

RIB FOR SUPPORTING AND CONSOLIDATING AN EXCAVATION AND METHOD
FOR INSTALLING A STRUCTURE TO SUPPORT AND CONSOLIDATE AN
EXCAVATION

The present invention concerns a rib for supporting and consolidating an excavation and a method for installing a supporting and consolidating structure within an excavation.

As is known, to support excavations, such as motorway or railway tunnels, consolidating arches called "ribs" are used. In particular, a rib usually comprises a plurality of shaped steel elements mutually connected in a "vault" configuration. These elements are formed by "open" profiles with H, INP, C or double T transverse cross-section, and are made integral with one another by a connection element known as a tie plate. In the majority of cases, the profiles are mutually connected at the level of the excavation to be reinforced, after having been shaped by metalworking. After being assembled, each rib is connected to the adjacent ribs through connection chains whose ends are connected to supports welded along the body of the rib profiles. The space between two consecutive ribs and the wall of the excavation is usually reinforced with sprayed concrete (shotcrete).

A method for installing a structure to support and consolidate an excavation is known from the document EP 2354447, which describes an excavation consolidation structure in which the ribs are mutually connected through the use of chains. Each connection chain is connected at a first end to a first connection ring welded to a first rib, and at a second end to a second connection ring welded to a second rib. For each rib, the connection rings are welded at predetermined distances along the rib. Each chain connects connection rings belonging to adjacent ribs, but arranged at the same height with respect to the plane on which the ribs

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are supported. According to this known method, two chains may be used crosswise to connect to adjacent ribs.

This method of making the connection between the ribs presents various disadvantages.

Since the chains must be connected to the connection rings, the operation must be performed manually. This operation requires a substantial investment of time, since for each rib there are four connecting points for the chains of each side with respect to the axis of symmetry of the rib concerned.

This operation is also difficult and might not be performed correctly. If, once the rib has been installed, it were to be found that a connection has not been completely made, it might be necessary to reposition the rib so as to reconnect the chain to the corresponding ring. On the other hand, if a chain were to become disconnected from the respective ring once the entire structure has been installed, it would be difficult to intervene in order to reconnect the chain to the ring, and the stability of the connection and consequently of the entire structure would be compromised.

The aim of the present invention is to provide a rib that can be easily and quickly connected to other adjacent ribs, where "adjacent" means a rib arranged at a preset distance with respect to the preceding and succeeding ribs.

A further aim of the present invention is to provide a method for simply installing a stable structure comprising a plurality of ribs.

These aims are achieved by means of a rib for supporting and consolidating an excavation, comprising at least a first structural element and at least one connection element for connecting the said structural element of the said rib to a corresponding connection element of an adjacent rib, in which the said connection element is capable of engaging through translatory motion with the said corresponding connection

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element of the adjacent rib so as to make the connection of the said ribs.

These aims are also achieved by means of a method for installing a supporting and consolidating structure comprising at least a first rib and at least a second rib, the said method comprising the following phases: installing the said first rib inside the excavation; transporting the said second rib inside the excavation to a position adjacent to the said first rib; moving the connection element of the said second rib in a translatable motion towards the connection element of the said first rib and making the connection between the said connection elements.

Advantageously, the connection element has an elongated form, extending in a direction essentially perpendicular to the plane of development of the rib. Preferably, the connection element has an essentially cylindrical form. In this way, the connection can be simply made by moving the rib in a direction parallel to the ground so as to connect the connection elements to each other.

Preferably, the connection element comprises at least a first insertion portion and at least a second locking portion, the said insertion portion being insertable by translatable motion into the locking portion of a corresponding connection element of an adjacent rib. In this way, a compact connection system is obtained in which all the means necessary for the connection are provided on a single element, increasing the security of the connection and facilitating assembly.

According to an advantageous implementation, the first insertion portion is associated with a projection capable of moving between a first sliding position and a second locking position. This projection makes it possible to lock the connection element of a rib with that of an adjacent rib.

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Preferably, the first insertion portion comprises at least one essentially cylindrical section. Advantageously, the first insertion portion is arranged at a first end of the said connection element. This implementation facilitates the insertion by translatable motion of a connection element into a corresponding connection element.

Advantageously, the first insertion portion comprises an insertion end and an intermediate portion. According to an advantageous implementation, the intermediate portion has a tubular section capable of forming with the said insertion end a housing throat for the said projection, preferably in the form of a ring. This solution facilitates the insertion and subsequent locking of the connection element.

