

Research Article

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Young's modulus and Poisson's ratio of the deformable cement adhesives

<https://doi.org/10.1515/secm-2020-0032>

Received May 12, 2020; accepted Aug 22, 2020

Abstract: The article outlines the methods, which has designated Young's Modulus and Poisson's Ratio of deformable cement adhesives. These indicators are necessary for the strength calculation of the lightweight floor systems (LFS), that do not require screeds with and without heating, using the finite element method. It was noticed that the diagrams of the dependence the stress on deformation in deformable cement adhesives are similar to the model of the 'Madrid parabola' used in testing concrete and cement mortar. In order to determine that the theory of 'Madrid parabola' is correct, calculations were performed using the least amount of squares approximation method. The data of the experimental studies combined with the formula calculations, allowed the study to achieve a reliable result, together to determine whether the theory of relative approximation is correct or not. All these actions have allowed determining the smallest deformations ε_{c2} in deformable cement adhesives type C2S1 and C2S2 and their compressive strength. Thanks, these two methods (experimental and calculation) the functions describing deformable cement adhesives are defined. They were named S1 and S2 Evola and can be used by designers and producers of floor systems that do not require screeds.

Keywords: Young's modulus; Poisson's ratio; cement adhesive

1 Introduction

For several years, the mechanical strength of the lightweight floor system (LFS) without screeds has been

tested. The design of this system is a board made of insulating material, most often as the XPS or EPS panels, covered with an adhesive-mesh layer, to which the floor of the artificial stone e.g. ceramic tiles, or natural stone, is directly glued. This type of floor is mounted on rigid substrates like concrete, wood or others, with the possibility of mounting the radiant floor heating. Mechanical endurance tests were preceded by the experiments that determined thermal performance and temperature distributions on the tiled floor. The basic loads of layered, lightweight floor will be exposed to different thermal factors (as a result of weather exposure and that generated by heating systems) and standard normal loads - imposed and self-weighted. Under the influence of these interactions, there are stresses and deformations inside the floor structure. The most important layer in the cross section of a lightweight floor system without screeds is cement mortar, as it must transfer the various types of internal stresses that are derived from external loads, including thermal impacts. To determine them, the authors of the article performed many experiments described in [1] and [2]. To confirm the results of conducted laboratory tests and the impact of possible applications of their various fixings on a durable base, numerical calculations should be made. They should be implemented by using the finite element method (FEM). For this purpose, you need the material strength data of the individual layer components in the LFS. The top of the floor consists of (Figure 1):

- ceramic tile floor
- cement adhesive mortar reinforced with fiberglass mesh
- thermal insulation from the XPS or EPS polystyrene
- mounting material for the substrate (adhesive mortar, mechanical fasteners or no fixing on perfectly equal substrates)
- PVC steam insulation foil, self-adhesive
- rigid substrate (concrete or wood-like)

The material strength indicators to be used for FEM numerical calculations are:

- Young's modulus E
- Poisson's ratio ν
- thermal linear expansion coefficient α

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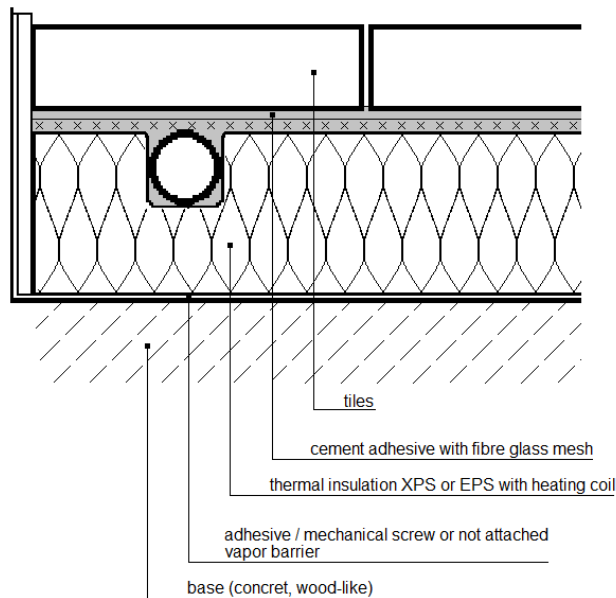


Figure 1: Cross section of layers in LFS with a heating coil

Most of the necessary material data can be found in the literature. There were no E , ν and α indicators for deformable cement mortars C2S1 and C2S2. This article describes experimental studies of compressive strength to designate E and ν in the laboratory of the Bialystok University of Technology. These strength indicators were additionally verified using least-squares approximation.

