METHOD FOR INSPECTING INTERNAL CONCRETE CROSS-SECTION IN STRUCTURE HAVING AN OUTER LAYER

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method for inspecting a concrete structure. More particularly to inspect non-destructively an internal concrete cross-section in a structure having an outer layer.

2. Description of the Related Art

Conventionally known non-destructive inspection methods for concrete structures include visual inspection, inspection by infiltration, inspection by ultrasound, or inspection by measuring acoustic emission (hereinafter, called 'AE method'), and so forth.

Visual inspection is a method for inspecting whether or not there are any defects present in the surface of the concrete, using the naked eye. This method depends on the inspection range and the level of skill of the inspector, but it does enable relatively small surface defects to be detected.

Inspection by infiltration is a method whereby an infiltrating liquid is caused to permeate into defects present

in the surface of the object under investigation, by means of capillary action. Thereby turning the defects into an image which is readily seen and detected with the naked eye. This method includes fluorescent infiltration testing and dye-based defect investigation. In fluorescent infiltration testing, an infiltrating liquid containing fluorescent material is caused to permeate into defects in the object under inspection, and under ultraviolet light, the defects emit a yellow/green light and hence form an image which is readily seen and detected with the naked eye. On the other hand, in dye-based flaw investigation, an infiltrating liquid containing a red dye is used, and a red pattern indicating the defects is inspected.

Furthermore, inspection using ultrasound is a method whereby ultrasonic pulses are input to the object under inspection, and the qualities of the object under investigation, for instance, its strength, fracture status, and the like, are determined from the speed of the ultrasonic waves through the object, or from the amplification of the received ultrasonic waves.

Moreover, inspection by 'AE method' involves detecting the elastic waves (AE) generated when the object under inspection undergoes plastic deformation or breaks, and determining the fracture status of the object under inspection from the generation rate, amplitude, and the like, of these elastic waves.

Here, the visual inspection method and permeation inspection method described above are based on the premise that the concrete surface of the structure forming the object under inspection can be observed externally. In the ultrasonic inspection method, the ultrasonic wave transmitters and receivers are placed in direct contact with the concrete surface of the structure, in order to ensure that the ultrasonic pulses are input and received in a reliable fashion. In the AE inspection method also, it is necessary to place the AE sensors (vibration receptors) in direct contact with the concrete surface of the structure, in order that the elastic waves generated are detected in a reliable fashion.

In the case of a concrete structure having an outer layer whereby the concrete surface of the structure is covered by a layer of different material, (for instance, a concrete structure wherein a cylindrical concrete section is covered by a thermal insulation layer, such as urethane resin, glass fibre, or the like, the outer surface of which is further covered by a structural casing of concrete or steel, as in a device for turning sea water into fresh water,) then when inspecting the internally situated concrete section, the outer layer forms a barrier and naturally, it is impossible to use either visual inspection or a permeation inspection method. In a concrete structure having an outer layer of this kind, since vibration emitters and receptors cannot be placed on the concrete surface of the internal structure. Consequently it is

difficult to use an ultrasonic inspection method or AE inspection method as described above.

SUMMARY OF THE INVENTION

The object of the present invention is to provide an inspection method whereby the failure status, and the like, of an internal concrete section located internally in a structure having an outer layer provided on a concrete section, can be inspected readily in a non-destructive manner.

In order to achieve the aforementioned object, in the present invention, a plurality of wave guide rods are placed in a concrete structure having an outer layer on a concrete section. Such as that one end of each rod passes through said outer layer and is exposed externally, while the other end thereof is fixed hermetically into the internal concrete section forming the object under inspection. By attaching transmitters, receptors, or the like, to the ends of the wave guide rods exposed at the aforementioned outer layer, inspection based on both an ultrasound method and an AE method can be applied to the internal concrete section by means of the wave guide rods.

In other words, according to the present invention, the operations consist of inputting ultrasonic pulses to the internal concrete section and receiving the output ultrasonic pulses in an ultrasound method, and detecting elastic waves

generated when the internal concrete section undergoes plastic deformation or break down in an AE method. The procedure is carried out by means of a plurality of wave guide rods which pass through the outer layer and are fixed hermetically into the internal concrete section forming the object under inspection.

