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DENTAL IMPLANT NUMERICAL MODELING USING PILE MODLEING SCHEME IN CIVIL ENGINEERING FIELD

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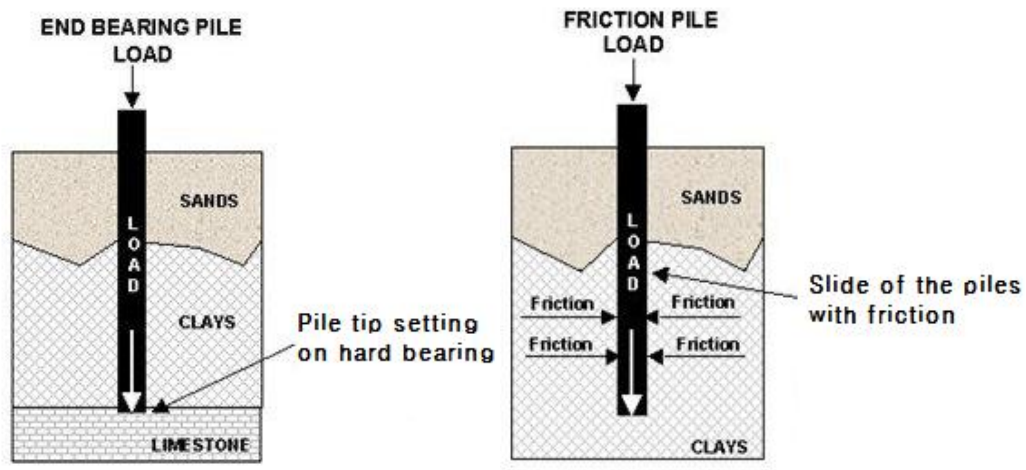
Abstract. Numerical modelling of dental implants in bioengineering field has an important role to understand the behaviour of human teeth after implants applied. It is highly involved mechanical concepts and biological concepts at the same time. In many cases, the modelling considered as a sub assembled part of components in machine. So, it is commonly modelled a single implant and tried to simulate the stress in the implant to check stress concentration in the implant. However, as we well known, human teeth cannot consider as a single component because it is interacted with jawbone and adjacent tooth. It should be considered because the effects of interaction with surrounding media and adjacent implants are already well established in the other field such as civil engineering especially geotechnical area. The concept for implant is very similar with the pile foundation in civil engineering. The definition of pile foundation is a system transferring loads coming from upper structure to bear stratum that the piles are driven. It the same definition and role for a dental implant as we understand. Here, the structure in civil engineering is crown in dental implants and the loadings are compression and shear loads that are occurred when we chew foods. The pile technology in civil engineering is one of the technologies that are well established during last 100 years and adopted well in many aspects of applying to different condition of surrounding media, soil and base rock. So, in this paper, we are trying to connect these two different but similar systems in civil and bio engineering area to learn each other to understanding more.

In this study, first, we are going to cover the design method for pile for civil engineering area. The reason why we selected this topic is the design of pile and implant is quite different. For the pile design, the loadings coming from super structures are the main parameters for the design. However, for the case of the implant design, loading is almost not a factor rather than patients condition such as a strength and size of jawbone. Here, we are introducing how civil engineers design pile according to the size of piles. For this purpose, the ultimate loadings that the pile systems can sustain are calculated to show that how much the ultimate loadings

varying with the size of piles. Such variation with the size of piles can be reflected to the capability of implant systems.

1 INTRODUCTION

Pile foundations are the lowest part of engineered structure systems. Those are constructed to strengthen ground to support the structural loads. These pile foundations are classified to 6 kinds of piles systems according to different structures to be supported and different ground conditions. Those pile systems are end bearing piles, friction piles, settlement reducing piles, tension piles, laterally loaded piles and piles in fill. Among these pile systems, friction pile foundations obtain a greater part of their carrying capacity by skin friction or adhesion. This tends to occur when piles do not reach an impenetrable stratum but are driven for some distance into a penetrable soil. Their carrying capacity is derived partly from end bearing and partly from skin friction between the embedded surface of the soil and the surrounding soil. Like friction piles, implant is derived partly from jawbone and partly from friction between the embedded surface of the bone and the surrounding bone. That is reason friction pile foundations are similar to dental implants. So in this paper, ultimate load-capacity of friction piles are calculated with variation of pile sizes. From these results, ultimate load-capacity of implants are estimated according to the size of implants. Also, pile foundations get less load when pile foundation are constructed as a group due to group effect, so called. Because teeth and implants are also embedded together, ultimate load-carrying-capacity of friction piles are calculated according to the number of piles. For the more exact results, three dimensional finite element method can be used to calculate ultimate load-carrying-capacity of implants. It is going to be included in the presentation of conference.