2 Research methodology

After analysing the literature, including a doctoral dissertation [3], in which the uniaxial compression and bending tensile strength tests were conducted on various samples of masonry mortar (cuboid and cylindrical), it was decided to take cylindrical samples of adhesive mortars as those that guarantee the final determination of the material data needed, namely Young's modulus and Poisson's coefficient when axial squeezing occurs. For this purpose, samples of each adhesive with a height of 50 mm and an equal diameter of approx. 46 mm were prepared, mixing cement mortars with water in the amounts provided by the producers. Each of the adhesives was arranged in cylindrical PVC forms (Figure 2).

After twenty seven days, the samples were removed from the moulds (Figure 3) and four of five samples of each type of adhesives were eventually taken for testing. Axial compression tests were performed on Sika Ceram 255 and C2S2 Basf Flex-mortel cement adhesives sam-

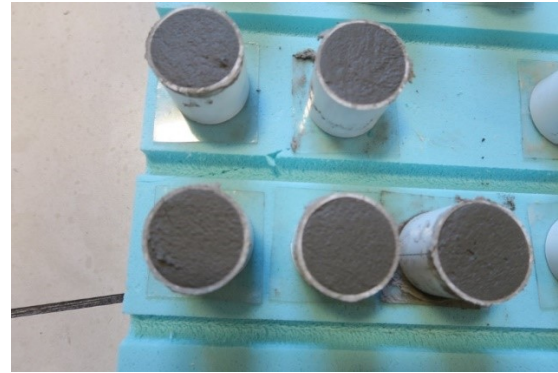


Figure 2: Samples of deformable cement adhesive mortars



Figure 3: Adhesive mortar samples of type C2S1 and C2S2 after removing from the moulds, $h \approx 5$ cm

ples, which was similar to the sample dimensions in the strength tests for masonry mortar compression according to normative [4], in which a diameter of 8 cm is taken. The smaller size of cement adhesive samples was dictated by the smaller grain size used in the cement adhesive, baring in mind the similar composition of both mortars. According to [5], more than 90% of adhesive mortars components are cement and aggregate.

Before the compressive strength test, the cement adhesive sample was aligned on a lathe to obtain equal planes.

After alignment, the following sample diameters were obtained:

- adhesive C2S1 Sika Ceram 255 in [mm]: No 1 – 46.8, No 2 – 47.1, No 3 – 46.7, No 4 – 46.7
- adhesive C2S2 Basf Flex-mortel in [mm]: No 1 – 46.85, No 2 – 47.15, No 3 – 46.7, No 4 – 46.7

After this treatment, one sample from each of the cement adhesives was initially compressed without the use of external extensometers. This allowed us to create the correct estimate for compressive stresses, which confirmed the use of the relevant test machines. The following maximum compression force and stress values were obtained:

- C2S1 – $F = 24.14 \text{ kN}$, $\sigma = 14.04 \text{ N/mm}^2$
- C2S2 – $F = 23.32 \text{ kN}$, $\sigma = 13.53 \text{ N/mm}^2$

For the compression strength test of the cement mortars, the dynamic dual-axis (torsional) strength machine MTS 809.10 was used, and it was controlled by MTS Flex-Test 40 controller with an axial load range $\pm 100 \text{ kN}$ (Figure 4).

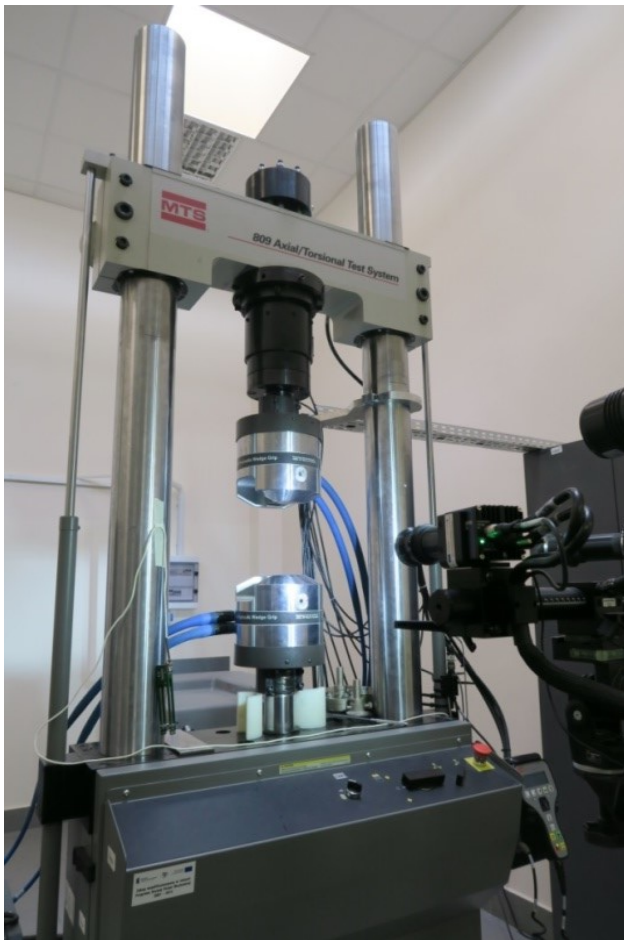


Figure 4: MTS 809.10 strength machine

After the preliminary tests were conducted, the target studies began, using the two extensometers, fixed for each of the cement adhesive samples transversely and oblongly to the axis. The extensometers were attached to a measuring transducer with the results read out on a computer screen. The longitudinal base of the extensometer was constant and read 37.5 mm. The following extensometer types were used:

- oblong Instron 2620, with a measurement accuracy of 0.15% FSD (full deflection scale)
- transverse Epsilon 3542050M-025-HT1, with a measurement accuracy of 0.15% FSD

The extensometers attached to the adhesive mortars by rubber O-rings were used to measure transverse and oblong deformations during the compressive strength test of the prepared samples, to determine the Poisson's ratio of adhesive mortars. The fastening method is shown in Figure 5.



Figure 5: One of the samples of adhesive mortar with the extensometers for measurement of deformation during the compressive strength test.

3 The research results

It was assumed that cement adhesive mortars are a homogeneous, isotropic material, with elastic properties. It is possible to determine material properties such as Poisson's ratio ν , Young's modulus E , Kirchhoff G and others under the action of compressive force. When we determine Young's modulus according to [6], initial readings are not included in the calculations due to possible small offsets,

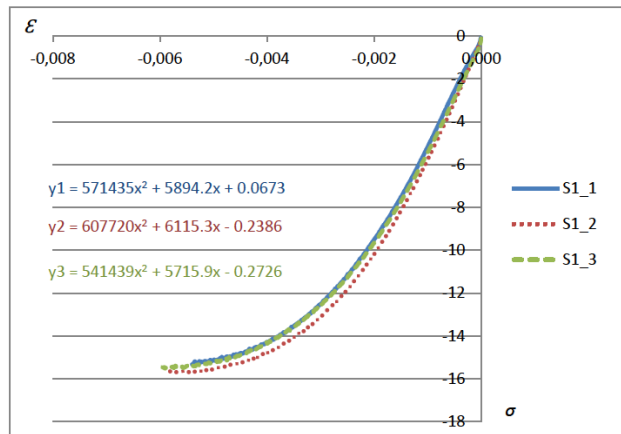


Figure 6: Dependence σ on C2S1 adhesive, three samples under compression

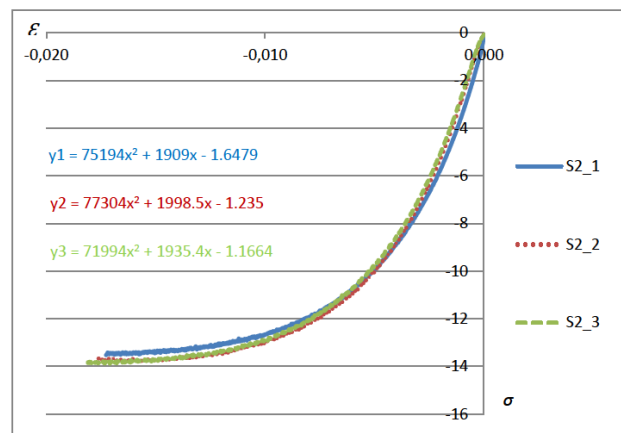


Figure 7: Dependence σ on C2S2 adhesive, three samples under compression

during the first low load increment. However, individual assessment of the strength characteristics of materials depends not only on their chemical composition but also on the procedure and apparatus used in the tests. The main purpose of the study was to designate the Poisson's ratio and Young's modulus of the two cement adhesives tested on the pre-prepared samples described in this paper.

Based on the test results (three samples of C2S1 and C2S2 adhesive were tested), 2-degree polynomial functions by the method of least squares were determined, within the range up to the maximum stress value (Figures 6–7). Then, using the same method, the polynomial functions of these adhesives were determined, taking the arithmetic means of the test results for individual adhesives, for calculations, as shown in Figures 8 and 9. The following names have been adopted: for C2S1 – function S1 and for C2S2 – function S2.

