The Techniques and Tools of Kazusabori Well-boring

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Abstract

The Kazusabori method of well-boring originated during the Bunka era years (1804 – 1818) of the Edo period in the area now called Kimitsu-gun, Chiba Prefecture. This method was used to bore a large number of flowing wells, which supplied water for the local community and farming. In the 25th year of the Meiji period (1892), Kazusabori was even utilized to develop oil wells in Niigata and Akita and was introduced outside of Japan (in India particularly) as the Kazusa System. It was the most advanced well-boring technique of the time in Japan.

Kazusabori well-boring is designated as an important cultural asset in Japan's List of Important Tangible Folk Cultural Properties (Occupations), and the tools associated with this method are archived at the Chiba Prefectural Kazusa Museum. However, few studies have been done on the development of and tools used for this technique.

In February 1981, the author had the opportunity to observe a reenactment of the Kazusabori method by a master borer working to keep the technique alive. The author utilized the occasion to conduct research on the technical details of the Kazusabori method, the tools used, and the history of its development.

As a result, much light was shed on the technical details of Kazusabori well-boring and the actual tools used in the process. Some questions still remain regarding the origin of this method and the use of clayey water. A document in FAO library indicates that Chinese Drilling bears a close resemblance to Kazusabori well-boring, and could provide clues for further research.

Introduction

Kazusabori, a well-boring technology developed in the area now called Kimitsu-gun, Chiba Prefecture, has contributed to construction of numerous flowing (artesian) wells for non-commercial and farming water supply, since its birth during the Bunka period (1804 - 1818) in the Edo era. In 1892, this method was employed even in oil well development in Niigata and Akita Prefectures. It was also introduced to the international community, to India in particular, as the Kazusa System. It was Japan’s most advanced well-boring technology of the time.

However, in the wake of the introduction of the rotary boring technology and the spread of waterworks, the Kazusabori method began losing its prevalence since the mid-1950s, and today, it is no longer used at all.

The Kazusabori technology is designated as an important folk-cultural asset, and the tools involved are kept in the Chiba Prefectural Kazusa Museum. Although Nagami (1948), Hishida (1955, 1960), and Hida (1973) studied its development and the tools, very few studies have been conducted so far on the technology itself.

In February 1981, the author had an opportunity of seeing reproduced Kazusabori processes demonstrated by Mr. Haruji Kondo (at Abe 12, Sodegaura-machi, Kimitsu-gun, Chiba), a well borer who inherited and passes on the Kazusabori technology. Making much of that opportunity, Hisahiro Ishiwatari (Rissho University) and the author carried out studies on the details of the technical aspects, tools and history of Kazusabori.

1. Geological Considerations on the History of Kazusabori

The Kazusa district occupies the central part of Chiba Prefecture, bordering on the Shimofusa district on the north, on Awa on the south, facing Tokyo Bay on the west and the Pacific Ocean on the east. In the southern area, a mountain range forms a border between Kazusa and Awa, from Mt. Kiyosumi (383 m) to Mt. Nokogiri (228 m). Having their headwaters in this area, the Yoro, Obitsu, Koito and Minato Rivers pour into the Tokyo Bay while the Ichinomiya and Isumi Rivers flow into the Pacific Ocean.

This district resides on the foundation of marine deposits that belong to the Mizuho series formed in the later Tertiary Era. Sedimentation continued from the Paleozoic Era through the Cenozoic Era. As a result of crustal movements at the end of the Mesozoic Era, the entire Kazusa district bulged. In particular, the area around the present district-bordering mountain range drastically bulged to emerge above the sea. Those movements formed the monoclinal structure that is sloping northwestward, as we see today. In the Quaternary Era, sedimentation of gravels, sand, and clay in the shallow-water zone to form the Narita group. Meanwhile, sedimentation and decomposition of volcanic ashes from activities of the volcanoes in the Kanto district formed a loam, which bulged due to the Kanto basin-forming movements. These movements along with development of alluvial formations of sand and clay produced the current topographic features of the Kazusa district.

Kimitsu-gun, the birthplace of Kazusabori, has a monoclinal structure that inclines northwestward. Presumably, its geological structure is founded around Mt. Kano (352 m). The aquifer resides in the Miura group formed in the Tertiary Era. As for the inclinations of these formations, the farther from Mt. Kano, the sharper the inclination becomes.

At Tawarada in Obitsumura located in the river basin of the Obitsu River, paddy cultivation was impossible since the shallow riverbed could not allow irrigation from the river, which caused this area to suffer a severe poverty level. However, once the pit well technology called Kazusabori was introduced to this area, the monoclinal structure allowed construction of flowing wells utilizing confined groundwater, enabling paddy cultivation to be carried out. This technology spread across the Kazusa district including the river basin of the Yoro River.

2. The Origin and Development of Kazusabori

1) The origin of Kazusabori

The literature on the origin of Kazusabori includes *The History of Kimitsu-gun* (1927). In that, there is a statement as follows: “A person named Hisazo Ikeda, a resident at Nukata, Nakamura, started a well-boring business around the year 14 of the Bunka Era (1817). It is unknown who conveyed the well-boring technique to him …” Supporting the fact, *The History of Well Boring*, kept at the Omiyaji temple located in the Nakamura area clearly indicates that a pit well was constructed on the premises of the Omiyaji temple in year 1 of the Bunsei Era (1818), in the following statement; "the Omiyaji temple completed a thrust-bored well, located at the end of Aza-Yarita, within the temple's enclosure that is neighboring Tsuneemon's property. Having shared the construction expenses, the parties shall share well water for drinking, and for irrigation in case the water supply from the well exceeds the parties' drinking water consumption. In that case, the parties shall use well water for farming once a day, on a day-to-day rotating basis, rain or shine."

