| FEDERATION
| OF PILING
| SPECIALISTS

Eurocode e-Pile Schedule
Guidance Note

Purpose

This guidance note accompanies the FPS electronic pile schedule to inform structural engineers on how to complete the schedule and pile designers on what to expect in a schedule. An example e-pile schedule is attached at the end of this note to assist. The need and benefits for a consistent format for communicating actions for pile design are also discussed.

Need for a standard pile schedule

Although pile design to Eurocode 7 has been adopted in the UK since March 2010, it is still rather surprising that the industry has not broadly adopted a suitable format for issuing pile loading information (Selemetas and Bell, 2014). The requirements of Eurocode design can result in pile load schedules with in excess of ten different characteristic actions, with various partial factors to be applied to each component and not all components necessarily acting in combination at any one time. The lack of consistency, completeness and clarity of the numerous variations of pile loading schedules currently used creates unnecessary confusion in pile design and does result in determination of incorrect piles sizes, both un-conservative and over-conservative.

Below are some common questions from pile designers that highlight the confusion that arises:

- has uplift due to groundwater been included in a temporary and/or permanent case?
- are the actions for heave & groundwater characteristic values or design values?
- if the actions for heave & groundwater are characteristic, do they represent permanent actions or variable actions? The nature of these actions (G_k or Q_k) would depend on the variation in the magnitude of the actions during the design life of the structure and the assumptions made by the engineer in deriving these actions.
- how can temporary actions e.g. crane, strut actions be correctly added/checked with permanent actions when only the maximum design action is given?
- which actions are favourable or unfavourable?
- which actions are permanent and which are variable?
- in which combinations should the actions be combined?

- which is the leading variable action?
- should a reduction factor be applied to accompanying variable actions, if so what value?
- what proportion of the permanent action should be considered in the temporary condition in combination with uplift forces?

When tendering for a project, such clarifications by a piling contractor are often difficult if not impossible within short tender return periods and communicating through third parties or formal channels. This can result in significant project risk which may be borne later by the contractor or client.

Benefits

The FPS e-pile schedule is recommended by the Institution of Civil Engineers in the Specification for Piles and Embedded Retaining Walls 3rd Edition (2017). It has been created to provide a consistent and transparent approach to transfer design information between structural engineer and pile designer for the design of piles to EC7 and EC2. Its format is simple and adaptable for the structural engineer to give the pile designer the information required for design. Adopting such a pile schedule, the industry will importantly create a level 'playing field' for pile design and will minimise the confusion that exists due to incomplete and unclear information, which in turn will eliminate delays and/or extra cost due to re-design at a later stage.

Also, the adoption of the FPS e-pile schedule across the industry will facilitate increasing take up of digital construction in piling to achieve a complete digital record of piled foundations.

The e-pile Schedule is free to download in Microsoft Excel format from the FPS website at: https://www.fps.org.uk/guidance/technical/

The e-Pile schedule format

There are three tabs in the spreadsheet: Index, Pile Schedule and Combinations of Actions. The Index tab defines terminology and symbols adopted from Eurocodes. The Pile Schedule tab provides a table for pile design information and the Combinations of Actions tab provides a table for the listing of Combinations of Actions for computing design actions from the characteristic actions.

The Pile Schedule itself comprises five sections; pile reference, pile geometry, EC7 vertical actions, EC7 horizontal actions and pile design. The example schedule gives guidance of the input required in the first four sections as if completed by a structural engineer. The fifth section is the output generated by the pile designer (i.e. pile toe level and reinforcement).

In the Pile Geometry columns, where pile diameters are specified they should be stated however, when not specified and the pile designer can determine, the pile diameter column should be left blank.

In the vertical and horizontal actions columns of the schedule, the structural engineer provides all individual characteristic actions of pile loading (e.g. G_k, Q_k, $Q_{k,wind}$, etc.), as well as the maximum ($E_{d, max}$) and minimum ($E_{d, min}$) Set B, Set C and other ultimate limit state design actions calculated from all the load case combinations in Table 2. Where moments are applied then their orientation must be stated in notes or detail provided on drawing.