According to the present invention, it is possible to apply non-destructive inspection using an ultrasound method and AE method to a concrete structure having an outer layer formed on a concrete cross-section, in a manner that was not possible in the prior art. In this way, it is possible readily to ascertain the state of deterioration of an internal concrete section, which cannot be observed directly from outside.

In the present invention, referring to the prior art, in the inspection by ultrasound, an ultrasonic pulse is input into the concrete cross-section and the failure status of the concrete cross-section is determined from the wave velocity of the wave form obtained when transmitter and receiver are located and setting by a predetermined distance from the input position to output position. The status of the failure could also be determined from the amplitude of the received ultrasonic wave form and so forth. Besides this, the efficiency of the input or output of the ultrasonic waves by means of the aforementioned wave guide rods, in other words, the efficiency of the wave guide rods as sensors, can be

inspected by means of the aforementioned ultrasound method. Because in the present invention, it becomes necessary to inspect whether or not the wave guide rods are in an appropriate measuring state, since it is not possible to ascertain the state of contact point between the wave guide rods and the concrete structure directly from the outside.

The efficiency of the wave guide rods as sensors can be inspected by inputting and outputting an ultrasonic pulse using the aforementioned wave guide rods at a time where it is certain that the wave guide rods are in a state of hermetic contact with the internal concrete section under inspection. For instance, directly after manufacture, taking the maximum amplitude of the ultrasonic wave measured at this time as a reference value, and then comparing this reference value with the maximum amplitude value of the ultrasonic wave measured when a similar ultrasonic pulse is input and output at a later time.

Inspection by an AE method is carried out with the aim of ascertaining the state of fracturing of the aforementioned concrete cross-section under inspection, at an early stage, from the rate of generation, amplitude, and the like, of elastic waves generated in the aforementioned concrete section during plant handling, and the like, as detected by means of the aforementioned wave guide rods.

It is important that the aforementioned wave guide rods installed in a state of hermetic contact with the

aforementioned concrete section are made from a material which transmits the ultrasonic waves input to the concrete section or output from the concrete section, via the wave guide rods. Therefore, wave guide rods made from stainless steel, ceramic, or the like, which has an acoustic impedance similar to that of concrete, are used. Moreover, the shape of the wave guide rods is taken as a linear shape, in order that they can be made to penetrate through the outer layer in the shortest possible distance. In order to increase the contact surface area between the wave guide rods and the concrete section, desirably, wave guide rods having a truncated conical shape should be used.

Furthermore, the structure of the aforementioned wave guide rods which are installed in a state of hermetic contact with the internal concrete cross-section of the structure under inspection is such that a large contact surface area with the concrete section is obtained, without causing instability. Therefore, desirably, a structure is adopted wherein a projecting section is formed at the end of each wave guide rod and the end comprising the projecting section is embedded in the concrete section, or a nut of a similar material to the wave guide rod is embedded in the concrete section and a screw section formed on the outer circumference of the end portion of the wave guide rod is screwed into the aforementioned nut.

Moreover, if the outer layer covering the concrete section through which the aforementioned wave guide rods pass is made from a material which readily transmits ultrasonic waves, then a material having a low acoustic impedance, such as elastic rubber, or the like, is interposed between the wave guide rods and the aforementioned outer layer. This serves to prevent ultrasonic waves which are supposed to be input to the concrete section or output from the concrete section, via the wave guide rods, from being transmitted into the outer layer.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a horizontal sectional view of a device for turning sea water into fresh water;

Fig. 2 is a vertical sectional view of a device for turning sea water into fresh water;

Fig. 3 is a partial enlarged sectional view showing the arrangement configuration of wave guide rods in a cylindrical concrete structure;

Fig. 4 is a partial enlarged sectional view showing the state in which the wave guide rods pass through the outer layer;

Fig. 5 is a compositional diagram of inspection by ultrasound, using wave guide rods relating to the present invention;

Fig. 6 is a compositional diagram of inspection by AE method, using wave guide rods relating to the present invention;

