Environmental and Climate Technologies

sciendo RIGA TECHNICAL UNIVERSITY

2019, vol. 23, no. 1, pp. 152–167
doi: 10.2478/rtuect-2019-0011
https://content.sciendo.com

Multicriteria Analysis of Glass Waste Application

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Abstract **– Increasing amounts of glass waste present serious challenges in waste management to avoid environmental problems that might be created if it was to be deposited in landfills. Theoretically, glass waste is fully recyclable, but, if contaminated, containing impurities, broken or mixed colour, it makes the re-melting process impractical. A great practice of using secondary recycling material was reached by the construction industry involving glass waste in concrete mixtures as fine aggregates – reuse of waste glass in concrete production not only preserves natural resources, reduces greenhouse gas emissions, saves energy, furthermore, it may improve concrete sustainability and enhance the properties of concrete when used at the optimum quantity. In this study the container glass waste evaluation was performed, as well as experimental research of mechanical properties of four types of concrete mixtures containing glass waste as fine aggregate. The best alternative of replacement of sand by glass waste scenario in concrete production was determined, employing the multicriteria decision-making method TOPSIS.**

Keywords **– Compressive strength; container glass waste; flexural strength; glass waste aggregate; multicriteria analysis; TOPSIS; water absorption**

1. INTRODUCTION

Glass waste creates serious environmental issues as it constitutes a large component of overall waste quantity because of its weight and density. It is extremely important for glass waste to be reused/recycled in order to avoid environmental problems that could evolve, if it was sent to landfill. Theoretically, glass is a 100 % recyclable material, it can be indefinitely recycled without any loss of quality. Nonetheless, broken and mixed colour waste glass makes the recycling process impractical as impurities and contaminants that can be found in waste glass can affect the properties of the produced new glass. There are many examples of successful recycling of waste glass in construction: thermal insulation (fiberglass and light-weight aggregates), aggregates for concrete and asphalt, base and sub-base filler materials, and as a component of cement. Usually, considerable volumes of contaminants can be tolerated in such applications [1]–[3].

The application of waste glass in concrete is a promising direction for waste glass recycling. Utilization of waste glass in concrete production is an attractive option that helps to achieve an effective management of glass waste and provides significant environmental benefits. Moreover, other benefits of reusing waste glass in the production of concrete include the preservation of natural resources from further depletion, reduction of greenhouse gases

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emissions and obtained energy savings, thereby achieving environmental greening and sustainability [4], [5]. Furthermore, it may enhance mechanical, as well as durability performance when used at optimum quantity [6].

1.1. Glass Waste Recycling

Recycled glass used as a raw material in glass production is known as cullet. Two different approaches can be adopted when considering the recycling of glass waste: closed loop and open loop recycling.

In closed loop recycling (primary recycling in some literature), the recovered container glass cullet is used for remelting in order to produce new glass packaging. The container glass industry requires high quality cullet that is ready for use in the oven. It means that the cullet must be free of substances such as ceramic, stone, plastic or inorganic matter from food, etc. Broken, mixed colour or contaminated waste glass make remelting impractical or even impossible: impurities and contaminants can affect the properties of the produced new glass [2]. Although the total amount of waste glass recovered may be high, only a fraction of this amount may be remanufactured due to the strict limitation of glass remanufacturing [7].

The open loop recycling (also known as a secondary recycling) is normally followed in circumstances in which the container glass waste is impossible to be recycled back into equivalent manufactured goods and thus must be used for the production of secondary materials or in alternative applications, thereby reducing costs and conserving resources [8]–[10].

1.2. Alternative Applications of Container Glass Waste

Scientific literature offers a lot of information about current and potential uses for glass waste. The alternative markets for container glass waste include the construction sector (using glass waste for road pavement construction, as an aggregate in asphalt, pipe bedding material, drainage or filler aggregate), the production of cement and concrete (using glass waste as aggregate [7], [11]–[14], as partial replacement to cement [6], [15]–[17], partial replacement for cement and aggregate in the same mixture [17] or raw material for cement production [18]), as well as decorative aggregate [9], abrasives [19] or filtration media [20].

