Development of a Guy Anchor Suitable for Hard Foundations

Yukio Nakamura†, Toshiyasu Tatsuno, Ryouichi Kaneko, and Shigehiro Miura

Abstract

We have developed two types of guy anchors for anchoring telegraph poles in hard foundations. Unlike the current ones, which must be installed manually, these can be installed by machine. Therefore, they will play a vital role in the construction of facilities required for the expansion of optical access.

1. Introduction

NTT Group is well on the way to achieving the goal of its medium-term strategy (announced in November 2004) of providing optical access and next-generation network services to 30 million subscribers by 2010 [1]. Active deployment and good demand for optical IP (Internet protocol) services resulted in 3.42 million installations of the B-FLET'S service by the end of Fiscal 2005 (16 months after the announcement). Moreover, service providers have installed about 50,000 km of optical cable per year in Japan over the past several years. Thus, the fixed-line telephone network (metallic cable) and optical service network (optical cable) now coexist. Since these developments increase the loads (e.g., cable weight and wind pressure) on overhead structures, such as telegraph poles supporting the cables, it is becoming very important in terms of safety to improve the design and construct the best possible equipment. In response to a request from NTT West for a guy anchor that can be constructed simply and easily, we have developed two new guy anchors for use with hard foundations.

2. Existing anchors and problems

The horizontal load (drag) and perpendicular load (lift) imposed on a telegraph pole from the lines it supports, such as a cable, can cause the pole to tilt, collapse, or lift. A guy line is attached to a telegraph pole at one end and to an anchor buried in the ground at the other end, which provides the bearing capacity. NTT currently uses three kinds of guy anchors, which are called the ordinary guy anchor, block anchor, and spiky bolt anchor. The appropriate type is selected depending on ground conditions (**Fig. 1**).

The ordinary guy anchor, which is a spiky steel piton driven into the ground until it is deep enough to open up and remain fixed under the ground, is used in most cases except when the installation is on rock (base rock compression of 1.96 kN/cm^2 or more) or when the driving action might damage existing underground installations or facilities. When it cannot be used, the next choice is the block anchor. The guy is held in place by an anchor block formed on site by pouring concrete into a hole, which is then refilled and compacted. However, this cannot be installed on rock either. For an installation on rock, a shallow hole is drilled and a spiky bolt is inserted and mortared in place. After carefully considering actual conditions, we developed two new guy anchors that can be installed by a machine. They can be installed on all types of non-rock ground, including hard foundations.

3. New guy anchors

The two new guy anchors that we have developed are dish-shaped earth anchors, which are inserted into

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an excavated hole and recovered with compacted ground. Called the globe anchor and the globe anchor L (L: large size), they are designed to be used on hard foundations (hard sandy soil, gravel and ball-stone mixture, soft rock, weathered granite soil, or hard and viscous ground) (**Fig. 2**). They both have a parabolic-

