**Scientific Substantiation of the Selection of Fabrics for Workers in the Construction Industry**

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**Abstract**. The purpose of this scientific research is to determine the main physical and mechanical indicators of materials for construction workers. To achieve the objectives, the tasks of studying the production environment of construction workers were solved, the protective and ergonomic functions of overalls were determined, the list of indicators that special fabrics should possess was determined. The article analyses the research work on determining the properties of textile materials for overalls. For this purpose, a sociological survey of employees of the construction company and material scientists of sewing production was conducted. The data of the sociological survey were analysed by the method of analysis of variance ‘ANOVA test’ in Excel program. For this purpose, one-factor analysis of variance was carried out to determine the difference between the mean values, the concordance coefficient of related ranks was determined, calculations were carried out to obtain data on the distribution of significance of the properties of textile materials affecting the quality of overalls of construction workers. It was revealed that the selection of fabrics for overalls should be carried out by analysing the values of material tear resistance, material abrasion resistance, air permeability, dust permeability and resistance to repeated washing. The article also researches work of determination of structural indices of 11 articules of fabrics. Studies of change of strength properties after multiple washings were carried out. 5 articules of fabrics with the best strength properties were selected for further laboratory studies of air permeability and dust permeability. The fabrics with the best performance will be recommended for designing special suits with dustproof properties. The results of the study were analysed in comparison with data from other research works. Based on this analysis, the results obtained can be considered plausible and appropriate for further use in experimental studies aimed at determining the properties and quality of existing fabrics for overalls.

**Keywords:** overalls, construction production, physical and mechanical parameters, materials, working conditions, a priori ranking, analysis of variance, wash resistance

**INTRODUCTION**

According to the State Register of Construction in Kyrgyzstan, the number of construction projects in cities and towns is increasing. The main harmful and hazardous factors for construction workers are increased gas and dust content in the air of the working area, increased vibration and noise levels, increased severity and tension of labour; climatic factors [1].

One of the main tools of safety compliance is wearing overalls [2]. Overalls are a means of individual protection of workers, protecting them from the action of general industrial pollution and mechanical effects, as well as creating comfortable working conditions to increase the efficiency and productivity of construction workers [3].

Despite the fact that the construction industry is one of the most dangerous, the field of designing special clothing for construction workers has not yet received sufficient scientific attention. However, a notable contribution to the development of this field was made by the works of a number of scientists, such as S.Sh. Tashpulatov, E.B. Koblyakova, P.P. Koketkin, V.E. Romanov, H.H. Kamilov and F.U. Nigmatov, E. A. Popadko. Also authors B.A. Buzov, K.G. Gushchina, S.A. Belyaeva, I.N. Savelieva, V.V. Hammatova and others have conducted many studies of the properties of materials for overalls. The issues of thermal insulation of overalls were studied by P.L.Kolesnikov, R.F.Afanasyeva, R.A.Dell, E.H.Melikov, I.Yu. Brink, I.V.Cherunova, R.O. Zhilisbaeva, U.M.Tileuberdieva, M.K. Rasulova, S.U. Pulatova, V.G. Petrunina, Watson Christopher, Ran‑i Eom, Yejin Lee, Park J. and others [4-19].

The process of designing special clothing for construction workers has a number of peculiarities, mainly related to the protective function, which require a comprehensive approach to solving problems in the field of human physiology (physique, proportions, psychology), clothing hygiene (heat and moisture exchange, toxicity, electrical sensitivity, flammability), protective and operational properties.

To develop reliable and high-quality special clothing capable of protecting a person from various industrial impacts, it is necessary to conduct a detailed study of the selection and analysis of the composition, as well as physical and mechanical properties of fabrics. Despite the extensive scientific literature published on this issue, this study focuses on the insufficiently disclosed problem of selection of physical and mechanical properties of fabrics of construction workers' overalls for the southern region of Kyrgyzstan.

The first part of this article defines a list of the most important indicators of fabrics from which overalls is designed. Working clothes for construction workers are subjected to frequent washing, so the research of fabrics resistance to washing is carried out.

