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New Raft Foundation Method (TNF Method) for Soft Ground

1. Background of Technical Development

In Japan or Asian countries, first-story or second-story buildings are being built on farmlands. Especially, several areas of river delta regions are located in Southeast Asian countries. There are soft ground and structurally weak, as these are typically unsuitable for buildings on soft ground. In these cases, raft foundation is considered to be effective, but uneven settlement and other damages become a problem. Therefore, we propose TNF (Tender Net Foundation) construction method. The proposed method is a simplified ground improvement of raft foundation with curb pattern structure of a combined unit of the improved ground and foundation. The combined unit is stable and can support to building's load. After that, it can restrain to uneven settlement and lifting of the building.

2. Technical Characteristics of TNF Method

The TNF method is different from pile foundation method or raft foundation method. As mentioned above, it is a foundation system to support the low structure on soft ground using both the raft foundation and shallow soil improvement mass constructed directly under the raft foundation. The image of this method is shown in Fig.1-1 and Fig.1-2. According to the Fig. 1-1, first improvement means improved ground as curb pattern at the deep position. It includes enclosure soil unimproved ground parts. The second improvement layer is constructed as entire surface improvement as a cover layer. And then, excavation for foundation with preparation mold of soil layer is included. The next step is foundation steel frame, slab concrete, and finally floor slab concrete is constructed.

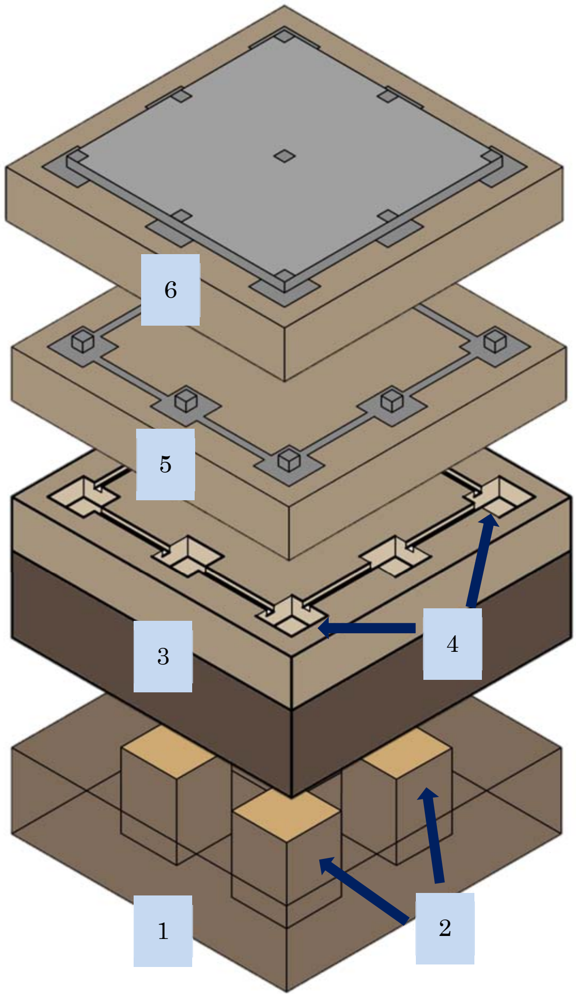

Fig. 1-1 Image of TNF Method

1: First Improvement
2: Enclosure Soil Improved Ground
3: Second Improvement
4: Excavation of Foundation
5: Steel Frame Foundation and Slab Concrete
6: Floor Steel Frame and Slab Concrete

A complete image of first improvement is shown in Fig. 1-2.

Fig. 1-2 Image of Shallow Improved Section

3. Benefits of TNF Method

The benefit points of TNF method are safety, relief, environmental friendly and low-cost. Safety is extremely important for a building, and safety buildings can secure in relief for people.

The advantages in safety and relief of this method are described as follows.

(1) TNF method is possible to prevent subsidence damage of the building.

(2) Unequal settlement of the building can be restrained.

(3) Lifting of foundation will be eliminated by using the TNF method.

(4) It is possible to prevent in liquefaction occurrence during an earthquake, because buildings are integrally responded due to entire improved ground. Even through liquefaction occurs, integrally resistance of entire improved ground.

By the above mentioned advantages, TNF method can support to durable and safety building.

TNF method is also an environmental friendly method including the following advantages.