According to a preferred implementation, the second locking portion comprises an essentially tubular section. Advantageously, the tubular section is associated with a funnel-shaped portion. The funnel-shaped portion makes it possible to guide the insertion end of a corresponding connection element into the interior of the tubular section.

Advantageously, the second locking portion comprises a recess capable of receiving the projection associated with the first insertion portion of a corresponding connection element of an adjacent rib. The locking system is therefore compact and stable.

According to a preferred implementation, the connection element is capable of moving in a translatable motion with respect to the relative structural element of the rib.

Advantageously, the connection element is capable of moving in a translatable motion with respect to the relative structural element of the rib from a first position in which the locking end is arranged in the proximity of the structural element to a second position in which the locking end is arranged at a predetermined distance from the structural element. This allows the connection to be easily

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made by arranging the rib in the proximity of the adjacent rib and then repositioning the rib at a predetermined distance from the adjacent rib. Preferably, the comprises means for arresting the relative translatory motion of the connection element with respect to the said structural element, so as to arrest the rib in the predetermined position.

According to an advantageous implementation, the structural element comprises a tubular body provided with an internal cavity. The closed section makes it possible to inject concrete into the cavity, thus obtaining a stronger structure. Advantageously, the connection element is arranged at least partially inside the relative structural element of the rib, so as to increase the security and stability of the connection.

According to an advantageous implementation, the structural element of the rib is associated with a supporting element, the said supporting element comprising means for adjusting the extension of the said supporting element, in order to allow both relative movement of the structural elements and adjustment of the support of the rib on the ground. The adjustment means preferably comprise a first portion of the said supporting element that slides with respect to a second portion of the said supporting element.

Further characteristics and advantages will emerge from the following detailed description of a preferred implementation of the invention, provided purely by way of non-limitative example, with reference to the annexed drawings, in which:

- Figure 1 shows a front view of a preferred form of implementation of the supporting and consolidating rib according to the present invention;

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- Figure 2 shows a side view of a preferred form of implementation of a supporting and consolidating structure consisting of ribs according to the present invention;
- Figure 3 shows a partially cross-section view of a preferred form of implementation of the connection element of the rib according to the present invention;
- Figure 4 shows the connection phases of a connection element of a rib to the connection element of an adjacent rib according to the present invention;
- Figure 5 shows a side view of a supporting element of the rib in a first position;
- Figure 6 shows a side view of a supporting element of the rib in a second position;
- Figure 7 shows a first phase of installation of a structure to support and consolidate an excavation according to the present invention, in which a rib is arranged in a position adjacent to a rib already fixed to the structure;
- Figure 8 shows a second phase of installation of the structure of Figure 7 in which the connection element is connected to the connection element of the adjacent rib;
- Figure 9 shows a third phase of installation of the structure of Figure 7 in which the rib is moved to a predetermined distance from the adjacent rib;
- Figure 10 shows a phase of installation of the structure of Figure 7 in which the supporting element is raised with respect to the ground;
- Figure 11 shows a phase of installation of the structure of Figure 7 in which the supporting element is lowered into contact with the ground.

Figure 1 illustrates a possible form of implementation of a supporting and consolidating rib 1 according to the present invention. The rib 1 is formed by one or more structural elements 5A, 5B, 5C, made from a metallic material such as construction steel (Fe 430 or other). The rib 1 has a

symmetrical "vault" configuration with respect to a plane of symmetry S. This configuration generally reflects that of the portion of the excavation intended to be reinforced by means of the said rib.

The rib in Figure 1 comprises a first structural element 5A, a second structural element 5B connected to the first structural element 5A and a third structural element 5C connected to the second structural element 5B so as to define the plane of development of the rib. As illustrated, the first structural element 5A and the third structural element 5C have an essentially mirror-image position with respect to the plane of symmetry S of the rib 1. The second structural element 5B is preferably developed symmetrically between the first structural element 5A and the third structural element 5C with respect to the said plane of symmetry.

The first structural element 5A is provided with a first end portion 51 operationally connected to a first terminal portion 81 of the second structural element 5B by first connecting means 61 and a second end portion 52 intended to be connected to a supporting element 90 of the rib.

The third structural element 5C has a first end portion 71 intended to be connected to a second terminal portion 82 of the second structural element 5B by connecting means 62 and a second end portion 72 intended to be connected to a second supporting element 90' of the rib 1.