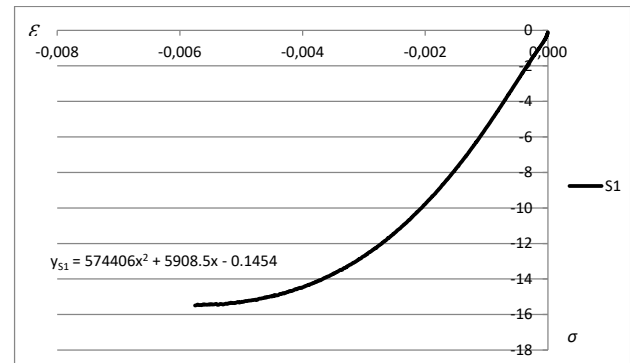


Figure 8: Dependence σ on C2S1 adhesive, as function S1 under compression

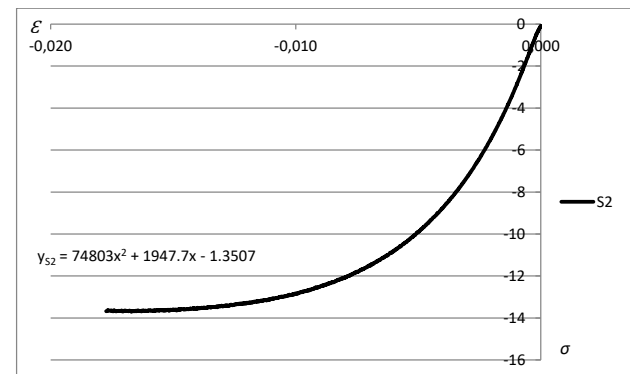


Figure 9: Dependence σ on C2S2 adhesive, as function S2 under compression

When it is difficult to determine the relationship between stress and deformation of the rectilinear part of quadratic function, in order to state the value of the potential modulus of longitudinal elasticity E , it is necessary to lead tangent or secant at point $x = 0$ to the S1 and S2 functions (Figures 8–9).

The tangents at points for $x = 0$ for functions S1 and S2 are written by the equations:

$$y_{S1} = 574406x^2 + 5908.5x + 0.1454,$$

$$y_{S2} = 74803x^2 + 1947.7x - 1.3507$$

The right sides of the equations are linear parts of polynomials describing the functions S1 and S2. Due to a low absolute value $c = 0.1454$, close to zero (relative to the high value of the b factor at x) we assume it as equal to 0. Hence, the Young's modulus is:

$$E_{S1} = \operatorname{tg} \alpha = \frac{y_{S1}}{x} = 5908.5 \text{ MPa} \approx 5900 \text{ MPa}$$

For C2S2 adhesive, due to a low absolute value $c = 1.3507$, close to zero (relative to the high value of the b factor at x) we assume it as equal to 0. Hence, the Young's modulus is:

$$E_{S2} = \operatorname{tg} \alpha = \frac{y_{S2}}{x} = 1947.7 \text{ MPa} \approx 1950 \text{ MPa}$$

The Poisson's ratio is the absolute value of the relation of transverse deformation to the corresponding axial deformation resulting from the evenly distributed axial stress below the material proportionality limit. It is described by the formula (1):

$$\nu = -\frac{\varepsilon_n}{\varepsilon_m} \quad (1)$$

ν – Poisson's ratio

ε_n – transverse deformation

ε_m – longitudinal (axial) deformation

The coefficient ν is estimated by the tensile or compression force tests, according to the standard [9] at axial stress. The arithmetic mean's value of the Poisson coefficient, in the phase of elastic compression stress of cement adhesives for each of the samples, was assumed in calculations to be within the range of linear, when it reaches stable numerical values in a given test sample. Examples of the dependence of stress from the quotient of the ratio transverse to longitudinal deformation ν C2S1 and C2S2 ad-

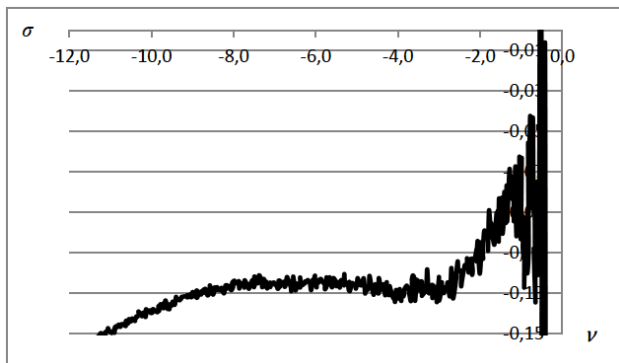


Figure 10: The dependence of the σ stress from the quotient of transverse to longitudinal deformation ν in the cement adhesive C2S1.

