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REEDS AS CONSTRUCTION SUPPORTING GREAT REED WARBLER (*ACROCEPHALUS ARUNDINACEUS* L.) AND REED WARBLER (*A. SCIRPACEUS* HERM.) NESTS

ABSTRACT: The nests of great reed warbler (*Acrocephalus arundinaceus* L.) and reed warbler (*A. scirpaceus* Herm.) are compared to platforms supported by columns (reeds). The paper presents a model of the nest structure. Variables of this structure, such as: number of reeds supporting the nest, height of reeds, their thickness, weight of a nest with its contents etc. show statistically significant differences for each species under investigation. However, stresses occuring at the base of the construction, which result from the above variables, are similar in both species. The wind is the main hazard to the stability of the construction. It was stated, that the majority of nests are built with a big durability margin, and the ecological reasons for this phenomenon were analysed.

KEY WORDS: *Acrocephalus arundinaceus, Acrocephalus scirpaceus,* nests structure, nests model.

1. INTRODUCTION

The great reed warbler (*Acrocephalus arundinaceus* L.) and the reed warbler (*Acrocephalus scirpaceus*) are two bird species widespread in the West Palearctic. The great reed warbler is the bigger of the two, ca 20 cm long and weighs ca 30 g. The reed warbler is ca 13 cm long and weighs ca 13 g (Szczepski and Kozłowski 1953).

Reed-beds are the typical habitats of these species. The ability of moving along vertical stems and the skill of suspending the nests among reeds (*Phragmites communis* Trin.) are the main adaptations which enabled the two warbler species to settle in reed-beds (Leisler 1977). The great reed warbler, being bigger, usually builds its nests on thicker reeds which grow in deeper water. It prefers fragments of reed-beds that lie near the open water. The reed warbler, smaller, builds its nests on thinner reeds, growing usually in shallower water, closer to the outer edge of reed-bed (at the land-side) (Dyrcz 1980, Beier 1981, Leisler 1981).

The birds build their nests both on old, i.e. the previous year's reeds, and on new reeds of the current year. They often use both kinds of reeds while building one nest; it depends on the kind of reeds accessible in a particular season and habitat. Some nests are built on other species of plants. When there are no reeds of suitable quality, the great reed warbler can build the majority of nests on cattail (*Typha* sp.) (Havlin 1971, Dorsch and Dorsch 1985). It also builds nests on willow bushes (*Salix* sp.) and other plants. The reed warbler also builds its nests on willow bushes (*Salix* sp.), cattail (*Typha* sp.), loosestrife (*Lysimachia* sp.), bitter sweet (*Solanum dulcamara*) and others. If reeds of suitable quality are present in the habitat in the period of nest building, usually the majority of them are built on reeds. Only such nests are analysed in this paper. The type of habitat such as reed-bed composed of several vertical elements, can be rather precisely described on the base of several measurements.

Ecological requirements for nest construction by these two species have been characterised by several authors (Havlin 1971, Catchpole 1974, Dyrcz 1980, Westphal 1980, Ölschlegel 1981, H. Dorsch and J. Dorsch 1985 and the others). Among these requirements authors include: numbers of reeds used to suspend the nest, thickness of the reeds, their height, height on which the nest is placed, diameter of the nest and so on. These variables are compared with analogous ones from the other areas and similarities and differences have been described. It is usually difficult to interpret what is the source of differences found and what they mean.

This paper develops a model of great reed warbler and reed warbler nest structure in which all the variables, up to now analyzed separately one from another, are linked together. Stresses occuring in this structure are the feature that ties together all these variables and at the same time results from them.

Thus, the aim of this paper is not to describe the technique of nest cup building. This has already been done by several authors, most particularly by Kluyver (1955) for the great reed warbler and by Borowiec (1985) for the reed warbler. The main factors ruling the nest construction in two warbler species are analyzed in this paper. Is it only the necessity of compliance with the durability requirements? What role do some particular variables of nest construction play for its stability? What are the main hazards to nest construction stability? By nest construction I mean reeds with nest suspended among them.

