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(54) Prestressing strand for concrete structures and concrete structures containing such strand.

(57) In a prestressing strand for use in stressing a concrete structure, having a central core wire and a plurality of outer wires extending helically around the core wire the helical pitch length (S) of the outer wires is chosen to be between 20 and 150 times the maximum diameter of the strand. This strand is found to give more accurate stressing, especially where the conduit in the concrete for the tensioned wire is curved.

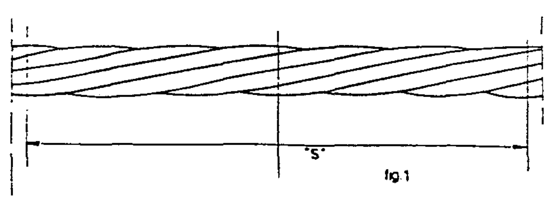

fig.1

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"Prestressing strand for concrete structures"

The invention relates to prestressing strand for concrete structures comprising at least one central core wire and outer wires helically enveloping the core wire. Such strands are often used as reinforcing elements in pre-stressed concrete structures, in which they offer the possibility of being inserted in curved channels in the concrete structure.

The channels are formed by enveloping tubes of steel or another material, which are pre-cast into the concrete structure.

A commonly used type of prestressing strand comprises six equally thick outer wires and one single core wire the diameter of which is between 2 and 5 per cent greater than that of the outer wires. This last feature is of importance in order to obtain a construction of strand with a good coherence in which the outer wires fit against the core wire. Although the strand form as described above is the one most used for prestressing strands, the invention is not restricted to this specific strand construction, but it also relates to other strand constructions of the type indicated at the outset.

In Figs. 1 and 2 a prestressing strand having a single core wire and six outer wires is illustrated in longitudinal view and in cross section respectively. In Fig. 1 also there is indicated the pitch of the helices in which each of the outer wires lies. For the whole strand, this pitch S is referred to by the expression "stroke length". In Fig. 2 it is indicated that by the diameter of the strand is understood the greatest cross-sectional dimension D. It is usual to express the stroke length as a multiple of the diameter. For prestressing strands, the stroke length S mostly varies between 12 and 18 times the diameter. In this connection it is remarked that in various countries regulations apply for the limits between which the stroke length can be chosen. These prescribed limits are often derived from concepts which are developed in relation to the use of hoisting cables. The invention is based on the concept that for prestressing strands investigations have not yet been carried out in order to find the most suitable strand construction in practice.

In the tensioning of a prestressing strand, use is as a rule made of the elongation properties of the strand under tensioning in an unhindered straight condition. For this it has been found that the ratio between the mean stress over the cross section of the strand and its strain deviate little from the elasticity modulus of the wire material. Small deviations can appear in dependence on the production method of the strand and its construction.

In the application of prestressing strands in curved channels through concrete structures, the effect of friction between the strand and the channel wall is encountered. Consequently, variations appear between the tension forces at the strand ends after the tensioning. By means of calculations it is possible to find a relationship between the total elongation of the strand in the curved channel and these tension forces at the ends, from which it is then possible to obtain an impression about the behaviour of the tension forces in the strand along its length, by applying a predetermined elongation to the strand.

It has now been found that as a consequence of variations within the frictional properties between strand and concrete, variations in the production methods of the cable and possibly other factors, great deviations can be found between the calculated elongations and elongations actually occurring in the tensioning of the prestressing strand. If the quotient of the mean stress over the strand cross section and the measured elongation of the strand per unit length is referred to by the expression "modulus of deformation", then it is found that, when using tension cables in curved channels this deformation modulus as a rule deviates considerably from the modulus of elasticity E of the wire material. More specifically it is found that the modulus of deformation in cases of substantial variation is as a rule smaller than the modulus of elasticity. This is the more serious, because in the application of a calculated elongation to the prestressing strand, an uncertainty exists whether along the whole length a sufficient tension exists in the strand, and whether the concrete structure arrives at the desired condition of prestress.