It was suggested by Dhir et al. that alternative markets for glass cullet can be categorized into three broad groups, based on its properties [11] as shown in Fig. 1.

In 2017, Mohajerani et al. wrote that reusing waste glass as a construction material is a promising way to lessen the amount of glass disposed of in landfills across the globe, reduce the consumption of natural resources, and lower the carbon footprint and impact of the construction industry on the environment [7]. Emersleben and Meyer, and Frinkle and Ksaibati agree that the characteristics of recycled glass waste can be used for many road applications like base courses because of drainage and strength properties [21]–[23].

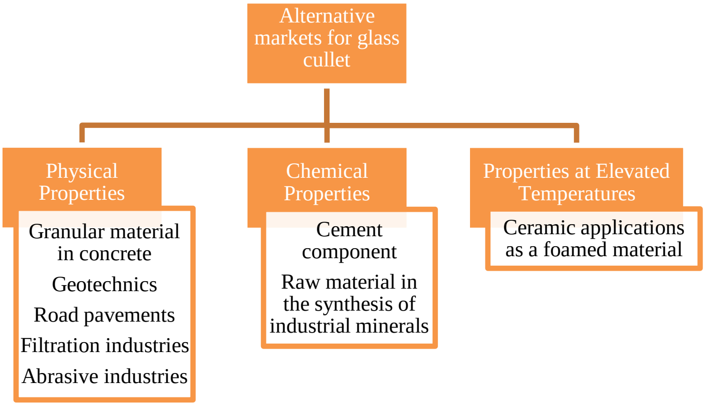

Fig. 1. Alternative market categorization according to glass cullet properties.

Tam and Tam described glass waste use as a substitute for sand and aggregates as pipe bedding material, backfill and crushed stone surfacing [24].

The large demand, as well as low cullet quality requirements of the construction industry, encourages the use of glass waste in the concrete industry and, in this respect, providing some environmentally friendly solutions.

Different studies have been done to determine if wastes can be used in concrete making or not, and what are the proportions of waste that can be added into concrete mixtures. This is done by checking the mechanical properties of concrete and by conducting leaching tests [25].

During earlier studies it was determined that the use of larger glass particles in concrete mixture resulted in excessive expansion and cracking of the specimens, in a so-called alkali-silica reaction (ASR) [26]. To minimize ASR, the partial replacement of fine aggregate and/or cement in concrete has been investigated. Meyer et al. discovered that the use of glass particles passing a mesh of size 50 mm helps to avoid ASR damaging effects [27]. Furthermore, Ismail and Al-Hashhimi found that the ASR expansion reduced with increasing the amount of glass waste [28].

When investigating the mechanical properties of concrete containing waste glass aggregate, Park et al. found that the mechanical properties of the concrete specimens containing waste glass did not display any noticeable differences, depending on the colour of the waste glass aggregates [29].

Controversial effects have been obtained regarding the compressive strength in investigations of glass waste incorporation in concrete as an aggregate. Studies undertaken by Chen et al., Pereira de Oliveira et al., Turgut and Yahlizade, Park et al., Adaway and Wang observed compressive strength in specimens with waste glass content higher than the control specimens [26], [29]–[31].

Park et al. as well as Adaway and Wang provided the results, claiming that 30 % is the optimum percentage replacement of sand with fine glass aggregate in the development of comprehensive strength as the concrete containing waste glass aggregates of 30 % mixing ratio gave the highest strength properties [26], [29].

Furthermore, the studies carried out by Ismail and AL-Hashmi showed that a concrete mixture containing 20 % of aggregate replacement by glass had higher compressive strength compared with a control concrete mixture without aggregate replacement by glass waste [28].

The demonstration of a substantial increase of compressive strength in concrete mixtures containing glass waste as an aggregate beyond 15 % was reported by Tuncan et al. [33].