Fig. 7 is a conceptual side view showing a steel-reinforced concrete test object and a method for applying load to the test object, used in Basic Test 1, which led to the discovery of the inspection method according to the present invention;

Fig. 8 - Fig. 11 are diagrams showing the results of Basic Test 1;

Fig. 12 is a diagram showing a method for finding the maximum amplitude value of a waveform;

Fig. 13 is a conceptual side view showing a steel-reinforced concrete test object having an outer layer used in Basic Test 2, which led to the discovery of the inspection method relating to the present invention;

Fig. 14 and Fig. 15 are diagrams illustrating the results of Basic Test 2;

Fig. 16 is a conceptual side view showing a steel-reinforced concrete test object having an outer layer used in Basic Test 3, whereby the inspection method relating to the concept of the present invention; and

Fig. 17 is a diagram showing the results of Basic Test 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Below, embodiments of the present invention are described in detail with reference to the drawings.

Firstly, Fig. 1 is a horizontal sectional view of a device (concrete structure) for turning sea water into fresh water, and Fig. 2 shows a vertical section of the structure.

The device 1 for turning sea water into fresh water have a three-layer structure composition: a cylindrical concrete section 2 of height 50m, with outer diameter 500 cm and inner diameter 460 cm, wherein a plurality of cylindrical concrete segments 2a having approximate thickness 200 mm. The outer diameter 500 cm and height 200cm are joined together in a vertical direction; a heat-insulating layer 3 made from glass fibre of thickness approximately 150 mm, which covers the outer surface of the aforementioned cylindrical concrete section 2; and a concrete structure casing 4 of thickness approximately 200 mm, which covers the outer surface of the heat-insulating layer 3.

During operation, the interior of this device 1 is filled with sea water of pH 2 - 3 at a temperature of 140°C and pressure of 2×10^5 Pa, and hence the operating environment is extremely harsh. Therefore, it is necessary to inspect the state of deterioration of the device, and in particular, the state of deterioration of the cylindrical concrete section 2 forming the innermost layer which is subjected directly to the

effects of temperature, pressure, and the like, at regular or irregular intervals.

The state of deterioration of the innermost cylindrical concrete section 2 is inspected by using a plurality of wave guide rods 5 which are inserted into the aforementioned cylindrical concrete section 2.

These wave guide rods 5 are solid rods made from stainless steel, which are approximately 20 mm in diameter and 40 cm in length. As illustrated in Fig. 1, eight of these wave guide rods 5 are inserted into the cylindrical concrete section 2 in a radial manner in the same horizontal plane, at 45° intervals. Groups of eight wave guide rods 5 are provided in a radial manner in the same horizontal plane in this manner, at intervals of approximately 200 cm in the vertical direction of the cylindrical concrete section 2, as illustrated in Fig. 2.

The disposition of the aforementioned wave guide rods 5 in the cylindrical concrete section 2 is as illustrated in Fig. 3. Namely, a stainless steel nut 6 made from the same material as the wave guide rods 5 is previously embedded in the cylindrical concrete section 2, and a screw section 7 formed in one end 5a of a wave guide rod 5 screws into the aforementioned nut 6.

The aforementioned wave guide rods 5 are installed in the cylindrical concrete section 2 in such a manner that they pass through the aforementioned heat-insulating layer 3 covering

the outer circumference of the cylindrical concrete section 2 and the concrete casing 4, whilst the other end 5b of each wave guide rod 5 is exposed at the surface of the device 1.

As illustrated in Fig. 4, an elastic rubber member 8 is provided between each wave guide rod 5 and the aforementioned concrete casing 4 through which it passes. This serves to prevent ultrasonic waves from being transmitted between the wave guide rods 5 and the concrete casing 4.

Next, a method for inspecting the state of deterioration of the aforementioned cylindrical concrete section 2, by using wave guide rods 5 installed in the cylindrical concrete section 2 as described above, will be explained.

Firstly, ultrasonic transmitters 10a and receivers 10b are placed in close contact with the end portions 5b of the wave guide rods 5, which are exposed at the surface of the device 1, in such a manner that they are not separated by any grease or other such material.