(1) TNF method is a shallow improvement ground method; therefore it does not disturb both original underground condition and underground buried objects.

(2) This method can reduce CO_2 emissions because less running machine and using small amount of materials.

The most effectiveness of this method is low-cost as described in the following.

(1) This method is raft foundation and the shallow soil improvement mass constructed directly under the raft foundation. According to this structure, foundation beams exist in the raft foundation with unifying of foundation slab and improvement layer.

(2) It is constructed in improvement of current situation of ground.

(3) It is short construction period.

According to above, this method is named as Tender Net Foundation.

4. Achievements of TNF Method in Japan

TNF method has already certified a patented technical system in Japan. It has been already applied to supermarkets, factories, warehouses and etc., all over the Japan and it is gradually increasing every year in history until now. Total applied buildings of this method are 664 buildings (1,664,339 m^2) at the end of June 2016 as illustrated in Fig. 2-1 and Fig. 2-2.

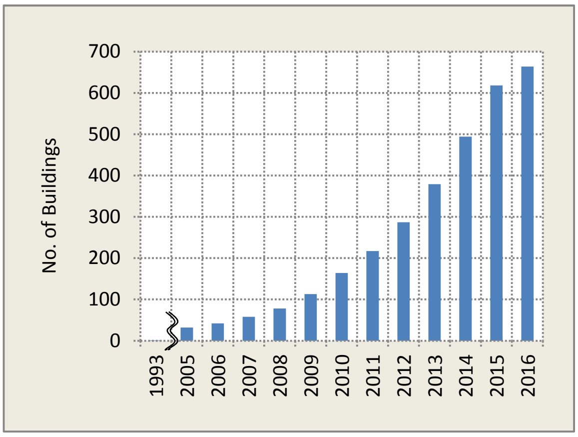

Fig. 2-1 Total number of TNF-based buildings
(At the end of June 2016)

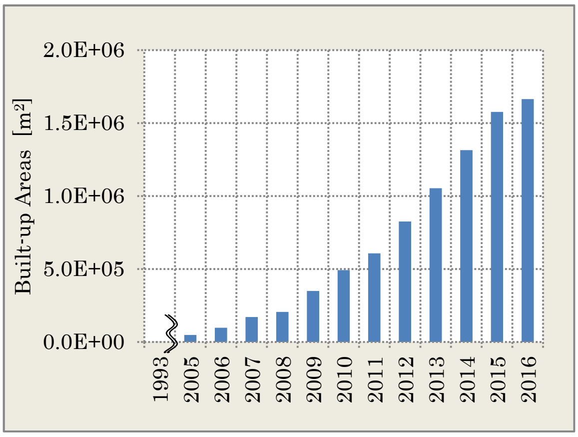

Fig. 2-2 Build-up areas of TNF-based Buildings
(At the end of June 2016)

Fig. 3-1 TNF-based Hardware Store
(Recorded Date: 17th March 2011)

The TNF method is widely applied after happening of the great east Japan earthquake in 2011 because almost TNF based buildings could not be affected by the earthquake. TNF- based building and conventional-based building conditions are compared in the following figures. According to our records, TNF-based building didn't occurred in unequally subsidence as described in Fig. 3-1. On the other hand, conventional-based building had wavy asphalt according to Fig. 3-2.

Fig. 3-2 Conventional-based building
(Recorded Date: 17th March 2011)

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Conservation and maintenance technologies offered by Kawasaki Geological Engineering

(Exploration, diagnosis and survey technologies for maintenance and management of roads, rivers, harbors and other social infrastructure)

1. Conservation and maintenance technologies of Kawasaki Geological Engineering

For more than 70 years since its inception in 1943, Kawasaki Geological Engineering Co., Ltd ("KGE") has provided information on the ground necessary for the construction and improvement of social infrastructure to be built as a group of specialists in the field of geological survey, building on their expertise in boring survey, geophysical exploration, and field measurement.

Meanwhile, facing the rapid aging of the infrastructure constructed for the high economic growth period in JAPAN, KGE found a field in which it could contribute as a geological consultant, created a conservation division, and has provided various technical services for exploration, diagnosis, and survey required for the maintenance of various infrastructure. This introduction presents a look at the specialized technologies in the field of conservation and maintenance KGE has to offer.