The event that led to construction of pit wells in this area is introduced as follows; "According to an oral tradition in the Nakamura area, Nakamura is the cradle of Kazusabori, whose invention was stimulated by an incident in which a child playfully butted the ground with a bamboo stick, causing water to belch out." (Hishida, 1955). Probably, people in this area were empirically aware of the fact that confined groundwater existed in this area due to the monoclinal structure of the foundation. However, they did not have any established, structured well-boring technology. Although the pit well technology was established in Tokyo (then Edo) in year 2 of the Shotoku Era (1712), there is no evidence that the well-boring technology employed in Edo was transferred to Kazusa. As the Kazusabori technology resembles the excavating method used for well construction in the continent of China before World War II, it may have been conveyed from the continent.

2) Development of Kazusabori

Since year 14 of the Bunka Era (1817), when the pit well construction method was conveyed to the Kazusa district, the technology went through a number of improvements before it was perfected in the final form, which involves a *higo* unit, made of jointed split bamboo members, with an iron pipe attached at the bottom section, an up-and-down movement booster connected to the bamboo unit above the ground for driving boring operation, and a wheel called *higo-guruma* that raises the bamboo unit along with the iron pipe by rolling *higo* members up (see Fig. 1). The following section provides an overview of the development process of the boring technology inherited in the Kazusa district by roughly dividing the period into its development phase and establishment phase (see Table 1).

Table 1—Chronology of Kazusabori Technology

	Year in Imperial Era	Dominical Year	Event	
			Nakamura	Obitsumura
Development phase	Bunka14	1817	Hisazo Ikeda bored wells using the pit well technology that he learnt from an unknown person.	
Development phase	Bunsei1	1818	Thrust-bored wells were made at 13 locations including Omiyaji in Momiyama (for drinking/ farming water supply). Eight wells among these wells naturally discharged water at the surface (e.i., flowing wells).	
Development phase	Meiji12	1879		A well borer from Senju, Tokyo, delivered a pit well, to whom Yasunosuke Omura apprenticed himself.
Development phase	Meiji14	1881		Omura purchased gas pipes.
Development phase	Meiji15	1882	Tokuzo Ikeda tried the *Kashibo-tsuki* method.	Omura developed the *Kashibo-tsuki* method (a thrust boring method using oak rods).
Development phase	Meiji16	1883		Omura developed the *Higo-tsuki* method (a thrust boring method using split bamboo).
Establishment phase	Meiji19	1886	Minejiro Ishii developed *hanegi* (bow-type bamboo spring).	
Establishment phase	Meiji26	1893	Kinjiro Sawada developed *tsukigi* (wooden thrust rod). Kinjiro Sawada developed *higo-guruma* (bamboo wheel).	

Peak	Meiji29	1896	Kazusabori spread across the country.
	Meiji35	1902	Kazusabori was introduced into India as "Kazusa System."
	Showa16	1941	Mechanical boring technology was developed.
Decline phase	Showa25	1950	The number of well borers was reported to be decreasing.
	Showa44	1969	Haruji Kondo retired from work as a well borer.
	Showa55	1980	Haruji Kondo re-performed the manual boring procedure.
	Showa56	1981	Haruji Kondo re-performed the manual boring procedure.
	Showa57	1982	The Asia Well Development Association transferred the Kazusabori technology to Philippines.

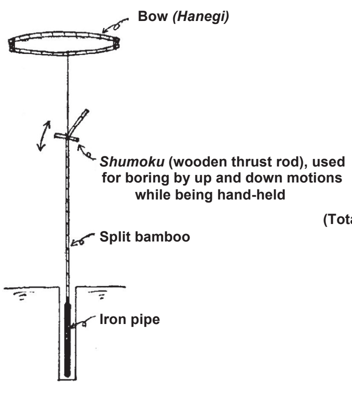


Fig.1 Kazusabori Schematic

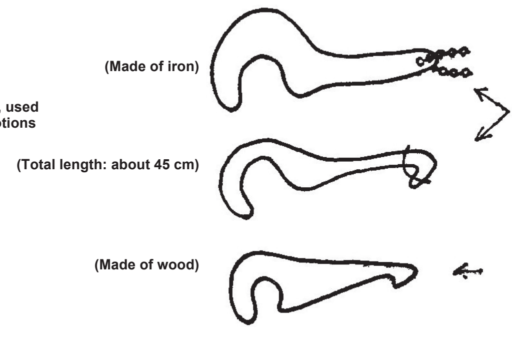


Fig.2 Vise (source: Nagami's literature)

The development phase is when improvements were made to extend the boring depth. As for the boring method, improvements were made for 66 years between year 14 of the Bunka Era (1817) through year 16 of the Meiji Era (1883), starting with use of metal rods for butting, to be replaced with oak rods, and ultimately, with split bamboos. Thus, the initial boring limit of around 50 m was thus extended to 500 m or more.

