option 1 card is used.<br>A and B depend on layer orientation, if option 2 card is used. |
| 13 | | $\sigma_y$ / $\sigma_B$ | |
| 14 | | $\sigma_z$ | |
| 15 | Reinforcement ratios | XR / RQA | XR, YR and ZR are reinforcement ratios in global directions, if option 1 card is used.<br>RQA and RQB are reinforcement ratios in A and B directions, if option 2 card is used. |
| 16 | | YR / RQB | |
| 17 | | ZR | |
| 18 | Crack vector directions | $x_{crack\_1}$ | [x y z] is a unit vector normal to the plane of the crack.<br>Crack plane passes through the centre of the element. |
| 19 | | $x_{crack\_2}$ | |
| 20 | | $x_{crack\_3}$ | |
| 21 | | $y_{crack\_1}$ | |
| 22 | | $y_{crack\_2}$ | |
| 23 | | $y_{crack\_3}$ | |
| 24 | | $z_{crack\_1}$ | |
| 25 | | $z_{crack\_2}$ | |
| 26 | | $z_{crack\_3}$ | |
| 27 | Principal concrete stresses | sf1 | |
| 28 | | sf2 | |
| 29 | | sf3 | |

| | | | |
|---|---|---|---|
| 30 | Crack Extension | ef1 | extension in 1st crack direction and two orthogonal directions |
| 31 | | ef2 | |
| 32 | | ef3 | |
| 33 | Plastic strains in reinforcement | $\varepsilon_{px}$ / $\varepsilon_{pa}$ | Plastic strains in reinforcement in x, y and z global directions, if option 1 card is used.<br>Plastic strains in reinforcement in A and B directions, if option 2 card is used. |
| 34 | | $\varepsilon_{py}$ / $\varepsilon_{pb}$ | |
| 35 | | $\varepsilon_{pz}$ | |
| 36 | Concrete Crack Indicators | crack_1 | 1 = cracked, i.e. on softening part of curve.<br>2 = crack has closed up<br>3 = fully cracked |
| 37 | | crack_2 | |
| 38 | | crack_3 | |
| 39 | Concrete Strains | eps1 | |
| 40 | | eps2 | |
| 41 | | eps3 | |
| 42 | | eps4 | |
| 43 | | eps5 | |
| 44 | | eps6 | |
| 45 | | ex1 | set equal to ef1, ef2, ef3, resp. if tensile |
| 46 | | ex2 | |
| 47 | | ex3 | |
| 48 | | tc1 | time that 1st, 2nd, and 3rd cracks initiate |
| 49 | | tc2 | |
| 50 | | tc3 | |
| 51 | | epv | volumetric yield strain |
| 52 | | nj | Counter for number of points if pressure-volume? |
| 53 | | sv | Volume Strain |
| 54 | | td1 | Crack opening history |
| 55 | | td2 | |
| 56 | | td3 | |

Set *DATABASE_EXTENT_BINARY parameter NEIPH=56 and post process using LS-PrePost under Fringe > Misc > History Variables 1-56

# Graphical Crack and AEA_CRACK Text Files

The LS-DYNA keyword *DATABASE_BINARY_D3CRACK can be used to specify the frequency for writing the graphical crack file indicated on the execution line by the parameter *q=crack_filename*. Unfortunately, the only acceptable value of the frequency is the same frequency used to write the d3plot database, i.e. *DATABASE_BINARY_D3PLOT, as apparently the information in the d3plot file is needed to display the additional information in the graphical crack file.

To display the graphical cracks, first open the d3plot files and then open the graphical crack file via the LS-PrePost Open > Others> Crack File. Step through the simulation to view cracks as they form. Under the *Post Processing* icon there is a *Settings* icon, check the radio button for *Concrete Crack Width*. By adjusting the number in the *minimum crack width* widow, the cracks with smaller widths can be made to disappear. As noted below, the crack widths are apparently in meters and independent of the user specified input length units.