2. MODEL OF NEST CONSTRUCTION

A multi-column structure fixed in the ground was taken as a computational model. A nest is a kind of a platform supported at points by columns (reeds) whose number vary from 2 to 11 (Fig. 1). The cross-section of a column is a ring and the

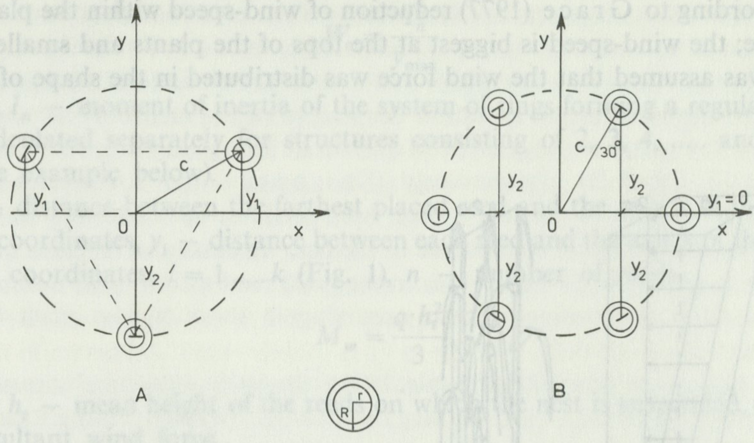

Fig. 1. Vertical view of great reed warbler or reed warbler nest construction composed of: A — three reeds and B — six reeds, o — centre of symmetry of the structure, c — external radius of the nest, y_1 and y_2 — distance between each reed and the axis x of the assumed system of coordinates, R — external radius of a reed stem, r — internal radius of a reed stem

thickness of its wall is equal to the thickness of the wall of a reed. The diameter of the columns at their base is equal to the mean diameter of reeds supporting the given nest and the height of the columns is equal to the mean height of reeds with the nest. The level on which the platform is suspended is equal to the height of the nest edge over the bottom of the lake. The stresses are calculated at the level at which the reeds are fixed in the ground, as this is the weakest point of the whole structure.

The following limitations and assumptions were taken into account:

1. The reeds supporting the nest were distributed regularly (at equal distances) on the periphery of a ring of a radius equal to the external radius of the nest (Fig. 1).

2. Reeds from this and the previous year found in particular nests' structure in various proportions were not distinguished and were all treated in the same way.

3. The reeds were fixed in the ground (like a column in concrete). In fact this is not quite so; the bottom of the lake is usually muddy, so the attachement with several roots causes slight flexibility of reeds moving out of the ground.

4. The fact that reeds grow in the water of various depth was not accounted for.

5. A set of reeds with a given nest suspended among them is treated to a certain extent as a structure isolated from the surroundings. This means that the possibility for this structure being supported by the surrounding reeds while it is bent by the wind is not taken into consideration.

6. The buckling ratio was $\beta = 1$ because cases of buckling were not observed.

7. The wind blows onto the surface of leaved reed stems supporting the nest. It was assumed that this surface is of rectangular shape with the length equal to mean height of reeds and with width equal to external diameter of the nest (Fig. 2). The sum of the reed stems' diameters most often makes about 25–50% of the value of nest's diameter, but the whole surface exposed to the wind is enlarged by leaves.

8. According to G r a c e (1977) reduction of wind-speed within the plant canopy takes place; the wind-speed is biggest at the tops of the plants and smallest at their bases. It was assumed that the wind force was distributed in the shape of a triangle (Fig. 2).