2. Vehicle towed multi-chirp radar exploration

Recently, there has been increasing demand for underground cavity investigation in order to prevent accidents caused by depression in roads, port facilities, river embankment, etc. In particular, some of the lifelines beneath the road surface are more than 40 years old since being laid, present advanced deterioration, and are one of the factors causing cavities. Since cavities are an invisible problem in the soil, geophysical exploration technologies capable of covering the underground linearly and in broad areas are required.

Among others, the ground penetrating radar exploration technology with excellent cavity detection ability and workability is applied in many cases. However, the ground beneath roads in Japan is mostly comprised of sand rich in fine-grained fractions, contains a high ratio of water, and hence attenuates radio wave significantly.

This limits the maximum detection depth of currently available ground penetrating radars to only 1.5 m under the ground and makes it impossible to detect all deteriorated life lines, which are laid at various depths going down to 4 to 5m. Therefore, to explore aging deterioration of the cavities, it has been necessary to carry out exploration periodically and repeatedly.

This problem has led to an increase in survey cost and collapses immediately after exploration, affecting both investigation cost and users' safety.

As one of the solutions, we have developed a vehicle-towed multi chirp radar, a ground penetrating radar for the exploration of deep cavities, capable of surveying down to the depths lifelines are buried.

[Characteristic of a Chirp-Radar]

A chirp radar is a radar that transmits electromagnetic sine waves into underground and compresses reflected signals into pulse waveforms. The radar transmits signals changing the frequency of sine waves according to desired bandwidth (frequency range of signals transmitted). In this case, the transmission output depends on the transmission time. Further, since the limit of resolution depends on the width of transmission frequencies, the radar can increase its transmission power without impairing its resolution ability, which has been difficult for conventional underground radars using conventional pulse waves.

Fig-1 shows the results of the comparison between a conventional radar and a chirp radar of exploration targeting iron pipes buried at different depths down to 3 m underground at 0.5 m intervals. While the conventional radar detected the iron pipes down to 2.0 m underground with semicircular waves, the chirp radar clearly detected all of the iron pipes down to

3 m underground.

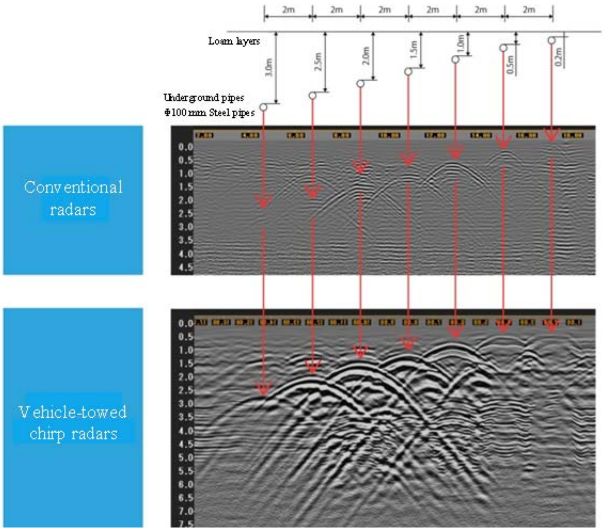

Fig. 1 Comparison of exploration ability between the conventional radar and a chirp radar

[Vehicle-towed Multi-Chirp Radar]

A vehicle-towed multi-chirp radar is an exploration device equipped with seven small antennas using chirp signals and a large antenna (Fig. 2). With transmission frequencies of 50 to 800 MHz, the seven small antennas are capable of exploring down to about 3 m underground while keeping high resolution equal to conventional radars. On the other hand, though using transmission frequencies of 50 to 300MHz and hence with resolution inferior to the small antennas, the large antenna is capable of exploring the underground even deeper, down to 4 to 5m.