Where notional actions relating to 'out of tolerance' structural elements (e.g. columns) are not included in the ULS actions but instead specified separately these must be identified as SLS (provided as permanent and variable components) or ULS (specified as Set B and Set C).

Groundwater uplift actions in the schedule have been scheduled as permanent <u>design</u> actions rather than characteristic actions ($G_{up,ULS,d}$, $G_{up,SLS,d}$). This follows current geotechnical practice to determine ULS and SLS groundwater levels without then applying partial factors.

Combinations of Actions can become numerous and complex and it is therefore important that the structural engineer provides a meaningful description for each combination case as well as combination equations and factors in Eurocode format which are used to derive the ULS loads in Table 2. SLS combination equations are also required to be provided in Table 2. These SLS equations allow both working pile test loads to be determined as well as calculating the serviceability performance of the piles including total settlement and differential settlement between piles.

Providing the characteristic actions, load case combinations and the ultimate design actions allows full transparency in the transfer of design information, allows the structural engineer to check the reasonableness of the design actions and allows the pile designer to add additional temporary loading actions e.g. crane loading, strut loading if appropriate and/or temporary load case combinations.

For structures with simple loading (e.g. no horizontal, moment or tension actions) the number of schedule columns required reduces. However, for complex load cases (e.g. bridges) additional columns can be added to capture all the relevant characteristic actions. The schedule is formatted assuming actions are applied at pile cut-off level.

Available in Microsoft Excel format the schedule can also be adapted by the structural engineer to suit particular project requirements. Additionally, the pile designer can use the e-pile schedule, when provided in electronic format, to detail the design of the piles, removing the risk of transcription errors when transferring data from a drawing schedule to an in-house electronic schedule.

Good practice scheduling tips

For ease of use, the following good practice scheduling tips are recommended:

- Use numeric values e.g. 250, -75 and avoid non-numerical values e.g. +/- or / or na. in cells.
- Only use a single numerical value in each cell i.e. avoid using +360/-150.
- Use zeros for zero values and leave cells blank where values not calculated, determined or provided.
- Clear load combination cases are to be given and clarify if ψ factors are already incorporated in the combination equations.
- Use standard symbols / terminology from Eurocodes.
- Include schedule reference, revision, issue date, designed by and checked by initials.
- Where characteristic G_{min} and G_{max} permanent actions apply, these should be clarified with relevant load combination cases.
- Add columns in schedule for additional actions as necessary.

Suggested Drawing Notes

The example schedule also includes a fourth tab with some drawing notes to accompany the schedule. Any notes adopted for a particular project should be reviewed for applicability.

Recommendation

The Federation of Piling Specialists have developed an electronic pile schedule to improve the transfer of pile design information between structural engineer and pile designer. The schedule also facilitates the increasing take up of digital construction in piling to achieve a complete digital record of piled foundations.

The completed e-pile schedule should be issued together with ground investigation AGS data and tender/design documents.

Feedback and suggestions on the e-pile schedule are welcome and can be sent to:
fps@fps.org.uk

References

British Standards Institution (2005). BS EN: 1990, Eurocode 0: Basis of Structural Design. British Standards.

British Standards Institution (2013). BS EN: 1997-1, Eurocode 7: Geotechnical Design Part 1: General Rules.

Institution of Civil Engineers (2017). Specification for Piling and Embedded Retaining Walls 3rd Edition, London.

Selemetas, D and Bell, A (2014). FPS E-Pile Schedule for Eurocode design. *The Structural Engineer*, Volume 92, Issue 3.

Index of Terminology used in FPS EC7 Pile Schedule Version 4.0

For Vertical Actions

Sign Notation: For all vertical actions, positive values indicate compression and negative values indicate tension.