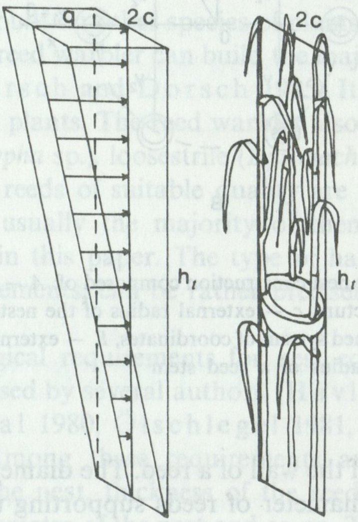

Fig. 2. Distribution of the wind load on the nest structure
q — value of the wind load, c — external radius of the nest, h_t — mean height of the reeds among which the nest is suspended

The following formula was used to calculate the stresses in the structure supporting the nest:

$$\delta = \frac{P}{\beta A} + \frac{M_g}{W_n} + \frac{M_w}{W_n} \qquad (1)$$

Particular components of it mean:

$P/\beta A$ — normal compression stresses due to the weight of the reeds and the nest with its contents, M_g/W_n — normal bending stresses due to the weight of the nest with its contents, M_w/W_n — normal bending stresses due to the wind load, where: δ — total normal stresses, P point load of whole reeds and the nest with its contents, β — buckling ratio (assumed as = 1), A — sum of areas of cross-sections of single reeds, M_g — bending moment of the nest with its contents, W_n — section modulus, M_w — bending moment of the wind.

Particular components were calculated in the following way:

$$A = \Sigma\, \pi (R^2 - r^2) \qquad (2)$$

where: R — external radius of the reed stem, r — internal radius of the reed stem.

$$M_g = P_g \cdot u \qquad (3)$$

where: P_g — point load of the nest with its contents, u — deflection of reeds supporting the nest (calculation was done for $u = 10$ cm).

$$W_n = \frac{I_n}{y_{max}} \tag{4}$$

where: I_n – moment of inertia of the system of rings forming a regular polygon (it was calculated separately for structures consisting of 2, 3, 4, ... and 11 reeds – see the example below).

y_{max} – distance between the farthest placed reed and the axis x of the assumed system of coordinates, y_i – distance between each reed and the axis x of the assumed system of coordinates, $i = 1 ..... k$ (Fig. 1), n – number of reeds.

$$M_w = \frac{q \cdot h_t^2}{3} \tag{5}$$

where: h_t – mean height of the reeds on which the nest is suspended, q – value of the resultant wind force,

$$q = 5.87 \cdot 2c \tag{6}$$

where: c – external radius of the nest.

Value of the wind load q was taken according to Polish Standard – 77/B–02011 for the wind velocity of 17 $m \cdot s^{-1}$ because, according to information of the Institute of Meteorology and Water Control and Exploitation, such velocity is most often typical for the strongest wind gusts occurring in Warsaw from May to July. The wind load was calculated for the first wind zone, to which Warsaw belongs, and for the open area. On the basis of parallel measurements of the force of the wind on the open area and in the reed-bed a wind force reduction ratio = 0.3 was assumed.

Below is an example of the method of calculation for the moment of inertia I_n and the section modulus W_n. Nests suspended among 3 reeds (Fig. 1):

$$y_1 = \frac{1}{2}c \qquad y_2 = c$$

$$I_3 = 2\left[\frac{\pi}{4}(R^4 - r^4) + \pi(R^2 - r^2)\cdot\left(\frac{c}{2}\right)^2\right] + \left[\frac{\pi}{4}(R^4 - r^4) + \pi(R^2 - r^2)\cdot c^2\right]$$

$$W_3 = \frac{I_3}{c}$$

Nests suspended among 6 reeds (Fig. 1)

$$y_1 = 0$$

$$\frac{y_2}{c} = \cos\ 30° \qquad y_2 = c\frac{\sqrt{3}}{2} \qquad y_2 = 0.866c$$

$$I_6 = 2\cdot\frac{\pi}{4}(R^4 - r^4) + 4\left[\frac{\pi}{4}(R^4 - r^4) + \pi(R^2 - r^2)(0.866c)^2\right]$$

$$W_6 = \frac{I_6}{0.866c}$$

In the calculation of stresses the maximum weight of nest contents was taken into consideration. It consisted of the weight of nestlings one day before leaving the nest, when they are heaviest (Dyrcz 1974) and the weight of an adult bird warming the nestlings. On the basis of the literature the weight of the reed warbler nestling was estimated at 11.1 g and of the great reed warbler at 25.8 g (Dyrcz 1974) and for the adult birds 13 g and 30 g respectively (Szczepski and Kozłowski 1953).

