THE MAKING MUSICAL INSTRUMENTS WITH PRESTRESSING STEEL WIRE AND ULTRA HIGH STRENGTH FIBER REINFORCED CONCRETE

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***ABSTRACT*:** This paper presents a research about the making musical instruments with prestressing steel wire and ultra high strength reinforced concrete (UFRC). The strings, the harp, was made by using the UFRC to thin the material's thinness of the sound box and prestressing steel wires were used as strings. From the results of this research, it was possible to increase in the natural frequencies of the sound box by making concrete board using the UFRC. Moreover, when prestressing steel wires were applied as strings those were suitable to use thinner wires to consider to tones. It can be expected that corresponding to various sounds by obtaining natural frequencies of the material that matches the materials to the frequency of the any sound in the future.

KEYWORDS: musical instruments, ultra high strength fiber reinforced concrete, prestressing steel wire

1. INTRODUCTION

A concrete is one of the most important construction materials and the necessities of the social infrastructure maintenance. Production of cement that is the main material of concrete needs many resources and energy, and process of the production discharges carbon dioxide that is one of greenhouse gasses. Sometimes, environment and ecosystem of construction field are destructed, because many concrete structures are constructed and used facing the nature. Moreover, after use, the structure is abandoned as waste. Therefore, concrete is a material that cannot be separated from environmental problems such as the reductions of the carbon dioxide exhaust limitation, nature conservation and waste management.

In Japan, the eco-concrete, this is the ecological concrete, is proposed as the concrete that considers environmental problems. The eco-concrete is useful concrete for contribution to the load decrease to the global environment, aiming at harmony or symbiosis with the ecosystem, and the creation of pleasant surroundings. The eco-concrete is classified into environmentally mitigatable concrete and organism adaptable concrete.

It is necessary to satisfy the following three conditions to rank eco-concrete as an eco-material, this is an ecological material.

1) Frontier where human race's activity environment is expanded.
2) Environmental harmony that tries harmony with natural environment and human race's sphere of endeavors.
3) The amenity that gives living conditions richness in sphere of activity.

In this study to develop the new eco-concrete style that has a frontier as musical instrument, an environmental harmony as eco-concrete and an

amenity as relaxation. Our life is enclosed by various sounds like person's voice, music and noise, etc. When the concrete is used for the sound, the most is used to erase it such as the muffling walls or the interception walls. Uniting concrete and the sound was aimed by using concrete that has negative images like "It is cold" or "It is hard", in general. As a result, it was thought that the positive images could be given to concrete.

The main materials of making musical instruments are wood for the strings and the woodwind instruments or metal for the brass. The key of making musical instruments is the best thinness. Every instrument's body is adjusted to thin to have the acoustics and it is necessary to adjust thinness to be suitable for the vibration frequency of the audible sound. Therefore, the instrument's body was made aiming at thinning it as much as possible by using the ultra high strength fiber reinforced concrete (UFRC). The purpose of this paper is to make the strings named KOTO by using prestressing steel wire as strings that is one of the construction materials.

2. The making method of musical instrument by using ultra high strength fiber reinforced concrete

2.1 The choice of the instruments

The harp was selected referring to the cable-stayed bridge that was called a harp bridge from shape and beauty of externals. Photo 1 shows the concrete harp. This is the first instrument and did not sound compares with wood harp, because only sound board was made with UFRC and used nylon fibers as strings. For that reason the new style musical instrument the name of KOTO using the prestressing steel wire as strings, like Japanese koto was made.

2.2 Design of the musical instrument the name of KOTO

Fig.1 shows a design of the KOTO. The size of the sound box was 745x810x160mm, and 800x976x330mm including the anchoring device.

The sound box was made referring to the structure of the violin. String's vibrations were transmitted to all over the KOTO through bridges to the belly of the sound box, and the sound-post transmits vibrations from the belly to the back of the instrument. Sounds were able to be tuned easily to move bridge's positions. The sound came out through two sound holes like f-holes of violin.