Similar members can be used for the ultrasonic transmitters 10a and receivers 10b. For example, for both the transmitters 10a and the receivers 10b, it is possible to use a piezoelectric sensor comprising a barium titanate, zirconate or lead titanate type piezoelectric element contained in a case. As illustrated in Fig. 5, the transmitters 10a are connected to an ultrasonic pulse generator and the receivers 10b are connected via a pre-amp to an ultrasonic measuring device.

Thereupon, an ultrasonic pulse is input from a transmitter 10a into the cylindrical concrete section 2, via one wave guide rod 5, and the ultrasonic waves transmitted through the cylindrical concrete section 2 are received by the receivers 10b, via the other wave guide rods 5 which are installed at prescribed intervals with respect to each other. By comparing the maximum amplitude of the ultrasonic wave thus received with the maximum amplitude of the ultrasonic wave measured by the same method directly after manufacture of the device 1, at a time when it is certain that each of the wave guide rods 5 is intimately fixed to the cylindrical concrete section 2 representing the object under inspection, it is possible to check the efficiency of each of the wave guide rod 5 sensors. Moreover, the state of deterioration, such as the fracture status, and the like, of the cylindrical concrete section 2 is determined from the velocity of the ultrasonic waves in the cylindrical concrete section 2, or the amplitude of the received ultrasonic waves, or the like, on the basis of similar criteria to those used in a standard ultrasonic inspection method.

Furthermore, when the device 1 is operating, AE sensors 10c (for which, piezoelectric sensors similar to the ultrasonic transmitters 10a and receivers 10b used in the ultrasound inspection method described above can be used) are positioned on the ends 5b of the aforementioned wave guide rods 5 which are exposed at the surface of the device 1. As

shown in Fig. 6, an AE measuring device is connected to the aforementioned AE sensor 10c, and elastic waves (AE) generated by the cylindrical concrete structure while the device 1 is operating are detected by the AE sensors 10c, via the wave guide rods 5. Thereupon, the occurrence of fractures in the cylindrical concrete section 2, the positions at which these fractures have occurred, and the like, is deduced from the rate of generation, amplitude, and the like, of the detected elastic waves, on the basis of similar criteria to those used in standard AE detection.

By applying the aforementioned inspection method to the device on a regular or irregular basis, it is possible to ascertain the state of deterioration of the internal cylindrical concrete section 2, which cannot be observed directly from the outside, and hence the device 1 can be operated in a properly functioning state.

The foregoing description related to an embodiment of the inspection method according to the present invention, but the invention is not limited to the composition described above. Various modifications and alterations are possible within the scope of the technical innovation of the present invention. The technical innovation being that, when inspecting an internal concrete section in a concrete structure having an outer layer, the operations of inputting ultrasonic pulses for an ultrasound inspection method into the concrete section, receiving the input ultrasonic pulses, and detecting the

elastic waves generated when the concrete section undergoes plastic deformation or decomposition by an AE method, are carried out by means of a plurality of wave guide rods installed in a tightly fitted state in the internal concrete section of the concrete structure under inspection.

For example, the cylindrical concrete section 2 that is the object of investigation in the aforementioned embodiment, and the device (concrete structure) 1 in which this cylindrical concrete section 2 is a constituent element, are simply intended as examples. Therefore the inspection method relating to the present invention may also be applied to a variety of concrete structures which cannot be inspected directly by the naked eye, or the like. For example, the internal concrete sections in the foundations of a structure, or in a nuclear power plant, or the like.

Moreover, the material, the shape, and so forth, of the wave guide rods 5 illustrated in the foregoing embodiment are simply examples. Therefore, provided that the material of the wave guide rods is a material having an acoustic impedance which approximates the acoustic impedance of the concrete section that is under inspection. For example, an acoustic impedance of 0.7×10^7 - 10×10^7 Pa s/m, then that of wave guide rods made from a material other than stainless steel, such as ceramic, aluminium, titanium, or the like. The shape of the wave guide rods is not limited to a rod shape. The wave guide rods which have a square cylindrical shape or a

truncated conical shape may also be used. With regard to the dimensions of the wave guide rods, desirably, the rods should have an end sections having a surface area which allows sensors to be positioned satisfactorily. The wave guide rods should be less than 1m in length, bearing in mind attenuation of the ultrasonic waves. Desirably, the intervals between the respective wave guide rods should be approximately 2 m.