In the case where a brood was robbed by a predator or the history of the brood was unknown, the potential consistence of the nest was assumed as three nestlings in the case of the reed warbler and as four in the great reed warbler, the numbers which were of the area under investigation occurring in these species most frequently (Jędraszko-Dąbrowska 1988).

In this paper, the possibility of calculating the value of critical stresses in nest structures was considered. It is necessary to know the value of Young's modulus (E) (modulus of elasticity) for reed for this purpose. The unpublished data of deflection of reeds taken on various lakes in North Poland by Szajnowski were used for calculating Young's modulus. Young's modulus was calculated on the basis of the value of deflection of 50 cm long fragments of reeds of a known diameter under the force of 250 G (2.5 N).

Differences between means were tested for significance using Student's test t. A correlation coefficient r was calculated for the chosen pairs of variables.

3. METHODS OF GATHERING DATA AND MATERIAL

Data were gathered during the breeding season 1988 in the Czerniakowskie Lake Reserve in Warsaw. The reed warbler and the great reed warbler breed there and the letter shows especially high density (Jędraszko-Dąbrowska 1988).

In the nests which were found the external diameter of the nest and the distance between the nest edge and the bottom of the lake were measured. The number of fledgelings that had left the nest was noted in the cases when it was known. When the breeding was over the reeds with the nest attached to them were cut at the level of bottom of the lake and the next measurements were done in the laboratory. The diameter of each reed at its base and the thickness of its wall were measured with the aid of a slide calliper. The length of each reed was measured up to the base of the youngest leaf. The nest as well as all the reeds supporting it were weighed (fresh).

Material for this paper consists of 10 nests of the reed warbler and 12 nests of the great reed warbler.

4. RESULTS

Characteristics of nests structure in the reed warbler and the great reed warbler and the stresses existing at the level at which this structure is fixed in the ground are shown in Tables 1 and 2. All the variables characteristic for the reed warbler nests are significantly different from analogous ones for the great reed warbler. The differences refer to: number of reeds among which the nest is hung ($t = 2.46$; $p < 0.05$), height of reeds ($t = 5.20$; $p < 0.001$), height on which the nest is suspended ($t = 2.44$; $p < 0.05$), diameter of the reeds ($t = 3.81$; $p < 0.002$), weight of the reeds ($t = 5.67$; $p < 0.001$), thickness of the walls of the reeds ($t = 3.53$: $p < 0.01$), nest's diameter ($t = 8.56$; $p < 0.001$), weight of the nest ($t = 9.38$; $p < 0.001$) and weight of this contents: nestlings with an adult bird (in all cases $d.f. = 20$). All the values are significantly smaller in the reed warbler.

At the same time, the values of stresses occurring in the nest structures of both species are similar to each other. For the group of nests under investigation, with the assumption of maximum wind velocity at 17 $m \cdot s^{-1}$ and wind force reduction ratio as 0.3, the values of total normal stresses (δ) lie in the majority of cases within the limits between 3 MPa and 10 MPa, only in few cases do they exceed this value. Average stresses are a little higher in the reed warbler but differences between stresses occuring in nests structure of both species are not statistically significant. It concerns partial stresses: $P/\beta A$ ($t = 0.00$), M_g/W_n ($t = 1.30$), M_w/W_n ($t = 0.80$), as well as total stresses (δ) ($t = 0.81$) (in all cases $d.f. = 20$).

In the sample of nests under investigation for both the reed warblers and the great reed warblers there were one or two nest structures found in which the stresses exceeded considerably those occuring in the other structures (Tables 1, 2). Stresses caused by wind (M_w/W_n) have the greatest share in the total stresses occuring in the nest structures. They exceed many times the values of stresses due to the weight of reeds and the nest with its contents ($P/\beta A$) and stresses at bending due to the weight of nest with its cotents (M_g/W_n).