(a) End bearing pile (b) Friction pile

Figure 1 : Type of pile(GlobalSecurity.org)

2 NUMERICAL CALCULATION OF ULTIMATE LOADING FOR PILES

Meyerhof(1963) suggested the following form of the general bearing capacity equation for shallow foundation :

$$q_{\ p} = c'N_c F_{cs} F_{cd} F_{ci} + qN_q F_{qs} F_{qd} F_{qi} + \frac{1}{2}\gamma B N_\gamma F_{\gamma s} F_{\gamma d} F_{\gamma i} \qquad (1)$$

In this equation :

c′ = cohesion
q = effective stress at the level of the bottom of the foundation
γ = unit weight of soil
B = width of foundation (=diameter for a circular foundation)
$F_{cs}, F_{qs}, F_{\gamma s}$ = shape factors
$F_{cd}, F_{qd}, F_{\gamma d}$ = depth factors
$F_{ci}, F_{qi}, F_{\gamma i}$ = bearing capacity factors

The ultimate load-carrying-capacity Q_u of a pile is given by the equation

$$Q_u = Q_p + Q_s \qquad (2),$$

where Q_p is load-carrying-capacity of the pile point, and Q_s is frictional resistance derived from the soil-pile interface.

Point Bearing Capacity, Q_p

The ultimate load-caryying-capacity is similarly, the general bearing capacity equation for shallow foundation. Hence, in general, the ultimate load bearing capacity may be expressed as

$$q_p = c'N_c^* + \ qN_q^* + \gamma D N_\gamma^*, \qquad (3)$$

where N_c^*, N_q^* and N_γ^* are the bearing capacity factors that include the necessary shape and depth factors.

Pile foundation are deep. However, the ultimate resistance per unit area developed at the pile tip ,q_p, may be expressed by an equation similar form to Eq.3, although the values of N_c^*, N_q^* and N_γ^* will change, when the pile foundations are deep.

Because the diameter D of a pile is relatively small, the term $\gamma D N_\gamma^*$ may be dropped from the right side of the preceding equation without introducing a serious error. Thus, the point bearing of piles is

$$Q_p = A_p q_p = A_p(c'N_c^* + q'N_q^*) \qquad (4)$$

A_p = area of pile tip
c' = cohesion of the soil supporting the pile tip
q_p = unit point resistance
q' = effective vertical stress at the level of the pile tip
N_c^*, N_q^* = the bearing capacity factors

Frictional Resistance, Q_s

The frictional, or skin, resistance of a pile may be written as

$$Q_s = \sum p\, \Delta L f \tag{5}$$

Where,

p = perimeter of the pile section,
ΔL = incremental pile length over which p and f are taken to be constant,
f = unit friction resistance at any depth z.

3 ULTIMATE LOADINGS OF PILES

As descrbed in session 2, ultimate load-carrying-capacity is sum of point bearing capacity and frictional resistance. Fig.2, ultimate load-carrying-capacity of piles are calculated in terms of ground condition and depth of foundation. In two condtions, ultimate load-carrying-capacity increase as depth of foundation increase. Especially, the amount of increase is bigger in sand. These results make sense because bigger particle can support high load. Also, areas of piles under skin friction force increase as depth of foundations increase. So, ultimate load-carrying-capacity increase by depth of foundation.

