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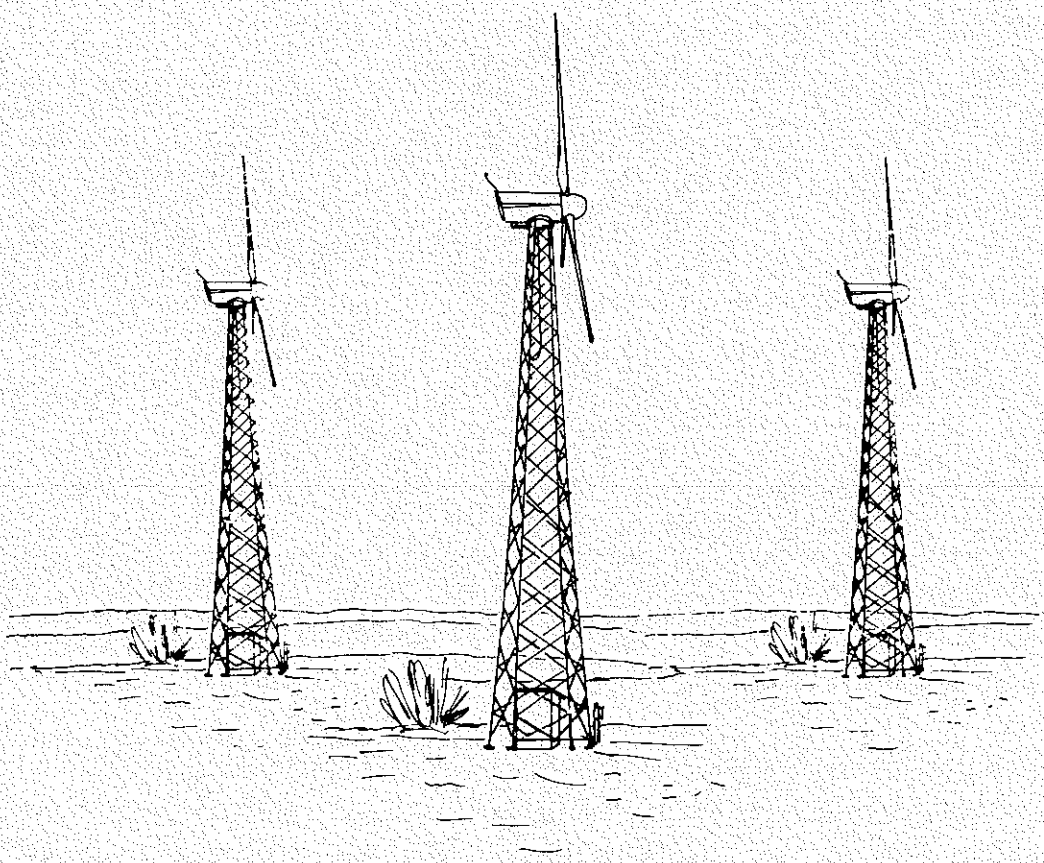
FC

WINDMILL REGULATIONS



VOLUME V

REGULATION ON THE APPLICATION OF FIBREGLASS TO WINDMILLS

1988

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REVIEW OF FC WINDMILL REGULATIONS

The following FC Windmill Regulations have been reviewed by Lloyd's Register of Shipping and are considered to be suitable as a design guide for the construction of Windmills.

In following these Regulations, the manufacturer should demonstrate the integrity of the construction to satisfy certification and local authority requirements.

The responsibility for the contents of the Regulations rested with the Folkecenter for Renewable Energy.

26th June 1989

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1. Lloyd's Register was requested to determine the appraisal requirements of Windmills designed to Folkecenter Windmill Regulations. These Regulations have been prepared and published with financial support from the Danish Council of Technology by its steering Committee for Renewable Energy.

Documents received are:-

FC Windmill Regulations

Volume I Regulation on the safety of Windmills, Feb 88.

Volume II Regulation on the determination of loads on Windmills, Feb 88.

Volume III Regulation on the application of timber to Windmills, Feb 89.

Volume IV Regulation on the application of steel to Windmills, Feb 89.