There is no evident correlation between different individual variables of nest structure and stresses occuring in them. Only in the case of the number of reeds supporting the nest in the great reed warbler is there a very week negative correlation with the value of stresses (the correletion coefficient $r = 0.52$; $d.f. = 10$; $0.05 < p < 0.1$). Though the greatest stresses occured in the structure built of the smallest number of reeds (three), but in some structures composed of five, six and eight reeds the stresses were similar. Lack of correlation between the number of reeds used in the nest structures and the stresses occuring in them is quite evident in the reed warbler ($r = 0.09$; $d.f. = 8$). In this species one nest structure built of only two reeds shows lower stresses than the others consisting of five and six reeds. There is also no correlation between the diameter of reeds on which the nest is suspended and the value of stresses occuring in the nest structure of the great reed warbler ($r = -0.24$; $d.f. = 10$) and the reed warbler ($r = -0.36$; $d.f. = 8$).

The positive correlation between the diameter of the reeds supporting the nest (measured at the level of the bottom) and the level on which the nest is hung was found in the great reed warbler ($r = 0.637$: $p < 0.05$; $d.f. = 10$) and in the reed warbler ($r = 0.632$; $p < 0.05$; $d.f. = 8$).

The values of Young's modulus (E) calculated for reed on the basis of unpublished data given by Szajnowski are shown in Table 3. The values of this

Table 1. Characteristics of reed warbler (*A. scirpaceus*) nests structure

a — number of a nest, b — number of reeds on which the nest is built, c — mean height of the reeds with the nest (cm), d — height of nest edge over the bottom of the lake (cm), e — mean diameter of the reeds supporting the nest, measured at their base (at the level of the bottom of the lake) (cm), f — external diameter of the nest (cm), g — thickness of the wall of the reed stem (cm), h — weight of the adult bird (g), i — weight of nestlings (g), j — weight of the nest (g), k — weight of the reeds supporting the nest (g). Values of the stresses are given in MPa

a	b	c	d	e	f	g	h	i	j	k	$\frac{P}{\beta A}$	$\frac{M_g}{W_n}$	$\frac{M_w}{W_n}$	$\delta = \frac{P}{\beta A} + \frac{M_g}{W_n} + \frac{M_w}{W_n}$
1	2	93	66	0.56	7.6	0.08	13	33.3	10	41	0.04	0.06	4.20	4.30
2	2	149	55	0.58	7.4	0.09	13	33.3	16	12	0.03	0.06	9.39	9.48
3	3	133	98	0.73	6.9	0.08	13	33.3	16	58	0.02	0.07	8.40	8.49
4	3	190	111	0.55	8.5	0.08	13	44.4	8	36	0.03	0.09	23.86	23.98
5	3	165	133	0.77	7.8	0.11	13	44.4	21	62	0.02	0.07	10.88	10.97
6	3	149	125	0.86	7.4	0.15	13	44.4	14	77	0.01	0.04	5.15	5.20
7	4	141	86	0.73	7.5	0.10	13	22.2	9	88	0.02	0.02	4.14	4.18
8	4	177	92	0.88	8.1	0.15	13	33.3	11	98	0.01	0.01	3.75	3.77
9	5	95	68	0.38	7.6	0.05	13	55.5	10	7	0.03	0.16	8.16	8.36
10	6	162	62	0.54	7.2	0.08	13	33.3	6	36	0.01	0.04	8.85	8.90
$\bar{x}$	3.5	145	90	0.66	7.6	0.10	13	37.7	12	51	0.02	0.06	8.68	8.76
SD	1.3	32	27	0.16	0.4	0.03	—	9.4	5	31	0.01	0.04	5.90	5.92