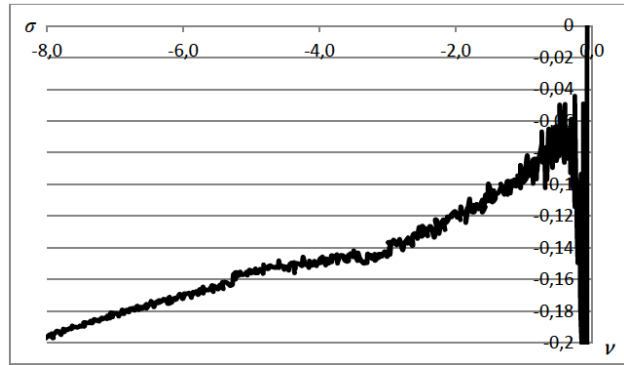


Figure 11: The dependence of the σ stress from the quotient of transverse to longitudinal deformation ν in the cement adhesive C2S2.

hesive, in tests with the extensometers, are shown in Figures 10 and 11.

The results of calculations of maximum stresses, Young's modulus and the Poisson' ratio for each type of adhesives are given in Table 1.

4 Analysis of test results

The relationship between stresses and deformations in the tested cement mortars subjected to compression is not a linear function. The shape is similar to the dependence of stress on the deformation of the compressed wall in reality. The dependence of stress on the strain was shown in the article [10] (Figure 1) on the first graph. The other two charts on this drawing show the above-mentioned dependencies calculated according to the standard [11]. Inside, it is possible to take calculations for four various dependencies of stress on deformation, including linear, rectan-

Table 1: Average value of the Young modulus and Poisson factor in the adhesive tested.

Type of adhesive	No of sample	σ_{\max} [MPa]	E [MPa]	E_e [MPa]	ν_i	ν_{avg}
C2S1	S1_1	15.32	5894.2	5900	0.128	0.13
	S1_2	15.72	6115.3		0.135	
	S1_3	15.52	5715.9		0.126	
C2S2	S2_1	13.52	1909	1950	0.153	0.15
	S2_2	13.78	1998.5		0.150	
	S2_3	13.89	1935.4		0.146	

σ_{\max} – maximum stress in compressing

E – Young's modulus of the sample

E_{eS1} , E_{eS2} – accepted potential Young's modulus of C2S1 and C2S2

ν_i – Poisson's ratio of the sample

ν_{avgS1} , ν_{avgS2} – average accepted Poisson's ratio of C2S1 i C2S2

gular, parabolic and parabolic-rectangular dependencies. These four graphs cannot be taken for calculations arbitrarily. It depends on the material used. In the article [10] due to the lack of standard indications [11–13], and after observations during the testing of masonry structures, it is proposed that the smallest wall deformations corresponding to the compressive strength should be equal to 0.002, i.e. at the same level as in ordinary concretes.

Concerning the tests of the cement adhesive mortars, in the initial compression phase of these samples, the stresses increase with deformations up to the maximum value. Then, as the strain increases, the stress decreases. For this reason, a parabolic graph of cement adhesive functions was used for the calculations. As pointed out in the publication [14], that in the initial phase of adhesive compression there are minimal disturbances (despite earlier alignment of samples for testing), caused by the adjustment of the loading force to the adhesive mortar. These disturbances stopped very quickly, without exceeding the stress level of 0.15 MPa. This is not a significant error amount of approx. 1% at the maximum compressive stress within 14–16 MPa. In this situation, as recommended in [14], it can be moved the vertical axis of stress to the point of intersection of the curve with the axis of deformation and thus start approximating the dependence of σ on ε at point 0.

4.1 Determining the smallest deformation of adhesives using a polynomial approximation with a reduced second-order polynomial

The analysed dependence of σ on ε has a fairly obvious feature for $\sigma = 0$ should be $\varepsilon = 0$. In addition, so called in the literature ‘Madrid parabola’, which well characterizes the dependence of σ on ε for concrete, has the form $\sigma = a\varepsilon^2 + b\varepsilon$ for $n = 2$ (10). Therefore, test result sets should be approximated with the polynomial $y = ax^2 + bx$ instead of $y = ax^2 + bx + c$. The application of the least-squares method for the function $y = ax^2 + bx$ boils down to finding the minimum of the function $f(a, b) = \sum (y_i - ax_i^2 - bx_i)^2$ with given measurement results x_i, y_i , for $i = 1, 2, \dots, n$. The function $f(a, b)$ reaches the minimum for:

$$a = \frac{rs - tq}{pr - q^2} \quad (2)$$

$$b = \frac{pt - qs}{pr - q^2}, \quad (3)$$

where

$$r = \sum x_i^2, \quad s = \sum y_i x_i^2, \quad t = \sum y_i x_i, \quad (4)$$

$$q = \sum x_i^3, \quad p = \sum x_i^4.$$

The value $x = -\frac{b}{2a}$ received for y_{\min} can be interpreted as ε_{c2} . Therefore:

$$\varepsilon_{c2} = -\frac{b}{2a} \quad (5)$$

By substituting to the formulas (2)–(5), the data from tests dependence of deformation to the stress of C2S1 adhesive obtained the following results:

a) at the arithmetic mean of three samples

$$a = 591397.8; \quad b = 6019.7; \quad \varepsilon_{c2} = 0.00509$$

b) for the total set of all three samples results

$$a = 587804.9; \quad b = 6010.2; \quad \varepsilon_{c2} = 0.00511$$

Finally accepted $\varepsilon_{c2} = 0.0051$ for adhesive C2S1

By substituting to the above formulas the data from tests dependence of deformation to the stress of C2S2 adhesive the following results were obtained:

a) at the arithmetic mean of three samples

$$a = 90463.7; \quad b = 2271.1; \quad \varepsilon_{c2} = 0.01255$$

b) for the total set of all three samples results

$$a = 89922.2; \quad b = 2265.0; \quad \varepsilon_{c2} = 0.01259$$

Finally accepted $\varepsilon_{c2} = 0.0126$ for adhesive C2S2

Using the ‘Madrid parabola’ to designate the E longitudinal elasticity modulus and parabolic functions of deformable cement adhesives

The formulas (6) and (7) for ‘Madrid parabolas’ is cited in Eurokod 2 [15] (paragraph 3.1.3, Table 3.1)

$$\sigma_c = f_c \left[1 - \left(1 - \frac{\varepsilon_c}{\varepsilon_{c2}} \right)^n \right], \quad \text{for } 0 \leq \varepsilon_c \leq \varepsilon_{c2}, \quad (6)$$

$$\sigma_c = f_c, \quad \text{for } \varepsilon_{c2} \leq \varepsilon_c \leq \varepsilon_{cu2}, \quad (7)$$

where:

f_c – computational strength of ordinary concrete, e.g. C12/15 ÷ C50/60, compressive strength,

ε_c – current concrete deformation,

σ_c – compressive stress in concrete corresponding to the ε_c , deformation

ε_{c2} – the smallest deformation in concrete for which the

stresses achieved are equal to the strength of concrete for compression (for normal concrete $\varepsilon_{c2} = 0.002$),

ε_{cu2} – limiting deformation of concrete (for ordinary concrete $\varepsilon_{cu2} = 0.0035$),

n – exponent (for ordinary concrete equal to 2).

The average arithmetic strength value of the C2S1 adhesive from three samples equal $f_c = 15.49 \approx 15.50$ MPa was taken from the experimental research (the maximum from the set of all results from the three tests was equal to 15.72 MPa). In the C2S2 adhesive, strength was equal respectively $f_c = 13.73 \approx 13.70$ MPa, and a maximum of 13.89 MPa. By substituting into formula (11) the data for the strength of the adhesives from the experiment and the smallest deformations $\varepsilon_{c2} = 0.0051$ in C2S1 and $\varepsilon_{c2} = 0.0126$ in C2S2, the functions referred to in section 5 were named S1 Evola and S2 Evola, and were designated by formulas (8) and (9).

These are:

→ Cement adhesive mortar C2S1

$$\sigma_{S1} = 15.5 \left[1 - \left(1 - \frac{\varepsilon_{S1}}{0.0051} \right)^2 \right] \quad (8)$$

σ_{S1} – compression stress in C2S1, corresponding to the ε_{S1} deformation

ε_{S1} – C2S1 adhesive deformation from the research

→ Cement adhesive mortar C2S2

$$\sigma_{S2} = 13.7 \left[1 - \left(1 - \frac{\varepsilon_{S2}}{0.0126} \right)^2 \right] \quad (9)$$

σ_{S2} – compression stress in C2S2, corresponding to the ε_{S2} deformation

ε_{S2} – C2S2 adhesive deformation from the research

Verification of the experimental adhesive strength results against experimental data can be performed using a formula (10) for the 'Madrid parabola', which have written in monograph [16] as follows:

$$\sigma = \sigma_0 \left(\frac{2\varepsilon}{\varepsilon_0} - \left(\frac{\varepsilon}{\varepsilon_0} \right)^2 \right), \quad 0 \leq \varepsilon \leq \varepsilon_0 = 0.003 \quad (10)$$

where:

$\sigma_0 = f'_c$ (axial compressive strength)

ε_0 – the smallest deformation of the test material corresponding to its strength

ε – strain corresponding to stress σ , wherein

$$\varepsilon_0 = 2\sigma_0/E_c \quad (11)$$

where $E_c = 57,000 \sqrt{f'_c}$ for longitudinal elasticity concrete modulus.