According to a preferred form of implementation, each structural element 5A, 5B, 5C is formed by a tubular body. The tubular body has a transverse cross-section that defines a respective internal cavity that develops over the entire length of the body. This internal cavity is intended to be filled with concrete following the installation of the rib 1. The transverse cross-section of the tubular body may be square, rectangular or circular.

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According to this form of implementation, the body of the first tubular element 5A is prepared to be associated with a filling device, not illustrated in the drawing, operationally capable of being connected to means for the injection of concrete into the internal cavity of the said body.

Preferably, the third structural element 5C is also capable of being associated with a filling device associated with the tubular body of the said element.

Advantageously, the connecting means 61, 62 that connect the second structural element 5B with the first structural element 5A and the third structural element 5C are configured so that the internal cavity of the second structural element 5B is in communication with those of the first structural element 5A and of the third structural element 5C. Through this solution, the concrete injected into the internal cavity of the first structural element 5A and of the third structural element 5C can also reach the internal cavity so as to allow it to be filled.

In other forms of implementation not illustrated in the drawings, the rib may be formed by one or more structural element consisting of profiles with an open transverse cross-section, for example an H or a C or a double T cross-section.

According to the invention, the rib comprises at least one connection element 10 for connecting the rib 1 to an adjacent rib 1', the said connection element 10 engaging through translatory motion with a corresponding connection element 10' of the adjacent rib 1'.

According to the preferred form of implementation illustrated in Figure 2, the connection element 10 has an elongated form, preferably cylindrical, that extends in a direction essentially perpendicular with respect to the axis of development of the rib 1. Advantageously, the rib 1 comprises a plurality of connection elements 10 arranged at a predetermined distance from each other. In the form of

implementation illustrated in Figures 1 and 2, each structural element 5A, 5C comprises three connection elements 10, while the structural element 5B comprises four connection elements 10.

In the preferred form of implementation illustrated in Figure 3, the connection element 10 has a tubular form comprising an insertion end 20, an intermediate portion 30 and a locking end 40.

The insertion end 20 comprises a tubular head 21 with a tapered end 22.

The intermediate portion 30 has a first tubular section 31 with a smaller external diameter with respect to the tubular head 21 of the insertion end 20 and a second tubular section 32 with an external diameter essentially equal to that of the head 21, so as to form with the insertion end 20 a throat 33. In the throat 33 is arranged an open ring 34 provided with a hole 35 and a pin 36. The pin 36 is associated with an elastic element, preferably a helical spring 37 fitted on to the said pin 36, so as to move from a position essentially external to the hole 35 to a position of insertion in the hole 35 under a closure force exerted on the ring 34.

The locking end 40 consists of a tubular section 41 that enlarges into a funnel-shaped portion 42 at the opposite end with respect to the intermediate portion 30.

The tubular section 41 of the locking end 40 is fitted and attached, preferably by welding, over one of its lengths L on to the external surface of the tubular section 32 of the intermediate portion 30. The internal surface of the tubular section 41 of the locking end 40 not associated with the intermediate portion 30 has a recess 43. This recess 43 is capable of receiving the ring 34 arranged in the throat 33 of the intermediate portion 30 of a connection element of the adjacent rib.

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More specifically, during the connection of two adjacent ribs, the insertion end 20 of a connection element 10 of a first rib 1 is inserted into the funnel-shaped portion 42' of the locking end 40' of a corresponding connection element 10' of the adjacent rib 1' and moves in a translatory motion inside the tubular section 41' of the locking end 40'. The ring 34 associated with the intermediate portion 30 of the connection element 10 of the first rib 1 closes when it comes into contact first with the funnel-shaped portion 42' and then with the tubular section 41' of the locking end 40' of the connection element 10' of the adjacent rib 10', moving the pin 36 into the hole 35 against the force of the spring 37.

Upon reaching the recess 43' created on the internal surface of the tubular section 42' of the connection element 10' of the adjacent rib 1', the spring 37 moves the ring 34 into the open position, locking the connection element 10 of the first rib 1 on to the corresponding connection element 10' of the adjacent rib 1'.

In a form of implementation not illustrated in the drawings, the connection element may have an elongated form other than cylindrical, for example a square or rectangular cross-section, and may be provided with locking means associated with its external surface.