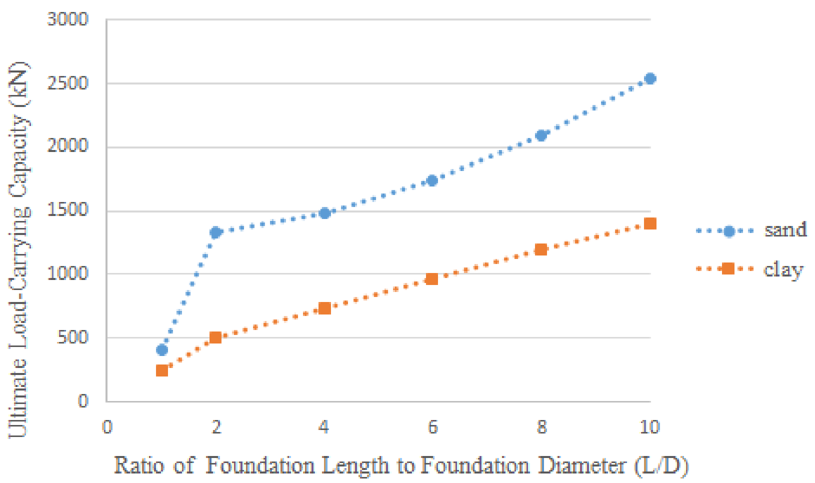


Figure 2 : Ultimate Load-Carrying-Capacity by Depth of Foundation

The Fig.3 shows that ultimate load-carrying-capacity decreases as the number of piles in a pile system increases. When ultimate load-carrying-capacity in 5 piles in a pile system is compared with 1 pile in a piles system, it decreases about 5% in 4D, 4 times diameter, and about 10% in 6D, 6 times diameter. In most cases, the length of teeth and implant is 4~ 6 times diameter. That is why ultimate load-carrying-capacity of 4D and 6D is investigated in this paper. When the piles are embedded together, stress on soil is overlapped. So, ultimate load-carrying-capacity per a pile in a pile system decreases. This situation is called group effect. The decrease ratio in length of piles, 6D, is bigger that in 4D. It makes sense because overlapped area of soil is bigger when the length of piles is longer.

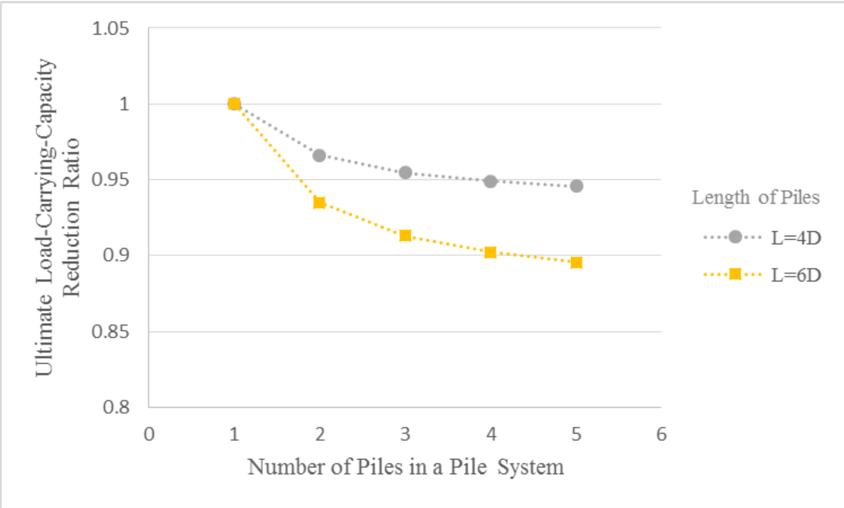


Figure 3 : Ultimate Load-Carrying-Capacity Reduction Ratio by The Number of Piles in a Pile System

4 CONCLUSIONS

In this paper, ultimate load-carrying-capacity is calculated by depth of foundation and ground condition. Also, group effect of piles is investigated. From the results,

1) Ultimate load-carrying-capacity increase as depth of foundation increase. And ultimate load-carrying-capacity in sand is bigger than in clay. From these results, when design implant, the length of implant has to be determined in terms of condition of jawbone and gum tissue of patients.

2) Ultimate load-carrying-capacity decrease as number of piles in a pile system increase due to group effect. This group effect should be larger when the length of piles is longer. So when design implant, group effect has to be considered.

For the more exact results, three dimensional finite element method can be used to calculate ultimate load-carrying-capacity of implants. It is going to be included in the presentation of conference.

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