The tension condition and the deformation condition of a prestressing strand in a curved configuration, in which the strand is subjected to transverse forces and frictional forces, is highly complex, and is dependent on a great number of factors which are related to the properties of the material and the production methods for the strand.

A complete understanding of this has not yet been achieved, though by an empirical method the inventor of the present application can indicate systematic variations. It is indicated below by what method strands were tested.

It is thus now surprisingly found that the modulus of deformation, in the use of prestressing strand in curved channels, is very sensitive to the stroke length of the strand. More particularly, the invention consists in that a considerably better consistency between the modulus of deformation and the modulus of elasticity is obtained when the stroke lengths of the prestressing strand is chosen between 20 and 150 times the greatest diameter of the cable. It is remarkable that these limits are considerably higher than those which hitherto have been used in the art. It must be assumed that, with the greater stroke length the core wire can be more completely tensioned over its whole length and can cooperate as a load bearing element. On the other hand the prestressing strand must sufficiently remain a unit in order that slip occurring between the core wire and the outer wires is prevented, since this slip has a result that the core wire is no longer fully under load. The rate at which slipless transfer of tension between strand and the wedge anchors is possible is given by the expression "grip efficiency". It has been found that both as to the modulus of deformation and as to the grip efficiency, strands within the limits given above for the stroke length of between 20 and 150 D are considerably more satisfactory than known reinforcing strands. It has been found, in this connection, that no slip occurs between the core wire and the outer wires.

It has also been found that, in the loading of the prestressed concrete construction with a varying load, the fatigue behaviour of the strands is better than that of known strands. This can be explained by the fact that there is less danger of local peak stresses at the line of contact between the core wire and the outer wires, which could result in local stresses above the yield stress of the material.

If the prestressing strand is of the type described above, in which there are six equally thick outer wires and a single core wire with a diameter 2 to 5 percent greater than that of the outer wires, it has been found that especially good results are obtained by choosing a stroke length of 20 to 100 times the diameter of the strand. Particularly preferred is a stroke length of between 22 and 50 times the cable diameter.

Below, with reference to Figs. 3 to 6, it will be further illustrated how the influence of the stroke length on the modulus of deformation is determined.

Fig. 3 shows a test apparatus in plan view.

Fig. 4 is a front view of this.

Fig. 5 shows some measured results obtained using the test apparatus of Figs. 3 and 4.

Fig. 6 finally shows test results obtained with various similar test apparatuses.

In Figs. 3 and 4, reference numeral 1 indicates a concrete plate with a thickness of 22 cm. Through this concrete plate, a channel 3 runs, which channel over an angle of 5.07 radians is curved with a radius of curvature R = 100 cm. The length of the curved channel part L2 is consequently 507 cm. Against the ends of the channel a support beam 2 is located, with at the left hand side a wedge anchoring 5 for a strand and at the right hand side a similar wedge anchoring 5 behind a hydraulic press 4.

After a strand is inserted through the channel 3, the strand is secured by the wedge anchors, whereupon it is tensioned by means of the hydraulic press 4. The tensioned strand then consists of a straight piece L1 of a length of 175 cm, a curved piece of a length of L2 of 507 cm and another straight piece of length L3 of 210 cm.

The tests were carried out with the most common prestressing strand of thickness D of 0.5 inches. First the strand was brought under nominal tension, in order to stretch it sufficiently, whereupon the tension force was increased up to a value near the usual full load value used in tension technology. During the increase of the tension force, the elongation and the tension force in the strand were measured continuously.

By the "element method" the strand was considered to be divided in elements, and for each element the stress and strain conditions were calculated with the application of a frictional force between the channel wall and the prestressing strand. By means of separate tests with small angles of wrap frictional coefficients were between the strand and the channel wall at various tension forces in the strand were determined. Per element, these friction coefficients were introduced into the calculation so that it was possible to determine by calculation, what tension forces should be present in the strand, on the basis of the total measured extension of the strand between the anchors 5. This value was compared with the actual tension forces obtained, from which a value could be obtained for the modulus of deformation in each test performed.