According to the preferred form of implementation illustrated in the drawings, the connection element 10 is arranged inside the structural element 5A, 5B, 5C of the rib 1 and can move in a translatory motion with respect to it. In particular,

in the structural element 5A, 5B, 5C is formed a hole 55 in which is fixed a sleeve 56 within which the intermediate portion 30 of the connection element 10 slides. In an alternative form not shown in the drawings, the connection

element is instead fixed to an external surface of the rib and associated with it by means of a sliding connection.

According to the illustrated form of implementation, the connection between adjacent ribs occurs as shown in Figure 4.

Phase 1 of Figure 4 shows a schematic side view of two ribs 1', 1'' positioned and already connected to each other. The rib 1' has the connection element 10' arranged so that the insertion end 20' and an initial section of the intermediate portion 30' project with respect to the structural element 5A' in which the connection element 10' is inserted.

Phase 2 of Figure 4 shows the approach by translatory motion of a corresponding structural element 5A of a successive rib 1 towards the relative connection element 10. The connection element 10 is arranged so that the locking end 40 is close to the respective structural element 5A.

Phase 3 of Figure 4 shows the connection between the two connection elements 10, 10', with the insertion end 20' of the element 10'

that slides inside the locking end 40 of the corresponding connection element 10, so as to move the ring 34' of the element 10' into the closed position while maintaining the pin inside the hole and then, once the recess 43 of the connection element 10 is reached, to allow the ring 34' to return to the open position while remaining locked inside the locking end 40 of the connection element 10.

Phase 4 of Figure 4 shows the successive positioning of the rib 1 obtained by making the structural element 5A slide with respect to the connection element 10, which is locked on the connection element 10' of the adjacent rib 1'. The structural element 5A slides until the point at which the sleeve 56 reaches a stop 57 created on the second tubular section 32 of the intermediate portion 30 of the connection element 10.

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Figures 5 and 6 illustrate a preferred form of implementation of the supporting element 90 of the rib 1 that allows relative movement of the structural elements and adjustment of the support of the rib on the ground. Reference is made below to the supporting element connected to the first structural element 5A, but the same considerations are also valid for the supporting element 90' connected to the structural element 5C.

Advantageously, the supporting element 90 comprises a first portion 94 that is movable, particularly by sliding, with respect to a second portion 95, so as to be capable of modifying the extension of the supporting element 90 in the direction of development of the rib 1 between a height H and a height H'. The second portion 95 is fixed to a supporting foot 97 of the rib 1, capable of being arranged in contact with the ground. The first portion 94 is connected to the second end portion 52 of the relative structural element 5A by connecting means 66.

In the form of implementation illustrated in the drawings, the second portion 95 is tubular and the first portion 94 is capable of sliding within the tubular portion 95. The supporting foot 97 comprises a base plate 91 and stiffening plates 93 connected, preferably by welding, to the tubular portion 95. Preferably, the first portion 94 is also tubular and connected telescopically to the second tubular portion 95.

Preferably, the internal cavity of the first structural element 5A is in communication with the internal cavity of the innermost tubular portion 95 of the supporting element 90 so as to allow the latter to be filled by injection with concrete.

The present invention also concerns a method for installing a supporting and consolidating structure comprising at least two ribs.

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Figures 7-11 show a preferred succession of phases for the installation of a support structure according to the present invention. The method provides for a phase of installation of a first rib inside the excavation, followed by the installation of successive adjacent to each other.

Figure 7 shows, in particular, the phase in which a successive rib 1 is transported into the excavation and arranged in the proximity of a rib 1' already present in the excavation and connected to other ribs.

Figure 8 shows, in particular, the phase in which the rib 1 to be installed is moved in a translatory motion towards the adjacent rib 1' so that the insertion end 20 of the relative connection elements 10 is inserted into the locking end 40' of the corresponding connection elements 10' of the adjacent rib 1'.

Figure 9 shows, in particular, the phase in which the rib 1 to be installed, once connected to the adjacent rib 1' and therefore to the support structure, is moved away by translatory motion with respect to the adjacent rib 1' to a preset distance.

Figures 10 and 11 show the adjustment of the supporting element 90. In Figure 10, the supporting element 90 has the internal portion 94 inserted into the external tubular portion 95 so that the supporting foot 91 is arranged at a determined distance from the ground. In Figure 11, the external tubular portion 95 is lowered by sliding on the internal portion 94 so as to bring the supporting foot 91 into contact with the ground.