**MATERIALS AND METHODS**

In order to determine the most significant indicators of fabrics affecting the safety and comfort of overalls for construction workers, a screening experiment was conducted. The following fabric indicators were considered in the experiment:

- abrasion resistance;

- tear resistance;

- resistance to industrial environment factors - dust permeability;

- resistance to dry cleaning or washing;

- resistance to atmospheric influences;

- hygroscopicity;

-air permeability.

The experimental survey involved specialists from the Department of ‘Light Industry Technology’ and the Department of Construction of Osh Technological University, as well as engineers and workers of the construction company ‘Nurzaman’, Osh.

Analysis of the sociological survey was carried out by the method of dispersion analysis ‘ANOVA test’ in the Excel program based on the data of m=10 expert specialists who gave a ranking assessment of n=8 properties x1, ..., xn, indicating the most important quality indicator by the rank R=l, and the least important - by the rank R= n.

To begin with, a one-factor analysis of variance is performed. One-factor analysis of variance is used to determine whether or not there is a statistically significant difference between the mean values of three or more groups. Here, the column ‘count’ shows the number of respondents who participated in the ranking. The column ‘sum’ indicates the sum of ranks for each factor, then the average sum of ranks ‘mean’ is found. In the column ‘variance’ is entered the value of the sum of squares of deviations of the ‘sum’ of ranks from the mean value ‘average’.

The sum of ranks Sj for each factor is determined by the formula

(1)

Then the average sum of the ranks T is found,

(2)

The sum of squares of deviations S of the sums of ranks Sj from the mean value T is calculated by the formula

(3)

Determine indicators of groups of related ranks

(4)

where *tk*i is the number of identical ranks in the *k -th* group of related ranks for *i* ranking (for the *i-th* expert);

*k* – index of a group of related ranks by ranking *k=1.. Ki*;

*Ki* – number of groups of related ranks in *i* ranking (for the *i-*th expert).

Determine the sum of indicators of groups of related ranks

(5)

and then find the sum of for all experts

(6)

Then it is necessary to determine the coefficient of concordance, which characterises the degree of consistency of experts' opinions taking into account the associated ranks:

(7)

Concordance coefficient can vary from 0 to 1. The closer the value of *W* is to one, the more significant is the connection between the opinions of individual experts. The closer the value of *W* is to zero, the stronger are the differences between the opinions of experts. But calculations show that the coefficient of concordance can be more than 1.

To assess the significance of properties, the relative significance coefficient is determined according to the formula:

(8)

where *Si* is the sum of *i* property ranks.

From all *n* property indicators, the most significant ones are selected, for which ri > 1/n. The significance coefficient is determined for the properties selected in this way:

(9)

where *n0* is the number of properties with ri ≥ 1/n;

*Si0* - sum of ranks for more significant properties *n0*.

The laboratory research was carried out in the laboratory ofOsh Technological University named by M. Adyshev (Osh city, Kyrgyzstan) and Namangan Institute of Textile Industry (Namangan city, Republic of Uzbekistan). To study the strength characteristics of textile materials 11 fabrics of different articles were selected.

Then laboratory tests on resistance of materials to washing were carried out. The tests were carried out according to GOST 3813-72 ‘Textile materials. Fabrics and piece goods. Methods of determination of tensile breaking characteristics’, as well as GOST 30157.0-95 ’Methods of determination of dimensional change after wet processing or dry cleaning. General provisions’. The change of tensile characteristics was recorded without washing, after the first washing and after 5 washings.

**RESULTS**

The results of expert ranking are presented in the matrix of table 1:

**TABLE 1.** Results of expert ranking

|  |  |
| --- | --- |
| **Factor designation** | **Factor Name** |
| **x1** | resistance to washing |
| **x2** | resistance to atmospheric influences устойчивость к |
| **x3** | hygroscopicity |
| **x4** | abrasion resistance |
| **x5** | dust permeability |
| **x6** | multiple stretching resistance |
| **x7** | air permeability |
| **x8** | tear resistance |

Table 2 contains the results of one-factor variance analysis of the matrix of expert ranking results. The column ‘count’ shows the number of respondents who participated in the ranking. The column ‘sum’ denotes the sum of ranks for each factor, then the average sum of ranks ‘average’ is found. In the column ‘dispersion’ is entered the value of the sum of squares of deviations of the ‘sum’ of ranks from the mean value ‘average’ [1].