In the foregoing embodiment, elastic rubber members 8 are positioned between the wave guide rods 5 and the outer layer (concrete structure casing 4) through which the wave guide rods 5 pass. But these members are not limited to elastic rubber members, and any material having a low acoustic impedance, for example, an acoustic impedance of 0.3×10^7 Pa s/m or less, may be used. Therefore, a member of styrene resin, acryl resin, or the like, may be used. If the outer layer through which the wave guide rods pass is made from a material having a low acoustic impedance, for example, a material having an acoustic impedance of 0.3×10^7 Pa s/m or less, then it is not necessary to provide an elastic rubber member, or the like, between the wave guide rods and the outer layer.

Next, a basic test through which the aforementioned inspection method relating to the present invention was discovered and is described as follow.

- Basic test 1 -

(Test under inspection)

Concrete having a slump of 4.5 cm was prepared using the material described below, under conditions of: water/cement ratio 49.8%; fine aggregate content 44.7%; dehydrating agent / cement ratio 0.25%.

Cement : Taiheiyo Cement Co. Ltd. Normal Portland cement

Fine aggregate : Aoume gravel

Coarse aggregate : Aoume rubble

Dehydrating agent : Pozorisu Bussan Co. Ltd. Pozorisu No.70

Water : Industrial water

The concrete prepared in this way was poured into a mould having dimensions of 125 × 200 × 2700 mm in which steel ribs of D13(SD295A) and D10 (SD295A) are positioned as illustrated in Fig. 7. Four stainless steel solid rods (wave guide rods) of diameter 20 mm and length 530 mm were installed at prescribed intervals in such a manner that the last 50 mm thereof were embedded in the concrete poured into the aforementioned mould. Thereupon, the concrete was allowed to mature in air for 28 days at 20°C, to form a steel reinforced concrete test object having dimensions of 125 × 200 × 2700 mm. Four wave guide rods ch1 - ch4 are fixed closely to the concrete.

As shown in the diagram, a notch with approximately 20 mm deep was provided in the centre of the lower edge of the

steel-reinforced concrete test object thus obtained, in order to control the position at which a fracture was generated.

(Method for applying load to test object)

The steel-reinforced concrete test object was subjected to a bending load by dual-line load application according to the loading steps listed below, using a fatigue test device (Shimazu Co. Ltd.: EHF-11D30-70L), as illustrated in Fig. 7.

Loading step 0 : Applied load 0 (test object : good condition)

Loading step 1 : Applied load 5.9 KN (test object : slight fracture generated)

Loading step 2 : Applied load 10.5 KN (test object : load equal to 1/3 of bending tolerance; fractures develop)

Loading step 3 : Applied load 20.9 KN (test object : load equal to 2/3 of bending tolerance; fractures develop significantly)

Loading step 4 : Applied load 31.4 KN (test object : breaks)

(Positioning of piezoelectric sensors on test object and measurement method)

Piezoelectric sensors (Japan Physical Acoustic Corporation : R6 sensors) were placed respectively on the ends of the wave guide rods ch1 – ch4 of the steel-reinforced concrete test object manufactured as described above. Such that they were not separated by grease, or the like. An ultrasonic pulse transmitter (Japan Physical Acoustic

Corporation : C-101-HV) was connected to the piezoelectric sensors positioned on the wave guide rod ch1 and measuring devices (Japan Physical Acoustic Corporation : MISTRAS) were connected respectively to the piezoelectric sensors positioned on the other wave guide rods ch2 – ch4. Thereupon, after applying each bending load according to the aforementioned load steps, a spike wave of 300V and rise time of 20 nsec was input to the steel-reinforced concrete test object by means of the wave guide rod ch1, and the input ultrasonic wave was received by the other wave guide rods ch2 – ch4. Then the velocity of the ultrasonic wave in the respectively steel-reinforce concrete test objects, and the maximum amplitude of the received ultrasonic waves were measured.

