A repair and strengthening system for a reinforced concrete structure has a ribbed steel plate, and a filler. The ribbed steel plate is disposed facing a strengthened area with a predetermined space therebetween. The strengthened area is an area to be strengthened in a structure surface that is a surface of a reinforced concrete structure. The filler is injected in the space between the structure surface and the ribbed steel plate. Ribs are formed on the ribbed steel plate by hot rolling. The ribs protrude from a steel-plate front face that is a side of the ribbed steel plate facing the structure surface.
REPAIR AND STRENGTHENING SYSTEM FOR REINFORCED CONCRETE STRUCTURE

TECHNICAL FIELD

[0001] The present invention relates to a repair and strengthening system for a reinforced concrete structure, in particular, a repair and strengthening system for a reinforced concrete structure which repairs or strengthens the reinforced concrete structure portion of civil engineering structures and architectural structures.

BACKGROUND ART

[0002] Hitherto, many civil engineering structures (such as beams, floor slabs, bent in landing piers, bridges, concrete lining of tunnels/shafts, box culverts, retaining walls, and caissons) and architectural structures (floor slabs, beams, and columns in large complex buildings or simple rooted and walled structures, chimneys, and silos) have been constructed in reinforced concrete.

[0003] Recent years have seen an increase in the number of strengthening works for strengthening existing reinforced concrete structures. These strengthening works are undertaken for purposes such as ensuring safety against powerful earthquakes under consideration such as the Great East Japan Earthquake and the Nankai Trough Earthquake, and ensuring safety against loads exceeding those originally envisioned at the time of construction due to increases in vehicle weight as well as widening or extension of roads.

[0004] Further, many reinforced concrete structures constructed in the past high growth era are now undergoing deterioration, giving rise to the need for repair and life extension works to extend the life of these structures.

[0005] As an efficient method to execute such repair and strengthening of reinforced concrete structures, a “steel-plate strengthening technique” has been used in related art. In this method, a steel plate is installed onto the surface of an existing reinforced concrete structure by using an anchor bolt or the like, a filler is injected into the space created between the surface of the reinforced concrete structure and the steel plate to integrate the reinforced concrete structure and the steel plate together, and repair and strengthening is performed in this state.

[0006] According to this method, the steel plate functions as formwork for injecting the filler, and also doubles as a steel reinforcement, thus cutting down the processes of rebar arrangement and formwork dismantling which are required for repair and strengthening. Because the work period can be shortened and cost can be reduced as a result, this method is used for many repair and strengthening works.

[0007] For the repair and strengthening effect of this method to be fully realized, it is necessary to ensure the reliability of the above-mentioned integration, and ensure that the force generated in the reinforced concrete structure is reliably transferred to the steel plate. For example, measures taken to this end include: carefully removing rust or dust on the surface of the steel plate to improve the adhesion between an adhesive filler and the steel plate; mounting a “shear connector” such as a stud bolt to the steel plate to improve transfer of force between a grout filler and the steel plate; and securing the steel plate in place with an anchor bolt anchored to the reinforced concrete structure, to directly transfer force to the steel plate (at this time, force is transferred by means of the shear acting on the anchor bolt).

[0008] Accordingly, a steel-plate bonding technique using an adhesive (epoxy) filler has been disclosed, which allows use of a plated steel plate with good corrosion resistance, and can simplify complicated pretreatment or coating process in comparison to related art (see, for example, Patent Literature 1).

[0009] Further, a seismic strengthening system for a reinforced concrete structure that uses a grout filler has been disclosed, which allows the steel plate to be easily attached to the concrete framework, and ensures that the grout spreads throughout the space between the concrete framework and the steel plate (see, for example, Patent Literature 2).

CITATION LIST

Patent Literature


SUMMARY OF INVENTION

Technical Problem

[0012] However, the invention (adhesive filler) described in Patent Literature 1 has the following problems.

[0013] (a) To protect the steel plate against corrosion by means of plating or coating, special treatment is required to make the roughness of its surface suitable for the bonding process.

[0014] (b) The condition (such as dust, dirt, or wetness) of the steel plate surface greatly affects the bond strength, and hence it is critical to control the quality of execution of work (to be also simply referred to as “execution” hereinafter). In particular, many repair and strengthening works are executed at sites that are narrow spaces to work in, making it difficult to ensure reliable quality.

[0015] (c) There is a problem of how to assure the quality of the resin used for bonding over the long term. For instance, deterioration of resin has been pointed out as a possible cause of the pulling out of anchor bolts used to secure the ceiling slabs of the Sasago tunnel. As demonstrated by this incident, factors such as long-term temperature changes, stress, dryness/wetness, and chemical actions cause the strength of bond with the steel plate to decrease, which is increasingly presenting a problem in terms of reliability.

[0016] Further, the invention (grout filler) described in Patent Literature 2 has the following problems.

[0017] (d) It is necessary to use a stud bolt, an anchor bolt, or a through-bolt to integrate the steel plate with an existing concrete structure so that the steel plate exerts its function, and significant amounts of time, machinery and materials, and cost are required to execute this work.

[0018] (e) If an anchor bolt or a through-bolt is used, the position to install the bolt is restricted in order to avoid interference with the rebar of an existing reinforced concrete structure. Depending on the case, this makes appropriate designing or execution impossible, or makes it impossible to employ this method.
(f) If a stud bolt is installed to the steel plate, the space between the surface of the existing reinforced concrete structure and the steel plate needs to be made larger than the length of the stud bolt, resulting in an increase in the area to be strengthened. Consequently, depending on the case, the amount (volume) of the grout to be injected increases, leading to higher cost, or the weight of the portion to be strengthened increases, which is structurally disadvantageous.

The present invention has been made to address the above problems. Accordingly, it is an object of the present invention to provide a repair and strengthening system for a reinforced concrete structure which can improve the delivery of force between a steel plate and a filler, without applying special surface treatment or meticulous surface cleaning to the steel plate, or without installing a stud bolt or using an anchor bolt for the steel plate.

Solution to Problem

(1) According to the present invention, there is provided a repair and strengthening system for a reinforced concrete structure including a steel plate that is disposed with a predetermined space to a structure surface, the structure surface being a surface of the reinforced concrete structure, and a filler that is injected in the space,

(2) According to the present invention, there is provided a repair and strengthening system for a reinforced concrete structure including a steel plate that is disposed with a predetermined space to a structure surface, the structure surface being a surface of the reinforced concrete structure, and a filler that is injected in the space,

(3) According to the present invention, there is provided a repair and strengthening system for a reinforced concrete structure including a steel plate that is disposed in contact with a structure surface, and is provided with a plurality of openings, the structure surface being a surface of the reinforced concrete structure, and a filler that blocks the openings.

(4) In (3) above, a plurality of protrusions are formed on a steel-plate front face that is a surface on one side of the steel plate, and the steel-plate front face faces the structure surface.

(5) In (3) or (4) above, a plurality of protrusions are formed on a steel-plate back face that is a surface on another side of the steel plate, and the plurality of protrusions formed on the steel-plate back face are surrounded by the filler.

(6) In any one of (3) to (5) above, the repair and strengthening system has a plurality of the steel plates, and in one steel plate pair of the steel plates, at least one of the openings of one steel plate and at least one of the openings of another steel plate overlap each other, and the one steel plate and the other steel plate are integrated together by the filler injected in overlapping openings of the one steel plate and overlapping openings of the other steel plate.

(7) In any one of (2) to (6) above, the plurality of openings are formed by enlarging a plurality of slits formed in the steel plate by stretching.

(8) In any one of (1), (4), (5), and (6) above, the plurality of protrusions are formed integrally when the steel plate is manufactured by hot rolling.

(9) In (8) above, the plurality of protrusions are spaced by 30 mm to 40 mm from each other, have a height of 2.5 mm to 5.0 mm, and have a width of 4 mm to 20 mm, the width being a distance in a direction perpendicular to a direction of the hot rolling at a base of the protrusions.