Volume V Regulation on the application of fibreglass to Windmills, Feb 88.

Volume VI Supplement, Feb 88.

2. The Regulations have been written as a set of guidelines for the design and construction of Windmills of various types. They stipulate specific rules for design and construction and do not rely on other codes. However exemptions are allowed in vol VI for using other valid bases of calculation and construction.

3. It is also stated that the Regulations will be withdrawn concurrently with the emanation of adequate national or international codes of practice, (P. 4-5, vol. II).

4. For design appraisal, Lloyd's Register will perform a review of the designer's calculations with independent checks if necessary. This checking process may rely on general engineering practice as to the choices of load data, material and manufacturing requirements. The Society also offers on site inspection and surveying. Independent assessments to comply with local authority requirements may also be required.

5. The Society has no objection if the FC Regulations were followed by the designers and manufacturers. However since the Regulations are not yet fully comprehensive, it is the designer's duty to demonstrate the integrity of the construction. They should show that the design is "appropriate" in the sense of the Regulations. Special effects such as extreme local environmental conditions (icing, temperature, wind, flood, earthquake, collision etc), noise disturbance, resonances, environmental interferences, unbalance, dynamic compling etc have already been taken into consideration.

6. The Regulations have specified construction details safeguarding the integrity of different components. These are useful guides to the designers. Design values are used throughout the Regulations with various safety factors for loads, materials and sectional properties. While this format may simplify the task of design, it is not directly comparable with other codes. The assessment of fatigue loads is of specific concern. The Society would prefer to use site specific wind regimes and design S-N curves for design appraisal.

7. During the course of this review, several versions of the Regulations have been commented upon and revisions have been submitted. The responsibility for the Regulations rested with the Folkecenter for Renewable Energy.

CONTENTS:

0. PREFACE:

The present set of FC windmill regulations forms a revised English edition of the NIVE windmill regulations published by FC in 1984, when FC assumed most of the activities of NIVE.

The FC windmill regulations comprise six volumes:

Volume I : Regulation on the safety of windmills.

Volume II : Regulation on the determination of loads on windmills.

Volume III : Regulation on the application of timber to windmills.

Volume IV : Regulation on the application of steel to windmills.

Volume V : Regulation on the application of fibreglass to windmills

Volume VI : Supplement.

When the NIVE Windmill Regulations were published in 1984, the purpose was to replace the rather simplistic and incoherent rules of thumb then in use as official guidelines with a flexible, coherent and comprehensive set of regulations, which might develop, through further considerations and exchange of experience, into a code of practice prepared for immediate use covering the various kinds and modes of operations of windmills.

Unfortunately the past years have brought no such development.

Thus the NIVE/FC Windmill Regulations still form the only complete set of guidelines and the only one considering a windmill a composition of a building and a machine and dealing with solidity and mode of operation, not to mention other kinds of windmills than the modern fast running horizontal axis windmill.

To avoid errors, safety factors are included in all final values throughout the regulations. Thus all values of loads, of strength and of stiffness rendered throughout the regulations are design values.

The values of loads, the values of strength and stiffness and the rules of construction form a whole specifically adapted to the conditions of windmills. Thus individual values are generally not comparable with analogous values rendered elsewhere.

Owing to the rather strict rules of construction, some of the strength values are somewhat higher than those laid down in national codes of practice, as those allow for a certain amount of strength reduction and stress intensification due to inconvenient constructions. Where the rules are not met, additional factors are used.

Units are left out in all expressions and tables throughout the regulations, as these are adapted to the units rendered in the relevant lists of symbols.

In order to complete and maintain the FC windmill regulations, the supplement comprising exemption clauses, additions and corrections will be issued according to need, thus forming the sixth volume of the regulations.

Except for specific exemptions, the FC regulations are indispensible.

Exemptions implying constant supervision or periodical inspection of load bearing members are ruled out.

Exemptions imply verification through measurement, through testing or through reference to a substitute regulation.

Measurement and testing may be performed according to the FC regulation in question or according to a substitute regulation.

An alternative regulation may only be regarded as substitute when recognized by FC and only to the extent that it covers windmills or has a similar field of application.