Thereafter the test was repeated, with strands of varying stroke length, but otherwise of the same dimensions. In each case, in a corresponding manner, a value for the modulus of deformation was determined.

The values thus found by measurement and calculation for the modulus of deformation are set out in Fig. 5. In this figure, the stroke length 5 is set out on the horizontal axis, expressed in mm and also as a multiple of the cable diameter D. For this purpose, the diameter D was measured separately.

Along the vertical axis, the modulus of deformation is set out, expressed in kN/mm^2. At the top of the figure a horizontal line shows the level of 201 kN/mm^2, which represents the value of the modulus of elasticity E of the wire material used. The tests were performed with strands having stroke lengths of respectively 210, 290, 470 and 550 mm. The measured points were connected by straight lines to one another although of course a continuous line would result if more tests were performed with more varying values of the stroke length.

The hatched area shows the area in which known strands are found. It is clear that the modulus of deformation for greater stroke length is considerably greater than for the known stroke lengths.

The tests were repeated with test apparatuses with various radii of curvature greater than 1 m. These radii of curvature are shown along the horizontal axis in Fig. 6.

Along the vertical axis are shown the values for a quantity K, which represents the relationship between the measured values for the modulus of deformation and the modulus of elasticity of the material used. It will be clear that, for an infinite value R, the quantity K would be approximately equal to 1.0.

For strands with stroke lengths varying between S = 150 mm and S = 500 mm, values of K were determined for various radii of curvature R (all for strands with a diameter of 0.5 inches).

It is clear from this figure that the factor K (and thus also the modulus of deformation), for strands with a small stroke length diminishes when the curvature of the channel through which the strand is inserted increases. Also, it is clear from this figure that this relationship to the curvature is much less sensitive if the stroke length is increased. For values of the stroke length of 400 to 500 mm (32 to 40 D), the factor K is hardly influenced by the shape of the channel, which means that when the strand is tensioned the elongation imposed on the strand is a reliable measure for the tension which can be expected in the concrete structure.

From this figure, there is not to be seen the occurrence of the risk of slip between core and outer wires. For values of the stroke length considerably above the values given, the risk of mutual slip between the wires begins to increase, so that the reliability of the calculation of the tensioning force on the basis of the elongation is reduced.

In all cases it has been found that an increase of the stroke length improves the grip efficiency of the connection of the strand with the wedge anchors.

CLAIMS

1. Prestressing strand for concrete structure, comprising at least one central core wire and outer wires helically enveloping the core wire, characterised in that the so-called stroke length of the reinforcing strand is selected at between 20 and 150 x the greatest diameter of the strand.

2. Prestressing strand according to claim 1, of the type comprising six equally thick outer wires and a single core wire with a diameter which is 2 to 5% greater than that of the outer wires characterised in that the stroke length is between 20 and 100 x the diameter of the strand.