G_k - Characteristic Value of Permanent Action (excluding pile self weight)
$Q_{k,imposed}$ - Characteristic Value of the Imposed Variable Action
$Q_{k,wind}$ - Characteristic Value of the Wind Action
$Q_{k,i}$ - Characteristic Value of the Accompanying Variable Action "i" (if present)
$Q_{k,j}$ - Characteristic Value of the Accompanying Variable Action "j" (if present)
A_d - Design Value of an Accidental Action (if present)
$G_{up,ULS,d}$ **(kN)** - Permanent Design Value of groundwater uplift pressure (ULS)
$G_{up,SLS,d}$ **(kN)** - Permanent Design Value of groundwater uplift pressure (SLS)
$G_{he,k}$ - Characteristic Value of Permanent Heave Action (tension, if present state source)
$Q_{he,k}$ - Characteristic Value of Variable Heave Action (tension, if present state source)
$G_{k,m}$ - Characteristic Value of Permanent Component of Applied Moment (if present)
$Q_{k,m}$ - Characteristic Value of Variable Component of Applied Moment (if present)
SET B DA1-1 (ULS-STR/GEO) $E_{d,\,max}$ - Design Approach 1-Combination 1 (Ultimate Limit State) Design Value of Effects of Actions (Maximum Value)
SET B DA1-1 (ULS-STR/GEO) $E_{d,\,min}$ - Design Approach 1-Combination 1 (Ultimate Limit State) Design Value of Effects of Actions (Minimum Value)
SET C DA1-2 (ULS-STR/GEO) $E_{d,\,max}$ - Design Approach 1-Combination 2 (Ultimate Limit State) Design Value of Effects of Actions (Maximum Value)
SET C DA1-2 (ULS-STR/GEO) $E_{d,\,min}$ - Design Approach 1-Combination 2 (Ultimate Limit State) Design Value of Effects of Actions (Minimum Value)

NOTE: For combinations of variable actions please specify the combination factors ψ_0 that are applicable. Where accidental design actions are applicable please specify the combination factors ψ_1 and ψ_2 that should be used for the frequent values and quasi permanent values of the relevant variable actions respectively.