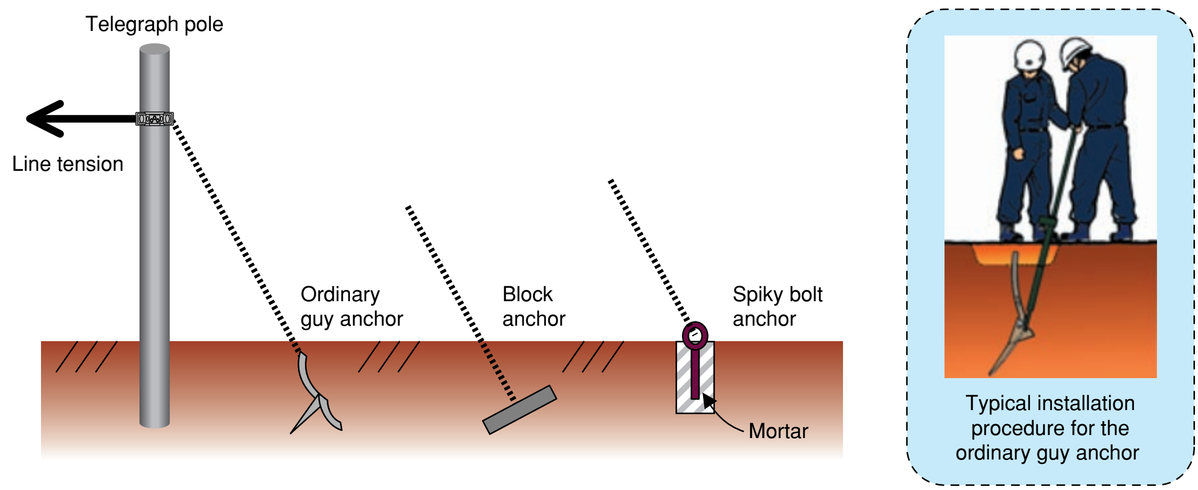
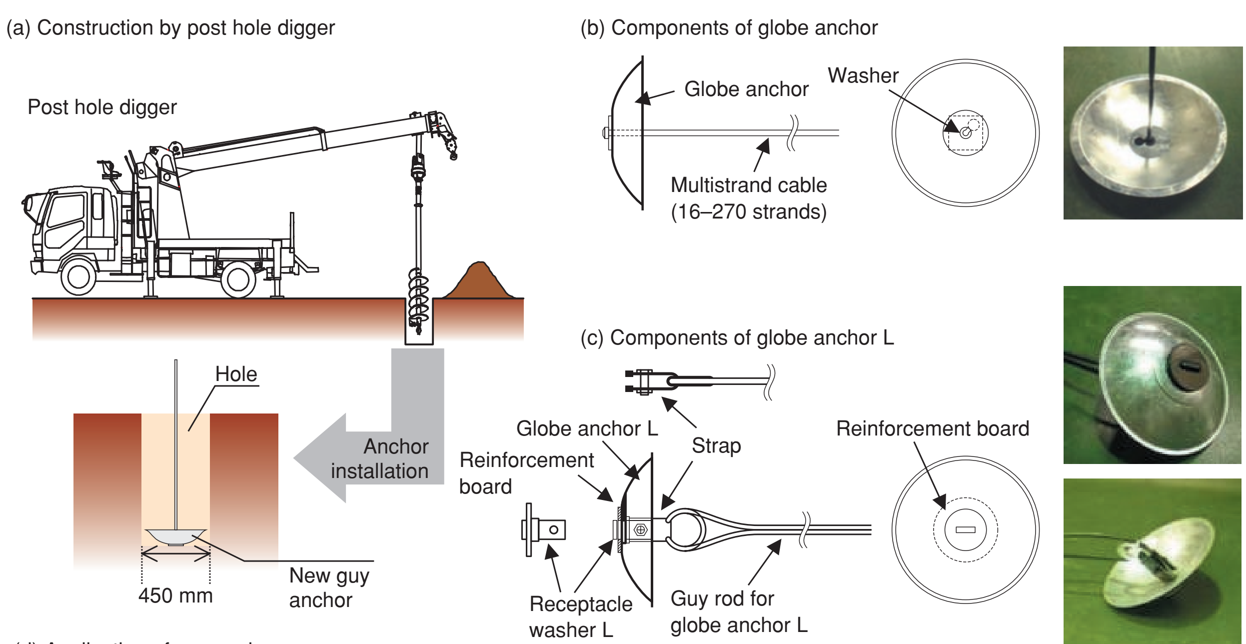


Fig. 1. Existing types of guy anchors.



(d) Application of guy anchor

Installation location	Type of guy anchor to use
General conditions (cases other than the following)	Ordinary guy anchor
Where the foundation is hard and the ordinary guy anchor is inappropriate	Globe anchor or globe anchor L
Where there is a possibility of damaging underground facilities	Block anchor
Where the base rock compression intensity is more than 1.96 kN/cm^2	Spiky bolt anchor

Fig. 2. Overview of new guy anchors.