(10) In any one of (1) to (9) above, the steel plate is supported by a hang bolt, the hang bolt being installed in the reinforced concrete structure and projecting from the structure surface.

(11) In any one of (1) to (10) above, the reinforced concrete structure includes the structure surface, and a pair of structure sides that are continuous with the structure surface.

(12) In (11) above, the vertical-member through-hole is elongated in a direction perpendicular to the support horizontal member.

(13) A height adjusting bolt is installed in the support vertical member, the height adjusting bolt being movable in the direction perpendicular to the support horizontal member and abutting against the support bolt at a distal end, and

(14) As the height adjusting bolt is turned, the steel-plate support member is moved in a direction perpendicular to the structure surface.

(15) In (11) or (12) above, a guide projection is provided on a steel-plate back face, the steel-plate back face being a side opposite to the steel-plate front face,

(16) The support horizontal member is provided with a support-member guide groove into which the guide projection enters, and

(17) As the guide projection is guided by the support-member guide groove and moves, the steel plate is able to move relatively with respect to the steel-plate support member.

(18) In any one of (11) to (13) above, the support horizontal member and the support vertical members are detachably coupled by a fastening bolt.

(19) In any one of (1) to (14), the steel plate includes a pair of steel-plate sidewall parts, the pair of steel-plate sidewall parts being continuous with opposite side edges of the steel plate and formed on a same side as the steel-plate front face.

(20) In any one of (2) to (7) above, the steel plate is bent into a U-shape in section that includes a bottom portion and a pair of side portions,

(21) A bar member is installed to penetrate a structure through-hole formed in the reinforced concrete structure, and

(22) As the bar member penetrates the openings, the steel plate is secured onto the reinforced concrete structure.

(23) In any one of (1) to (16) above, the steel plate is made of plain steel, high tension steel, stainless steel, or weathering steel.
[0049] (18) In any one of (1) to (17) above, the filler is mortar, shrinkage-compensating mortar, polymer cement mortar, resin mortar, fiber reinforced concrete, superplasticized concrete, high-strength concrete, an epoxy resin injection material, a polyurethane resin injection material, or a sodium silicate injection material.

Advantageous Effects of Invention

[0050] The repair and strengthening system for a reinforced concrete structure according to the present invention has the following advantageous effects.

[0051] (i) The plurality of protrusions are formed on the steel-plate front face that faces the structure surface, and the filler is injected in the space between the structure surface and the steel-plate front face. Consequently, the plurality of protrusions mechanically interlock with the filler, allowing transfer of shear therebetween.

[0052] Accordingly, when a bending load acts on the reinforced concrete structure, the steel plate behaves integrally with the reinforced concrete structure. Consequently, the tensile stress at the structure surface is shared by the steel plate, thereby strengthening the corresponding area. If this area is damaged, this damage is repaired.

[0053] (ii) Further, the filler injected in the space between the structure surface and the steel plate blocks the plurality of openings formed in the steel plate. Consequently, the filler mechanically interlocks with the plurality of protrusions, allowing transfer of shear therebetween. Therefore, the same effect as (i) above is obtained.

[0054] (iii) In the repair and strengthening system for a reinforced concrete structure according to the present invention, the filler is injected in the openings of the steel plate that is disposed in contact with the structure surface. Consequently, the openings of the steel plate (more precisely, the areas of the steel plate surrounding the openings) mechanically interlock with the filler, allowing transfer of shear therebetween. Therefore, the same effect as (i) above is obtained.

[0055] (iv) The protrusions formed on the steel-plate back face are surrounded by the filler, allowing strong adhesion between the steel plate and the filler. Therefore, the same effect as (i) above is obtained.

[0056] (v) A pair of steel plates partially overlap, and the pair of steel plates are integrated together by means of the filler injected in the respective openings of the steel plates in the overlapping area. This eliminates the need to couple the pair of steel plates together by welding or by using a coupling member, thereby facilitating execution. The term "integration" as used in the present invention refers to a state in which force is transferred between steel plates, and includes a case where the steel plates partially overlap each other, and a case where the steel plates are not in direct contact with each other.

[0057] (vi) The openings are formed by enlarging the plurality of slits by stretching, allowing easy workability and reduction of the execution cost and the execution period.

[0058] (vii) The steel plate provided with the protrusions is manufactured by hot rolling. Consequently, there is no special working required in the factory that prepares the components or at the work site, allowing reduction of the execution cost and the execution period.

[0059] (viii) The steel plate is supported by the hang bolt that projects from the structure surface. The hang bolt is not used for the purpose of transferring the force acting on the reinforced concrete structure to the steel plate, and there is no need for a shear anchor bolt to transfer the force acting on the reinforced concrete structure to the steel plate. The number of components thus decreases, leading to lower components cost. Further, drilling required for installing a shear anchor bolt is unnecessary. Therefore, no drilling equipment is required, and the ease of execution at narrow space work sites improves, allowing reduction of the execution cost and the execution period.

[0060] (ix) The steel plate is installed on the support horizontal member of the steel-plate support member that includes the support horizontal member and the pair of support vertical members, and the pair of support vertical members are supported by the supporting bolt installed to the sides of the structure. Consequently, installation of the supporting bolt is easy, thus improving the ease of execution.

[0061] (x) Further, as the height adjusting bolt is turned, the steel-plate support member is moved in the direction perpendicular to the structure support. This facilitates execution, and also improves the accuracy with which the steel-plate support member is positioned with respect to the direction perpendicular to the structure surface.

[0062] (xi) As the guide projection is guided by the support member guide groove and moves, the steel plate is able to move relatively with respect to the steel-plate support member. This facilitates execution, and also improves the accuracy with each the steel-plate support member is positioned with respect to the direction parallel to the structure surface.

[0063] (xii) The support horizontal member and the support vertical members are detachably coupled by the fastening bolt to allow for easy storage and transport, reducing the execution cost.

[0064] (xiii) Further, the steel plate includes the pair of steel-plate sidewalk parts, thus functioning as formwork when injecting the filler. Consequently, installation and dismantling of formwork are unnecessary, allowing reduction of the work period and cost.

[0065] (xiv) The steel plate including the openings is bent into a U-shape in section, and as the bar member installed in the reinforced concrete structure penetrates the openings, the steel plate is secured onto the reinforced concrete structure. Consequently, execution is facilitated, and execution cost can be reduced.

BRIEF DESCRIPTION OF DRAWINGS

[0066] FIGS. 1A to 1C illustrate a strengthening example for explaining a repair and strengthening system for a reinforced concrete structure according to Embodiment 1 of the present invention, in which FIG. 1A is a partially see-through front view, FIG. 1B is a sectional side view taken along A-A in FIG. 1A, and FIG. 1C is a sectional side view taken along B-B in FIG. 1A.

[0067] FIG. 2 is an enlarged front view of a part of a steel plate constituting the repair and strengthening system for a reinforced concrete structure illustrated in FIGS. 1A to 1C.

[0068] FIG. 3A to 3D illustrate a repair example for explaining the repair and strengthening system for a reinforced concrete structure according to Embodiment 1 of the present invention, in which FIG. 3A is a partially see-through front view, FIG. 3B is a partially enlarged, partially see-through front view, FIG. 3C is a sectional side view taken along A-A in FIG. 3A, and FIG. 3D is a sectional side view taken along B-B in FIG. 3A.

[0069] FIG. 4A to 4C illustrate a repair example for explaining the repair and strengthening system for a reinforced concrete structure according to Embodiment 2 of the present
invention, in which FIG. 4A is a partially see-through front view, FIG. 4B is a sectional side view taken along A-A in FIG. 4A, and FIG. 4C is a sectional side view taken along B-B in FIG. 4A.