The present invention thus makes it possible to easily install the ribs so as to obtain a stable structure. Connection requires a simple translatory motion of the rib and the connection element associated with it until the

connection is made with the corresponding element of the adjacent rib. Locking takes place rapidly, does not require manual intervention and is more stable and secure with respect to the connection with chains. It is also possible to automatically position the rib in the correct manner. The structure consisting of multiple ribs is therefore easy to install and offers a high degree of security and stability.

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CLAIMS

1. Rib for supporting and consolidating an excavation, comprising at least a first structural element (5A) and at least one connection element (10) for connecting the said structural element (5A) of the said rib (1) to a corresponding connection element (10') of an adjacent rib (1'), characterised in that the said connection element (10) is capable of engaging through translatory motion with the said corresponding connection element (10') of the adjacent rib (1') so as to make the connection of the said ribs (1, 1').

2. Rib according to claim 1, characterised in that the said connection element (10) has an elongated form, in particular essentially cylindrical, extending in a direction essentially perpendicular to the plane of development of the rib (1).

3. Rib according to any of claims 1 or 2, characterised in that the said connection element (10) comprises at least a first insertion portion (20, 30) and at least a second locking portion (40), the said first insertion portion (20, 30) being insertable by translatory motion into the locking portion (40') of a corresponding connection element (10') of an adjacent rib (1').

4. Rib according to claim 3, characterised in that the said first insertion portion (20, 30) is associated with a projection (34) capable of moving between a first sliding position and a second locking position.

5. Rib according to claim 3 or 4, characterised in that the said first insertion portion (20, 30) comprises at least at least one essentially cylindrical section, the said first

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insertion portion (20, 30) being preferably arranged at a first end of the said connection element (10).

6. Rib according to claim 4 or 5, characterised in that the said first insertion portion (20, 30) comprises an insertion end (20) and an intermediate portion (30), the said intermediate portion (30) having a tubular section (31) capable of forming with the said insertion end (20) a housing throat (33) for the said projection (34), the said projection (34) being preferably in the form of a ring.

7. Rib according to any of claims 3 to 6, characterised in that the said second locking portion (40) comprises an essentially tubular section (41), preferably associated with a funnel-shaped portion (42).

8. Rib according to any of claims 3 to 7, characterised in that the said second locking portion (40) comprises a recess (43) capable of receiving the projection (34') associated with the first insertion portion (20', 30') of a corresponding connection element connection (10') of an adjacent rib (1').

9. Rib according to any of the preceding claims, characterised in that the said connection element (10) is capable of moving in a translatory motion with respect to the relative structural element (5A) of the said rib, in particular from a first position in which the locking end (40) is arranged in the proximity of the structural element (5A) to a second position in which the locking end (40) is arranged at a predetermined distance from the structural element (5A).

10. Rib according to claim 9, characterised in that it comprises means (57) for arresting the relative translatable motion of the connection element (10) with respect to the said structural element (5A).

11. Rib according to any of the preceding claims, characterised in that the said structural element (5A) comprises a tubular body provided with an internal cavity, the said connection element (10) being arranged at least partially inside the relative structural element (5A) of the said rib.

12. Rib according to one of the preceding claims, characterised in that the said structural element (5A) of the said rib is associated with a supporting element (90), the said supporting element comprising means (94, 95) for adjusting the extension of the said supporting element (90), the said adjustment means (94, 95) comprising preferably a first portion (94) of the said supporting element (90) that slides with respect to a second portion (95) of the said supporting element.

13. Method for installing a structure to support and reinforce an excavation comprising at least a first rib (1) and at least a second rib (1') according to any of the preceding claims, characterised in that it comprises the following phases:

installing the said first rib (1) inside the excavation;
transporting the said second rib (1') inside the excavation to a position adjacent to the said first rib (1);
moving the connection element (10') of the said second rib (1') in a translatable motion towards the connection element (10) of the said first rib (1) and making the connection between the said connection elements (10, 10').

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14. Method according to claim 13, characterised by the insertion of a first insertion portion (20', 30') of the connection element (10') of the said second rib (1') into a corresponding locking portion (40) of the corresponding connection element (10) of the said first rib (1) in order to make the connection between the said connection elements (10, 10').

15. Method according to claim 13 or 14, characterised by the translatory motion of the structural element (5A') of the said second rib (1') with respect to the relative connection element (10') in order to position the said second rib (1') at a predetermined distance with respect to the said first rib (1).