3. Prestressing strand according to claim 2 characterised in that the helical length is 22 to 50 x the diameter.

NDI 1

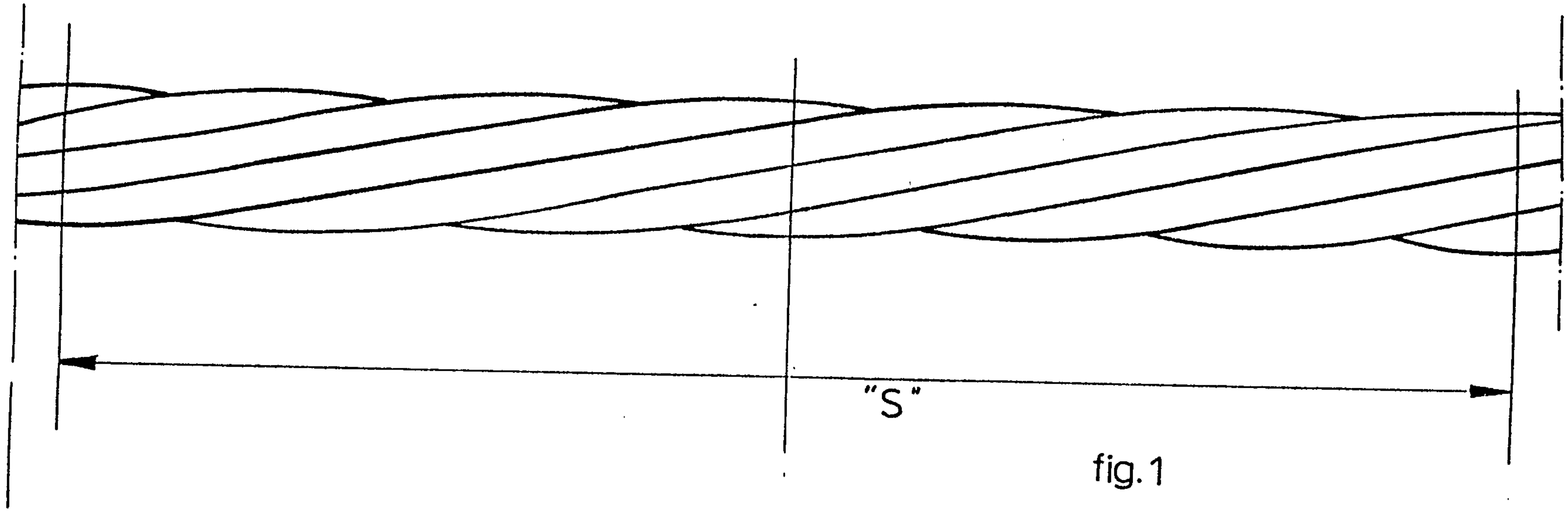

fig. 1