Moreover, all of the aforementioned piezoelectric sensors placed on the wave guide rods ch1 – ch4 were connected to a measuring device (Japan Physical Acoustic Corporation : MISTRAS). Elastic waves generated in the steel-reinforced concrete test object, while the bending load according to the first load step was being applied to the test object, were detected respectively by means of the wave guide rods ch1 – ch4.

(Test results)

The measurement data for the steel-reinforced concrete test object after loading step 0, as detected using the ultrasound method described above, was plotted on a logarithmic graph where the maximum amplitude of the

ultrasonic waves was represented on the vertical axis and the measurement position was represented on the horizontal axis. The corresponding results are shown in Fig. 8.

Furthermore, the measurement data for the respective steel-reinforced concrete test objects after the loading steps 0 – 4, as detected using the ultrasound method described above, was plotted on a graph where the speed of the ultrasonic waves was represented on the vertical axis and the loading step was represented on the horizontal axis. The corresponding results are shown in Fig. 9.

The measurement data for the respective steel-reinforced concrete test objects after the loading steps 0 – 4, as detected using the ultrasound method described above, was plotted on a graph. The maximum amplitude ratio (maximum amplitude measured respectively after loading step 1 – 4 + maximum amplitude measured after loading step 0 (good condition)) of the ultrasonic waves was represented on the vertical axis and the loading step was represented on the horizontal axis. The corresponding results are shown in Fig. 10.

The measurement data for the steel-reinforced concrete test object during application of the bending load according to loading step 1, as detected using the AE method described above, was plotted on a graph. The number of detected AE hits was represented on the vertical axis and the measurement

position was represented on the horizontal axis. The corresponding results are shown in Fig. 11.

The maximum amplitude of the aforementioned ultrasonic waves is illustrated in Fig. 12.

- Basic Test 2 -

(Test object)

A steel-reinforced concrete test object of dimensions 125 × 200 × 2700 mm, in which four wave guide rods ch1 — ch4 were fixed tightly, was prepared in a similar manner to Basic Test 1. Thereupon, a 250 mm thick glass fibre layer, and a separate 50 mm thick concrete slab made from the same concrete material, were placed on top of the aforementioned steel-reinforced concrete test object, as illustrated in Fig. 13, such that a load could be applied thereto. Holes of 30 mm diameter for inserting wave guide rods ch1 — ch4 were provided in the aforementioned concrete slab, and an elastic rubber material was introduced into these holes.

Similarly to Basic Test 1 described above, a notch with approximately 20 mm deep was provided in the centre of the lower edge of this steel-reinforced concrete test object having an outer layer, in order to control the fracture process zone.

(Testing method and test results)

The aforementioned steel-reinforced concrete test object having an outer layer was subjected to similar testing to that

in Basic Test 1 described above, thereby yielding measurement data based on an ultrasound method and an AE method.

The measurement data for the steel-reinforced concrete test object having an outer layer after the respective loading steps 0 — 4, as detected using the ultrasound method described above, was plotted on a graph. The speed of the ultrasonic waves was represented on the vertical axis and the loading step was represented on the horizontal axis. The results are shown in Fig. 14, which corresponds to Fig. 9 relating to Basic Test 1.

Furthermore, the measurement data for the steel-reinforced concrete test object having an outer layer during application of the bending load according to loading step 1, as detected using the AE method described above, was plotted on a graph where the number of detected AE hits was represented on the vertical axis and the measurement position was represented on the horizontal axis. The results are shown in Fig. 15, which corresponds to Fig. 11 relating to Basic Test 1.