**TABLE 2.** Single-factor analysis of dispersion

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Groups** | **Count** | **Sum** | **Average** | **Dispersion** |
| **x1** | 10 | 42 | 4,2 | 1,1 |
| **x2** | 10 | 66 | 6,6 | 1,2 |
| **x3** | 10 | 57 | 5,7 | 3,8 |
| **x4** | 10 | 29 | 2,9 | 4,1 |
| **x5** | 10 | 40 | 4,0 | 9,6 |
| **x6** | 10 | 61 | 6,1 | 1,4 |
| **x7** | 10 | 33 | 3,3 | 2,0 |
| **x8** | 10 | 21 | 2,1 | 1,7 |

From table 2 we can see that the mean score for each of the eight groups is different, to know if these differences are statistically significant we need to analyse table 3 which contains the values of the concordance coefficient *W*.

The calculations show the *F* test statistic, the critical *F* value and the *p* value.

**TABLE 3.** F test statistics

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Source of variation** | **SS** | **df** | **MS** | **F** | **P-mean** | **F kr** |
| **Between groups** | 183,59 | 7,00 | 26,23 | 8,47 | 0,000000 | 2,14 |
| **Within groups** | 222,90 | 72,00 | 3,10 |  |  |  |
| **Total** | 406,49 | 79,00 |  |  |  |  |

Table 3 shows that the *F*-test statistic is 8.47, and the critical value of *Fkr* is 2.14. Since the *F*-test statistic is greater than the critical value of *Fkr*, the degree of consistency of experts' opinions is not in doubt.

This conclusion is supported by a *p*-value less than 0.00000, which is much less than the alpha value of 0.05.

Also, using the value of the coefficient of concordance equal to W=3.14, which is more than one, it can be stated that the opinion of respondents regarding the degree of influence of factors influencing the selection of parameters of physical and mechanical properties of materials is consistent.

Significance of properties of textile materials influencing the quality of protective function of overalls is presented in table 4.

**TABLE 4.** Distribution of significance of textile materials properties influencing the quality of protective clothing of construction workers

|  |  |  |
| --- | --- | --- |
| **Physical and mechanical properties** | **Relative significance coefficient *ri*** | **Significance coefficient *ri0*** |
| **Resistance to washing** | 0,14 | **0,16** |
| **Resistance to atmospheric influences** | 0,05 | - |
| **Hygroscopicity** | 0,08 | - |
| **Abrasion resistance** | 0,18 | **0,22** |
| **Dust permeability** | 0,14 | **0,17** |
| **Multiple stretching resistance** | 0,07 | - |
| **Air permeability** | 0,17 | **0,20** |
| **Tear resistance** | 0,21 | **0,25** |

To visualise the collective opinion of the expert respondents who participated in the expert assessment of the degree of influence of physical and mechanical properties of fabrics, an a priori histogram of ranks was constructed (See Fig. 1).

**FIGURE 1.** Histogram of ranks of physical and mechanical properties of overalls for construction workers

The results of the physical and mechanical properties of Chinese and Turkish manufactured fabrics are presented below (see Table 5).

Table 6 and Figures 2, 3 present the results of determination of breaking load of fabrics used for overalls of construction workers.

Analysis of the obtained data shows that in all the samples studied, the breaking load on the warp exceeds the breaking load on the weft. This is explained by different structural characteristics of fabrics: fabric density, fibre type (e.g. natural cotton is less strong than synthetic fibres), weave (e.g. plain weave is stronger than sateen weave), fabric treatment (e.g. impregnation of fabric with water repellent composition can reduce its strength).