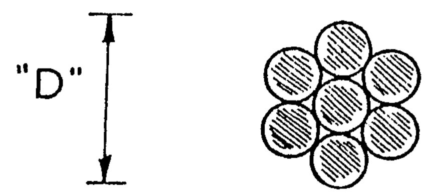

fig. 2

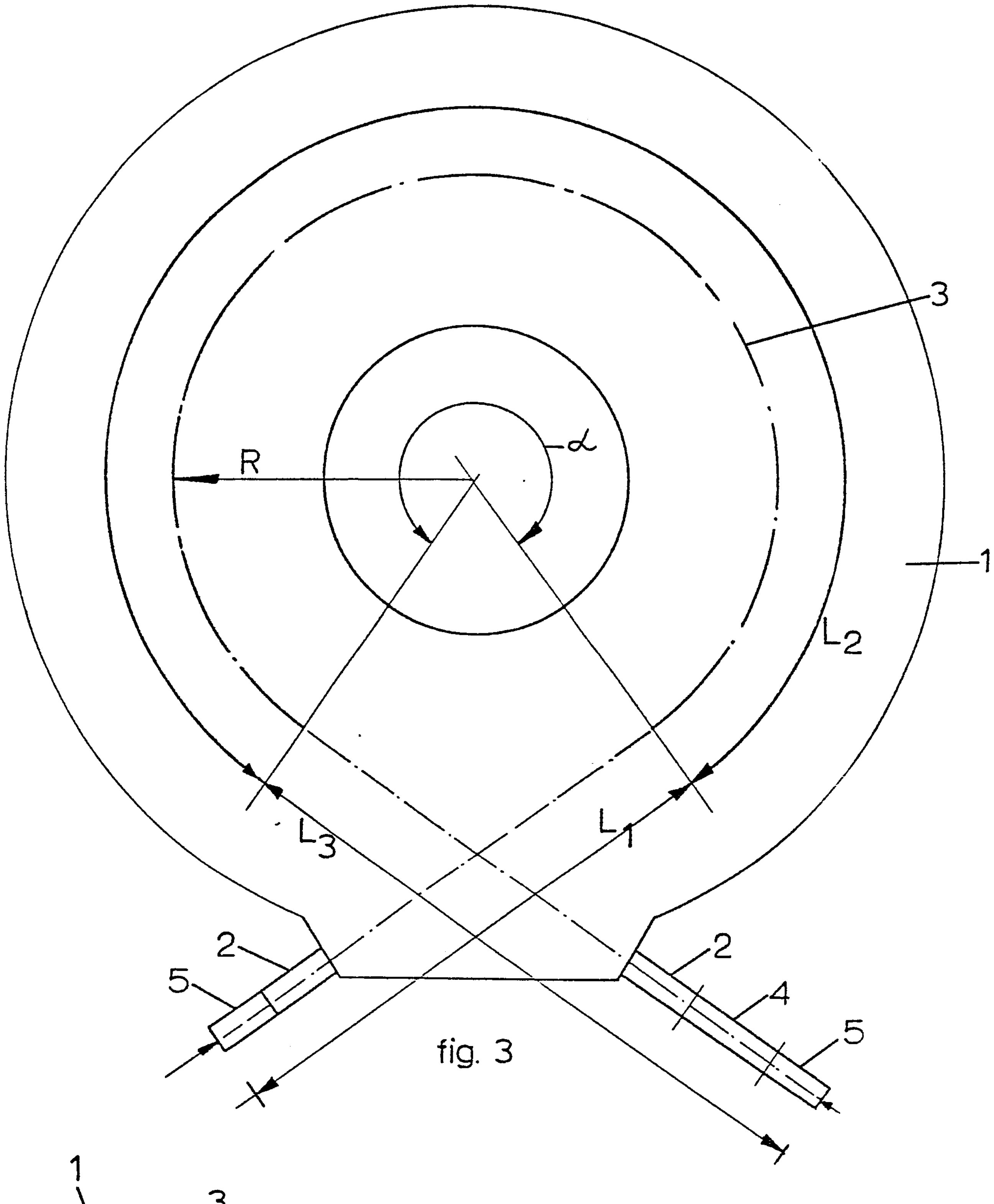

fig. 3

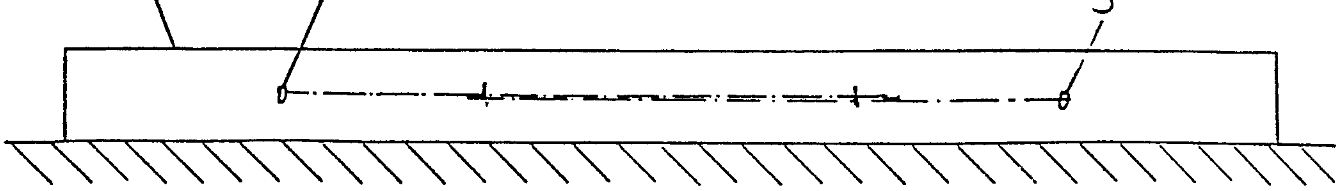

fig. 4