Table 2. Characteristics of great reed warbler (*A. arundinaceus*) nests structure
Symbols as in Table 1

a	b	c	d	e	f	g	h	i	j	k	$\frac{P}{\beta A}$	$\frac{M_g}{W_n}$	$\frac{M_w}{W_n}$	$\delta = \frac{P}{\beta A} + \frac{M_g}{W_n} + \frac{M_w}{W_n}$
1	3	220	175	0.99	8.9	0.14	30	103.2	47	137	0.03	0.07	10.04	10.14
2	3	234	95	0.75	10.6	0.10	30	103.2	30	85	0.04	0.10	20.92	21.06
3	4	230	133	1.08	8.5	0.18	30	103.2	34	289	0.02	0.04	6.036	6.09
4	4	223	140	1.08	10.0	0.16	30	103.2	42	247	0.02	0.04	6.26	6.32
5	4	214	123	0.87	8.7	0.17	30	103.2	36	172	0.02	0.05	7.15	7.22
6	5	209	109	1.12	9.5	0.20	30	103.2	33	294	0.02	0.02	3.52	3.56
7	5	222	128	1.05	9.4	0.18	30	103.2	24	266	0.02	0.03	4.67	4.72
8	5	207	96	0.81	9.8	0.13	30	103.2	41	116	0.02	0.05	7.21	7.28
9	6	223	157	1.01	9.3	0.18	30	103.2	32	278	0.02	0.02	3.56	3.60
10	7	265	111	1.02	9.8	0.16	30	103.2	31	327	0.02	0.02	5.41	5.45
11	8	181	77	0.80	9.8	0.11	30	103.2	43	135	0.02	0.03	3.71	3.76
12	11	143	85	0.56	9.7	0.08	30	103.2	28	106	0.02	0.04	3.20	3.26
$\bar{\chi}$	5.4	214	119	0.93	9.5	0.15	30	103.2	35	204	0.02	0.04	6.81	6.87
SD	2.3	30	29	0.17	0.6	0.04	–	0.0	7	87	0.01	0.02	4.87	4.90

Table 3. Values of Young's modulus (E) for reed on various lakes (calculated on the basis of non published data given by Szajnowski)

Lake	Year	E(MPa)
Tałty 1st stand	1968	10500
2-nd stand	1968	8100
	1970	5800
	1971	10200
Juksty 1-st stand	1968	7500
2-nd stand	1968	5900
	1970	7100
	1971	10800
Tałtowisko	1968	8900
	1970	23800
	1971	11600
Zdrężno	1968	20400
	1970	13600
	1971	6200

modulus range from 5800 MPa on Tałty Lake in 1970 to 23 800 MPa on Tałtowisko Lake in 1970. Also, the reed on a given lake shows a great variability on Young's modulus (E) in particular years, eg. on Zdrężno Lake from 6200 MPa in 1971 to 20 400 MPa in 1968. Even the reed taken in the same year from the same lake but from different stands was of different modulus (E). Although the differences were not as great as over a number of years and on various lakes but still they were quite significant, eg. the value of Young's modulus (E) on Tałty Lake in 1968 on two different stands was 10 500 MPa and 8100 MPa.

5. DISCUSSION

In spite of the fact that all variables of nest structure in the great reed warbler and the reed warbler show statistically significant differences, the stresses occuring in the majority of nest structures are similar to each other. This is the evidence for the similarity in principles of nest construction in both species.

All nest structures investigated, including those in which especially high stresses occured, were stable throughout the whole breeding period. Thus, it can be stated, that the stresses occuring in them did not reach the critical values. One may conclude that the majority of both species' nests are built with high factors of safety. This means that the compliance with the durability requirements makes a necessary but not sufficient condition when constructing the nests. According to Alexander (1981), who investigated factors of safety in the structure of animals, low factors of safety are feasible for structures subject to closely predictable loads, but higher factors of safety must be expected where loads are highly unpredictable. Calculation of the value of critical stresses for the analized nest structures was impossible because the value of Young's modulus (E) for reed on the investigated area is unknown.

The possibility of using the value of the modulus (E) measured for reed from various lakes (Table 3) was considered. According to calculations, the values of the modulus (E) show great variability for reeds on various lakes, on one lake in different years, and also on particular parts of reed-bed of a lake. Therefore, the data concerning durability characteristics of reeds on any lake cannot be treated as universal and used as representative for the other area.