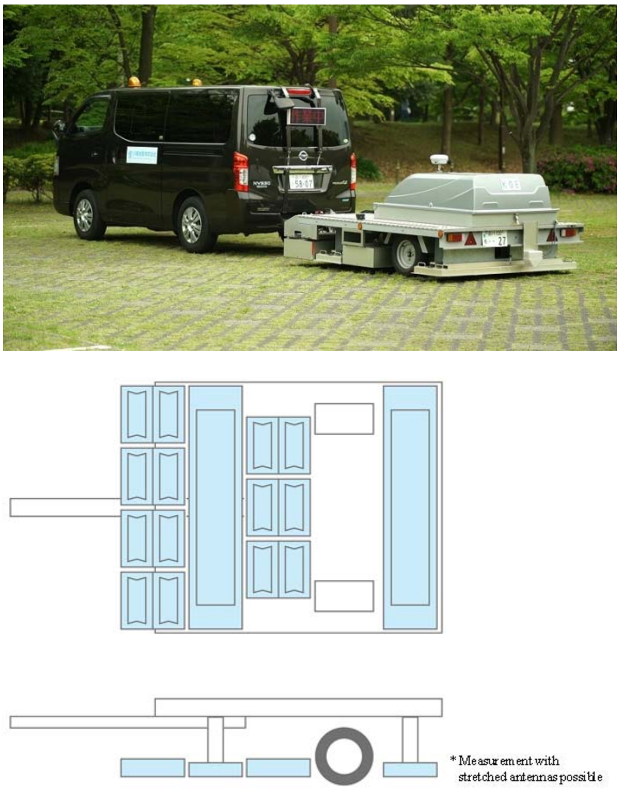

Fig. 2 Overview of the vehicle-towed multi-chirp radar

Towing the radar of a vehicle makes it possible to scan underground at a speed of 40 to 50km/h. In addition, the width of the radar being 2.5m (with the antennas stretched out), the whole single lane of the road can be scanned at a time.

Further, the radar features a drive camera that films front and side outside scenes in sync with the radar data and a VRS-GPS system capable of high-accuracy position management of abnormal points.

[Applications of vehicle-towed multi-chirp radars]

As shown in Fig. 3, vehicle-towed multi-chirp radars made it possible to explore underground cavities deeper than 1.5 m that has been difficult for conventional radars. Hence, we think it is possible to use these radars not only for the exploration of shallow hollow cavities under public roads, service roads along river embankments, or under harbor quay aprons, but also for the exploration of cavities or ground structures at a variety of underground depths. Hence, they will be very useful in detecting cavities in their early development, estimating their causes, and developing effective maintenance plans.

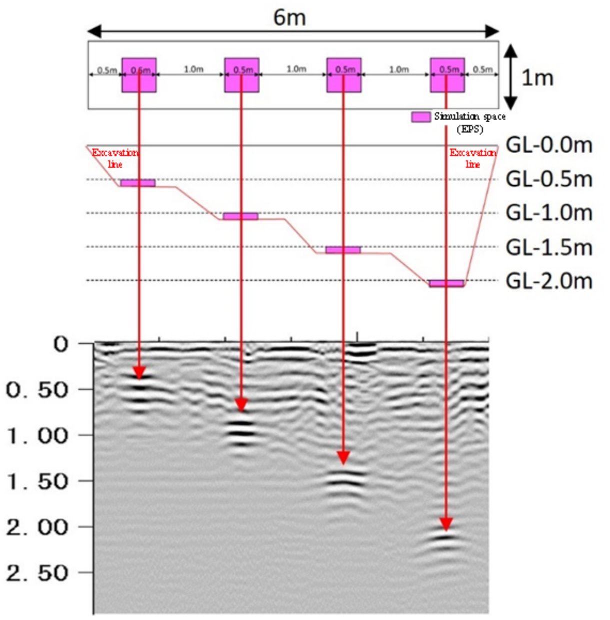

Fig. 3 Examples of cavities detected by chirp radars

3. Concrete diagnostic technology

The measurement of ultrasonic propagation velocity on core holes, on obtained cores, or on concrete surfaces, the measurement of intensity of obtained core samples, including small-diameter cores, and/or the improved on site pull-off method are typical survey or diagnosing methods to identify the depth of deterioration of concrete structures. However, in addition to having difficulty in quantitative evaluation, all of the above methods still have limitations (such as evaluation in the direction of depth in the structure being only the average over several centimeters) and have not yet been established as a research and diagnostic techniques of degradation depths. There has not been any method for surveying and diagnosing concrete structures capable of checking their physicality at desired depths of structures and identify the depth of deterioration.

That is an exact reason why we have developed GoTEN (partial loading test in boreholes), a new test method aimed at evaluating and diagnosing the deterioration depth of concrete structures.