[0070] FIGS. 5A and 5B illustrate a repair and strengthening system for a reinforced concrete structure according to Embodiment 3 of the present invention, in which FIG. 5A is a partially enlarged, partially see-through front view, and FIG. 5B is a partially enlarged side sectional view.

[0071] FIGS. 6A and 6B illustrate a repair example for explaining a repair and strengthening system for a reinforced concrete structure according to Embodiment 4 of the present invention, in which FIG. 6A is a partially enlarged, partially see-through front view, and FIG. 6B is a partially enlarged side sectional view.

[0072] FIGS. 7A and 7B illustrate a steel plate used for the repair and strengthening system for a reinforced concrete structure illustrated in FIGS. 6A and 6B, in which FIG. 7A is a partially enlarged, partially see-through front view, and FIG. 7B is a partially enlarged side view.

[0073] FIGS. 8A to 8C illustrate a repair example for explaining a repair and strengthening system for a reinforced concrete structure according to Embodiment 5 of the present invention, in which FIG. 8A is a partially see-through front view, FIG. 8B is a sectional side view taken along A-A in FIG. 8A, and FIG. 8C is a sectional side view taken along B-B in FIG. 8A.

[0074] FIGS. 9A and 9B illustrate a steel plate used for the repair and strengthening system for a reinforced concrete structure according to Embodiment 5 of the present invention, in which FIG. 9A is an enlarged, partially see-through front view of a part of the steel plate, and FIG. 9B is an enlarged side view of a part of the steel plate.

[0075] FIGS. 10A to 10C illustrate a repair example for explaining a repair and strengthening system for a reinforced concrete structure according to Embodiment 6 of the present invention, in which FIG. 10A is a partially see-through front view, FIG. 10B is a sectional side view taken along A-A in FIG. 10A, and FIG. 10C is a bottom view illustrating the repair example.

[0076] FIGS. 11A to 11C illustrate a steel plate used for the repair and strengthening system for a reinforced concrete structure according to Embodiment 6 of the present invention, in which FIG. 11A is an exploded plan view of the steel plate, FIG. 11B is a plan view of an original plate prior to being worked into the steel plate, and FIG. 11C is an enlarged plan view of a part of the original plate prior to being worked into the steel plate.

[0077] FIGS. 12A to 12E illustrate another form of the steel plate used for the repair and strengthening system for a reinforced concrete structure according to Embodiment 6 of the present invention, in which FIG. 12A is a plan view, FIG. 12B is a sectional view taken along B-B in FIG. 12A, FIG. 12C is a sectional view taken along C-C in FIG. 12A, FIG. 12D is a plan view of an original plate prior to being worked into the steel plate, and FIG. 12E is a sectional view taken along A-A in FIG. 12D.

[0078] FIGS. 13A and 13B illustrate another form of the steel plate used for the repair and strengthening system for a reinforced concrete structure according to Embodiment 6 of the present invention, in which FIG. 13A is a plan view, and FIG. 13B is a plan view of an original plate prior to being worked into the steel plate.

[0079] FIG. 14 is a perspective view of a components kit used for a repair and strengthening system for a reinforced concrete structure according to Embodiment 7 of the present invention.

[0080] FIG. 15 is a partially see-through front view for explaining a repair and strengthening system for a reinforced concrete structure according to Embodiment 8 of the present invention.

[0081] FIG. 16 is a partially see-through front view of a repair and strengthening system for a reinforced concrete structure according to Embodiment 9 of the present invention.

[0082] FIGS. 17A and 17B illustrate a repair and strengthening system for a reinforced concrete structure according to Embodiment 10 of the present invention, in which FIG. 17A is a partially see-through front view, and FIG. 17B is a perspective view of a part of the repair and strengthening system.

DESCRIPTION OF EMBODIMENTS

Embodiment 1

A repair and strengthening system for a reinforced concrete structure according to Embodiment 1 of the present invention is used to repair or strengthen a reinforced concrete structure. Hereinafter, a strengthening example will be described with reference to FIGS. 1 and 2, and a repair example will be described with reference to FIG. 3.

(Strengthening Example)

[0083] FIGS. 1 and 2 illustrate a strengthening example for explaining the repair and strengthening system for a reinforced concrete structure according to Embodiment 1 of the present invention. FIG. 1A is a partially see-through front view, FIG. 1B is a sectional side view taken along A-A in FIG. 1A, and FIG. 1C is a sectional side view taken along B-B in FIG. 1A. FIG. 2 is an enlarged front view of a part of a steel plate. These figures are schematic only, and not intended to limit the present invention to the particular forms (such as shapes or quantities) illustrated.

[0084] In FIG. 1, a repair and strengthening system for a reinforced concrete structure (to be referred to as "repair and strengthening system" hereinafter) 100 strengthens a reinforced concrete structure 10.

[0085] The reinforced concrete structure 10 is a floor, a beam, or a column. The reinforced concrete structure 10 includes concrete 11 placed in a planar fashion, rebars 12 that are disposed in parallel to each other along the longitudinal direction (left-right direction in FIG. 1A) within the concrete 11, and a hoop reinforcement 13 that is disposed in a perpendicular plane (vertical plane in FIG. 1A) with respect to the rebars 12 so as to surround the rebars 12 within the concrete 11.

[0086] A predetermined area of a surface on one side (to be referred to as "surface structure 14" hereinafter) of the concrete 11 is referred to as strengthened area 15. While in FIG. 1A the strengthened area 15 is depicted as a surface with minute irregularities in order to clearly indicate the strengthened area 15, the present invention is not limited to this. The strengthened area 15 may be flat instead. For example, the strengthened area 15 may be an area where a relatively large bending moment acts.

[0087] In the concrete 11, a hang bolt 40 is installed (post-installed) into the strengthened area 15 of the concrete 11. A part of the hang bolt 40 projects from the structure surface 14,
and penetrates a through-hole 23 formed in a steel plate (to be referred to as “ribbed steel plate” hereinafter) 20. A nut 41 is in threaded engagement with the hang bolt 40. That is, by the composite mechanism of the hang bolt 40 and the nut 41, the ribbed steel plate 20 is disposed facing the strengthened area 15 (which is the same as a part of the structure surface 14) with a predetermined space 16 therebetween (so that the ribbed steel plate 20 is unable to move or fall). The space 16 is filled with a filler 30.

(Steel Plate)

[0089] In FIG. 2, the ribbed steel plate 20 is about 9 mm to 25 mm in thickness, and its surface on one side (to be referred to as “steel-plate front face 21” hereinafter) is provided with a plurality of protrusions (to be referred to as “ribs” hereinafter) 22. The ribs 22 are formed integrally by grooves formed in the surface of a reduction roll when the ribbed steel plate 20 is manufactured by hot rolling. The ribs 22 are spaced by 30 mm to 40 mm from each other in the direction at right angles to that of rolling (left-right direction in FIG. 2), have a height of 2.5 mm to 5.0 mm, and have a width (the distance in the direction at right angles to that of rolling) at the base of 4 mm to 20 mm. The sectional shape of the ribs 22 is not limited to trapezoidal or rectangular.

[0090] The present invention is not intended to limit the constituent material or the like of the ribbed steel plate 20. As long as the ribs 22 are formed by hot rolling, the ribbed steel plate 20 may be made of alloy steel such as plain steel (carbon steel), high tension steel, stainless steel, or weathering steel. Accordingly, the composition or the like of the ribbed steel plate 20 may be selected as appropriate in accordance with the installation condition (load or environment such as weather).

[0091] In the following, for the convenience of explanation, the side opposite to the steel-plate front face 21 is referred to as “steel-plate back face 24”.