It has been noted that the function described in the formula (10) is $\sigma = a\varepsilon^2 + b\varepsilon$, where

$$a = -\frac{\sigma_0}{\varepsilon_0^2}, \quad b = \frac{2\sigma_0}{\varepsilon_0} \quad (12)$$

Having the values of a and b , determined earlier by means of polynomial approximation, from the formula (12) the values σ_0 , ε_0 , were calculated, described by the formula (13):

$$\sigma_0 = -\frac{b^2}{4a} \text{ for } \varepsilon_0 = -\frac{b}{2a} \quad (13)$$

From the condition (11) it is directly visible that the quantities (13) are related to the modulus of elasticity E .

Taking data $a = 587804.9$ and $b = 6010.2$, for C2S1 adhesive and $a = 89922.2$ and $b = 2265.0$ for C2S2 adhesive, calculated by the approximation square function in the set of all experimental results, the following strengths of these adhesive mortars were obtained:

$$\sigma_{0(S1)} = 15.36 \text{ MPa}$$

$$\sigma_{0(S2)} = 14.26 \text{ MPa}$$

The calculated values of the compression strength of the adhesives do not differ significantly (they are within a statistical 5% error) from the arithmetic means given, resulting from experimental tests, which are 15.5 MPa (S1) and 13.7 (S2), respectively.

Knowing the smallest deformations of cement adhesives C2S1 and C2S2 at which they reach their strengths, and using formula (11), their longitudinal elasticity modules E were determined.

$E = \frac{2\sigma_0}{\varepsilon_0}$, where $\varepsilon_0 = \varepsilon_{c2}$ respectively for designated C2S1 and C2S2, we have:

$E_{S1} = 6023$ MPa, adopted **6000 MPa** (for cement adhesive **C2S1**)

$E_{S2} = 2264$ MPa, adopted **2300 MPa** (for cement adhesive **C2S2**)

The graphs of the determined functions S1 Evola and S2 Evola based on formulas (8) and (9), confirmed by calculations, are shown in Figures 12 and 13, compared to the

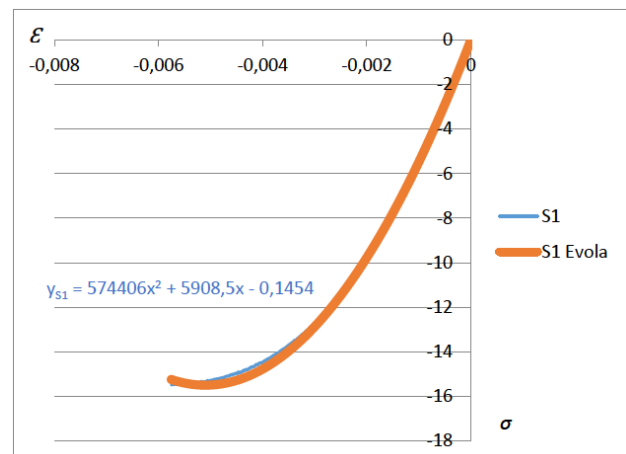


Figure 12: S1 Evola function compared to S1 (from researches)

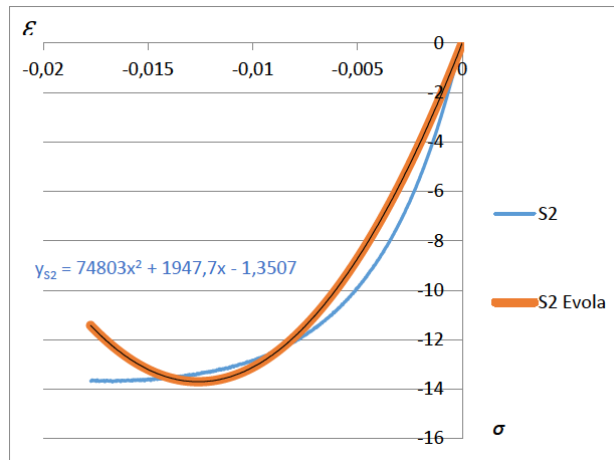


Figure 13: S2 Evola function compared to S2 (from researches)

values of the average functions S1 and S2 developed based on the research.

Figure 12 shows a greater convergence of function graphs compared to Figure 13. This is due to the fact that a larger error occurred during the testing of C2S2 adhesive, which is determined by the relationships of the coefficients for the functions S1 and S2, including the value of the coefficient c of the square function (in S1 $c = 0.1454$, and in S2 is 10 times larger, equal to 1.3507).