[Overview of GoTEN]

The test apparatus of GoTEN is comprised of a cylindrical "body" of 40 mm in diameter and about 270 mm in length with a built-in displacement meter and hydraulic piston, a hemispherical “loading tip” of 6 mm in diameter to be inserted into a core hole drilled in the structure, and a “CCD camera" used to visually check the loading point (attached as necessary) (Photo 1).

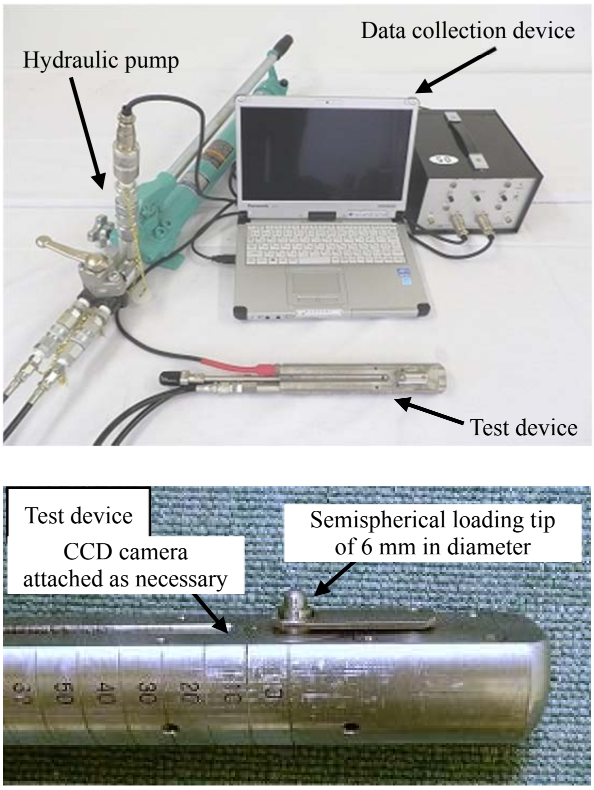

Photo-1 GoTEN

The procedure of measurement is as follows:
(i) Drill a core hole of 42 mm or more in diameter;
(ii) Insert the test device into the core hole;
(iii) Fix the test device at the measurement depth;
(iv) Pressurize the test device with a hydraulic pump and penetrate the loading tip into the hole wall;
(v) Collect data on the load and amount of penetration during the penetration into the hole wall; and
(vi) Turn the test device to change directions of measurement, and collect data on six or more points at the same depth.

The amounts of penetration and load obtained by measurement are expressed in a load-penetration curve and the "penetration resistance" is determined from the slope of this curve. Fig. 4 shows the method for calculating the value of penetration resistance. The penetration resistance value represents how the penetration of the loading tip into concrete is easy or difficult and is used as an indicator in estimating the strength of the concrete. As shown in Fig. 5, from the results of measurement of concrete test pieces in laboratory and actual structures, it has been found that we can estimate concrete strength by multiplying the penetration resistance by about 4.

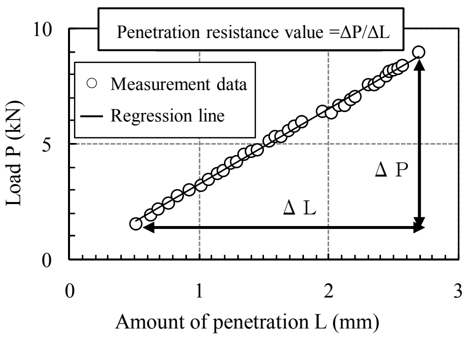

Fig. 4 Method for calculating the penetration resistance value

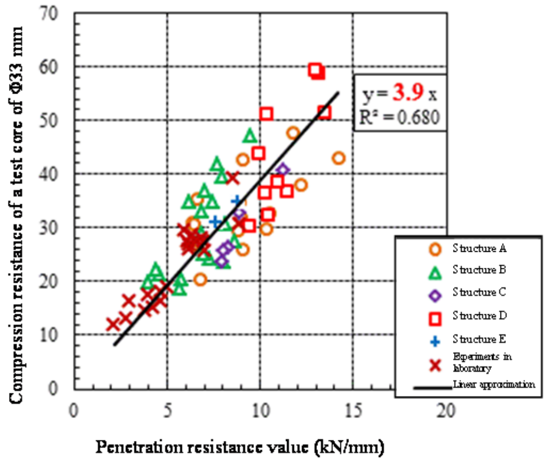

Fig. 5 Relationship between the penetration resistance value and the strength of concrete

4. Asset management of anchor slope

Ground anchors to stabilize soil structures have been widely used in slope stabilization work for natural or cut slopes for their workability and economic efficiency. To ensure safety of social activities, it is important that we can continue using these ground anchors installed everywhere effectively, safely for a long time.