(Filler)

[0092] Further, the present invention is not intended to limit the constituent material or the like of the filler 30. Examples of grout filler include mortar, shrinkage-compensating mortar, polymer cement mortar, resin mortar, fiber reinforced concrete, superplasticized concrete, and high-strength concrete, and examples of adhesive filler include an epoxy resin injection material, a polyurethane resin injection material, and a sodium silicate injection material. Accordingly, the composition or the like of the filler 30 may be selected as appropriate in accordance with the installation condition (load or environment such as weather).

(Operational Effects)

[0093] The structure surface 14 is a surface on which the tensile stress acts. The steel-plate front face 21 of the ribbed steel plate 20 faces the structure surface 14. That is, the ribs 22 bite into the filler 30 injected in the space 16 so that the ribs 22 mechanically interlock with the filler 30, allowing transfer of shear therebetween. Further, the filler 30 is in intimate contact with the strengthened area 15.

[0094] (a) Accordingly, when a bending load acts on the concrete 11, the ribbed steel plate 20 behaves integrally with the concrete 11. Therefore, the tensile stress at the structure surface 14 is shared by the ribbed steel plate 20 in the strengthened area 15, and the strengthened area 15 is thus strengthened.

[0095] (b) At this time, as mentioned above, the ribs 22 mechanically interlock with the filler 30, allowing transfer of shear therebetween. This means that factors such as the surface roughness of the steel-plate front face 21, and dust or the like adhering to the steel-plate front face 21 do not cause strengthening to become inadequate, thus ensuring high reliability of strengthening.

[0096] (c) Because there is no need to provide a shear anchor bolt to transfer the force acting on the concrete 11 to the ribbed steel plate 20, components cost is reduced. Further, drilling required for installing a shear anchor bolt is unnecessary. Therefore, no drilling equipment is required, and the ease of execution at narrow space work sites improves, allowing reduction of the execution cost and the execution period.

[0097] (d) Because the ribbed steel plate 20 provided with the ribs 22 is manufactured by hot rolling, there is no special working required in the factory that prepares the components of the repair and strengthening system 100 or at the work site, allowing further reduction of the execution cost and the execution period.

[0098] (e) Further, the hang bolt 40 is not used for the purpose of transferring the force acting on the concrete 11 to the ribbed steel plate 20. Accordingly, the hang bolt 40 may be a thin one, with just enough thickness to bear the self-weight of the ribbed steel plate 20. Further, the hang bolt 40 does not need to be located close to the rebars 12 or the hoop reinforcement 13 to exchange forces with the rebars 12 or the hoop reinforcement 13, ensuring high degree of freedom of the position to install the hang bolt 40.

[0099] (f) Moreover, the ribbed steel plate 20 itself functions as formwork when injecting the filler 30, thus eliminating costs associated with the installation and dismantling of formwork. In this respect as well, reduction of the execution cost and the execution period is facilitated.

(Repair Example)

[0100] FIG. 3 illustrates a repair example for explaining the repair and strengthening system for a reinforced concrete structure according to Embodiment 1 of the present invention, in which FIG. 3A is a partially see-through front view, FIG. 3B is a partially enlarged, partially see-through front view illustrating the repair example. FIG. 3C is a sectional side view taken along A-A in FIG. 3A, and FIG. 3D is a sectional side view taken along B-B in FIG. 3A. These figures are schematic only, and not intended to limit the present invention to the particular forms (such as shapes or quantities) illustrated. Further, portions that are the same as or equivalent to those in FIG. 1 are denoted by the same reference signs, and a description of these portions is partially omitted.

[0101] In FIG. 3, the repair and strengthening system 100 repairs the reinforced concrete structure 10.

[0102] Corrosion or deterioration occurring in a predetermined area of the structure surface 14 of the reinforced concrete structure 10 causes a part of the concrete 11 to dislodge, forming a damaged surface 17. Hereinafter, an area bounded by the structure surface 14 prior to dislodging of the concrete 11, and the damaged surface 17 formed after dislodging of the concrete 11 is referred to as a dislodged concrete portion 31. In the dislodged concrete portion 31, the rebars 12 are partially exposed, and the exposed portion of the rebars 12 is corroded and decreases in outside diameter. Hereinafter, the area where the outside diameter of the rebars 12 decreases is referred to as a “corroded/deteriorated rebar portion 12a”.
In the concrete 11, the hang bolt 40 is installed (post-installed) into the damaged surface 17, with a part of the hang bolt 40 projecting from the structure surface 14 via the dislodged concrete portion 31. Then, the hang bolt 40 penetrates the through-hole 23 formed in the ribbed steel plate 20, with the nut 41 being in threaded engagement with the hang bolt 40. At this time, the steel-plate back face 24 of the ribbed steel plate 20 is located in the same plane as the structure surface 14.

That is, by the composite mechanism of the hang bolt 40 and the nut 41, the ribbed steel plate 20 is disposed in such a way that makes the ribbed steel plate 20 unable to move or fall, while being contained within the dislodged concrete portion 31.

Further, the portion between the steel-plate front face 21 and the damaged surface 17 (corresponding to the volume of the dislodged concrete portion 31 minus the volume of the ribbed steel plate 20) is filled with the filler 30, with the result that the corroded/deteriorated rebar portion 12a is embedded in the filler 30. (Operational Effects)

Accordingly, the repair and strengthening system 100 provides the same operational effects for repair as in the case of strengthening. At this time, the force acting on the corroded/deteriorated rebar portion 12a is shared mainly by the ribbed steel plate 20, resulting in repair of strength. Corrosion of the corroded/deteriorated rebar portion 12a is arrested mainly by the filler 30, resulting in repair of deterioration.

Embodiment 2

FIG. 4 illustrates a repair example for explaining a repair and strengthening system for a reinforced concrete structure according to Embodiment 2 of the present invention, in which FIG. 4A is a partially see-through front view, FIG. 4B is a sectional side view taken along A-A in FIG. 4A, and FIG. 4C is a sectional side view taken along B-B in FIG. 4A. Portions that are the same as or equivalent to those in Embodiment 1 are denoted by the same reference signs, and a description of these portions is partially omitted. Further, these figures are schematic only, and not intended to limit the present invention to the particular forms (such as shapes or quantities) illustrated.

Repair Example

In FIG. 4, a repair and strengthening system for a reinforced concrete structure (to be referred to as “repair and strengthening system” hereinafter) 200 uses a steel-plate support member 50 that is square U-shaped, instead of the hang bolt 40 of the repair and strengthening system 100.

That is, the reinforced concrete structure 10 includes the structure surface 14, and a pair of structure sides 18 that are continuous with the structure surface 14. The reinforced concrete structure 10 has a structure through-hole 19 formed in parallel to the structure surface 14 and spanning the pair of structure sides 18. At this time, the pair of structure sides 18 are perpendicular to the structure surface 14, and are parallel to each other. However, the present invention is not limited to this. The pair of structure sides 18 may be non-parallel to each other (V-shaped) so that the distance between the pair of structure sides 18 increases with increasing distance from the structure surface 14.

The steel-plate support member 50 includes a support horizontal member 51 and a pair of support vertical members 52. The support horizontal member 51 is disposed in parallel to the structure surface 14 (more precisely, facing the damaged surface 17). The pair of support vertical members 52 are disposed in parallel to the pair of structure sides 18. A vertical-member through-hole 53 is formed in each of the pair of support vertical members 52.

The opposite end portions of a supporting bolt 60 that penetrates the structure through-hole 19 project from the structure sides 18, and penetrate the vertical-member through-hole 53. A nut 61 is in threaded engagement with either end of the supporting bolt 60. That is, the steel-plate support member 50 is installed onto the reinforced concrete structure 10 with the supporting bolt 60 that penetrates the structure through-hole 19.

Further, the ribbed steel plate 20 is installed on the support horizontal member 51 of the steel-plate support member 50, with the steel-plate front face 21 facing the damaged surface 17 (the steel-plate back face 24 is abutting against the support horizontal member 51). The filler 30 is injected into the portion between the steel-plate front face 21 and the damaged surface 17 (which substantially corresponds to the dislodged concrete portion 31).