For Horizontal Actions

G_k - Characteristic Value of Permanent Action
$Q_{k,imposed}$ - Characteristic Value of the Imposed Variable Action
$Q_{k,wind}$ - Characteristic Value of the Accompanying Wind Action
A_d - Design Value of an Accidental Action
SET B DA1-1 (ULS-STR/GEO) $E_{d,\,max}$ - Design Approach 1-Combination 1 (Ultimate Limit State) Design Value of Effects of Actions (Maximum Value)
SET C DA1-2 (ULS-STR/GEO) $E_{d,\,max}$ - Design Approach 1-Combination 2 (Ultimate Limit State) Design Value of Effects of Actions (Maximum Value)
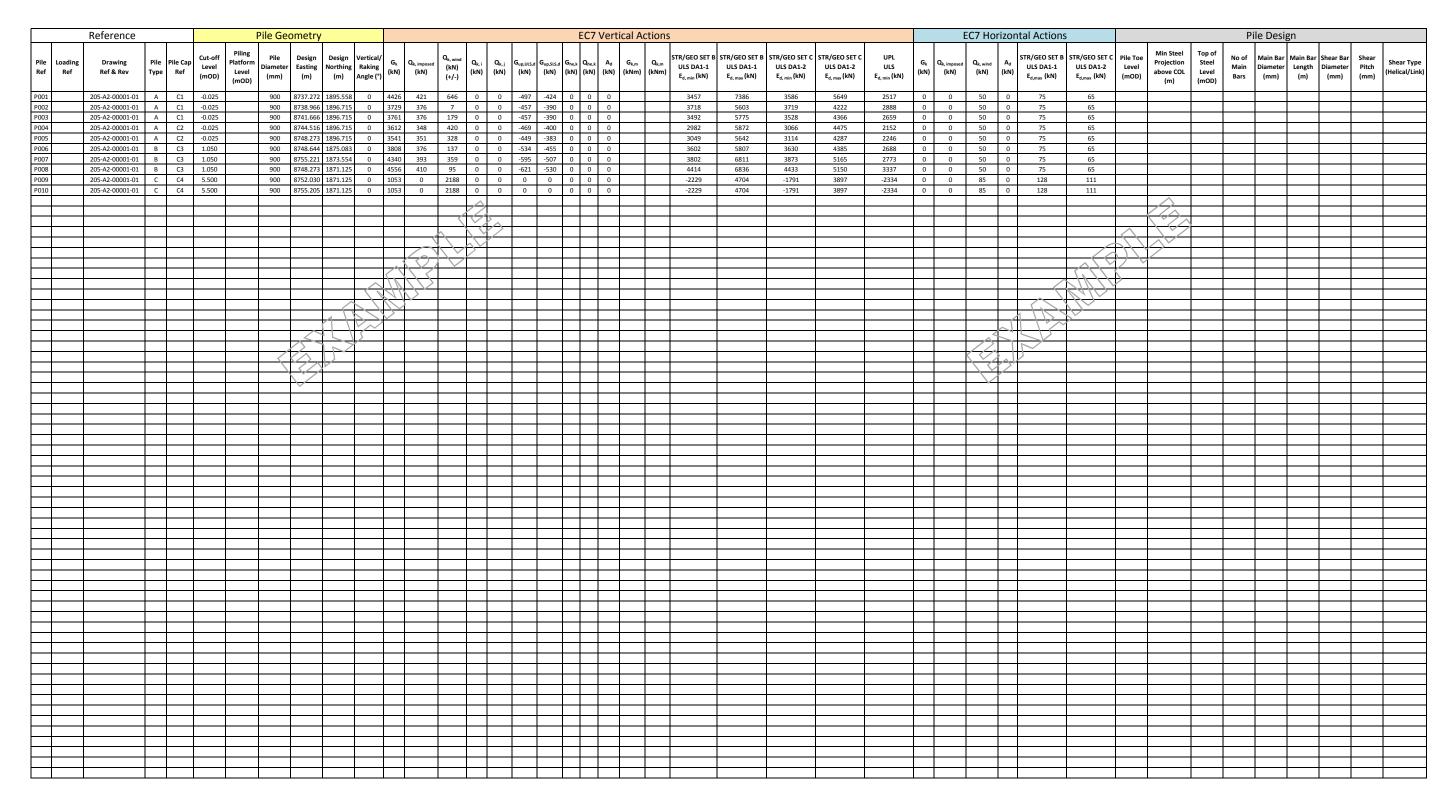
Reference					Pile Geometry						EC7 Vertical Actions																	EC7 Horizontal Actions						Pile Design								
Pile Ref	Loading Ref	Drawing Ref & Rev	Pile Type	Pile Cap Ref	Cut-off Level (mOD)	Piling Platform Level (mOD)	Pile Diameter (mm)	Design Easting (m)	Design Northing (m)	Vertical/ Raking Angle (°)	G_k (kN)	$Q_{k,imposed}$ (kN)	$Q_{k,wind}$ (kN) (+/-)	$Q_{k,i}$ (kN)	$Q_{k,j}$ (kN)	$G_{up,ULS,d}$ (kN)	$G_{up,SLS,d}$ (kN)	$G_{he,k}$ (kN)	$Q_{he,k}$ (kN)	A_d (kN)	$G_{k,m}$ (kNm)	$Q_{k,m}$ (kNm)	STR/GEO SET B ULS DA1-1 $E_{d,min}$ (kN)	STR/GEO SET B ULS DA1-1 $E_{d,max}$ (kN)	STR/GEO SET C ULS DA1-2 $E_{d,min}$ (kN)	STR/GEO SET C ULS DA1-2 $E_{d,max}$ (kN)	UPL ULS $E_{d,min}$ (kN)	G_k (kN)	$Q_{k,imposed}$ (kN)	$Q_{k,wind}$ (kN)	A_d (kN)	STR/GEO SET B ULS DA1-1 $E_{d,max}$ (kN)	STR/GEO SET C ULS DA1-2 $E_{d,min}$ (kN)	Pile Toe Level (mOD)	Min Steel Projection above COL (m)	Top of Steel Level (mOD)	No of Main Bars	Main Bar Diameter (mm)	Main Bar Length (m)	Shear Bar Diameter (mm)	Shear Pitch (mm)	Shear Type (Helical/Link)
P001		205-A2-00001-01	A	C1	-0.025		900	8737.272	1895.558	0	4426	421	646	0	0	-497	-424	0	0	0			3457	7386	3586	5649	2517	0	0	50	0	75	65									
P002		205-A2-00001-01	A	C1	-0.025		900	8738.966	1896.715	0	3729	376	7	0	0	-457	-390	0	0	0			3718	5603	3719	4222	2888	0	0	50	0	75	65									
P003		205-A2-00001-01	A	C1	-0.025		900	8741.666	1896.715	0	3761	376	179	0	0	-457	-390	0	0	0			3492	5775	3528	4366	2659	0	0	50	0	75	65									
P004		205-A2-00001-01	A	C2	-0.025		900	8744.516	1896.715	0	3612	348	420	0	0	-469	-400	0	0	0			2982	5872	3066	4475	2152	0	0	50	0	75	65									
P005		205-A2-00001-01	A	C2	-0.025		900	8748.273	1896.715	0	3541	351	328	0	0	-449	-383	0	0	0			3049	5642	3114	4287	2246	0	0	50	0	75	65									
P006		205-A2-00001-01	B	C3	1.050		900	8748.644	1875.083	0	3808	376	137	0	0	-534	-455	0	0	0			3602	5807	3630	4385	2688	0	0	50	0	75	65									
P007		205-A2-00001-01	B	C3	1.050		900	8755.221	1873.554	0	4340	393	359	0	0	-595	-507	0	0	0			3802	6811	3873	5165	2773	0	0	50	0	75	65									
P008		205-A2-00001-01	B	C3	1.050		900	8748.273	1871.125	0	4556	410	95	0	0	-621	-530	0	0	0			4414	6836	4433	5150	3337	0	0	50	0	75	65									
P009		205-A2-00001-01	C	C4	5.500		900	8752.030	1871.125	0	1053	0	2188	0	0	0	0	0	0	0			-2229	4704	-1791	3897	-2334	0	0	85	0	128	111									
P010		205-A2-00001-01	C	C4	5.500		900	8755.205	1871.125	0	1053	0	2188	0	0	0	0	0	0	0			-2229	4704	-1791	3897	-2334	0	0	85	0	128	111									