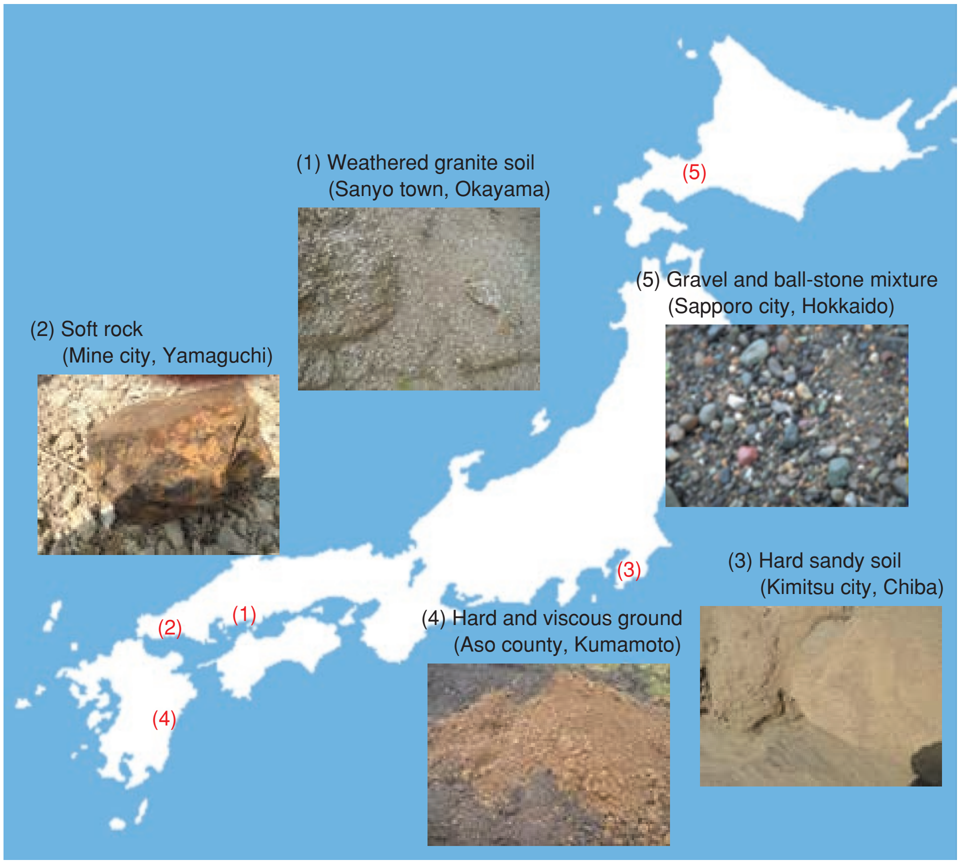


Fig. 3. Experiment on the quality of ground with a hard foundation.

dish-shaped resistance plate made of 3.2-mm-thick steel designed to fit in the hole (diameter: 450 mm) dug by a post hole digger. They are lighter than the conventional guy anchor and block anchor, and the construction time on a hard foundation is only about 25% of that for the ordinary guy anchor. The globe anchor has greater bearing capacity than the currently used "M type guy anchor" (M: medium size), which is driven into the ground. It was introduced in April 2005 by NTT West (Fig. 2(b)). The globe anchor L is larger than the globe anchor and has a more robust guy attachment method using a reinforcement board and strap and a solid guy rod instead of a multistrand cable. It has more bearing capacity than the currently used "L type guy anchor", which is driven into the ground. It is scheduled to be introduced in the 2nd quarter of Fiscal 2006 by NTT West (Fig. 2(c)).

4. Bearing capacity evaluation

We performed an experiment to determine the amount of force required to extract the anchors from the ground in five regions of Japan having different types of ground and established a bearing capacity theory for the new guy anchors. We also performed an evaluation to establish whether the theoretically predicted bearing capacity was accurate (**Fig. 3**).

4.1 Mechanism of foundation destruction

In our extraction experiment, we observed two modes of ground destruction (**Fig. 4**).

(1) Destructive mode A

Destructive mode A occurred with ordinary foundations: the extraction force pulled out a piece of ground in the shape of an inverted cone. This same inverted cone shape was also seen when a large hole was excavated in a hard foundation by stepped digging.