The boring method inherited in the Kazusa district was referred to as *Kanabo-tsuki* (thrust boring with metal rods) according to *The History of Kimitsu-gun* (1927), as in the following statement; "In those days (around 1817, annotated by the author), they used boring tools composed of metal rods equipped with herringbone/octagonal ball-shaped metal fixtures…" They used a vice, as shown in Fig. 2, to raise the entire boring unit and then dropped it to produce boring force. With this method, it was difficult to continue boring vertically, and the vibration generated when dropping caused breakage of the metal rods' joints. Another problem was the limitation of the boring depth that was dependent on the weight of metal rods used, which was 27–28 *ken* (about 50 m) long. Although it may be questionable if they could construct a well that could supply required amounts of water under this limitation of the boring depth, no improvement was made before the Meiji Era. In year 12 of the Meiji Era (1879), a well borer came to Obitsumura from Senju, Tokyo, who started well construction in that area, after which Kazusabori started evolving around the two development centers, Nakamura and Obitsu.

In year 15 of the Meiji Era (1882), Yasunosuke Omura, working in Obitsumura as an apprentice under the well borer from Tokyo, invented the *Kashibo-tsuki* method (a thrust boring method using oak rods) and, in the same year, Tokuzo Ikeda, a resident in Nakamura, also tried this method. With the *Kashibo-tsuki* method, they installed scaffolding like the one in Fig. 3. The iron ring fixed on an oak rod joint was hooked onto the lever rod to enable the oak rod to be raised when the lever rod was operated. Then this oak rod was dropped to butt the ground for boring. This method solved the problem with heavy metal rods previously used and made it possible to extend the boring depth up to 50–60 *ken* (about 100 m).

For placing cleaning tools into the wellhole to remove the muck, Omura used split bamboo members joined together. In the year 18 of the Meiji Era (1885), he invented a boring method reusing these split bamboos for boring by attaching 5 to 6 m-long iron rods, with a diameter of 3.5 cm, on the bamboo tip. This was the birth of the *Higo-tsuki* method (a thrust boring method using split bamboo). Meanwhile, Tokuzo Ikeda of Nakamura used joined iron pipes, rather than iron rods used by Omura, for boring, that were equipped with a bit called *sentanrin-sakurin-ichi* (ring-type chisel at the tip section). These improvements helped extend the boring depth limit to around 1,000 m.

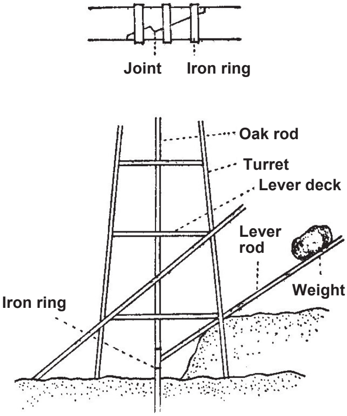
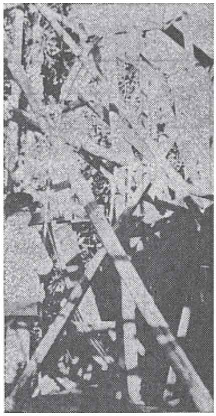


Fig.3 Kashibo-tsuki method – Oak Rod Joints and Scaffolding (Source: Nagami's literature)



Phot. 1 Higo-guruma (Bamboo wheel)

Phot. 2 Turret and Hanegi (Spring bars)

With these developments by year 19 of the Meiji Era (1886), the improvement of the boring depth achieved with the Kazusabori method was completed with the invention of the *Higo-tsuki* method. Thereafter, the focus of improvement effort was placed on innovation for streamlining the operation. This period forms the establishment phase. First, in 1886, Minejiro Ishii of Nakamura invented *hanegi* (bow-type bamboo spring).

When excavating by moving up and down a split bamboo device with an iron pipe on the tip section, the resilience of *hanegi* was utilized to reduce manual labor. Additionally, in year 26 of the Meiji Era (1893), Kinjiro Sawada invented *shumoku* (wooden thrust rod) and *higo-guruma* (bamboo wheel). The invention of *shumoku* enabled well borers to change the operating manner from manually moving the *higo* (split bamboo) unit up and down it to holding it with both hands at a right angle to it, which contributed to higher efficiency. With the invention of *higo-guruma*, the operating efficiency of raising iron pipes also improved as a well borer could enter the wheel unit to turn it in a manner like a pet mouse revolving a wheel in a cage. This invention of *higo-guruma* perfected the Kazusabor technology that had been rooted in the Kazusa district since year 14 of the Bunka Era (1817).

3) Mechanization of Kazusabori and its decline

Perfected in 1893 as a well-boring technology, as described above, Kazusabori was also applied to oil well boring in Niitsu, Niigata Prefecture, leading to the discovery of some oil fields. In year 29 of the Meiji Era (1896), it was transferred to Taiwan, Kyushu, and Hokkaido to be widely applied in coal mining and boring for hot springs.

Around year 16 of the Showa Era (1941), the previous manual boring was replaced with mechanical excavation using engines. This improvement enabled reduction of the *higo-guruma* diameter to half of the initial dimension (to about 2 m). The wheel was now operated using a belt to roll up split bamboo members. A crank was also introduced to convert the rotary movement into up-and-down movement to drive excavation. The development of this mechanical excavation technology enabled to reduce the manpower involved to just one borer for most of the entire well-boring process, from two to three borers previously required for boring, operating *higo-guruma*, and shifting.