TABLE 2 - COMBINATIONS OF ACTIONS FOR PILE DESIGN

Load Case	Type	Description	Leading / accompanying variable action	ψ for accompanying variable action	Combination
C1a	ULS-STR/GEO SET B DA1-1 E_{dmax} (kN)	Maximum building load	$Q_{k,imposed}$ = leading variable action $Q_{k,wind}$ = accompanying variable action	0.5	$1.35G_k + 1.5Q_{k,imposed} + 0.75Q_{k,wind}$
C1b	ULS-STR/GEO SET B DA1-1 E_{dmax} (kN)	Maximum building load	$Q_{k,wind}$ = leading variable action $Q_{k,imposed}$ = accompanying variable action	0.7	$1.35G_k + 1.05Q_{k,imposed} + 1.5Q_{k,wind}$
C1c	ULS-STR/GEO SET B DA1-1 E_{dmin} (kN)	Minimum building load, No bouyancy uplift	$Q_{k,imposed}$ = favourable variable action $Q_{k,wind}$ = unfavourable variable action	-	$1.0G_k + 0.0Q_{k,imposed} + 1.5Q_{k,wind}$
C2a	ULS-STR/GEO SET C DA1-2 E_{dmax} (kN)	Maximum building load	$Q_{k,imposed}$ = leading variable action $Q_{k,wind}$ = accompanying variable action	0.5	$1.0G_k + 1.3Q_{k,imposed} + 0.65Q_{k,wind}$
C2b	ULS-STR/GEO SET C DA1-2 E_{dmax} (kN)	Maximum building load	$Q_{k,wind}$ = leading variable action $Q_{k,imposed}$ = accompanying variable action	0.7	$1.0G_k + 0.91Q_{k,imposed} + 1.3Q_{k,wind}$
C2c	ULS-STR/GEO SET C DA1-2 E_{dmin} (kN)	Minimum building load, No bouyancy uplift	$Q_{k,imposed}$ = favourable variable action $Q_{k,wind}$ = unfavourable variable action	-	$1.0G_k + 0.0Q_{k,imposed} + 1.3Q_{k,wind}$
C3	ULS-UPL	Bouyancy Uplift	$Q_{k,imposed}$ = favourable variable action $Q_{k,wind}$ = unfavourable variable action	-	$0.9G_k + 0.0Q_{k,imposed} + 1.5Q_{k,wind} + G_{up,ULS,d}$
C4a	SLS-STR/GEO	Servicability building load	$Q_{k,imposed}$ = leading variable action $Q_{k,wind}$ = accompanying variable action	0.5	$1.0G_k + 1.0Q_{k,imposed} + 0.5Q_{k,wind}$
C4b	SLS-STR/GEO	Servicability building load	$Q_{k,wind}$ = leading variable action $Q_{k,imposed}$ = accompanying variable action	0.7	$1.0G_k + 0.7Q_{k,imposed} + 1.0Q_{k,wind}$
C4c	SLS-UPL	Bouyancy Uplift	$Q_{k,imposed}$ = favourable variable action $Q_{k,wind}$ = unfavourable variable action	-	$1.0G_k + 0.0Q_{k,imposed} + 1.0Q_{k,wind} + G_{up,SLS,d}$
C5	F_{rep}	For pile load testing	-	-	Greater of Load Cases C4a and C4b