**FIGURE 2.** Dependence of breaking load on the basis of fabrics for overalls of construction workers on the number of washings

**TABLE 5.** Structural characteristics of fabrics

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sample number** | **№1** | **№2** | **№3** | **№4** | № 5 | **№ 6** | **№7** | **№ 8** | **№9** | **№10** | **№11** |
| Weight, g | 5,5 | 5,5 | 8,5 | 7,75 | 5,5 | 4,75 | 6,5 | 5,04 | 5,92 | 5,82 | 6,12 |
| Manufacturer's country | China | China | Turkish | Turkish | Turkish | Turkish | Turkish | China | China | China | China |
| Fibre composition of fabric, % content | 20% CV 80% POL | 35% CO 65% POL | 100% CO | 52%CO 16%HA 16%BA  16%TE | 35% CO 65% POL | 35% CO  65% POL | 93% CO  7% EL | 45% CO 55% OL | 93% CO  7% EL |  | 15% CO  85% POL |
| Fabric thickness b, mm | 0,64 | 0,61 | 0,9 | 0,82 | 0,52 | 0,54 | 0,65 | 0,762 | 0,579 | 0,484 | 0,734 |
| Surface density M1, g/m2 | 229,2 | 229,2 | 354,2 | 322,9 | 229,2 | 197,9 | 270,8 | 210,0 | 246,7 | 242,5 | 255,0 |
| Number of warp threads per 1 cm at length of 5 cm | 72,0 | 57,0 | 30,0 | 33,0 | 47,0 | 46,0 | 47,0 | 46,0 | 44,0 | 50,0 | 48,0 |
| Weight of warp yarns | 0,0894 | 0,0812 | 0,1241 | 0,1179 | 0,0719 | 0,0701 | 0,0756 | 0,071 | 0,0836 | 0,0783 | 0,0878 |
| Linear density of warp yarns To, tex | 25 | 28 | 83 | 71 | 31 | 30 | 32 | 31 | 38 | 31 | 37 |
| Number of weft yarns per 1 cm at length of 5 cm | 45 | 24 | 16 | 29 | 26 | 22 | 19 | 27 | 25 | 26 | 23 |
| Weft yarn weight | 0,0347 | 0,0484 | 0,0812 | 0,0701 | 0,0601 | 0,0353 | 0,0788 | 0,041 | 0,0482 | 0,0512 | 0,0493 |
| Linear density of weft yarns Tu, tex | 15 | 40 | 102 | 48 | 46 | 32 | 83 | 31 | 39 | 39 | 43 |
| Number of warp yarns per 100mm of fabric Po | 720 | 570 | 300 | 330 | 470 | 460 | 470 | 460 | 440 | 500 | 480 |
| Number of weft yarns per 100mm of fabric Pu | 450 | 240 | 160 | 290 | 260 | 220 | 190 | 270 | 250 | 260 | 230 |
| Estimated surface density of the fabric without taking into account yarn processing, g/m2 | 223,38 | 233,28 | 369,54 | 338,4 | 237,6 | 189,72 | 277,92 | 202,3 | 237,24 | 233,1 | 246,78 |
| Deviation of calculated surface density Deviation of calculated fabric surface density from actual Δ, % | 2,6 | 1,8 | 4,2 | 4,6 | 3,5 | 4,3 | 2,5 | 3,8 | 4,0 | 4,0 | 3,3 |