In the third decade of the Showa Era (after the mid-1950s), with the introduction of the rotary boring technology, Kazuzabori gradually lost opportunities to be used even though it had spread throughout the country. According to an old document in Mr. Haruji Kondo's collection, well borers around the Yokota area where he lives, organized a union named Suijin-ko (water-god union, literally) and set out arrangements twice a year (on the 5th of February and the 5th of October) concerning well prices. The union had twelve members at the beginning of the Showa Era (around the mid-1920s), but continued to decrease after World War II. Mr. Kondo continued to work as a well borer despite the trend of decreases in the number of well-boring job opportunities and the number of well borers. In year 44 of the Showa Era (1969), when the order placements for wells dropped to about three per year, he ended his career as a well borer. That marked the end of Kazusabori as an active technology, after being used for nearly 150 years.

3. Major Tools Used in Kazusabori and Their Structures

The major tools used in Kazusabori can be roughly classified into two categories: boring tools and power transmission devices used by well borers on the ground.

1) Boring tools

Iron pipe
An iron pipe is a tool used for breaking into the bottom layer by butting for boring in the Kazusabori technology. The iron pipe is complete with *sakiwa* (tip chisel) and claws, as shown in Fig. 4.

Fig.4 Iron Pipe Schematic

Sakiwa is the very tool that breaks the bottom layer of soil, whose tip is made of steel. This tool can be considered to be the core device in Kazusabori. There are three types of *sakiwa* for different soil properties (Table 2).

Table 2—Types of Sakiwa

Name	Purpose
Nagawa (double-ring)	For general-purpose boring into layers of clay/sand or rock mass
Ichimonji (bar-shaped chisel)	For general-purpose boring into layers of sand or rock mass
Gravel thrust-boring bar	For boring into layers of gravel

Among these, the gravel thrust iron rod is an independent 6.3 m-long iron rod, to be used separately to break gravel layers, and not to be equipped on any other iron pipe tip.

Inside the assembly of *nagawa* and *ichimonji* chisel, a device called *koshita* (component at the lower section with valve) is installed, which is used to suck out the muck from boring, which floats in clayey water through the discharge port provided on the iron pipe at its upper section. *Koshita* has a valve fixed on a frame made of oak.

At the tip of the iron pipe and at the back of *sakiwa*, two projections called claws are provided. These projections are made of steel and assist boring with a long iron pipe by creating an extra clearance between the iron pipe and the bore so that friction may be controlled and the muck be prevented from being stuck between the pipe and the bore, which may cause problems.

The length and the diameter of the iron pipe section vary depending on the well diameter, special usage of the well, and other requirements specific to the well. At the upper section of the iron pipe, *kama* (tapered hook) is provided to enable the pipe to be joined with split bamboo members so that the iron pipe can be suspended from the section above the ground.

Suiko (suction pipe)
The muck from excavation is let float in clayey water that is constantly poured into the bore during boring operation to settle over time. *Suiko* cleans up the muck by sucking and discharging them out of the bore.

The *suiko* is a light-weight device made of galvanized sheets. For protection from breakage due to water pressure, claddings made of galvanized sheets are wrapped around the iron pipe at a certain interval, called *hotai* (literally, bandage). Like the iron pipe, a *Koshita* valve is provided at the lower section and a discharge port at the upper section (Fig. 5). The length and the diameter of *suiko* are determined based on those of the iron pipe, as classified in Table 3.

Fig.5 Suction Pipe Schematic

Operation using *suiko* is performed at the start and end of the day's operation, at every two to three meters of boring, or when boring operation has slowed down due to a massive amount of muck clogging the iron pipe when boring a layer of sand.

Table 3—Classification of Boring Tools

Iron pipes

Name	Diameter (cm)	Length (cm)	Weight (kg)	Claw (cm)	Remarks
Large iron pipe	7.5	630	28.0	4.5	
Iron pipe	4.5	900	28.0	3.0	
Hon (main) iron pipe	4.5	810	19.1	3.0	
Iron pipe	4.2	630	14.5	---	
Tateire (vertical setup) iron pipe	4.6	270	9.1	---	Used for starting boring
Uchizuki (inside thrusting) iron pipe	3.3	810	13.2	---	For boring inside vertical water duct (inner diameter: 4.8 cm)
Uchizuki (inside thrusting) iron pipe	2.7	540	6.2	---	For boring inside nested pipes (inner diameter: 3.3cm)
*Gravel thrust-boring bar	---	630	50.0	---	

* See the section describing *sakiwa*

Suiko (suction pipes)

Name	Diameter (cm)	Length (cm)	Weight (kg)	Claw (cm)	Remarks
Suiko	6.0	630	---		
Suiko	3.0	---	---		For cleaning inside vertical water duct
Suiko	2.7	---	---		For cleaning inside nested pipes
Suiko for cleaning	4.2	---	---		For cleaning inside completed wells

2) Power transmission devices

Higo (split bamboo)

Higo suspends the boring tools placed inside the wellhole and transmits the power for boring. Tapered hooks called *kama,* made of long-jointed bamboo stems, are provided as joints of *higo* members. To make a *kama* hook, a bamboo stem is shaved off, as shown in Fig. 6, in a width slightly less than 2 cm and cut in the length indicated in the figure, and the bamboo stem joints close to the cut end are utilized. With the joining method using *kama* (called *kama-tsugi*), two *kama* hooks are engaged and iron rings called *higo-wa* are installed from each end to completely fix the bamboo members with the tapered sections.