Similar experiments were performed by Du and Tan and they obtained no significant difference in compressive strength replacing up to 100 % sand by glass waste after 28 days of concrete hardening, furthermore, the increase of compressive strength after 90 days was obtained together with increasing of glass percentage [34].

With no clear consensus currently available in literature, this study will seek to clarify the effects that glass waste aggregate has on the properties of concrete, especially focusing on the concrete mix that is usual for concrete pavement tile upper layer.

2. METHODOLOGY OF EXPERIMENTAL RESEARCH

The research plan was divided into three parts (see Fig. 2). The first part was assigned for investigation of crushed container glass waste (CGW) and the laboratory analysis has been done to determine whether the waste is hazardous or not in order to evaluate the possibility of using this waste for the partial replacement of sand in concrete production: sieving method, described in LST EN 933-1, was applied for determination of particle size distribution, chemical composition of crushed CGW was determined in accordance to EN 15309:2007 by wavelength dispersive X-ray fluorescence spectrometer; one stage batch leaching test was performed and metals concentrations in leachate were determined.

In the second part, an experiment was carried out to find the suitability of using CGW in concrete, determining fresh and hardened concrete properties. Four types of mixtures for concrete specimens were made in the laboratory: containing 0 %, 10 %, 30 % of glass cullet as sand replacement, and concrete mixture containing 30 % of CGW as sand replacement and 25 % of water content was replaced by a modified acrylic-based polymer blend. Six standard prisms of size 40·40·160 mm were produced for each concrete mixture. Three of them were used for mechanical properties characterization (three-point bending test and compressive test) and the remaining three specimens of each mixture were used for the determination of water absorption. The flow table test was carried out in accordance with LST EN 12350-5:2009 to determine the concrete consistency. After 28 days of hardening in water, the flexural strength and compressive strength determinations were performed in accordance with procedures specified in LST EN 12390-5:2009 and LST EN 12390-3:2009, respectively. Determination of water absorption was performed according to the procedure described in methodical references for testing of building materials [35]. Prices of each concrete mixture were calculated in accordance with the current prices of raw materials in the market, excluding taxes.

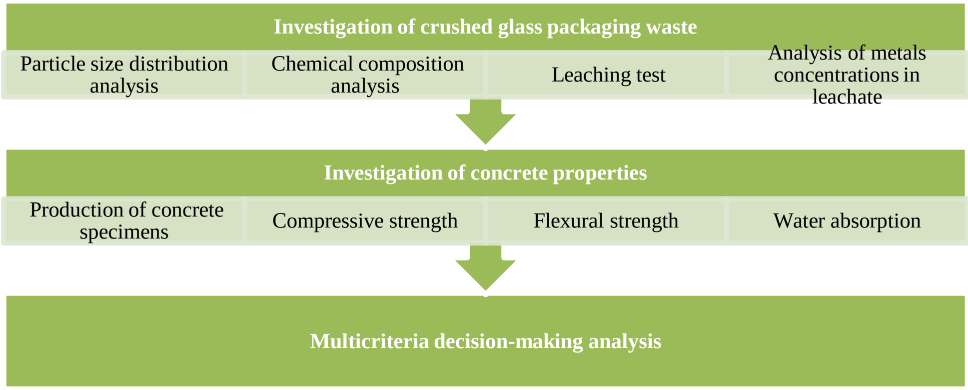

Fig. 2. Scheme of methodology of research.

The third part of the research was assigned to reveal a topic determining the best alternative of replacement of sand aggregate by crushed container glass waste scenario in concrete production, employing the multicriteria decision-making method TOPSIS, by considering technical and economic properties.

Waste glass for this experimental research was sourced from a materials recovery facility (MRF) located in Panevezys, located in the northern part of Lithuania. Recycled glass is a product of the glass recycling industry and is comprised of mixed coloured glass particles which are often angular in shape with a noticeable value of flat and elongated particles in the mixture [36]. The source of waste glass that was used in this experimental resource was the municipal solid waste (MSW) stream from household and commercial waste collection. Mixed colour CGW was collected, washed, and crushed to create a glass cullet as fine aggregate.