(2) Destructive mode B

Destructive mode B occurred for guy anchors installed using a post hole digger on a hard foundation (circular digging). When a globe anchor was extracted, an interface remained between the material filling the hole and the original ground, the anchor

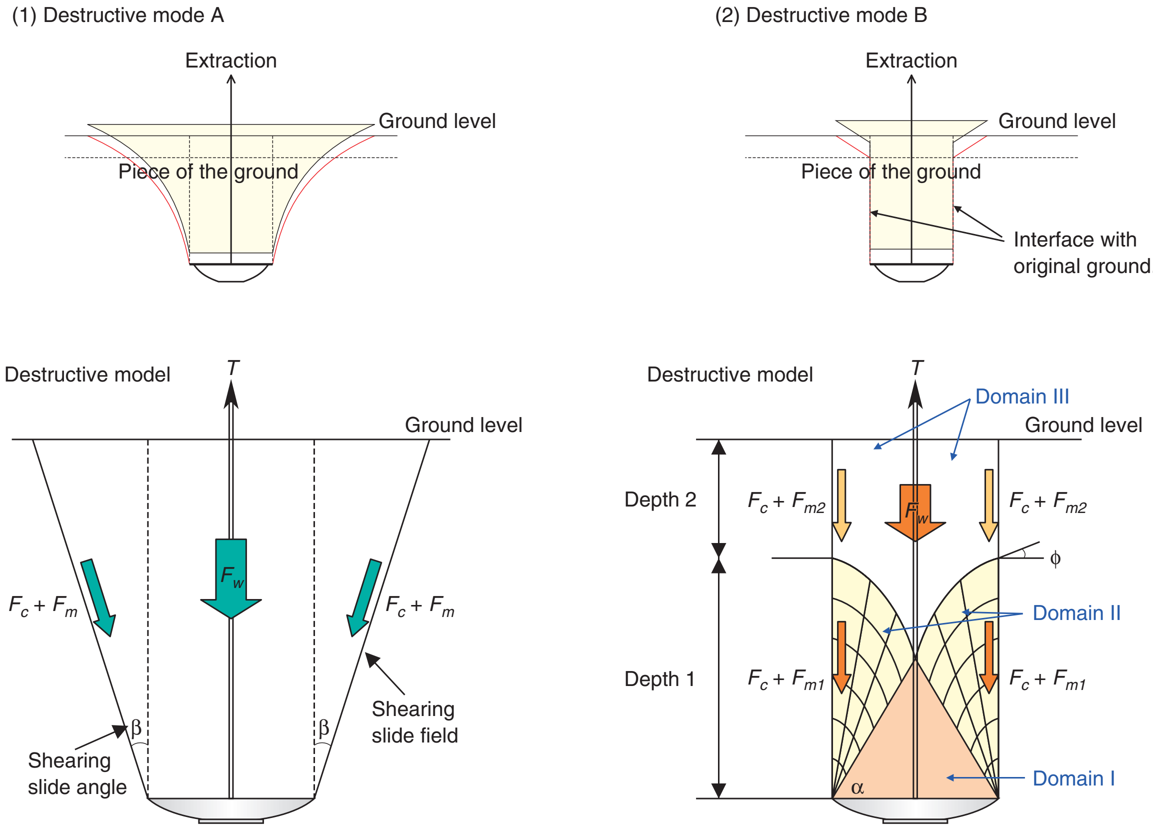


Fig. 4. Modes of destruction of ground holding the globe anchor.

emerged through the originally dug hole, so a cylindrical section of earth with a small volume was obtained.

4.2 Bearing capacity in destructive mode B

Here, we describe destructive mode B, which is equivalent to the case where installation is performed using a post hole digger. As the bearing capacity formula for destructive mode A is known, we initially assumed that the formula for mode B was the same and checked how well the experimentally measured values compared with the theoretically calculated ones. The bearing capacity for destructive mode A is

$$T = F_w + F_c + F_m,$$

where T is the bearing capacity, F_w is the force corresponding to the weight of the ground holding the anchor in place, F_c is the adhesive force related to the shearing field, and F_m is the friction force related to the shearing field.

4.2.1 Tentative formula for bearing capacity of a hard foundation

In destructive mode B, the element that constitutes the bearing capacity is also considered to be the weight of the piece of ground and the resistance related to the shearing field (the standard measure of destruction in the Coulomb mechanism), the same as in destructive mode A. Here, F_w is the force corresponding to the weight of the piece of ground pulled up when the anchor foundation is destroyed by excessive tension in the guy wire. The adhesive strength (F_c), which is related to the shearing field, depends on the ground classification and the shearing field area as the total adhesive force in relation to the ground level of the foundation destruction model. Therefore, the difference in the bearing capacity of destructive modes A and B can be said to depend on the difference in friction force (F_m), which is related to the shearing field.