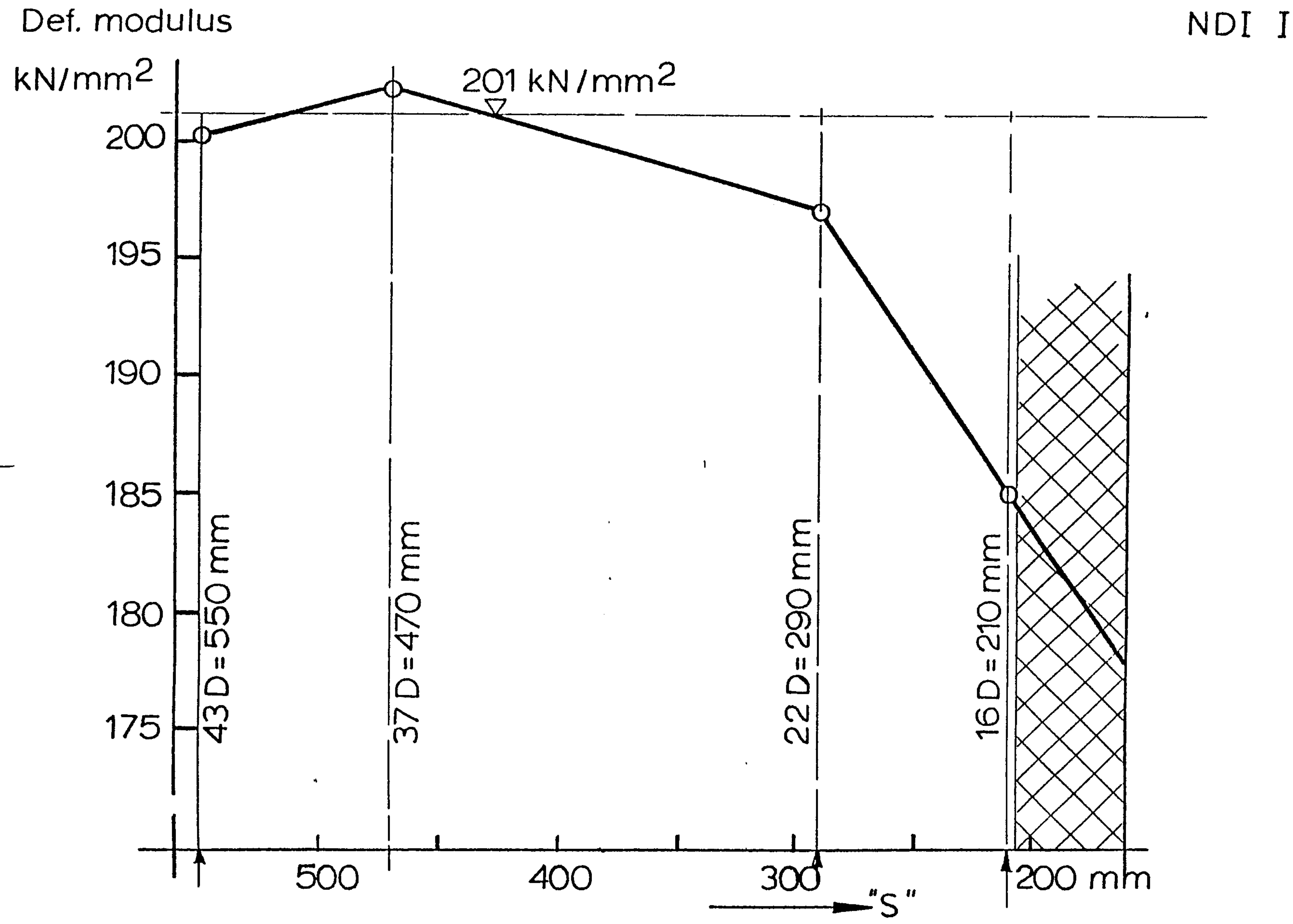
Def. modulus
kN/mm2
201 kN/mm2
200
195
190
185
180
175
43 D = 550 mm
37 D = 470 mm
22 D = 290 mm
16 D = 210 mm
500
400
300
200 mm
"S"
NDI I