3. Results and Analysis of Experimental Research

3.1. Analysis of Particle Size Distribution of Crushed Container Glass Waste

The sieve analysis of crushed CGW is given in Table 1. The data in Table 1 includes the weight of the tested specimen which remained on each sieve, cumulative mass retained, cumulative percentage mass retained, and cumulative percentage mass passing.

TABLE 1. RESULTS OF SIEVE ANALYSIS

Sieve size, mm	Retained mass, kg	Cumulative retained mass, kg	Cumulative percentage mass, %	Cumulative percentage mass passing, %
4	0	0	0	100.00
2	2.793	2.793	43.90	56.10
1	2.083	4.876	76.64	23.36
0.5	0.902	5.778	90.82	9.18
0.25	0.352	6.130	96.35	3.65
0.125	0.105	6.235	98.00	2.00
0.063	0.088	6.323	99.39	0.61
Pan	0.039	6.362	100.00	0

We can see that all the particles were smaller than 4 mm as it is required for fine aggregate, and the largest percentage of obtained particles (43.9 %) was of size from 2 mm to 4 mm.

3.2. Results of Determination of Chemical Composition of Cullet

It was determined by XRF analysis that the main part of the CGW is silicon oxide, which takes up more than half (68.9 ± 1 %) of all the total weight (Table 2). It was also determined that the composition includes 12.3 ± 1 % Na_2O, 12.2 ± 1 % CaO, 0.9 ± 0.15 % Al_2O_3, the quantity of heavy metals oxides (PbO, BaO, Cr_2O_3, SrO, TiO_2, ZrO_2, ZnO, MnO, CuO, Rb_2O) is less than 0.1 % of total mass.

TABLE 2. CHEMICAL COMPOSITION OF CGW, WT%

Constituent	CGW, wt%	Constituent	CGW, wt%
SiO_2	68.933	PbO	0.08
Na_2O	12.323	Rb_2O	0.003
CaO	12.197	BaO	0.069
MgO	2.738	Cr_2O_3	0.067
Fe_2O_3	1.089	SrO	0.066
Al_2O_3	0.927	TiO_2	0.062
K_2O	0.92	ZrO_2	0.03
SO_3	0.154	ZnO	0.017
NiO	0.107	MnO	0.009
CuO	0.004	–	–

As mentioned in the literature review, the heavy metals are used as additives in the glass composition to impact the colour and specific properties.

3.3. Analysis of Batch Leaching Test

Further options for waste management should be decided after evaluating the hazardous properties of glass waste. There are no uniform EU requirements for leaching parameters of recycled aggregates yet, but several member states include criteria of leaching behaviour of the aggregates that are going to be used as construction materials in their national regulations and guidelines. These countries associate the use of recycled aggregates to waste legislation – the release of dangerous substances must be evaluated by performing the leaching tests considering leaching limit values established as waste acceptance criteria for inert waste and non-hazardous waste that are listed in Table 3.

TABLE 3. LEACHING LIMIT VALUES APPLIED FOR WASTE ACCEPTABLE FOR INERT WASTE AND NON-HAZARDOUS WASTE (2003/33/EC)

Element	Limit values L/S = 10 l/kg, mg/kg dry substance	
	Inert waste	Non-hazardous waste
As	0.5	2
Ba	20	100
Cd	0.04	1
Cr total	0.5	10
Cu	2	50
Hg	0.01	0.2
Mo	0.5	10
Ni	0.4	10
Pb	0.5	10
Sb	0.06	0.7
Se	0.1	0.5
Zn	4	50

Table 3 indicates that there is a requirement to evaluate the leaching of As, Ba, Cd, Cr total, Cu, Hg, Mo, Ni, Pb, Sb, Se and Zn. In chemical analysis of CGW, As, Cd, Hg, Mo, Sb and Se were not detected, so the determination of metals concentration in leachate was performed for the detected elements: Ba, Cr total, Cu, Ni, Pb and Zn. The results of determination of metals concentrations in leachate using atomic absorption spectroscopy are presented in Table 4.