The depth already bored determines the length of the *higo* section. As explained in the "*Suiko*" section above, muck deposited inside the iron pipe might affect the boring efficiency due to an increase of the weight of the iron pipe. When that situation arises, the iron pipe is replaced with a *suiko* pipe to clean up inside the wellhole. One unit of boring depth is called one *sage*, which is about 1.8 m for manual boring. Each time boring is completed for a depth of one *sage, higo* is added to the existing *higo* section. Therefore, the unit length of *higo* members is also 1.8 m.

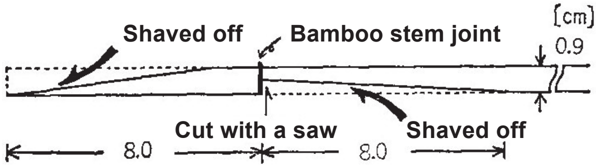


Fig.6 Preparation of Split Bamboo

As boring develops, additional *okkake-higo* (extension split bamboo) having that unit length is attached to the *higo*. As the joint is the weak point of *higo* that can lead to accidents if any joint is broken, *okkake-higo* is replaced with 5.4 m-long *hon-higo* (main split bamboo member) whenever three *okkake-higo* members have been added, reducing the number of junctions.

Kama hooks for engaging *higo* members are fabricated in symmetrical shapes at the ends for *okkake-higo* and *hon-higo*. This is an innovative idea with considerations given to the balance and strength of the bamboo members involved, allowing *higo* members to be joined using a *kama* hook with its thicker portion down and the back-side portion up. This way, when rolling up *higo* members around the *higo-guruma* wheel, the back of the bamboo stems face outward.

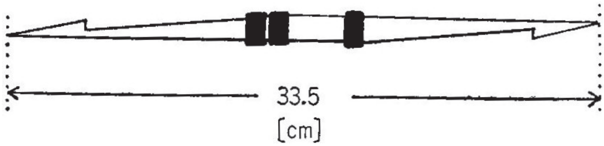


Fig.7 Kama (Tapered Hook) Made of Iron

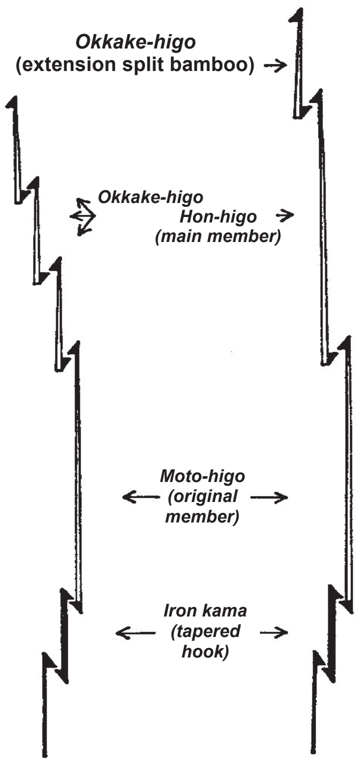


Fig.8 Higo Junctions

In addition to such arrangements, iron hooks (Fig. 7) are also employed to protect *higo* junctions from wear due to repeated operations to attach/detach to/from iron pipes or the *suiko* unit. The ends of this iron hook are made in the opposing orientation. To accommodate this design, one *higo* member called *moto-higo* (original split bamboo member) is used (Fig. 8) that is joined with a hook in the same orientation.

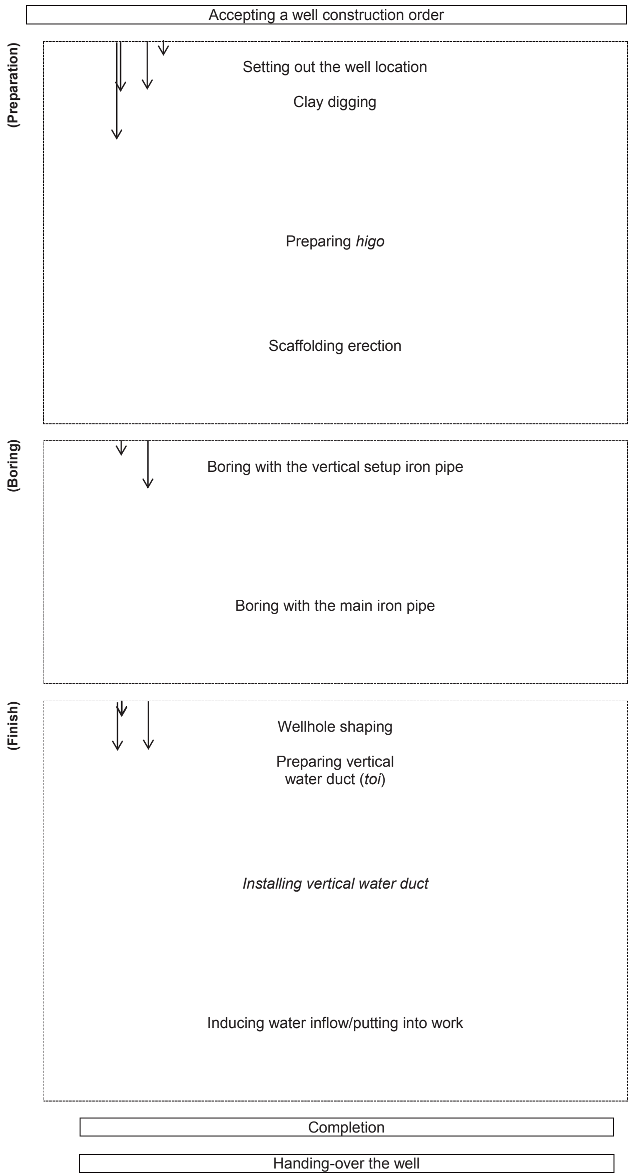
Hanegi (spring bars)
Hanegi is also referred to as *yumi* (bow). As shown in Fig. 1, it is connected to the *higo* unit that suspends an iron pipe with a rope. This power transmission unit utilizes the resilience of bamboo to drive up-and-down movements of the pipe for boring. Two long-jointed bamboo stems (with a diameter of 12 to 13 cm) are bound together with a straw rope, providing a certain distance between the connecting points, and mounted onto the uppermost section of the scaffold. The total length of the *hanegi* unit is about 5 to 6 m.