Anchoring devices were designed to have strength more than prestressing force of 29400N. One steel wire was set up for one anchoring device.

Photo 1 The concrete harp

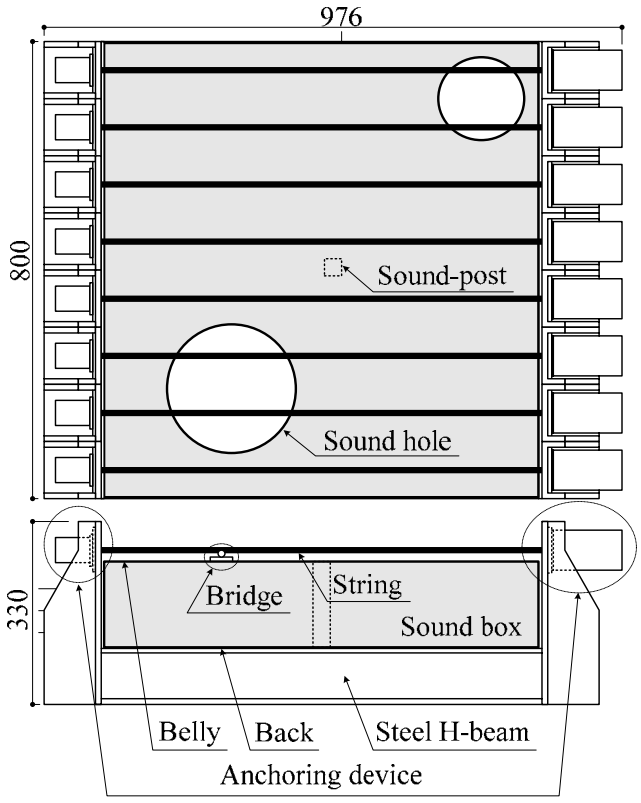

Fig.1 Design of KOTO

2.3 Materials

Table 1 shows materials for making KOTO. Sound box was made of UFRC. Prestressing steel wire 2.57mm and 5mm in diameter were used as strings. Anchoring devices were made by steel H-beams. Bridges were made by ebony.

In this study, UFRC was used to make thin part of the sound box. Table 2 shows materials of UFRC and Table 3 shows mix proportion of UFRC. The materials and mix proportion were based on the standard of Ductal.

2.4 The making process of musical instrument

The procedure for mixing UFRC is shown as follows.

(1) Ductal-premix, water and admixture was mixed in eight minutes at low speed.

(2) After a flow adjusted from 240mm to 270mm, steel fibers were added, and for two minutes mixed. The flow was measured based on JIS R 5201.

Table 1 Materials of for making KOTO

Materials	Properties
Sound box	Ultra high strength fiber reinforced concrete: UFRC
Strings	Prestressing steel wire of 2.57mm and 5mm in diameter
Anchoring devices	Steel H-beam
Bridges	Ebony

Table 2 Materials of UFRC

Materials (abbreviation)	Properties
UFRC premixed Steel fibers	Ductal-premix DP-200 Tensile strength: 2700N/mm^2 Diameter of fibers: 0.2mm, Length of fiber: 15mm
Admixture	Water reducing agent only for Ductal-premix

Table 3 Mix proportion of UFRC (kg/m^3)

Water	Premix	Steel fibers	Admixture *
180	2254	157	25

* Admixture was included to water

The sound box was made up with six UFRC boards. Thinness of each board was 5mm. The belly had two sound holes. Materials of board's forms were acrylic resin board and aluminum L-frames. The thin of acrylic resin board was 2mm and the height of aluminum L-frame was 5mm. Aluminum L-frames were stuck on the acrylic resin board with double-faced tape and the gap of the board and L-frames were closed by clay.

Photo 2 shows the UFRC mortar was poured in the form. So as not to capture entrapped air, the UFRC

mortar was poured in the form from one direction. To make no joint, the water was supplied to the surface of UFRC mortar by sprayer and the surface was covered with plastic sheet to protect the surface dry. Removal of forms was carried out on age of two-day. The curing of boards were heat curing of standard, steam curing at 90℃ 48-hour. After curing of boards a sound box was made up with epoxy resin glue.