TABLE 4. METALS CONCENTRATIONS IN LEACHATE

Element	Symbol	Units	CGW	Compliance to the requirements in 2003/33/EC	
				Inert waste	Non-hazardous waste
$Chromium_{total}$	Cr	mg/kg	<LOD	met	met
Nickel	Ni	mg/kg	<LOD	met	met
Lead	Pb	mg/kg	0.164	met	met
Barium	Ba	mg/kg	0.23	met	met
Zinc	Zn	mg/kg	1.278	met	met
Copper	Cu	mg/kg	0.06	met	met

When evaluating the results in Table 4, it is evident that leaching is insignificant, and it is expedient to use this waste as secondary raw material while reducing the use of natural resources.

3.4. Producing Concrete Specimens

Three types of mixtures contained a different percentage of sand replacement by CGW: 0 %, 10 %, 30 % of glass cullet as sand replacement. Also, there was produced a mixture containing 30 % of CGW as sand replacement and 25 % of water content was replaced by a modified acrylic-based polymer blend (see Table 5).

TABLE 5. QUANTITIES OF RAW MATERIALS FOR EACH CONCRETE MIXTURE

Mixture, %	Cement content, kg	Water content, kg	Polymer content, kg	Sand content, kg	GW content, kg	Plasticizer content, kg
0	0.7	0.46	0	3.58	0	0.0056
10	0.7	0.46	0	3.222	0.358	0.0056
30	0.7	0.46	0	2.506	1.074	0.0056
30 + polymer	0.7	0.368	0.092	2.506	1.074	0

3.5. Results of Experiments of Fresh Concrete

The experiment of fresh concrete flow was performed to estimate the consistency of each concrete mixture.

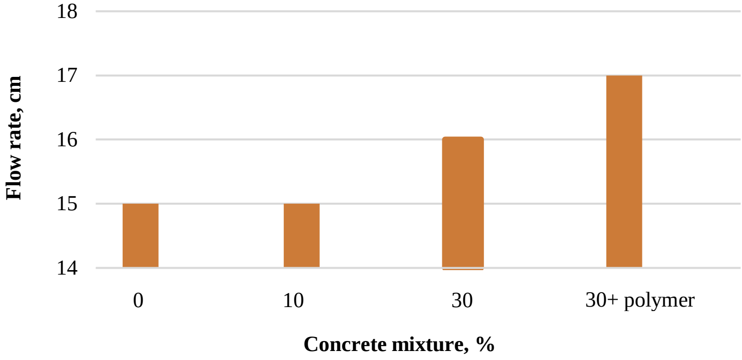

Fig. 3. Fresh concrete flow.

In Fig. 3 we can see the change of consistency using different amounts of CGW instead of usual aggregate – sand. The flow remains the same in case of 10 % of sand replacement by CGW in concrete mixture and it is equal to 15 cm. When the replaced amount of sand increases up to 30 %, the flow rate increases too and reaches 16 cm. In case when 30 % of sand was replaced by CGW and 25 % of water was replaced by polymer blend, the flow rate increased even more and reached 17 cm.

3.6. Results of Experiments of Hardened Concrete

Mechanical properties of hardened concrete were tested after 28 days hardening in water. Flexural and compressive strength tests were carried out using an electromechanical universal testing machine LFM 100.

Firstly, the equipment for centre-point loading method was installed in a universal testing machine to determine the flexural strength of concrete specimens. Three specimens of each concrete mixture were tested in accordance to LST EN 12390-5:2009.

Maximum loads were obtained and recorded for each specimen while they were loaded until the failure. After that, calculations of flexural strength were performed.