Therefore, the repair and strengthening system 200 provides the same operational effects as the repair and strengthening system 100 with respect to strength and deterioration.

Further, the hang bolt 40 is changed to the steel-plate support member 50. Accordingly, the operation of erecting the hang bolt in an upright position is replaced by a relatively easy operation of boring the structure through-hole 19 in the transverse direction, thus improving the ease of execution.

In the above example, the opposite end portions of the supporting bolt 60 project from the structure sides 18. However, the present invention is not limited to this. Another approach may be used in which the supporting bolt 60 is divided into two parts, the structure through-hole 19 is changed to a blind hole with a predetermined depth from the structure sides 18, and each of the two divided parts of the supporting bolt is installed in the blind hole. Alternatively, the supporting bolt 60 may be a bar member having male threads formed only at the ends.

The steel-plate support member 50 may be formed either by integrating the support horizontal member 51 and the pair of support vertical members 52 together (for example, by bending a plate member, or by cutting light gauge steel with a square U-shaped section), or by joining three plate members together by welding or mechanically (such as by a thread/threaded hole mechanism, or a fitting protrusion/fitting hole mechanism).

Embodiment 3

FIG. 5 illustrates a repair and strengthening system for a reinforced concrete structure according to Embodiment 3 of the present invention, in which FIG. 5A is a partially enlarged, partially see-through front view, and FIG. 5B is a partially enlarged side sectional view. Portions that are the same as or equivalent to those in Embodiments 1 and 2 are denoted by the same reference signs, and a description of these portions is partially omitted. Further, these figures are schematic only, and not intended to limit the present invention to the particular forms (such as shapes or quantities) illustrated.
[0118] In FIG. 5, a repair and strengthening system for a reinforced concrete structure (to be referred to as “repair and strengthening system” hereinafter) 300 makes it possible to adjust the position of the steel-plate support member 50 in the repair and strengthening system 200 for a reinforced concrete structure. Otherwise, the repair and strengthening system 300 is the same as the repair and strengthening system 200 for a reinforced concrete structure. Therefore, only the portion of the repair and strengthening system 300 that enables such positional adjustment will be described.

[0119] In the steel-plate support member 50 of the repair and strengthening system 300, the vertical-member through-hole 53 is an elongated hole that is elongated in a direction perpendicular to the support horizontal member 51, and a through-hole 55 that reaches the vertical-member through-hole 53 is provided at an end face (to be referred to as “vertical-member upper end face” hereinafter) 54 of the support vertical members 52 opposite to the support horizontal member 51. A height adjusting bolt 71 is brought into threaded engagement with the through-hole 55, with the distal end of the height adjusting bolt 71 abutting against the supporting bolt 60.

[0120] Accordingly, turning the height adjusting bolt 71 causes the steel-plate support member 50 to ascend or descend with respect to the supporting bolt 60.

[0121] Therefore, even if the structure through-hole 19 is not positioned accurately (displaced) with respect to the vertical direction, by turning the height adjusting bolt 71, the steel-plate support member 50 can be installed in its normal position.

[0122] Another approach may be used in which the steel-plate support member 50 is installed in such a way that the support horizontal member 51 is located at a low position away from the structure surface 14, and in this state, the ribbed steel plate 20 is moved in parallel to the structure surface 14 and slid onto the support horizontal member 51, and then the height adjusting bolt 71 is turned to lift the ribbed steel plate 20 to the normal position.

[0123] Therefore, the repair and strengthening system 300 further facilitates execution, and makes it possible to further promote the operational effects of the repair and strengthening system 200.

[0124] In FIG. 5, a spacer 63 is disposed between each of the structure sides 18 and each of the support vertical members 52, and the nut 61 presses each of the support vertical members 52 against each of the structure sides 18 via a fastening washer 62.

Embodiment 4

[0125] FIGS. 6 and 7 illustrate a repair and strengthening system for a reinforced concrete structure according to Embodiment 4 of the present invention, in which FIG. 6A is a partially enlarged, see-through front view, FIG. 6B is a partially enlarged side sectional view, FIG. 7A is an enlarged, partially see-through front view of a part of a steel plate, and FIG. 7B is an enlarged side view of a part of the steel plate. Portions that are the same as or equivalent to those in Embodiments 1 and 2 are denoted by the same reference signs, and a description of these portions is partially omitted. Further, these figures are schematic only, and not intended to limit the present invention to the particular forms (such as shapes or quantities) illustrated.

[0126] In FIG. 7, the steel-plate back face 24 of the ribbed steel plate 20 is provided with a guide projection 25 extending in the longitudinal direction. The guide projection 25 is substantially trapezoidal in section, and becomes wider with increasing distance from the steel-plate back face 24.

[0127] In FIG. 6, a repair and strengthening system for a reinforced concrete structure (to be referred to as “repair and strengthening system” hereinafter) 400 has a guide groove 56 provided in the support horizontal member 51 of the steel-plate support member 50 of the repair and strengthening system 200 for a reinforced concrete structure. The guide groove 56 is wider at the back (bottom) than at its mouth.

[0128] Then, with the steel-plate back face 24 of the ribbed steel plate 20 abutting against the support horizontal member 51, the guide projection 25 enters the guide groove 56 in such a way that makes the guide projection 25 able to move in the longitudinal direction and unable to move out of position in the vertical direction.

[0129] Therefore, even if the structure through-hole 19 is not positioned accurately (displaced) with respect to the longitudinal direction, by placing the ribbed steel plate 20 on the support horizontal member 51, and moving the ribbed steel plate 20 in the longitudinal direction, the ribbed steel plate 20 can be disposed at its normal position. At this time, the position in the widthwise direction is maintained by the composite mechanism of the guide projection 25 and the guide groove 56.

[0130] Therefore, the repair and strengthening system 400 further facilitates execution, and makes it possible to further promote the operational effects of the repair and strengthening system 200.

[0131] In FIG. 6, the support horizontal member 51 and the support vertical members 52 are detachable from each other. A threaded hole 57 is provided at the side end face of the support horizontal member 51, and a through-hole 58 is provided in a lower end portion of each of the support vertical members 52. A fastening bolt 72 penetrates the through-hole 58 and comes into threaded engagement with the threaded hole 57, thus forming the steel-plate support member 50. Accordingly, the support horizontal member 51 and the support vertical members 52 can be brought to the work site in a detached state, and used to easily construct the steel-plate support member 50 on site, thus allowing easy stocking and transport, which contributes to lower cost of execution as a result.

[0132] Each of the support vertical members 52 has a vertical-member locking portion 59 provided in a lower end portion for locking engagement with a part of the side edge of the support horizontal member 51. In the vertical-member locking portion 59, the load exerted on the support horizontal member 51 is transferred to the support vertical members 52. Therefore, no shear acts on the fastening bolt 72.

[0133] The guide groove 56 may be provided in the support horizontal member 51 of the steel-plate support member 50 that is not of a detachable type but is formed integrally.

Embodiment 5

[0134] FIGS. 8 and 9 illustrate a repair example for explaining a repair and strengthening system for a reinforced concrete structure according to Embodiment 5 of the present invention, in which FIG. 8A is a partially see-through front view, FIG. 8B is a sectional side view taken along A-A in FIG. 8A, FIG. 8C is a sectional side view taken along B-B in FIG. 8A, FIG. 9A is an enlarged, partially see-through front view of a part of a steel plate, and FIG. 9B is an enlarged side view of a part of the steel plate.
Portions that are the same as or equivalent to those in Embodiments 1 and 2 are denoted by the same reference signs, and a description of these portions is partially omitted. Further, these figures are schematic only, and not intended to limit the present invention to the particular forms (such as shapes or quantities) illustrated.