LS-DYNA also generates a text based crack information file named `aea_crack` . This text file is written with the frequency specified via the keyword *DATABASE_BINARY_D3CRACK. NOTE: if the graphical crack file is omitted, i.e. no *q*= on the execution line, then the frequency specified via the *DATABASE_BINARY_D3CRACK will be used to write the text based crack file and thus may differ from the frequency specified via *DATABASE_BINARY_D3PLOT.

Sample `aea_crack` output:

```
 time =  0.190E+01   number of cracked elements =       3
 elements with cracks > 0.1mm wide are printed
element state                crack widths
   1101 3 0 0       0.201E-03  -0.426E-06  -0.133E-04
   1300 3 0 0       0.202E-03   0.723E-05  -0.248E-04
   1301 3 0 0       0.197E-03  -0.774E-06  -0.125E-04

 time =  0.190E+01   tensile damage energy
 part ID      non-crack    crack       total
    1        0.0000E+00  0.0000E+00  0.0000E+00
 total       0.0000E+00  0.0000E+00  0.0000E+00
```

The current simulation time and total number of cracked elements are indicated on the first line. Although the text “>0.1mm” is hardwired into the format statement, the Winfrith model internal units are kilograms-meters-seconds, so the crack lengths are provided in meters and thus independent of the user’s input length units. The next lines list the element numbers of the cracked elements, the ‘crack status’, and crack widths in the three ordinal directions.

The crack status is an integer 0-3 with the following meaning (I think):
0 = Uncracked.
1 = Cracked, but still on strain softening curve (still taking some tensile stress).
2 = Cracked, but crack is closed (i.e. can take compressive stress).
3 = Cracked fully (i.e. crack open and zero tensile stress).

Since cracks smaller than 0.1 mm are not printed to the aea_crack file, the most common crack status indicator is the number 3.

NOTE: When the strain rate form of the Winfrith concrete model (MAT084) is used, the tensile damage energies are negative values, else when MAT085 is used, the values always appear to be zero.

The information in the aea_crack file is also available via the Extra History Variables and thus can be visualized via LS-PrePost using the afore mentioned Fringe >Misc > History Variables. Perhaps one item that could be added to LS-PrePost, from the ASCII aea_crack file is a histogram of the crack widths at a given time. Figure 1 shows a sample of such a crack width histogram

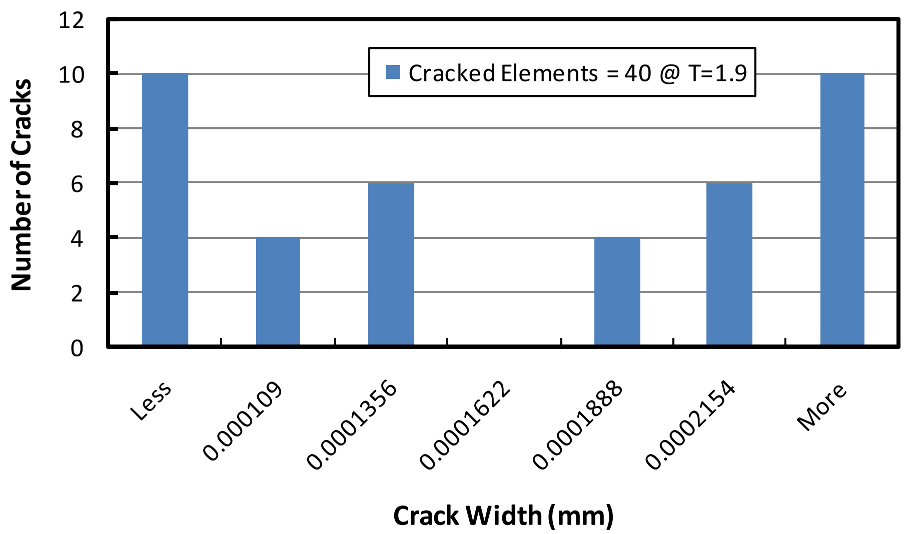


Figure 1 Example of a crack width histogram obtained from the aea_crack file.

In this case, the aea_crack file a T=1.9 reported there were 40 cracked elements and then proceeded to list the 30 elements with crack widths greater than 0.1 mm (1.0E-4 m).