Generally, national and international codes of practise and the like are not recognized as substitute regulations, as they deal with installations either without movable parts, of a rigid construction, protected from the weather or subject to frequent inspection, whereas windmills are installations with unprotected, flexible and movable parts operating lengthily without inspection.

The purpose of the NIVE/FC windmill regulations being to meet an immediate want and to prepare the ground for a comprehensive set of codes of practice, the FC regulations will be withdrawn concurrently with the emanation of adequate national or international codes of practice.

Thus the present edition of the regulation on the application of fibreglass to windmills has been reduced to a supplement to Dansk Ingeniørforenings Code of Practice for the Structural Use of Glas Fibre Reinforced Unsaturated Polyester, DS 456.

The present set of regulations is prepared and published with financial support from the Council of Technology by its Steering Committee for Renewable Energy.

1. INTRODUCTION:

This volume forms a supplement to the corresponding Dansk Ingeniørforening's Code of Practise for the Structural Use of Glass Fibre Reinforced Unsaturated Polyester, DS 456, Teknisk Forlag 1985

As fibreglass is sensitive to weather induced decomposition due to microscopic cracks, which may form early in the lifetime of the windmill under ultimate loads, the corresponding strain is considered together with ultimate values, fatigue values and long duration values of strength.

Likewise the rules of construction in chapter 3 are set up to prevent decomposition, especially tearing of single glass fibres.

The expressions in chapter 4 dealing with intensification of stresses due to natural oscillations correspond to the first natural frequency in a material exclusive of damping, thus securing conservative estimates.

The strength and stiffness values apply to stresses resulting from the corresponding stress resultants according to vol II. Pertaining to fatigue stresses, stress resultants with a load cycle number of 10^6 apply.

2. SYMBOLS:

The following symbols apply:

B	Width	m
E	Modulus of elasticity	N/m^2
H	Heigth or thickness	m
K	Coefficient	-
L	Length	m
e	Frequency	s^{-1}
s	Compressive strength	N/m^2
t	Shear strength	N/m^2
σ	Tensile or compressive stress	N/m^2

3. DESIGN AND CONSTRUCTION:

In addition to the rules of DS 456, the following rules apply to joints, none but the following types of joints being allowed.

3.1. MOULDED JOINTS:

Moulded joints along the lengthways direction only are allowed. Apart from meeting the strength and the protection rules of the members themselves, a moulded joint must match the properties of the joined members, especially with regard to flexibility.

3.2. FIBREGLASS TO STEEL JOINTS:

Fibreglass to steel joints according to the following subsections 3.2.1 and 3.2.2 only are allowed.

3.2.1. CLAMPED JOINTS:

The fibreglass cross section must be clamped as a whole between two or more steel parts so as to transfer the loads through a surface pressure and to avoid crossways expansion. Either the loads must result in a compressive stress across the surface of the fibreglass member only, or the clamping stress must at the least equal 20 times the shear stress resulting from the load.

3.2.2. FLEXIBLE JOINTS:

An extensive joint is formed by moulding the fibreglass member around a flexible extension of the steel member composed of one or more parts.

Apart from meeting the strength and the protection rules according to volume IV, the extension must match the properties of the fibreglass member, especially with regard to the rigidity of the complete structure.

A relative stepwise change in the rigidity at the end of the extension must not exceed the coefficient K_S.

Likewise the gradual lengthways change in the rigidity along the compound structure must not exceed that of the pure fibreglass structure by a factor of more than the coefficient K_G.

The following values of K_S and K_G apply:

$$K_S = 0.1 \qquad (3.2.2.1)$$

$$K_G = 2.0 \qquad (3.2.2.2)$$

4. NATURAL OSCILLATIONS:

e denotes the natural frequency of a part of member in question according to volume II. Correspondingly e_c denotes the frequency of a cyclic load, the most important values being the frequency of rotation and the frequency of blade passage.