- Basic Test 3 -

(Test object)

A steel-reinforced concrete test object of dimensions 125 × 200 × 2700 mm, in which four wave guide rods ch1 — ch4 were fixed tightly, was prepared in a similar manner to Basic Test 1. Thereupon, wave guide rod ch3 only was hit with a hammer, thereby causing it to assume a state where it was not in

hermetic contact with the steel-reinforced concrete test object. Next, similarly to Basic Test 2, a 250 mm thick glass fibre layer, and a separate 50 mm thick concrete slab made from the same concrete material, were placed on top of the aforementioned steel-reinforced concrete test object, in such a manner that a load could be applied formally. Holes of 30 mm diameter for inserting wave guide rods ch1 – ch4 were provided in the aforementioned concrete slab, and an elastic rubber material was introduced into the holes for inserting wave guide rod ch1 – ch3, while a mortar (cement : 1 , standard sand : 2 (weight ratio), water/cement ratio : 0.65) was introduced into the hole for inserting wave guide rod ch4.

Similarly to Basic Test 1 described above, a notch with approximately 20 mm deep was provided in the centre of the lower edge of this steel-reinforced concrete test object having an outer layer, in order to control the fracture process zone.

(Testing method and test results)

The aforementioned steel-reinforced concrete test object having an outer layer was subjected to similar testing to that in Basic Test 1 described above, thereby yielding measurement data based on an ultrasound method and an AE method.

The measurement data for the steel-reinforced concrete test object after loading step 0 and loading step 3, as detected using the ultrasound method described above, was plotted on a logarithmic graph. The maximum amplitude of the

ultrasonic waves was represented on the vertical axis and the measurement position was represented on the horizontal axis. The results are shown in Fig. 17, which corresponds to Fig. 8 relating to Basic Test 1.

- Summary of Basic Tests 1 — 3 -

The test results for Basic Test 1 clearly reveal that the operations of inputting ultrasonic pulses to a concrete structure for an ultrasound inspection method, receiving the input ultrasonic pulses, and detecting elastic waves generated when the concrete structure undergoes plastic deformation or break down, by an AE method, can be carried out efficiently by means of wave guide rods installed in the concrete structure under test in a state of hermetic contact.

The test results from Basic Test 2 reveal that even in the case of a concrete structure having an outer layer, inspection by an ultrasound method and inspection by an AE method can be carried out in a similar manner, by means of wave guide rods installed in a hermetic state in the concrete structure under test, which pass through the aforementioned outer layer.

Furthermore, the test results from Basic Test 3 reveal that the efficiency of the sensors on the wave guide rods can be judged from the maximum amplitude of the ultrasonic waves received via the aforementioned wave guide rods.

Industrial Applicability

The inspection method relating to the present invention described above can be applied to inspecting, in a non-destructive manner, devices wherein a different material layer is formed on a concrete structure in order to provide heat-shielding, protection, reinforcement, or the like, of the concrete structure, or internal concrete sections in concrete structures which cannot be inspected directly due to the presence of an outer layer.



What Is Claimed Is:

1. A method for inspecting an internal concrete section in a concrete structure having an outer layer, wherein a plurality of wave guide rods are installed in a concrete structure having an outer layer formed on a concrete section, in such a manner that one end of each wave guide rod passes through said outer layer and is exposed externally, while the other end is fixed hermetically into the internal concrete cross-section of the structure under inspection, and wherein, in an ultrasound inspection method, ultrasonic pulses are input to the internal concrete section and these input ultrasonic pulses are received as output, and in an AE inspection method, elastic waves generated when the concrete section undergoes plastic deformation or break down are detected, by means of the wave guide rods exposed at the aforementioned outer layer.

2. The method for inspecting an internal concrete section in a concrete structure having an outer layer according to claim 1, wherein the efficiency of said wave guide rods as sensors is determined from the maximum amplitude of the ultrasonic wave measured when an ultrasonic pulse is input to the internal concrete section and then outputting, by means of said wave guide rods.

3. The method for inspecting an internal concrete section in a concrete structure having an outer layer according to claim 1, wherein the acoustic impedance of the

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aforementioned wave guide rods is in the range of 0.7×10^7 – 10×10^7 Pa s/m.

4. The method for inspecting an internal concrete section in a concrete structure having an outer layer according to claim 1, wherein members having an acoustic impedance of 0.3×10^7 Pa s/m or less are interposed between said wave guide rods and the outer layer through which said wave guide rods pass.