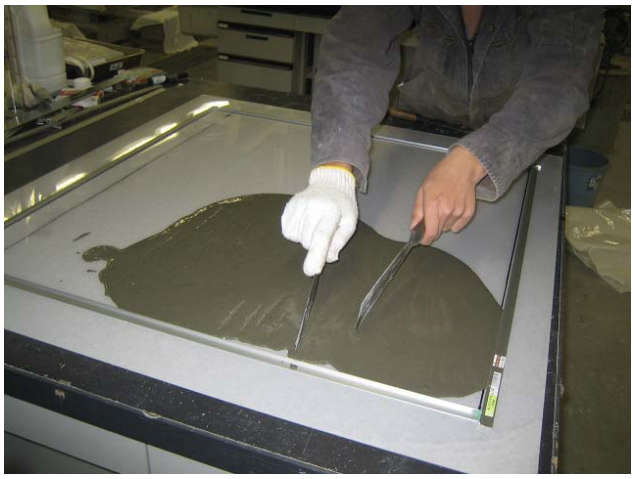

Photo 2 The UFRC mortar was poured in the form

2.5 Anchoring device of prestressing steel wire

Anchoring devices of prestressing steel wire were made with steel H-beam and anchoring devices were attached. The wire's prestressing force was adjusted with bolt. The wires of 5mm in diameter were used on lower sound from C3 to E3, and wires of 2.57mm in diameter were used on higher sounds from F3 to C4.

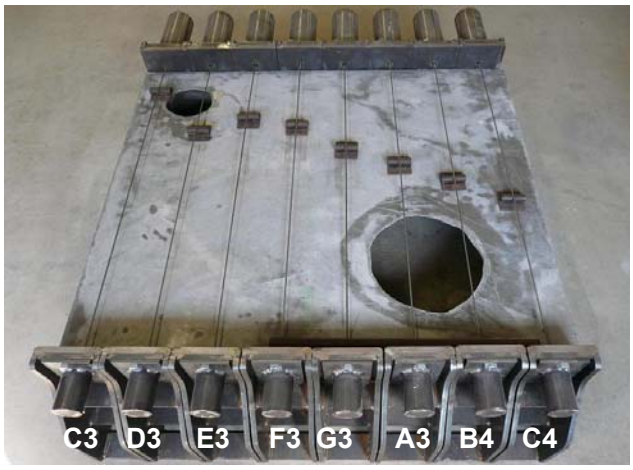

Photo 3 The KOTO

Prestressing force of each wire was designed to 11.8N/mm^2. The prestressing force was measured in terms of strain and the strain of a prestressing steel wire was measured with strain gauge. The strain of wires 2.57mm in diameter was 4000x10^{-6}, wires 5mm in diameter was 6000x10^{-}6. The music scale has been adjusted by the position of the bridge.

3. Evaluation of KOTO as musical instruments

3.1 Choice of prestressing steel wire's diameter

Photo 3 shows the complete KOTO. The KOTO of photo was tuned from C3 to C4. The KOTO emits the sound beating with the stick of ebony. The sound was not a tone and was not a comfortable sound, when the wire of 5mm in diameter was used. On the other hand, when the wire of 2.57mm in the diameter was used, the sound was a tone that was healthier and clearer than the wire of 5mm. As a result the prestressing steel wires of 2.57mm in the diameter were used for all strings. It showed more fine wire is better as strings of the strings.

3.2 Acoustic analysis: FFT analysis and microphone

The natural frequencies of the belly of the KOTO were analyzed by using the Fast Fourier Transform analyzer. The reaction from 300 to 400Hz vibration frequency was the largest though the natural frequency was not able to be specified because the structure was too complex to conclude the natural frequency of the KOTO.