It can be supposed that there are at least three reasons of ecological significance that cause the stresses in the majority of nest structures to be much lower than the critical values:

1. The fact that the reeds differ very much as far as their durability is concerned may be one of the reasons. Constructing nests with high factors of safety, the birds, therefore, avoid the risk of their destruction.

2. The destruction of the nest structure caused by exceeding the value of permissible stresses is not the only danger for the great reed warbler and the reed warbler broods. Heavy bending of reeds supporting the nest may also cause the nest's contents to fall out. The broods of both species are partly protected from falling out by the shape of the nest which has margins turned inside, but the protection is not sufficient when the bending is too strong. A nest may find itself in such a critical position before the stresses occuring in the structure reach the critical value. This is why the structure supporting the nest is usually built with rather high factors of safety.

3. The thickness of reed stems used for the nest structures is correlated with the size of legs (the length of fingers and claws) of the great reed warbler and the reed warbler. Foot morphology is a significant factor in habitat selection of *Acrocephalus* species (L e i s l e r 1975). The birds build nests on reeds which are easiest to grasp with their legs. This counteracts using too thin (and also to thick) reeds.

The value of stresses caused by the wind, much greater than the value of the two other component stresses, proves that the wind is the main hazard to the stability of nest construction. Breeding losses caused by wind are found most often in the reed warbler (D y r c z 1980, N i l s s o n and P e r s s o n 1986, J ę d r a s z k o-D ą b r o w- s k a 1988) but also in the great reed warbler (J ę d r a s z k o-D ą b r o w s k a 1988).

The stresses caused by wind are many times higher than the two other components of the total stresses that even the modification of assumptions taken for calculation would not significantly change the mutual relations of these values. The change of, for example, the wind force reduction ratio from 0.3 to 0.2 or the assumption that the surface on which the wind blows is more open-work and makes, for example, 0.8 of the surface calculated before, does not make any essential alteration to the values of stresses caused by wind. They will still amount in the majority of cases several MPa.

At the constant value of wind force together with the increasing height on which the nest is situated, the degree of its bending from vertical position increases. Consequently, the stresses accompanying it also increase. Stresses caused by nest with its contents by bending of the structures (M_g/W_n), calculated for deflection (u) of

50 cm, would be five times greater than shown in Tables 1 and 2 for deflection of 10 cm. But they still will not exceed a few tenth MPa and will be considerably less than the stresses caused by the wind.

The height, therefore, on which the nest is placed has little effect on the stresses occuring in the structure supporting the nest. If it were otherwise, one could expect that in the structures in which stresses caused by the wind are high, the nest would be placed lower than in the structures which are more stable, so that stresses caused by wind are less. In the nest structures under investigation such a tendency was not observed. Consequently, it is not increasing stress that limits the height on which the nest is placed, but probably the danger for eggs or nestlings of dropping out as a result of bending the reeds. Probably the range of the optimum thickness of reed stems on which it is easiest for a bird to climb, characteristic and different for each of the two species, may be the second factor limiting the height on which the nest is placed. It is proved by the positive correlation between the thickness of reeds supporting the nest and the height on which the nest is placed.

It is often stated, that as the breeding season proceeds, both warbler species place their newly built nest at higher levels (Catchpole 1974, Dyrcz 1980, Borowiec 1985). The interpretation most often concerns pressure from predation. The above described correlation between reed stem diameter and level at which the nest is placed suggests another explanation of this phenomena. Later in the breeding season, as the reeds grow up, the fragments of reeds of optimal thickness for each of two bird species are at higher level than before. This induces the birds to place their nests at a higher level.

The stresses caused by the weight of the nest with its contents ($P/\beta A$) have the least share in the total value of the stresses existing on the level at which the columns of structures are fixed in the ground. Therefore, the weight of the nest and its contents is not limited by the section moduluses of the whole structure. If it is limited in any way, it is rather by the danger for the nest of becoming detached from the supporting reeds or of its sliding down the stem. It is often the case that the great reed warbler nests built on *Typha* or *Scirpus* receive insufficient support (Kluyver 1955).

