**Guidance for Eurocode Pile Loading Schedules /**

**Calculation of Eurocode Bearing Pile Design Actions**

**Introduction**

This technical note identifies concerns raised by Federation of Piling Specialist Members (FPS) regarding variability in the quality of pile loading schedules issued by Structural Engineers. It aims to explain why, in certain circumstances, it is beneficial for all parties that the pile designer should be provided with design pile actions rather than a multitude of individual components of characteristic actions. In particular, the use of the FPS e-pile schedule (Selemetas and Bell, 2014) is recommended to avoid misinterpretation and ensure consistency in the industry.

**Eurocode 7**

20 years after its original issue, BS EN 1997-1 (Eurocode 7) is now generally used as the default standard for the specification and design of piled foundations in the UK. The design of piled foundations to Eurocode 7 requires the basic inequality to be satisfied:



Where; *Ed* is the effect of design actions and

*Rd* is the design (pile) resistance

In the UK, Design Approach 1 (DA1) is invoked which requires two ultimate limit states (ULS) to be considered, Combination 1 (STR) & Combination 2 (GEO), in addition to the serviceability limit state (SLS). The calculation of the design pile actions from the individual values of actions is as follows:



Where; *ɣG* is the partial factor for permanent actions

*Gk* is the characteristic value of the permanent action

*ɣQ.* is the partial factor for variable actions

*Qk,1* is the characteristic value of the leading variable action

Ψ0,1 is the reduction factor applied to accompanying variable actions

*Qk,i* is the characteristic value of the accompanying variable action (if present)

**Simple Load Cases**

In many situations, the specified loading provided by the Structural Engineer is relatively straightforward, an example of which is presented in Table 1 below.

|  |  |  |
| --- | --- | --- |
|  | **Permanent Action**  **Gk**  **(kN)** | **Variable Action (Imposed)**  **Qk**  **(kN)** |
| Example 1 | 1000 | 500 |

**Table 1 – Simple Pile Load Case Example**

Thus, the pile design actions are calculated as follows :



In such cases as above the calculation is routinely undertaken by the pile designer without misinterpretation.

**Complex Load Cases**

Over recent years, it is the experience of FPS members that pile loading schedules can frequently contain outdated or incorrect terminology / symbols and a multitude of columns of characteristic values of actions including permanent, earth pressure, heave, groundwater, variable (imposed), thermal, wind, experiment & accidental, as detailed in a real example in Table 2 below.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Dead**  **(kN)** | **Live**  **(kN)** | **Experiment**  **Min / Max**  **(kN)** | **Earth**  **(kN)** | **Groundwater**  **(kN)** | **Heave**  **(kN)** | **Thermal**  **(kN)** | **Wind Min/Max**  **(kN)** |
| Example 2 | 800 | 50 | -300 / 900 | 40 | -200 | -100 | +/-40 | -30 / 20 |

**Table 2 – Complex Pile Load Case Example**

In order to attempt to calculate the individual minimum and maximum effects of design pile actions from such information the pile designer is required to make a number of decisions, which are often only assumptions until clarification has been sought from the Structural Engineer, examples of which are as follows.

* which actions are permanent and which are variable? (e.g. heave / groundwater)
* are the actions for heave & groundwater characteristic values or worst credible values?
* which actions are unfavourable and which are favourable?
* which is the leading variable action?
* should a reduction factor be applied to accompanying variable actions, if so what value?
* should all actions be considered in combination or do only selected actions act in combination in the temporary / permanent load cases?
* what proportion of the permanent action should be considered in the temporary condition in combination with uplift forces?

At tender stage in a project, such clarifications are often not possible within the programme constraints and thus presents is a significant project risk which may be borne by the Piling Sub-Contractor or Client.

**Recommendations for Complex Pile Load Schedules**

On specific projects, it is accepted that complex loading may be necessary, however the way in which the specified loading schedules are structured can have a significant impact on the level and ease of understanding for the pile designer. The following are recommended

* Structural Engineer to provide characteristic values of actions and minimum / maximum effects of design actions (SLS, ULS Comb 1 & ULS Comb 2)
* use standard symbols / terminology from Eurocodes
* provide load schedule in digital format
* avoid the use of non-numerical values in spreadsheets (i.e. +/-) which restricts manipulation of the data
* where applicable provide accompanying notes to identify and explain the load schedules / combinations

FPS e-Pile Schedule

The FPS e-Pile schedule (Selemetas and Bell, 2014) was developed as a standardised format for the communication of pile loading data, an example of which is shown below.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Reference | | | | | Pile Geometry | | | | | |
| **Pile Ref** | **Loading Ref** | **Drawing Ref** | **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 (°)** |
|  |  |  |  |  |  |  |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| EC7 Vertical Actions | | | | | | | | | | | | |
| **Gk (kN)** | **Qk, l (kN)** | **Qk, wind (kN)** | **Qk, i (kN)** | **Qk, j (kN)** | **Tk (kN)** | **Ad (kN)** | **Gk,m (kNm)** | **Qk,m (kNm)** | **DA1 Comb1 (ULS-STR) Ed, max (kN)** | **DA1 Comb1 (ULS-STR) Ed, min (kN)** | **DA1 Comb2 (ULS-GEO) Ed, max (kN)** | **DA1 Comb2 (ULS-GEO) Ed, min (kN)** |
|  |  |  |  |  |  |  |  |  |  |  |  |  |

**Table 3 – Example of FPS e-Pile Schedule**

The standard format and terminology ensure consistency and allow the specifier to provide both the values of characteristic actions in addition to the minimum and maximum effects of design actions. Available in Microsoft Excel format the schedule can also be adapted 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 one schedule to another.

**Conclusions**

The requirements of Eurocode design can result in pile load schedules with in excess of 10 values of characteristic actions, with differing partial factors to be applied to each component and not all components necessarily acting in combination at any one time. As a result, interpretation by the pile designer is difficult and can be conservative or equally non-conservative which carries a significant risk to the project as a whole. The FPS recommend that in such cases of greater than 2 No. variable actions, the Structural Engineer should provide both the values of characteristic actions and the effect of design actions for Combination 1 and Combination 2 ultimate limit states in addition to the serviceability limit state. The FPS e-Pile schedule, freely available in Microsoft Excel format, is recommended to provide a consistent and unambiguous template which can be issued to the pile designer in digital format.

**References**

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