On the other hand, from a result of the measurement the duration of the sound with the microphone, the duration of tones of F3 and G3 were the longest as

about 5 seconds. The vibration frequency of F3 is 347.7Hz and it of G3 is 391.1Hz. It is shown that the sound box made from UFRC can easily resonate to the compass from 300 to 400Hz. It is one of the factors for the sound-post set up in the center part of the sound box to complicate the vibration. Therefore, it is necessary to confirm whether to possess the function that the sound-post transmits the vibration from the belly to the back and to the entire musical instruments.

The characteristic frequencies of musical instruments can be raised to the level that to thin the constructional element. Therefore, the vibration of all the sounds can be amplified by assuming that the material thinness with the natural frequency corresponding to the frequency of each sound and the upgrade as musical instruments be expected.

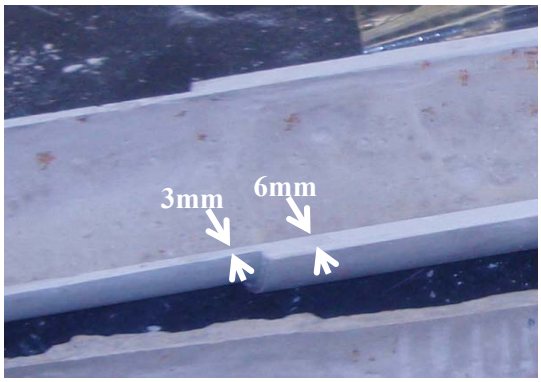

Photo 4 The parts of alphorn

4. The making various musical instrument

4.1 The wind instrument

It can be expected that it becomes possible to correspond to all the sounds by thinning the material in addition, and making the material with the natural frequency matched to the frequency of each sound in the future. The transmission route of the vibration becomes complex so that the strings may amplify the vibration of the string with the sound body and play the sound.

The strings amplifies the vibration of the string with the sound body and emits the sound, the transmission route of the vibration is complex. On the other hand, the winds vibrates air in the tube and is amplified the sound. Therefore, it is thought that the wind instrument is suitable to attempt upgrades


Photo 5 The alphorn made of UFRC

of musical instruments made of UFRC.

4.2 The Alphorn made by UFRC

The alphorn was made by UFRC as the wind instrument. Alphorn has cylinder tube expands straight, and the diameter of the blowing mouth is the 2cm and in the tip it becomes to 20cm. Photo 4 shows the parts of alphorn and Photo 5 shows the alphorn made of UFRC. From the experience of making the board of the thinness of 5mm at the time of making the KOTO, the main part of semicircle cylinders' thinness were 6mm and the joint were 3mm. The pair of the outside form and inside one had gap the width of 6mm or 3mm, and UFRC was placed into the gap. In the alphorn of UFRC, it was blowing person's impression to emit the sound to be emitted easily compared with the wooden alphorn.

5. Conclusions

5.1 Performance of concrete musical instruments

The following have been understood from making musical instruments that use the above-mentioned prestressing steel wire and the UFRC.

1) When the prestressing steel wire was applied as a bowstring, it is preferable to use a thinner steel wire for considering the tone.

2) It was possible to an increase in the characteristic frequency of a concrete board by making the sound box by using the UFRC.

5.2 Development of concrete musical instruments

Making a thin material becomes possible by developing the UFRC, and concrete coverage to anew field of musical instrument material is extending.

Making musical instruments with concrete is a total challenge of the technology. The formwork, the formwork removal, and the crack are controlled, and do not break even if it is thin, and a beautiful form in the streamline... The challenge starts because it makes the formwork according to the desire though shape as one's intention can be made in concrete as long as there is a formwork.

The enjoyment of performed anything, the enjoyment of creation music and the enjoyment of listening to music. Music is often said that it will exceed the border. There is power to unite the technology and other technology, the person and another person in concrete musical instruments. The appearance that concrete and the earth fuse thinks that it is by telling the enjoyment previously.

Making musical instruments only imitates the existing one now. However it is necessary to challenge to discover the appearances of musical instruments by which concrete wants to become it.