In FIG. 9, a repair and strengthening system for a reinforced concrete structure (to be referred to as “repair and strengthening system” hereinafter) 500 uses a steel plate (to be referred to as “steel grid plate” hereinafter) 90.

The steel grid plate 90 has a plurality of openings 93 formed in a flat steel plate (original plate). The steel grid plate 90 is bent into a square U-shape in section including a bottom portion 97 and a pair of side portions 98.

The structure through-hole 19 is formed in the reinforced concrete structure 10. Opposite end portions of a bar member (to be referred to as “PC bar steel” hereinafter) 67 that penetrates the structure through-hole 19 project from the structure sides 18.

The bottom portion 97 of the steel grid plate 90 is disposed in parallel to the structure surface 14, and the side portions 98 are disposed in parallel to the structure sides 18.

In this state, the steel grid plate 90 surrounds the dislodged concrete portion 31. At this time, opposite end portions of the PC bar steel 67 penetrate the corresponding openings 93, with a nut 68 being in threaded engagement with a threaded portion formed at either end of the PC bar steel 67. Therefore, the steel grid plate 90 is held at a predetermined position by the PC bar steel 67. At this time, the PC bar steel 67 penetrates a washer 69. That is, the washer 69 is pressed against a grid portion 94 between the openings 93, and is installed in place with the nut 68 in such a way that the washer 69 is unable to move out of position.

Further, the filler 30 is injected into the dislodged concrete portion 31 surrounded by the steel grid plate 90, and the filler 30 blocks the openings 93. That is, the filler 30 is a high-viscosity filler, for example, a polymer cement mortar, which is sprayed onto the dislodged concrete portion 31 through the openings 93.

In the above example, the steel grid plate 90 is bent for use. However, the present invention is not limited to this. The steel grid plate 90 may be used in its original flat form prior to being bent, as a substitute for the ribbed steel plate 20 of the repair and strengthening system 100.

FIGS. 10 and 11 illustrate a repair example for explaining a repair and strengthening system for a reinforced concrete structure according to Embodiment 6 of the present invention, in which FIG. 10A is a partially see-through front view, FIG. 10B is a sectional side view taken along A-A in FIG. 10A, FIG. 10C is a bottom view illustrating the repair example, FIG. 11A is an exploded view of a steel plate, FIG. 11B is a plan view of an original plate prior to being worked into the steel plate, and FIG. 11C is an enlarged plan view of a part of the original plate prior to being worked into the steel plate.

Portions that are the same as or equivalent to those in Embodiments 1 and 2 are denoted by the same reference signs, and a description of these portions is partially omitted. Further, these figures are schematic only, and not intended to limit the present invention to the particular forms (such as shapes or quantities) illustrated.

In FIG. 10, a repair and strengthening system for a reinforced concrete structure (to be referred to as “repair and strengthening system” hereinafter) 600 uses a steel plate (to be referred to as “steel grid plate” hereinafter) 90.

The steel grid plate 90 has a plurality of openings 93 formed in a flat steel plate (original plate). The steel grid plate 90 is bent into a square U-shape in section including a bottom portion 97 and a pair of side portions 98.

The structure through-hole 19 is formed in the reinforced concrete structure 10. Opposite end portions of a bar member (to be referred to as “PC bar steel” hereinafter) 67 that penetrates the structure through-hole 19 project from the structure sides 18.

The bottom portion 97 of the steel grid plate 90 is disposed in parallel to the structure surface 14, and the side portions 98 are disposed in parallel to the structure sides 18.

In this state, the steel grid plate 90 surrounds the dislodged concrete portion 31. At this time, opposite end portions of the PC bar steel 67 penetrate the corresponding openings 93, with a nut 68 being in threaded engagement with a threaded portion formed at either end of the PC bar steel 67. Therefore, the steel grid plate 90 is held at a predetermined position by the PC bar steel 67. At this time, the PC bar steel 67 penetrates a washer 69. That is, the washer 69 is pressed against a grid portion 94 between the openings 93, and is installed in place with the nut 68 in such a way that the washer 69 is unable to move out of position.

Further, the filler 30 is injected into the dislodged concrete portion 31 surrounded by the steel grid plate 90, and the filler 30 blocks the openings 93. That is, the filler 30 is a high-viscosity filler, for example, a polymer cement mortar, which is sprayed onto the dislodged concrete portion 31 through the openings 93.

In the above example, the steel grid plate 90 is bent for use. However, the present invention is not limited to this. The steel grid plate 90 may be used in its original flat form prior to being bent, as a substitute for the ribbed steel plate 20 of the repair and strengthening system 100.

FIG. 11A illustrates the steel grid plate 90 includes the plurality of openings 93 (corresponding to the square cells of a checkerboard) arranged in a pattern of squares, and the grid portion 94 (corresponding to the lines of a checkerboard) that is the tangible, physical portion between the openings 93 that are empty spaces.

The steel grid plate 90 is formed by, for example, in-plane stretching of an original plate 91 (see FIG. 11B) in which a plurality of slits 92 (see FIG. 11C) are machined by a laser or the like. As the slits 92 expand, the plurality of openings 93 are formed, and the discontinuous portions between the slits 92 become the grid portion 94 between the openings 93.

In the above example, the discontinuous portions between the slits 92 are arranged in the original plate 91 in a pattern of squares, forming the openings 93 of a rectangular shape including sides that are parallel to the side edges of the steel grid plate 90, and sides that are perpendicular to the side
edges of the steel grid plate 90. However, the present invention does not limit the shape of the openings 93. For example, the discontinuous portions between the slits 92 may be arranged in a staggered fashion, forming the openings 93 of a rhombic shape including sides that are inclined with respect to the side edges of the steel grid plate 90.

(Operational Effects)

[0153] As described above, the repair and strengthening system 600 uses the steel grid plate 90 instead of the steel plate with sidewalk 80. Therefore, as mentioned above, the openings 93 are blocked by the filler 30 injected in the dislodged concrete portion 31, and the filler 30 bites into and mechanically interlocks with the openings 93, allowing transfer of shear therebetween. Further, the filler 30 is in intimate contact with the damaged surface 17 where a part of the concrete 11 becomes dislodged and exposed.

[0154] (a) Accordingly, when a bending load acts on the concrete 11, the steel grid plate 90 behaves integrally with the concrete 11. Therefore, the repair and strengthening system 600 provides the same operational effects as the repair and strengthening system 100.

[0155] (b) At this time, factors such as the surface roughness of the original plate 91, and dust or the like adhering to the original plate 91 do not cause repair or strengthening to become inadequate, ensuring high reliability of repair and strengthening.

[0156] (c) Because supporting means such as the steel-plate support member 50 is unnecessary, components cost is reduced. Further, drilling required for installing a steel anchor bolt is unnecessary. Therefore, no drilling equipment is required, and the ease of execution at narrow space work sites improves, allowing reduction of the execution cost and the execution period.

[0157] (d) In comparison to the steel plate with sidewalk 80, the steel grid plate 90 is lightweight, is easy to store and transport, and also allows easy handling at the time of work execution, resulting in low execution cost.

[0158] (e) The openings 93 of the steel grid plate 90 are blocked by the filler 30 injected in the dislodged concrete portion 31. Accordingly, by inspecting the condition of the filler 30 blocking the openings 93, the condition of the filler 30 injected in the dislodged concrete portion 31 (such as whether proper filling has been achieved, or aging) can be monitored.

[0159] (f) The dislodged concrete portion 31 can be filled with the filler 30 by spraying the filler 30 onto the dislodged concrete portion 31 via the openings 93 (the same as the space between adjacent portions of the grid portion 94). Therefore, there is a wide choice of options for execution work, thus making it possible to keep the cost of execution low.

[0160] If the filler 30 has low viscosity, the steel grid plate 90 does not function as formwork. Therefore, it is necessary to impart the filler 30 with a sufficient viscosity for keeping the filler 30 from flowing out from the openings 93.