The relationship between the friction force (F_m) and the shearing field is generally expressed as

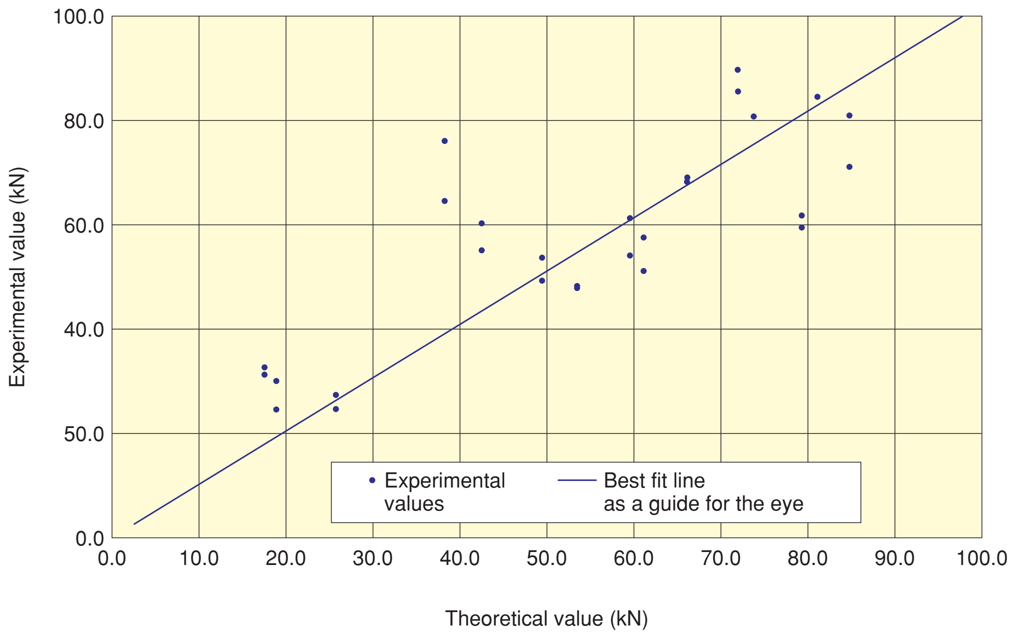


Fig. 5. Comparison of theoretical and experimental values.

F_m = drag f × frictional resistance of the ground.

Since the frictional resistance of the ground is determined by the ground classification, we used Rankine's earth pressure theory taking into consideration the influence of drag f. If the tensile force in the direction of the rod is applied to a globe anchor, the wedge-shaped resistance object (domain I) defined by angle α will be formed by the ground above the anchor's resistance plate in Fig. 4(b). This wedge will press the plastic domain of rediation shape (domain II) and the force pressing the walls of the hole outwards will be generated in domain II. Moreover, domain II is influenced by the earth pressure from the surface, which is generated by a large drag (friction force F_{m1}) in terms of the earth pressure in Rankine's plastic balance state.

Furthermore, in upper domain III, on which domain II does not act, a drag (friction force F_{m2}) is generated on the digging side by the earth pressure exerted from the surface.

On the basis of the above discussion, the bearing capacity formula of a globe anchor in a hard foundation was taken to be

$$T = F_w + F_c + F_{m1} + F_{m2}$$

F_{m1}: direct stress caused by passive earth pressure × frictional resistance of ground

F_{m2}: direct stress caused by earth pressure from surface × frictional resistance of ground

4.2.2 Theoretical and experimental values for the hard foundation bearing capacity

The anchor extraction experiment showed that the theoretical and experimental results were in fairly good agreement. Thus, we believe that the globe anchor bearing capacity formula that we used for hard foundations is valid. As an example, comparison data for hard sandy soil (Kimitsu city, Chiba) is shown in **Fig. 5**.

4.3 Confirmation of bearing capacity for hard foundations

The required bearing capacities of the globe anchor and globe anchor L are 57 and 114 kN, respectively. For various hard foundations, we confirmed that these capacities could be achieved by using an underground installation depth of 1.5 m and a guy angle range of 25 to 45°, as shown in **Fig. 6**.