The average square error of approximation in C2S1 and C2S2

Experiments for measuring the size of ε (deformation) and σ (stress) were performed for two types of adhesives C2S1 and C2S2 in a three-series (three series of test results: S1_1, S1_2, S1_3; S2_1, S2_2, S2_3) and after joining each of the two series independently (S1, S2) into one set of S_i points ($i = 1, 2$). The measure of approximation accuracy, data set $(x_i, y_i)_{i=1,2,\dots,n}$, function $f(x)$ is the relative approximation error given by formulas (14) and (15):

$$\delta_\sigma = \max_{0 \leq i \leq n} \frac{|y_i - f(x_i)|}{|f(x_i)|} \cdot 100 [\%] \quad (14)$$

which in relation to the function $f(x) = ax^2 + bx$ has the form:

$$\delta_\sigma = \max_{0 \leq i \leq n} \frac{|y_i - (ax_i^2 + bx_i)|}{|ax_i^2 + bx_i|} \quad (15)$$

Using the above equations, the following relative error results were obtained for C2S1 and C2S2 adhesives:

C2S1 adhesive mortar

For the C2S1 adhesive mortar, the relative approximation error calculated by the formula (15), without taking into account the initial measurement disturbances resulting from the adjustment of the device to the tested samples in the stress range from 0.8–15.5 MPa, is on average 3.8%, and in the range 0.6–15.5 MPa is on average 4.5%.

C2S2 adhesive mortar

For the C2S2 adhesive mortar, the relative approximation error calculated using formula (15), without taking into account the initial measurement disturbances resulting from the adjustment of the device to the tested samples in the stress range from 0.8–13.7 MPa, is on average 13.4%, and in the range from 0.6–13.7 MPa is on average 14.1%.

A much larger relative approximation error calculated for the series S2_1, S2_2, S2_3 than for the series S1_1, S1_2, S1_3 can be explained by the results of approximation using the function $f_i(x) = a_i x^2 + b_i x + c_i$ ($i = 1, 2$). The approximation results, obtained using the function $f_i(x)$, differ significantly in the values of c_i . Non-zero values of c_i indicate a certain imperfection of approximation, which means that the zero value ε (deformation) corresponds to a non-zero value of σ (stress). The reason for this may be the unstable initial readings of the instruments when the test apparatus corrects slight irregularities of the tested samples, as well as the results from the permissible errors of the test instruments themselves. Another reason may be that the test apparatus does not record measurable deformations when the stresses are small (near zero).

5 Conclusions

There are not exist Young's modulus E and Poisson's ratio ν for deformable cement adhesives, type C2S1 and C2S2 in the literature. Compressive strength tests of adhesives cylindrical samples C2S1 and C2S2 allowed to determine these strength indexes. After verification of the results, the elastic modulus E was finally adopted 6000 MPa (C2S1), 2300 MPa (C2S2), and Poisson's ratio ν was assumed in the C2S1 adhesive equal to 0.13 and the C2S2 adhesive equal to 0.15. These data can be used by producers and designers in calculations of the mechanical strength in the lightweight floor systems (LFS) no required screeds with or without heating by using the Finite Element Method, as well as for all other calculations needed.

In addition, it has been determined that:

1. The functions defining selected adhesives – S1 Evola characterizes C2S1 cement adhesive and S2 Evola function characterizes C2S2 cement adhesive.
2. The smallest deformations of the adhesives correspond to their compressive strength after using approximation with a polynomial, the least-squares method, respectively $\varepsilon_{c2} = 0.0051$ (C2S1), $\varepsilon_{c2} = 0.0126$ (C2S2).
3. The mistakes of the potential modulus E were corrected by determining the tangent equation to the function graph. It was confirmed by comparing the graphs of functions obtained from experimental tests and obtained after applying the 'Madrid parabola' formula.
4. The greater convergence of functions from S1 and computational S1 Evola tests (C2S1 adhesive) concerning to the corresponding functions S2 and S2 Evola (C2S2 adhesive) as indicated by the c coefficients for these functions, has been confirmed by calculating the approximation error, which was about 4% (for C2S1) and approx. 14% (for C2S2).

When we use the cement adhesive mortar with the same designation, but with another manufacturer, Young's modulus or Poisson's ratio may differ slightly from those adopted in the article. The cause is that Cement adhesive mortars type C2S1 and C2S2 according to the standard [17] should have transversal deformation in the range of 2.5–5 mm at the designation S1 and ≥ 5 mm for S2. From these ranges of deformability, it can be concluded that adhesive mortar manufacturers can be used to produce different components that can affect strength indicators. The differences in these indicators should not be significant due to the 90% majority share of aggregate and cement in these adhesives.

To confirm that the obtained characteristics of the designated functions and strength indicators are universal and that they apply to all cement deformable adhesives of type C2S1 and C2S2, the authors suggest to perform the same experiments in the future, testing the same type of cement adhesives, but from other manufacturers.

Acknowledgement: The authors of this article would like to thank Prof. Edwin Kozniowski from the Bialystok University of Technology for his math suggestions and the Sika Poland & Basf Poland Companies for providing materials. The research was performed as part of statutory work from the Bialystok University of Technology No. WI/WB-III/7/2020, financed from the subsidy provided by the Ministry of Science and Higher Education.

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