(Another Form of Steel Grid Plate)

[0161] FIG. 12 illustrates another form of a steel plate used for the repair and strengthening system for a reinforced concrete structure according to Embodiment 6 of the present invention, in which FIG. 12A is a plan view, FIG. 12B is a sectional view taken along A-A in FIG. 12A, Portions that are the same as or equivalent to those in FIG. 11 are denoted by the same reference signs, and a description of these portions is partially omitted.

[0162] In FIG. 12E, the slits 92 machined in the original plate 91 are not perpendicular to the plane of the original plate 91. Instead, opposing slits 92 have a V-shape in section.

[0163] Consequently, when the slits 92 are stretched in parallel to the plane of the original plate 91, the grid portion 94 having a trapezoidal shape in section, and the openings 93 surrounded by the grid portion 94 are formed as illustrated in FIG. 12B and FIG. 12C.

[0164] Therefore, the interlocking between the filler 30 and the steel grid plate 90 improves.

(Another Form of Steel Grid Plate)

[0165] FIG. 13 illustrates another form of a steel plate used for the repair and strengthening system for a reinforced concrete structure according to Embodiment 6 of the present invention, in which FIG. 13A is a plan view, and FIG. 13B is a plan view of an original plate prior to being worked into the steel plate, and FIG. 13C is a sectional view taken along A-A in FIG. 12D. Portions that are the same as or equivalent to those in FIG. 11 are denoted by the same reference signs, and a description of these portions is partially omitted.

[0166] In FIG. 13B, the slits 92 machined in the original plate 91 are formed not linearly but in the shape of rectangular waves. Consequently, either side face of the grid portion 94 illustrated in FIG. 13A is formed not linearly but in the shape of rectangular waves. That is, the grid portion 94 is provided with a plurality of protrusions that protrude toward the openings 93, thus improving the interlocking between the filler 30 and the steel grid plate 90.

[0167] The slits 92 illustrated in FIG. 13B may be formed as slits that have the shape of rectangular waves and are not perpendicular to the plane of the original plate 91, like the slits 92 illustrated in FIG. 12E, thereby further improving the interlocking between the filler 30 and the steel grid plate 90.

Embodiment 7

[0168] FIG. 14 is a perspective view of a components kit used for a repair and strengthening system for a reinforced concrete structure according to Embodiment 7 of the present invention. In FIG. 14, individual components are detached, and disposed at positions close to those in actual use. Portions that are the same as or equivalent to those in Embodiments 3 to 6 are denoted by the same reference signs, and a description of these portions is partially omitted. Further, FIG. 14 is schematic only, and not intended to limit the present invention to the particular forms (such as shapes or quantities) illustrated.

[0169] In FIG. 14, a components kit for a repair and strengthening system for a reinforced concrete structure (to be referred to as "repair and strengthening system components kit" hereinafter) 700 is used to install the steel plate with sidewalk 80 onto the reinforced concrete structure 10 including the structure sides 18. The repair and strengthening system components kit 700 is made up of disassembled components.

[0170] That is, the steel plate with sidewalk 80 includes the ribbed steel plate 20 and the steel-plate sidewalk parts 26 that are integrated together, and the steel-plate back face 24 of the ribbed steel plate 20 is provided with the guide projection 25.
In the steel-plate support member 50, the support horizontal member 51 and the pair of support vertical members 52 are disassembled, and the fastening bolt 72 and the height adjusting bolt 71 for fastening these two components are provided. The support horizontal member 51 is provided with the guide groove 56. Further, the supporting bolt 60 and the nut 61 are provided to attach the steel-plate support member 50 to the reinforced concrete structure 10.

Accordingly, the repair and strengthening system components kit 700 is obtained by disassembling the individual components described above with reference to Embodiments 3 and 5 and then collecting these components into a “components kit”. Therefore, the repair and strengthening system components kit 700 can be stored in relatively narrow spaces, and is also easy to transport.

Because these components can be assembled and installed to the reinforced concrete structure 10 to repair or strengthen the reinforced concrete structure 10, these components function as the repair and strengthening systems 300 to 500 for the structure. The sizes and quantities of individual components are determined by the size of the portion to be repaired or strengthened.

FIG. 16 is a partially see-through front view of a repair and strengthening system for a reinforced concrete structure according to Embodiment 9 of the present invention. Portions that are the same as or equivalent to those in Embodiment 1 or Embodiment 6 are denoted by the same reference signs, and a description of these portions is partially omitted. Further, FIG. 16 is schematic only, and not intended to limit the present invention to the particular forms (such as shapes or quantities) illustrated.

In FIG. 16, a repair and strengthening system for a reinforced concrete structure (to be referred to as “repair and strengthening system” hereinafter) 900 strengthens the reinforced concrete structure 10 by using a steel grid plate 990.

In the steel grid plate 990, the grid portion 94 of the steel grid plate 890 (Embodiment 8) is provided with ribs 95. Some of the ribs 95 of the steel grid plate 990 are in contact with the structure surface 14 of the reinforced concrete structure 10.

At this time, the filler 30 injected in the openings 93 of the steel grid plate 990 surround the ribs 95, and is also in intimate contact with the strengthened area 15 of the structure surface 14. Consequently, the grid portion 94 and the ribs 95 of the steel grid plate 990 mechanically interlock with the filler 30, allowing transfer of shear between the structure surface 14 and the steel grid plate 990. Therefore, the same operational effects as the repair and strengthening system 100 (Embodiment 1) are provided.

The shape of the ribs 95 is not limited. For example, the ribs 95 may be protrusions having the shape of a truncated cone, or may be projections with a predetermined length. Further, in the above example, the steel grid plate 990 covers the strengthened area 15 having irregularities. However, the present invention is not limited to this. The steel grid plate 990 may cover an area of the structure surface 14 which has no irregularities. Further, the steel grid plate 990 may be used also in Embodiments 2 to 7, in such a way that the ribs 95 of the steel grid plate 990 are in contact with the structure surface 14.

At this time, the filler 30 injected in the openings 93 of the steel grid plate 990 surround the ribs 95, and is also in intimate contact with the strengthened area 15 of the structure surface 14. Consequently, the grid portion 94 and the ribs 95 of the steel grid plate 990 mechanically interlock with the filler 30, allowing transfer of shear between the structure surface 14 and the steel grid plate 990. Therefore, the same operational effects as the repair and strengthening system 100 (Embodiment 1) are provided.

Further, the ribs 95 may be formed on both sides of the grid portion 94 (not illustrated). At this time, the ribs 95 formed on both sides are surrounded by the filler 30, allowing strong adhesion between the steel grid plate 990 and the filler 30, thus promoting the same operational effects as the repair and strengthening system 100 (Embodiment 1).

Further, the ribs 95 of the steel grid plate 990 may be formed on the side of the steel grid plate 990 opposite to the structure surface 14, and the ribs 95 may be surrounded by the filler 30 in such a way that the side of the steel grid plate 990 without the ribs 95 is partially in contact with the structure surface 14. In this case as well, the same operational effects as the repair and strengthening system 100 (Embodiment 1) are provided.

In the above example, the steel grid plate 890 covers the strengthened area 15 having irregularities. However, the present invention is not limited to this. The steel grid plate 890 may cover an area of the structure surface 14 which has no irregularities.

Further, the steel grid plate 890 may be used also in Embodiments 2 to 7, in such a way that the steel grid plate 890 is in contact with the structure surface 14.
matic only, and not intended to limit the present invention to the particular forms (such as shapes or quantities) illustrated. [0190] In FIG. 17, a repair and strengthening system for a reinforced concrete structure (to be referred to as “repair and strengthening system” hereinafter) 1000 strengthens the reinforced concrete structure 10 by using two steel grid plates 890 (hereinafter, one and the other of which are to be referred to as steel grid plate 890a and steel grid plate 890b, respectively). The hang bolt 40 and the nut 41 are not illustrated.