Load intensification must be taken into account, if the value of e is within the following range:

$$0.739 \times e_c < e < 2.45 \times e_c \qquad (4.1)$$

In this case, the following value of the load intensification coefficient K applies:

$$K = \left| \frac{1}{1 - \left(\frac{e_c}{e}\right)^2} \right| \qquad (4.2)$$

5. SPECIAL STRENGTH PROPERTIES:

The following subsections 5.1. and 5.2. deal with the special strength properties of fibreglass most frequently relevant to windmills.
Other properties may prove decisive.

5.1. COMPRESSION MEMBERS:

L_B denoting the buckling length and r denoting the radius of gyration, the following value of the buckling strength S_{-B} of a centrally loaded compression member applies:

$$s_B = \frac{\pi^2 \times r \times E}{L_B^2} \qquad (5.1.1)$$

The values of the ratio L_B/L, as stated in the following table 5.1.1., apply:

Table 5.1.1.

Values of L_B/L.

Type of beam	$L_B L$
Simply supported	1.0
Restrained at one end and simply supported at the other end	0.7
Restrained at both ends	0.5
Cantilever	2.0

5.2. PLATE SECTIONS:

L and B denote the distance between the supports in the lengthways and crossways directions of the plate.

The following subsections 5.2.1. and 5.2.2. deal with cases of in plane stresses.

5.2.1. IN PLANE COMPRESSION:

σ_{max} and σ_{min} denoting the maximum and minimum stresses across the plate as calculated with sign, the stress distribution K_σ denotes the following value:

$$K_\sigma = \frac{\sigma_{max}}{\sigma_{min}} \qquad (5.2.1.1)$$

In case of pure in plane bending, the following value of K_σ applies:

$$K_\sigma = -1 \qquad (5.2.1.2)$$

In case of pure in plane compression, the following value of K_σ applies:

$$K_\sigma = 1 \qquad (5.2.1.3)$$

Buckling may be disregarded, if either of the following conditions considering K_σ and the quotient L/B is satisfied:

$$K_\sigma \leq -2 \qquad (5.2.1.4)$$

$$L/B \leq 0.25 \qquad (5.2.1.5)$$

The following value of the buckling strength S_{-B} applies:

$$S_{-B} = K \times \frac{E \times H^2}{B^2} \qquad (5.2.1.6)$$

Depending on the value of L/B, the following values of K apply:

To $L/B \geq 0.75$:

$$K = 1.65 + 2.45 \times (1 - K_\sigma)^2 \qquad (5.2.1.7)$$

To $0.25 < L/B < 0.75$:

$$K = 1.65 + 2.45 \times (1 - K_\sigma)^2 + 200 \times (0.75 - \frac{L}{B})^4 \qquad (5.2.1.8)$$

5.2.2. IN PLANE SHEAR:

Buckling may be disregarded, if the quotient L/B satisfies the following condition:

$$L/B \leqq 0.5 \qquad (5.2.2.1)$$

The following value of the buckling strength t_B applies:

$$t_B = K \times \frac{E \times H^2}{B^2} \qquad (5.2.2.2)$$

Depending on the value of L/B, the following values of K apply:

To $L/B \geq 4$:

$$K = 2.65 \qquad (5.2.2.3)$$

To $2 \leq L/B < 4$:

$$K = 2.65 + 0.08 \times 4 - \frac{L}{B})^2 \qquad (5.2.2.4)$$

To $0.5 < L/B < 2$:

$$K = 3.00 + 1.15 \times (2 - \frac{L}{B})^5 \qquad (5.2.2.5)$$

6. ALLOWABLE STRESSES:

With the modifications stated in the following subsections 6.1. and 6.2., the high safety class values of allowable stresses with regard to failure as well as to serviceability according to DS 456 apply.

6. SAFETY CLASSES:

The allowable stresses are multiplied by the safety class coefficient K_s.

Depending on the safety class according to volume I, the following values of K_s apply:

To safety class 1 and 2:

$$K_s = 1 \qquad (6.1.1)$$

To safety class 0:

$$K_s = 1.35 \qquad (6.1.2)$$

6.2. SPECIAL STRENGTH PROPERTIES:

On occasion, strength values according to chapter 5 are inserted.

7. TESTING:

Testing of fatigue and long term properties must simulate exposure to weather, especially with regard to precipitation and humidity.