Shumoku (wooden thrust rod)
Shumoku is the section that the well borer holds to give thrust to the boring device. *Shumoku* units are made of oak, to the size of each borer's hand. It has a grove in the middle for fixing *higo* in place with a wedge. It is installed so that it comes just above the borer's knee when the iron pipe is driven down all the way. So the *shumoku* unit is moved downward as boring develops.

4. Boring Method in Kazusabori

This section summarizes the actual boring procedure used in Kazusabori, based on the manual boring performance reproduced by Mr. Haruji Kondo, an ex-well borer, demonstrated at the residence of Mr. Hiroshi Kamei, at Abe, Sodegaura-machi, Kimitsu-gun, Chiba Prefecture, along with the description of how the tools introduced in the previous chapter were actually used. Table 4 shows the flow of the processes.

Table 4—Flow of Kazusabori Processes



1) Scaffolding

In preparation for boring, a scaffold is set up that is unique to the Kazusabori method (Fig. 9). Logs with an average thickness at the bottom of 12 to 13 cm are used for the main members of the scaffold, with each node fixed with a rope.

First, three columns called *tateji* are erected in line, oriented in the east or south, at an interval appropriate for the diameter of the *higo-guruma* used. In parallel to them, another line of columns is installed 120 cm away from the original columns, on the opposite side of the wellhole position that is in between. Next, three rows of horizontal connection members called *yokonuno* are fixed in place with ropes for each line of *tateji* member.

The lowest *yokonuno* members are fixed at a level about 30 cm above the ground so that they can support a scaffold plate that functions as the working deck for boring operations. The middle *yokonuno* members are for supporting the *higo-guruma*, fixed at a level about 2.2 m above the ground, slightly higher than the radius of the *higo-guruma* wheel (2 m). Since this section takes the greatest load, particularly thick logs are used for this part. The uppermost members are for maintaining the scaffold's stability and for mounting the *hanegi* unit that is used for boring, and are fixed at a level about

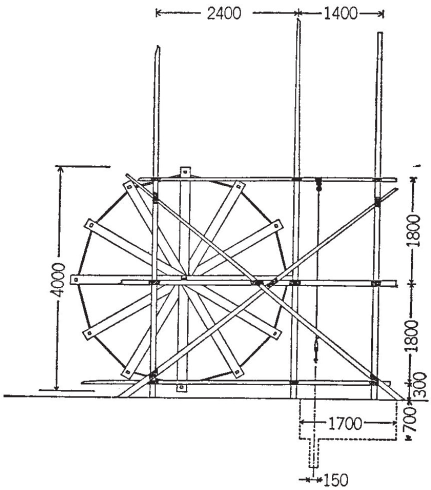


Fig.9 *Higo-guruma* (bamboo wheel) on the scaffolding

4 m above the ground.

At the position of the wellhole, a hole called *do-ana* is provided, whose approximate dimensions are 1.8 m in length, 0.8 m in width, and 0.7 m in depth. This *do-ana* contains clayey water for sucking up muck, protecting the wellhole wall from collapsing, and cooling bits used. As for the origin of clayey water used this way, no specific explanation is given in the related literature, except that it was already in use in year 12 of the Meiji Era (1879). As for the clay, black clay with relatively high viscosity was collected from around rice paddies in the area where well borers lived. It was mixed with water and the supernatant liquid was collected and stored in a barrel buried next to the scaffold.

2) Boring [1]

- Boring with tateire iron pipe (vertical setup pipe)

The first phase of boring is carried out by means of a *tateire* iron pipe of about 2.7 m in total length. A *sakiwa* is installed at the tip of the iron pipe, and *okkake-higo* (extension split bumboo) (2.7m) is joined with the *kama* (tapered hook) at the upper position. Then, this pipe assembly is made to stand *tateire* iron pipe in the *do-ana* in the wellhole.

