Concrete Q&A

Load Factors are *Load* Factors

Q. *My company has recently negotiated a contract to provide design services for wind turbine foundations. The turbine manufacturer will provide the allowable soil pressure and forces at the tower base (including shear and overturning moment due to wind as well as dead load due to turbine and tower weight). I plan to size the footings using the service loads and an allowable soil pressure.*

For design of the reinforced concrete in the footing, should I factor the reactions or the loads? It makes a difference to the pressure distribution because under service loads, the footing is in full contact with the soil, but with factored loads, there is footing uplift.

A. You should apply the load factors to the loads and analyze the footing to determine the induced soil pressures and resulting load effects (internal moments, shears, and compression or tension forces). The factored loads specified in Section 9.2 of ACI 318-08[1] are not fictional. The factored loads represent an unusual, but real load case that one must resist with the appropriate level of safety.

Load factors may cause eccentricities and reactions that are different from those obtained using unfactored loads. If the factored overturning effects cause lift-off of the footing, the system becomes nonlinear because the soil-footing interface cannot resist tension.

Questions in this column were asked by users of ACI documents and have been answered by ACI staff or by a member or members of ACI technical committees. The answers do not represent the official position of an ACI committee. Only a published committee document represents the formal consensus of the committee and the Institute.

We invite comment on any of the questions and answers published in this column. Write to the Editor, *Concrete International*, 38800 Country Club Drive, Farmington Hills, MI 48331; contact us by fax at (248) 848-3701; or e-mail Rex.Donahey@concrete.org.

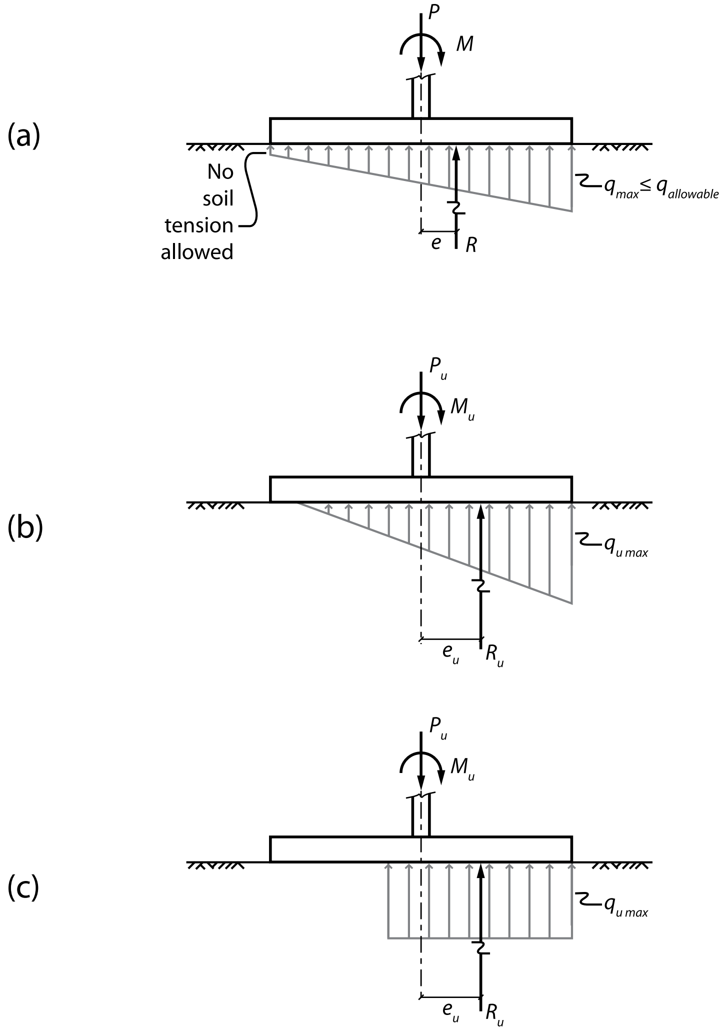

Fig. 1: Soil pressures on a spread footing: (a) induced by unfactored loads; (b) induced by factored loads on nonyielding soil; and (c) induced by factored loads on yielding soil (after Reference 2). Note that each applicable load combination specified in Section 9.2.1 of Reference 1 must be considered

For a free-body diagram of the footing to be in equilibrium (that is, the summation of moments about any point must be equal to zero), the eccentricity of the soil reaction must equal the eccentricity of the applied loads. Figure 1 shows schematically how the soil pressures and eccentricity may change under a footing under unfactored and factored loads.

The footing plan dimensions are generally established by keeping the soil pressure with unfactored loads below the allowable soil pressure established by the geotechnical engineer. With factored loads, the maximum soil pressure will generally exceed the allowable soil pressures. While it needs to be confirmed with the geotechnical engineer, this is generally acceptable because the factored loads are roughly 1.6 times the service loads, whereas the factor of safety implied in the allowable soil pressure is 2.5 to 3.0. That is, with factored loads, the ultimate strength of the soil should not be exceeded.

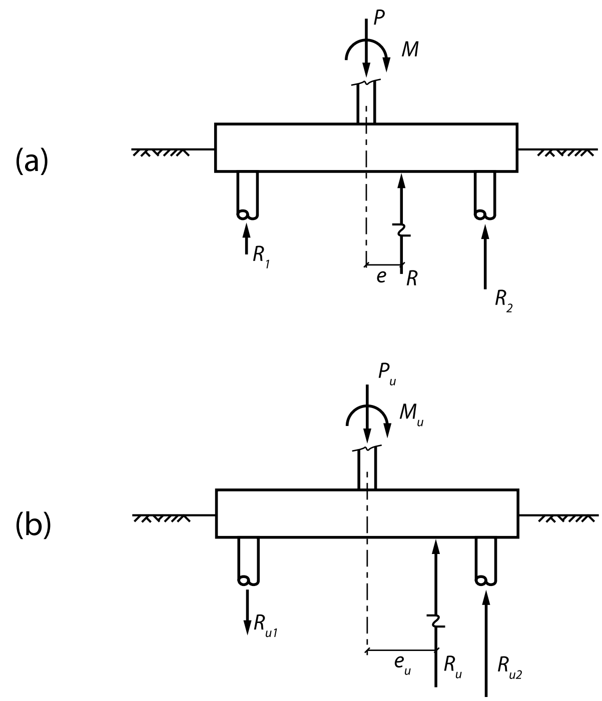

Fig. 2: Pile reactions for pile-supported footing: (a) induced by unfactored loads; and (b) induced by factored loads. Note that each applicable load combination specified in Section 9.2.1 of Reference 1 must be considered

If the footing is pile supported, there is a similar need to apply the load factors to the forces rather than the pile reactions. While the left pile in Fig. 2(a) may have a small compression with unfactored loads, it may well have tension with the factored forces shown in Fig. 2(b).

While not a direct part of the question, given that the loads did not come from ASCE 7-02,[3] one should confirm that the dead load and wind load information from the turbine manufacturer has been provided at statistical risk levels that are appropriate for use of the dead and wind load factors in Section 9.2 of ACI 318-08.

References

1. ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary," American Concrete Institute, Farmington Hills, MI, 2008, 473 pp.

2. CAN/CSA-S6-06, "Canadian Highway Bridge Design Code," Canadian Standards Association, Mississauga, ON, Canada, 2006, 800 pp.

3. SEI/ASCE 7-02, "Minimum Design Loads for Buildings and Other Structures," American Society of Civil Engineers, Reston, VA, 2002, 376 pp.

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