NOTES

1. THE COMBINATION EQUATIONS SHOWN ABOVE INCORPORATE THE APPLICATION FOR ψ VALUES FOR ACCOMPANYING VARIABLE ACTIONS.

2. THE '+' IN COMBINATION EQUATIONS ABOVE MEANS COMBINED WITH. REFER TO SCHEDULE FOR -/+ ACTIONS.

NOTES

1. THIS DRAWING TO BE READ IN CONJUCTION WITH RELEVANT ARCHITECT'S AND ENGINEER'S DRAWINGS AND SPECIFICATIONS.

2. PILE DESIGN TO BE BY SPECIALIST CONTRACTOR. REFER TO GROUND INVESTIGATION REPORTS FOR GROUND CONDITIONS.

3. ALL DIMENSIONS ARE IN MILLIMETRES AND LEVELS IN METRES UNLESS OTHERWISE STATED.

4. WHERE DISCREPANCIES BETWEEN E-PILE SCHEDULE AND DRAWINGS, THE DRAWINGS SHALL TAKE PRECEDENCE.

5. THE EASTINGS AND NORTHINGS ARE IN LOCAL COORDINATES SYSTEM.

6. FOR PILE DESIGN LOAD COMBINATIONS REFER TO TABLE 2.

7. FOR ALL VERTICIAL ACTIONS, POSITIVE VALUES INDICATE COMPRESSION AND NEGATIVE VALUES INDICATE TENSION.

8. ACTIONS ARE APPLIED AT PILE CUT OFF LEVEL UNLESS OTHERWISE STATED.

9. VERTICAL ACTIONS DUE TO WIND ACT IN BOTH COMPRESSION AND TENSION.

10. MINIMUM PERMANENT DESIGN GROUNDWATER PRESSURES ARE BASED ON ULS +5.5mOD AND SLS +4.5mOD DESIGN LEVELS.

11. PILES HEADS ARE UNRESTRAINED AGAINST ROTATION. IN ADDITION TO THE HORIZONTAL LOADS GIVEN, PILES TO BE DESIGNED FOR CONSTRUCTION TOLERANCES BY CONTRACTOR.

12. WORKING PILE TEST LOAD SHALL BE DVL + 0.5 x F_{rep}, REFER TO F_{rep} IN TABLE 2 AND THE SPECIFICATION. CONTRACTOR SHALL CALCULATE DVL WHICH SHALL INCLUDE ANY PILE LOAD UNDER UTILISATION.