The well borer installs the scaffold at the second stage of *yokonuno* to start the work. Boring is performed by vertical movement of the *higo* on which the iron pipe is suspended; the iron pipe end is made to hit the well bottom, to break ground. The *shumoku* serves as grip for this job. As shown in Fig. 10, the well borer sets it nearly at knee height, and holds it with both hands. The well borer continues the job, with the upper part of the *higo* put on the shoulder.

The muck generated by digging is made to float by the specific gravity of the clayey water, and it is discharged onto the ground through the outlet at the upper part of the pipe, by means of a *koshita* valve installed at the lower section of the iron pipe inside.

Along with the progress of the boring, the *shumoku* is displaced. When boring advances, with the whole of the pipe entered into ground, the work bench is moved to the 1st stage of *yokonuno*, and work is resumed.

When boring corresponding to one *okkake-higo* is completed, another *okkake-higo* is joined with the end of the *higo*.

Boring by the *tateire* iron pipe is carried out to the depth equal to the iron pipe length (2.7 m) plus two *okkake-higo* (2.7 m each), that is, 8.1 m.

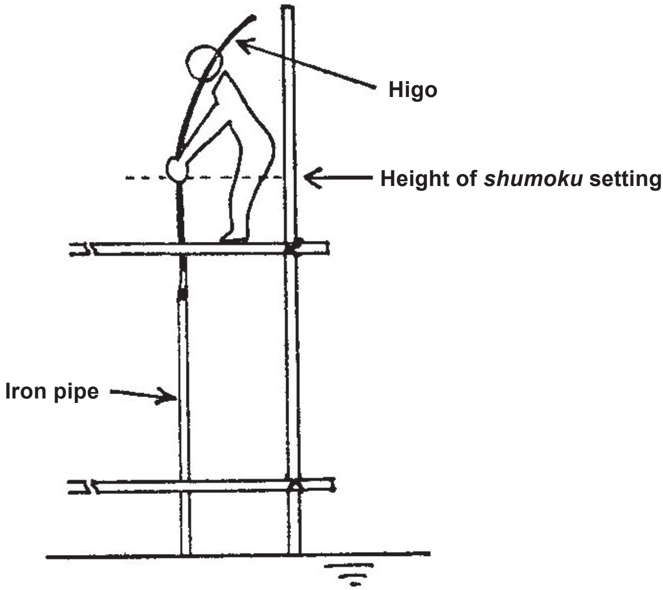


Fig.10 Sketch of boring with tateire iron pipe

3) Boring [2]

- Boring with a hon iron pipe

When ground is dug to a depth of 8.1 m, a *hon* (main) iron pipe whose total length is 8.1 m is used for well digging, instead of *tateire* iron pipe.

With the *hon* iron pipe that is heavier than *tateire* iron pipe, it is easier to break the wellhole bottom layer. However, the work efficiency becomes lower. To compensate, a rope is connected to the center of *hanegi* installed on the top of *yokonuno*, and the end of the rope is wound around the *shumoku*, to lift the iron pipe by utilizing the resilience of the bamboo.

The *hon* iron pipe is provided with two projections about 3 cm, called *tsume* (claws), at an interval of 180 degrees near the end (see IV 1) [Iron pipe], to prevent the work efficiency from lowering because of the friction between the iron pipe and wellhole wall. While vertical motions for boring are repeated 20 times, the claws alternately turn clockwise and counter-clockwise around the center line of the wellhole.

Boring is carried out at a rate of about 1.8 m per day. This job is continued, adding extension *higo*, while evaluating the nature of soil at the bottom by reactions transmitted to hands, and replacing *sakiwa*, until the target aquifer is reached.

4) Boring [3]

- Job with suiko (suction pipe)

Along with progress of boring, muck floating in the clayey water increases in amount, and begins to settle in the iron pipe and wellhole. Then, the iron pipe is lifted up by means of the *higo-guruma*, to be replaced with *suiko* to clean the wellhole.

The *suiko* is lowered into the wellhole, and moved vertically more than ten times, to suck the clayey water containing much muck in the bottom. Then, the *suiko* is lifted up, and moved vertically above ground to discharge the clayey water. This job is repeated several times. As a general rule, this job with the *suiko* is performed when ground is excavated about 2 to 3 m.

After cleaning the wellhole, the *suiko* is replaced with the iron pipe to resume boring.

5) Finishing process [1]

- Wellhole shaping

When boring reaches, through the clay layer, the sand layer, i.e., aquifer (called "*shikiba*" by well borers), which contains many shells, the well borer stops boring to proceed with the finishing process.

To smoothly insert the *toi* (vertical water duct) (see the next page), the wellhole is shaped. This job uses a hole shaping tool made of a cedar log around which nails are driven. The diameter of the *toi* is measured, and a margin is added to the measured diameter. Based on this dimension, the projecting length of the nails is adjusted so that the finished hole may have the desired diameter. Then, this tool is mounted at the tip of the *hon* iron pipe, and the *shumoku* (wooden thrust rod) is set as in the boring job, to shape the wellhole wall.

When the hole is shaped to the bottom, muck generated by shaping is removed by means of the *suiko*.

6) Finishing process [2]

- Placing toi (vertical water duct)

To prevent the wellhole from collapsing, a *toi* is inserted into the whole length of the wellhole (Fig. 11). The *toi* was initially made of *moso* bamboo (a species of bamboo of large diameter). Currently, PVC pipes are used. It is easy to connect *toi* of PVC pipes together, and also easy to make connected pipes straight. In contrast, with bamboo *toi*, rather difficult preparations are necessary, involving correction of bend, piercing nodes, and processing the jointed portion.