Each particular variable of the nest structure has its share in the total value of the stresses. This fact explains the weak negative correlation between the number of the reeds supporting the nest of the great reed warbler and the stresses in the structures. But such correlation was not found in the reed warbler. As it was stated earlier, there was also no correlation in both species between the thickness of the reeds supporting the nest and the stresses. Thus in the majority of cases there is no direct correlation between any individual variable of the nest structure and the stresses. Therefore, the choice by an individual or a population of a particular value of one element of nest structure should not be analyzed separately from the value of the other elements which compose the structure as a whole.

One may suppose that the differences in the values of particular variables of nest structures found by several authors result from the variety of characteristics of reeds being at the birds' disposal in various areas. In the structure as a whole, these variables balance each other in such a way that the structure complies with the described above durability requirements. However, as it was shown above, the compliance with the durability requirements in the nest structure makes for two investigated species a necessary but not sufficient condition, because there exist also important limitations of the ecological significance.

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6. SUMMARY

The nests of the great reed warbler (*Acrocephalus arundinaceus*) and the reed warbler (*A. scirpaceus*) are compared to platforms supported by columns (reeds) (Figs. 1, 2). This paper presents a model of the nest structure. Characteristics of this structure, such as number of reeds supporting the nest, height of reeds, their thickness, weight of a nest with is contents etc. show statistically singnificant differences for each species under investigation. However, stresses occuring at the base of the construction, which result from the above variables, are similar in both species (Tables 1, 2). The characteristics of the nest itself, such as its weight and the level on which it is placed have almost no share in the stresses occuring in the structure supporting the nest. Therefore, there are other than of durability significance reasons which limit the height on which the nest is placed. These are probably the danger for the nest contents of dropping out as a result of bending the reeds and the level on which the bird can find reed stems of the optimum thickness for climbing. The wind, which has the predominant share in the whole value of stresses occuring in the structure supporting the nest, is the main hazard to its stability. It was stated that the majority of nests are built with high factors of safety what is feasible for structures subject to highly unpredictable loads.

7. POLISH SUMMARY

W pracy przedstawiono model konstrukcji gniazda trzciniaka (*Acrocephalus arundinaceus*) i trzcinniczka (*A. scirpaceus*). Gniazdo porównano do platformy podpartej punktowo na słupach (trzcinach) (rys. 1, 2). Zmienne tej konstrukcji, takie jak liczba trzcin użytych do zawieszenia gniazda, wysokość trzcin, ich grubość, ciężar gniazda wraz z zawartością itp. wykazują istotne statystycznie różnice dla obu badanych gatunków. Jednakże naprężenia występujące u podstawy konstrukcji, będące wynikiem powyższych zmiennych, są podobne dla obu gatunków (tab. 1, 2). Cechy samego gniazda, jak jego ciężar i wysokość, na jakiej jest umieszczone, mają minimalny udział w naprężeniu ogólnym, występującym u podstawy konstrukcji podtrzymującej gniazdo. Dlatego o wysokości zawieszenia gniazda nie decydują czynniki wytrzymałościowe, lecz raczej niebezpieczeństwo osiągnięcia przez gniazdo przy wychyleniach pozycji, w której mogłaby wypaść jego zawartość. Drugim czynnikiem wyznaczającym wysokość zawieszenia gniazda jest prawdopodobnie zakres optymalnej grubości trzciny, po jakiej najłatwiej jest się ptakom poruszać, charakterystyczny i inny dla każdego z badanych gatunków. Wartość naprężeń powodowanych przez wiatr, wielokrotnie większa od pozostałych składowych naprężeń, świadczy o tym, że jest on głównym zagrożeniem dla trwałości konstrukcji nośnej gniazda. Większość gniazd została zbudowana z dużym zapasem wytrzymałości, co jest charakterystyczne dla konstrukcji narażonych na trudne do przewidzenia obciążenia.

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