**TABLE 6.** Performance of fabrics for overalls of construction workers in uniaxial tension to rupture

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Number of washes** | **Sample №1** | | **Sample №2** | | **Sample №3** | | **Sample №4** | | **Sample №5** | | **Sample №6** | | **Sample №7** | | **Sample №8** | | **Sample №9** | | **Sample №10** | | **Sample №11** | |
| **О 1** | **У1** | **О2** | **У2** | **О3** | **У3** | **О4** | **У4** | **О5** | **У5** | **О6** | **У6** | **О7** | **У7** | **О8** | **У8** | **О9** | **У9** | **О10** | **У10** | **О11** | **У11** |
| **NO WASHING** | | | | | | | | | | | | | | | | | | | | | | |
| Рр0,N | 1445 | 1382 | 1255 | 944 | 1459 | 678 | 1885 | 479 | 1177 | 664 | 1075 | 506 | 1291 | 646 | 1319 | 989 | 1197 | 521 | 1309 | 473 | 1399 | 634 |
| lp0, mm | 59 | 21 | 21 | 20 | 20 | 16 | 20 | 37 | 18 | 16 | 15 | 16 | 15 | 51 | 19 | 28 | 56 | 26 | 35 | 28 | 16 | 29 |
| εp0, % | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rp0, J | 48 | 8 | 15 | 10 | 8 | 4 | 11 | 3 | 10 | 5 | 6 | 3 | 6 | 6 | 2 | 8 | 30 | 8 | 26 | 6 | 8 | 4 |
| tp0, s | 12 | 4 | 4 | 4 | 4 | 3 | 4 | 7 | 4 | 3 | 3 | 3 | 3 | 10 | 6 | 8 | 17 | 8 | 10 | 9 | 5 | 9 |
| **AFTER 1 WASH** | | | | | | | | | | | | | | | | | | | | | | |
| Рр1,N | 1488 | 1316 | 1414 | 993 | 1254 | 526 | 1711 | 469 | 1240 | 678 | 1021 | 478 | 1301 | 402 | 1253 | 949 | 1113 | 485 | 1244 | 440 | 1329 | 602 |
| lp1, mm | 64 | 19 | 24 | 23 | 17 | 15 | 17 | 33 | 20 | 17 | 16 | 15 | 19 | 49 | 18 | 27 | 52 | 24 | 33 | 27 | 15 | 28 |
| εp1, % | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rp1, J | 53 | 7 | 19 | 12 | 6 | 2 | 9 | 3 | 12 | 5 | 6 | 2 | 7 | 3 | 1 | 8 | 28 | 7 | 25 | 6 | 8 | 4 |
| tp1, s | 13 | 4 | 5 | 5 | 3 | 3 | 3 | 7 | 4 | 3 | 3 | 3 | 4 | 10 | 5 | 8 | 16 | 7 | 10 | 8 | 4 | 8 |
| **AFTER 5 WASHES** | | | | | | | | | | | | | | | | | | | | | | |
| Рр5,N | 1435 | 1052 | 1404 | 775 | 1131 | 406 | 1484 | 410 | 1046 | 624 | 1018 | 482 | 1182 | 478 | 1215 | 854 | 957 | 412 | 1206 | 400 | 1289 | 554 |
| lp5, mm | 68 | 19 | 26 | 17 | 20 | 15 | 20 | 32 | 19 | 18 | 17 | 17 | 19 | 38 | 17 | 24 | 45 | 20 | 32 | 25 | 14 | 26 |
| εp5, % | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rp5, J | 49 | 7 | 19 | 7 | 6 | 2 | 8 | 3 | 9 | 5 | 6 | 3 | 6 | 4 | 1 | 7 | 24 | 6 | 24 | 6 | 7 | 4 |
| tp5, s | 14 | 4 | 5 | 3 | 4 | 3 | 4 | 6 | 4 | 4 | 3 | 3 | 4 | 8 | 5 | 7 | 13 | 6 | 10 | 7 | 4 | 8 |

\*О - Warp yarns, У - Weft yarn

**FIGURE 3.** Dependence of breaking load on weft of fabrics for overalls of workers of construction specialities on the number of washings

**DISCUSSION**

The analysis shows that the main characteristics highlighted by the experts are tear resistance, abrasion resistance, breathability, dust permeability and resistance to washing. The physical and mechanical parameters obtained as a result of the study fully meet the requirements to fabrics for workwear of construction workers, prescribed in special standarts. Let us discuss and confirm the significance of the first five indicators:

- fabrics should be resistant to mechanical damage, i.e. be durable and resistant to cuts and abrasion. Therefore, the tear and abrasion resistance indicators took the first places in the ranking histogram;