The bend of bamboo is corrected by warming its nodes of the bent portion over fire, and cooling down it to solidify. For allowing water to pass through the bamboo duct, its nodes are pierced by means of a rod about 1.2 m long with wavy projections. To connect the bamboos made straight, joints called

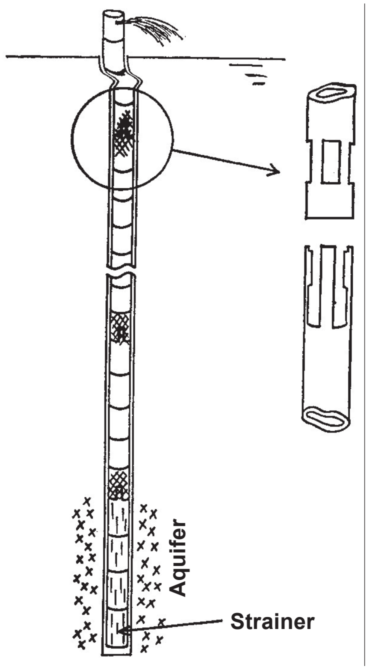


Fig.11 Toi (vertical water duct) and its joint

hane are provided.

After these preparations, four to eight water collecting ports, called *mado* (window), are made between nodes. These ports are designed to introduce groundwater contained in the aquifer into the *toi*. These ports are made in parallel with the bamboo fiber with a *tatebiki noko* (saw with teeth for cutting along the direction of grain). Except for flowing (artesian) wells, to prevent sand from entering through *mado* during pumping, two or three plies of palm barks are wound around the *mado*. The *toi* duct is introduced into the shaped wellhole, and their joints are wound with newspaper and palm barks to prevent intrusion of mud and sand. In the case of a flowing well, the *toi* is made to project about 50 cm on the surface, to provide a flowing port.

7) Finish process [3]

- *Mizuyobi* (inducing water inflow), *Ikashi* (putting into work)

During the jobs described above, groundwater springing is prevented by injecting clayey water of large specific gravity into the wellhole. At the final stage of well creation, the clayey water in the pit is discharged, and jobs for making groundwater spring start.

At first, *mizuyobi* (inducing water inflow) is carried out. For this purpose, a *suiko* thinner than the *suiko* for cleaning is lowered to the position of *mado*, which is lifted up about one meter per cycle. Generating zero water pressure at an instant, groundwater is made to flow into the well pit. This priming job is repeated several tens of times.

After priming, *ikashi* (putting into work) begins. This job is to pump up the clayey water in the wellhole to decrease the concentration of clayey water, thereby removing the clay sticking to the well wall, and making groundwater spring. Nowadays, a pump is used for this job, but once clayey water was pumped with the *suiko*.

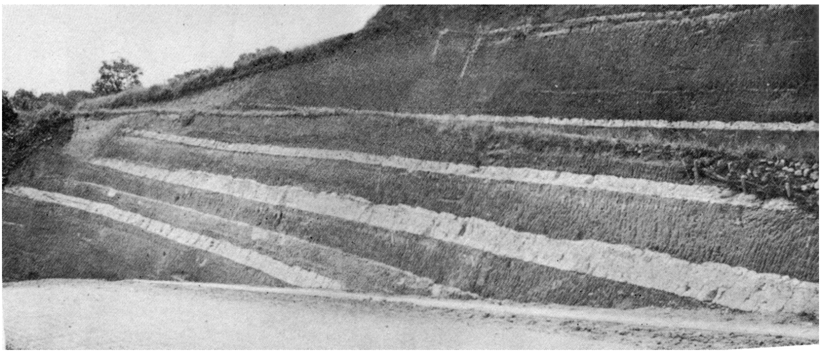
After *mizuyobi* and *ikashi,* the creation of a well by the Kazusabori is completed, and the well is handed over by the well borers to the client.

Conclusions

This study has overviewed the Kazusabori manual well-boring method, its tools and the history of its development. However, there are still some facts yet to be revealed, including the origins of the Kazusabori technique and of the use of clayey water. With regard to the technical origin among others, a document in the FAO library shows that Chinese Drilling bears a close resemblance. The investigation should be left to future studies.

Triggered by this restoration of the technology, a second restoring demonstration was carried out in the city of Kimitsu by Mr. Haruji Kondo and Mr. Aoto Morooka (cinematographist), and this technology was exported to the Philippines through the Asia Well Development Association. As seen by this fact, this well boring technology is being reevaluated in developing countries. (Accepted on September 16, 1982)

Those wishing to conduct an in-depth research on distribution of Kazusabori wells and their status of use are advised to refer to Hiroki Takamura (1973) "*Jifuntai no Kotai to Jifunryo*" (Recession of the area of artesian flow and the flowing volume) in Isamu Kayane (ed.) *Chikasui Shigen Kaihatsu to Hozen* (Development and Conservation of Groundwater Resources), Water Science Research Institute, in addition to the following references.



Phot. 3 The monoclinal structure of the stratum allowing artesian well development

Phot. 4 Artesian wells for residential use

Phot. 5 Simple kazusabori well-boring method

Phot. 6 Bits at the tips of Kazusabori well-boring tools

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