However, it is said that all of anchors have not been adequately maintained up to date. One of the reason is the high testing cost due to the size and weight (100 to 200 kg) of the center hole jack for construction work commonly used. It is important to monitor the tension load of the anchor in the lift off test. It is we have developed an SAAM system aiming at mitigating, even slightly, the difficulties of the lift-off test necessary for anchor health survey.

[Characteristic of SAAM system]

SAAM system is a lift-off-only compact jack (Photo-1). The lift-off test consists in pulling up the anchor head with a jack and determining the residual tension load at the moment it lifts up. In practice it is possible to determine the residual tension by lifting the anchor head a few millimeters. Hence the SAAM system reduces the weight and size of the jack by adopting low-strokes (2 to 5 cm).

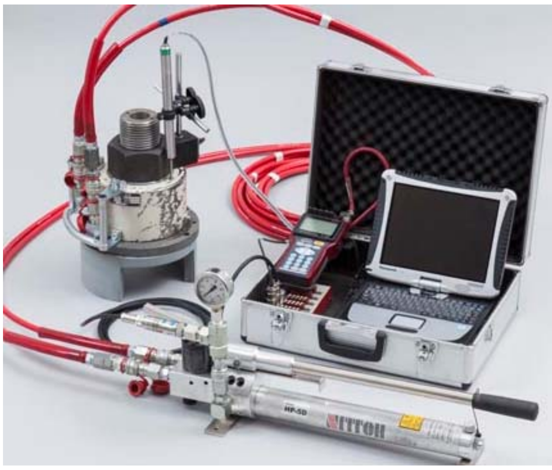

Photo 1 SAAM system

The current lineup of SAAM systems is as shown in Table-1. The commonly used system, SAAM-J II 20-82, is weighs of only 19 kg, and can be transported by persons, which makes it possible for surveyors carry out measurements by rope access on slope surfaces. In principle, use of rough terrain cranes, etc. for carrying in equipment or temporary scaffolding are not necessary (Photo 2).

Table 1 SAAM system line-up

SAAM Jack Types											
Specifications		J I-300	J II-600			J II-1000				J II-1500	J II-2000
Performance	Maximum pull force (kN)	300	**600**			1000				1500	2000
	Maximum stroke (mm)	10	20	**20**	50	20	10	50	20	20	20
	Center hole diameter (mm)	62	43	82		59	82		102	67	75
Lengths & weight	Maximum outer diameter (mm)	153	155	185	185	195	210	210	230	230	260
	Jack length (mm)	151	108	114	144	125	115	155	125	145	175
	Jack weight (kg)	14	15	**19**	23	25	25	32	30	40	63

Photo 2 Lift-off test by rope access

[Utilization of SAAM system]

By performing the lift-off test with a small and light-weight SAAM system, it is now possible to comprehend the residual tension of existing anchors more quickly and efficiently than the conventional testing method using large center hole jacks. This made it possible to provide distribution of residual tension land on broader areas (Fig. 6), while the number of survey had been carried out. Utilizing these residual tension force distribution charts on broad areas has made monitoring locations and range of necessary work more practical.

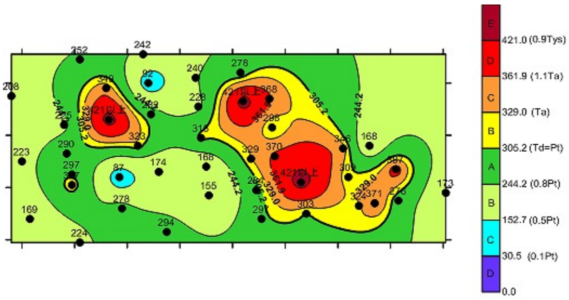

Fig. 6 Example of residual tension load distribution

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IDI has been publishing the free quarterly journal "IDI Quarterly" since1996 for the purpose of introducing information relating to public works and construction technologies developed in Japan to foreign countries. We have distributed the journal to administration officials in more than 90 countries around the world by e-mail.

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