- construction works under hot and cold climatic regimes, the garment is also designed to protect from overheat and hypothermia and provide the feeling of being in the state of comfort. To this end, all the various heat insulation qualities of the fabric find their expression: light and permeable for the hot climatic regime, warming and watertight for the cold one. To this end, the value of the air permeability is required for the microclimate formation under the garment;

- large amounts of dust are emitted indoors during construction work. Dust is generated during processing of stones, concrete, expanded clay, wood, etc. Therefore, it is necessary to choose fabrics with low dust permeability values;

- no less important indicators - resistance of fabrics to repeated washing and dry cleaning. Construction workers' clothes are often subjected to cleaning, as various types of dust, contamination with construction mixtures, chemical substances settle on the fabric, which leads to a decrease in hygienic properties of the clothes. After cleaning, fabrics should retain their protective and ergonomic properties.

It is necessary to note that in the works devoted to the design of acid-protective overalls, special clothes for workers of oil and fat enterprise, overalls with improved operational properties [6], the indicators of ranks of physical and mechanical properties have approximately the same values. Only, for each production there are specific properties that protect from harmful and dangerous indicators that bring harm to the body of workers.

Analysing the structural data of the tissues yields the following results:

1. Samples No. 3 (Turkey) and No. 8 (China) have the greatest thickness, but the surface density of sample No. 8 is 1.6 times less than No. 3.

2. Sample #3 has the greatest thickness and sample #6 (Turkey) has the least density.

3. The linear density on the backbone of most samples is less than that on the base.

4. The fill value per 100 mm is maximum in sample No. 1 (China) and the lowest in sample No. 3. In terms of fibre composition, sample No. 3 consists of 100% cotton and sample No. 1 consists of a blend of synthetic fibres. The rest of the fabrics are blended fabrics containing natural and artificial fibres.

5. The fill value per 100 mm is maximum in sample No. 1 (China) and least in sample No. 3.

6. In terms of fibre composition, sample No. 3 consists of 100% cotton and sample No. 1 consists of a mixture of synthetic fibres. The rest of the fabrics are blended fabrics containing natural and artificial fibres.

Repeated washing has a significant effect on the strength of textile materials. After repeated washing, the general strength of the fabric is reduced. This is due to the cumulative breakdown of the fibers by the chemical breakdown from the detergents and the mechanical breakdown from the shear and the elongation during the washing machine. Sample No. 4 (Turkey) with 85% content of natural fibre blend had the best strength characteristics on the base after 5 washes. The difference in the change of strength characteristics after the number of washes in samples No. 1, No. 6, No. 7, No. 8, No. 10, No. 11 on the base is at the same level of about 5%. After 5 washes in the weft, the strength characteristics of samples No.3, No.4 and No.9 decreased the most.

The highest breaking load in the weft is in sample No.1. This can be explained by the high density of the yarns, as well as the fibre composition, in which there are no natural fibres. Samples No.2 and No.8 (China) have satisfactory strength properties, also these fabrics have fibres of natural origin - cotton more than 35%. But samples No. 5 and No. 6 (Turkey) with the same fibre composition and approximately the same density have lower strength characteristics (by 15%). The analysis showed that the strength of weft yarns directly depends on the density of yarns in the fabric. So on the weft strength of materials containing natural fibres after repeated washing is the highest in sample No. 8, because the fabric is blended with 45% cotton and 55% polyester.

**CONCLUSION**

In the process of research to determine the most significant physical and mechanical properties of materials for the design of special clothing for construction workers, the following work was carried out:

- analysis of the sociological survey was carried out by the method of dispersion analysis ‘ANOVA test;

- in the course of analysing the data of the sociological survey, the most significant indicators for the fabrics of construction workers' clothing were identified: tear resistance, abrasion resistance, breathability, dust permeability and resistance to washing;

- discussion and comparison of the results of this study with other scientific sources showed the validity of the results of this study.

According to the results of experimental studies of strength properties of fabrics, 5 articles were selected for further research: No. 1, No. 2, No. 8, No. 9 and No. 11, which have high indices of structural characteristics and the best results of resistance to repeated washing. In the future, the selected fabrics will be tested for hygienic characteristics and dust permeability.

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