fig. 5

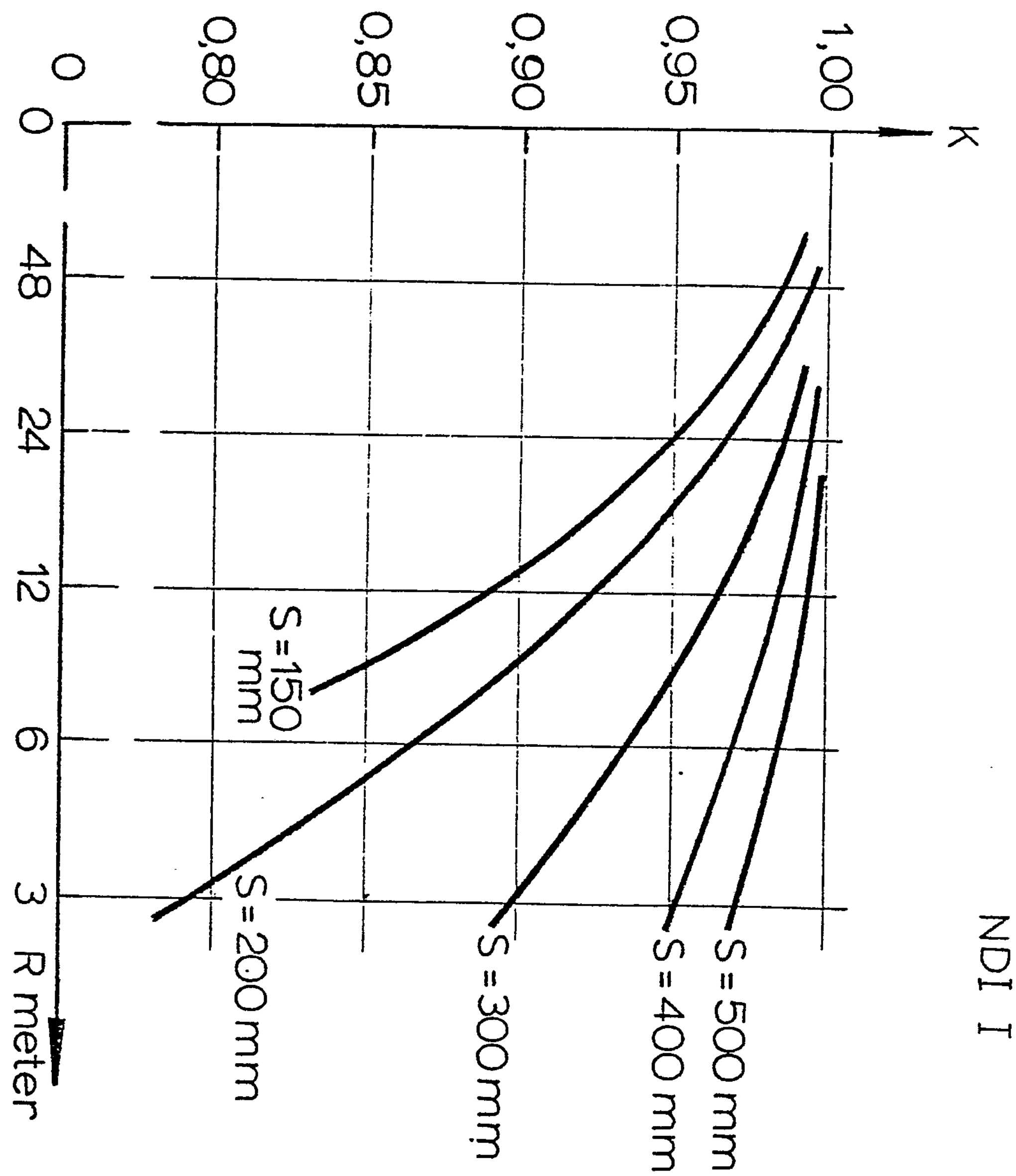
K
1,00
0,95
0,90
0,85
0,80
0
0
48
24
12
6
3
R meter
S = 150 mm
S = 200 mm
S = 300 mm
S = 400 mm
S = 500 mm
NDI I

fig. 6

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EUROPEAN SEARCH REPORT

Application number
EP 82 20 0892

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int Cl. 3)
A	DE-C- 483 351 (FELTEN) *Page 1, lines 37-60* ---	1	E 04 C 5/08 D 07 B 1/06
A	CH-A- 170 415 (SALVISBERG) *Page 1, column 1, paragraph 2; figures 1,2,3* ---	1	
A	US-A-1 822 189 (ZAPF) *Page 1, lines 8-26; figures 1,2* ---	1	
A	BE-A- 824 403 (TOKYO ROPE) *Claim 1* ---	1	
A	GB-A-1 424 672 (GKN) *Page 1, lines 68-73; figure 3* -----	2	

TECHNICAL FIELDS SEARCHED (Int. Cl 3)

E 04 C
D 07 B
E 01 D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	11-10-1982	HENDRICKX X.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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