Moreover, in terms of commercial introduction, we expect this approach to be additionally applied to ground with a new ground quality classification. Since our approach is applicable to ground with a higher N value, we added a new ground quality classification AA above the existing category A in the ground quality classification list (**Table 1**) for use upon commercial introduction of the new anchors.

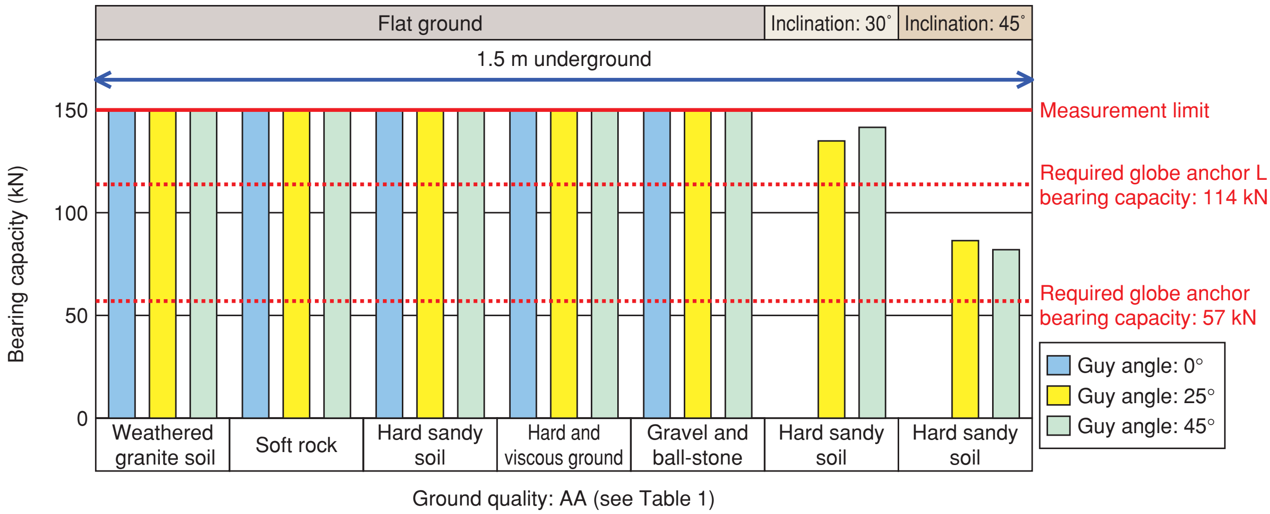


Fig. 6. Bearing capacity in a hard foundation.

Table 1. New ground quality classification.

Judgment of ground quality				Ground quality classification		Typical type of land
Hard sandy soil	*N value	Viscous ground	*N value			
A survey stake cannot be driven in even with powerful hammer blows.	50 or more	Thumb cannot dent surface.	15 or more	AA	Very hard ground	Road, natural ground, etc.
A survey stake can be driven in, but only with powerful hammer blows.	30-50	Dented by thumb, but not penetrated	8-15	A	Very hard ground	Road, natural ground, etc.
A survey stake can be easily driven in with a hammer.	10-30	Penetrated by thumb when pressed strongly	4-8	B	Ordinary ground	Housing site, field, site of the road side, etc.
A survey stake can be driven in with both hands.	4-10	Penetrated easily by thumb	2-4	C	Comparatively soft ground	Paddy field, seashore, dry riverbed (sand), etc.
A survey stake can be driven in with one hand.	4 or less	Penetrated easily by fist	2 or less	D	Very soft ground	Rice field of peat (except for Fukada and Numata) etc.

*N value: an index of the strength or stiffness of soil obtained by a standard penetration test

5. Conclusion

In contrast to the conventional guy anchors, which require a great amount of time and labor for construction in a hard foundation, our new guy anchors—the globe anchor and globe anchor L—enable easy mechanized installation while providing high bearing capacities. We are continuing to work to improve their characteristics.

Reference

[1] "NTT Group's Medium-term Management Strategy," NTT Technical Review, pp. 38-44, Vol. 3, No. 2, 2005.

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