[0191] Some of openings 93a of the steel grid plate 890a and some of openings 93b of the steel grid plate 890b overlap (at two locations in FIG. 17). A part of a grid portion 94a of the steel grid plate 890a and a part of a grid portion 94b of the steel grid plate 890b overlap (at three locations in FIG. 17; hereinafter, the overlapping area is to be referred to as “lap portion 890ab”).

[0192] At this time, the steel grid plate 890a and the steel grid plate 890b are integrated together by the filler 30 injected in the overlapping openings 93a of the steel grid plate 890a and the overlapping openings 93b of the steel grid plate 890b. That is, the filler 30 injected in the lap portion 890ab also functions as a “joint” for transferring force between the steel grid plate 890a and the steel grid plate 890b.

[0193] A part of the grid portion 94a of the steel grid plate 890a and a part of the grid portion 94b of the steel grid plate 890b are each in contact with the structure surface 14, and the grid portion 94b of the steel grid plate 890b is bent at a bending portion 96b so that in the lap portion 890ab, the grid portion 94a of the steel grid plate 890a and the grid portion 94b of the steel grid plate 890b are located close to or abut against each other.

[0194] The bend at the bending portion 96b may be removed. Instead, each of the steel grid plate 890a and the steel grid plate 890b may be formed in a planar shape so that a part of the grid portion 94a of the steel grid plate 890a is in contact with the structure surface 14, and a part of the grid portion 94b of the steel grid plate 890b is opposed to the structure surface 14 with a predetermined space therebetween.

[0195] While the above description is directed to the case of using two steel grid plates 890, the present invention is not limited to this. Three or more steel grid plates 890 may be made to partially overlap in a similar manner.

[0196] Further, in the repair and strengthening system 900 (see Embodiment 9), a plurality of steel grid plates 990 may be used, and the plurality of steel grid plates 990 may be made to partially overlap in a similar manner. At this time, the ribs 95 may be provided either on one side or both sides.

[0197] Further, a part of the steel grid plate 890 (Embodiment 8) and a part of the steel grid plate 990 (Embodiment 9) may be made to overlap.

INDUSTRIAL APPLICABILITY

[0198] According to the present invention, delivery of force between the steel plate and the filler can be improved. Therefore, the present invention can be used for a wide variety of applications as a repair and strengthening structure for a reinforced concrete structure to repair or strengthen various reinforced concrete structures such as floors, beams, and columns.

We claim:

1. A repair and strengthening system for a reinforced concrete structure, comprising:

   - a steel plate that is disposed with a space to a structure surface, the structure surface being a surface of the reinforced concrete structure; and
   - a filler that is injected in the space, wherein a plurality of protrusions are formed on a steel-plate front face that is a surface on one side of the steel plate, and the steel-plate front face faces the structure surface.

2. A repair and strengthening system for a reinforced concrete structure, comprising:

   - a steel plate that is disposed with a space to a structure surface, the structure surface being a surface of the reinforced concrete structure; and
   - a filler that is injected in the space, wherein a plurality of openings are formed in the steel plate, and the openings are blocked by the filler.

3. A repair and strengthening system for a reinforced concrete structure, comprising:

   - a steel plate that is disposed in contact with a structure surface, and is provided with a plurality of openings, the structure surface being a surface of the reinforced concrete structure; and
   - a filler that blocks the openings.

4. The repair and strengthening system for a reinforced concrete structure of claim 3, wherein a plurality of protrusions are formed on a steel-plate front face that is a surface on one side of the steel plate, and at least one of the plurality of protrusions is in contact with the structure surface.

5. The repair and strengthening system for a reinforced concrete structure of claim 3, wherein a plurality of protrusions are formed on a steel-plate back face that is a surface on another side of the steel plate, and the plurality of protrusions formed on the steel-plate back face are surrounded by the filler.

6. The repair and strengthening system for a reinforced concrete structure of claim 3, wherein the repair/strengthening system has a plurality of the steel plates, and in one steel plate pair of the steel plates, at least one of the openings of one steel plate and at least one of the openings of another steel plate overlap each other, and the one steel plate and the other steel plate are integrated together by the filler injected in overlapping openings of the one steel plate and overlapping openings of the other steel plate.

7. The repair and strengthening system for a reinforced concrete structure of claim 2, wherein the plurality of openings are formed by enlarging a plurality of slits formed in the steel plate by stretching.

8. The repair and strengthening system for a reinforced concrete structure of claim 1, wherein the plurality of protrusions are formed integrally when the steel plate is manufactured by hot rolling.

9. The repair and strengthening system for a reinforced concrete structure of claim 8, wherein the plurality of protrusions are spaced by 30 mm to 40 mm from each other, have a height of 2.5 mm to 5.0 mm, and have a width of 4 mm to 20 mm, the width being a distance in a direction perpendicular to a direction of the hot rolling at a base of the protrusions.

10. The repair and strengthening system for a reinforced concrete structure of claim 1, wherein the steel plate is supported by a hang bolt, the hang bolt being installed in the reinforced concrete structure and projecting from the structure surface.

11. The repair and strengthening system for a reinforced concrete structure of claim 1, wherein:
the reinforced concrete structure includes the structure surface, and a pair of structure sides that are continuous with the structure surface;

the repair/strengthening system comprises

- a steel-plate support member including
  - a support horizontal member that is disposed in parallel to the structure surface,
  - a pair of support vertical members that are disposed in parallel to the pair of structure sides, and
  - a supporting bolt that is installed in the reinforced concrete structure, and projects from the pair of structure sides;

the steel-plate support member is installed onto the reinforced concrete structure with the supporting bolt that penetrates a vertical-member through-hole formed in the pair of support vertical members; and

the steel plate is installed on the support horizontal member of the steel-plate support member.

12. The repair and strengthening system for a reinforced concrete structure of claim 11, wherein:

- the vertical-member through-hole is elongated in a direction perpendicular to the support horizontal member;
- a height adjusting bolt is installed to each of the support vertical members, the height adjusting bolt being movable in the direction perpendicular to the support horizontal member and abutting against the supporting bolt at a distal end; and
- as the height adjusting bolt is turned, the steel-plate support member is moved in a direction perpendicular to the structure surface.

13. The repair and strengthening system for a reinforced concrete structure of claim 11, wherein:

- a guide projection is provided on a steel-plate back face, the steel-plate back face being a side opposite to the steel-plate front face;

- the support horizontal member is provided with a support-member guide groove into which the guide projection enters; and
- as the guide projection is guided by the support-member guide groove and moves, the steel plate is able to move relatively with respect to the steel-plate support member.

14. The repair and strengthening system for a reinforced concrete structure of claim 11, wherein the support horizontal member and the support vertical members are detachably coupled by a fastening bolt.

15. The repair and strengthening system for a reinforced concrete structure of claim 1, wherein the steel plate includes a pair of steel-plate sidewall parts, the pair of steel-plate sidewall parts being continuous with opposite side edges of the steel plate and formed on a same side as the steel-plate front face.

16. The repair and strengthening system for a reinforced concrete structure of claim 2, wherein:

- the steel plate is bent into a U-shape in section that includes a bottom portion and a pair of side portions;
- a bar member is installed to penetrate a structure through-hole formed in the reinforced concrete structure; and
- as the bar member penetrates the openings, the steel plate is secured onto the reinforced concrete structure.

17. The repair and strengthening system for a reinforced concrete structure of claim 1, wherein the steel plate is made of plain steel, high tension steel, stainless steel, or weathering steel.

18. The repair and strengthening system for a reinforced concrete structure of claim 1, wherein the filler is mortar, shrinkage-compensating mortar, polymer cement mortar, resin mortar, fiber reinforced concrete, superplasticized concrete, high-strength concrete, an epoxy resin injection material, a polyurethane resin injection material, or a sodium silicate injection material.