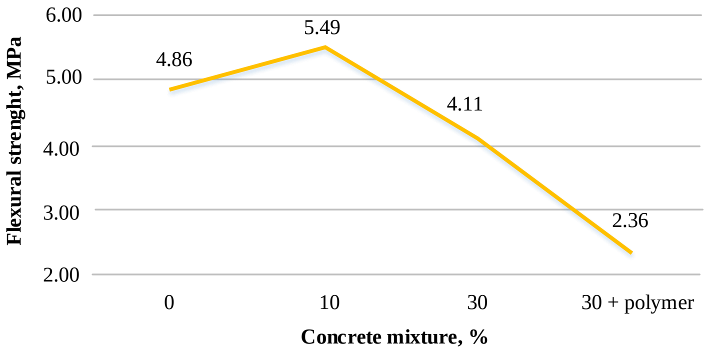

Fig. 4. Flexural strength of specimens.

From Fig. 4 it can be seen that the flexural strength of hardened concrete increased when 10 % of sand was replaced by CGW. A test of specimens with 30 % of sand replacement by CGW showed that the flexural strength decreased even lower compared with the concrete without sand replacement by CGW. A similar result was also reported by Abdallah and Fan where glass waste replacement showed an increase in flexural strength, as well as a higher percentage of replacement had adverse behaviour [37]. Specimens of mixture with 30 % of sand replacement by CGW and 25 % of water content replacement by polymer blend showed the worst results and the decrease of flexural strength was significant compared with all three remaining mixtures.

After the flexural strength test, the equipment of the universal testing machine was changed for the compressive strength equipment. Two parts of each broken specimen were tested loading them until the failure, and maximum loads were recorded.

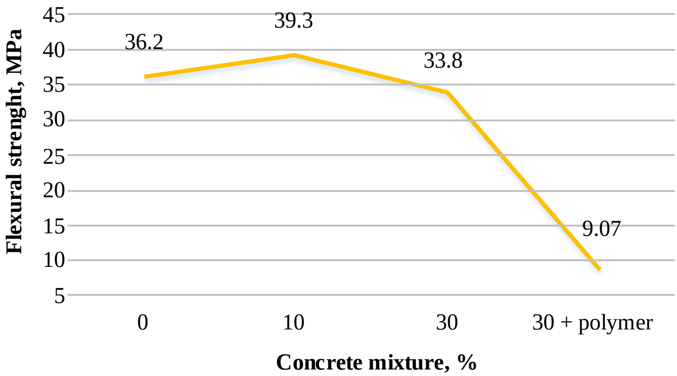

Fig. 5. Compressive strength of specimens of different concrete mixtures.

The best result of compressive strength (36.2 MPa) was obtained in specimens containing 10 % of sand replacement by CGW. When the replaced amount of sand was increased up to 30 %, the compressive strength decreased and was equal to 33.8 MPa. The worst result (9.07 MPa) was shown by specimens containing 30 % of sand replacement by CGW and 25 % of water content replacement by polymer blend.

Three specimens of each type of concrete mixture were weighed after drying them in the oven for 24 hours. After drying to constant mass, specimens were immersed in water at a temperature of 20 ± 2 ºC for a specific period of time and the increase in mass was determined. In order to determine water absorption, 5 periods of time were used: 15 min, 30 min, 60 min, 4 h and 24 h. After each period, specimens were taken out of the water, wiped lightly with a damp cloth, weighed and immediately immersed back into water. Results are presented in Table 6.

TABLE 6. DETERMINATION OF WATER ABSORPTION

No.	Mixture, %	Mass of dry specimen, g	Mass of a specimen after soaking, g				
			15 min	30 min	60 min	4 h	24 h
1	0	0.637	0.652	0.657	0.664	0.678	0.679
2	10	0.660	0.677	0.683	0.691	0.704	0.705
3	30	0.634	0.653	0.659	0.667	0.676	0.677
4	30 + polymer	0.511	0.516	0.517	0.519	0.524	0.539

Water absorption in a 24-hour-period for each concrete mixture is shown in Fig. 6.

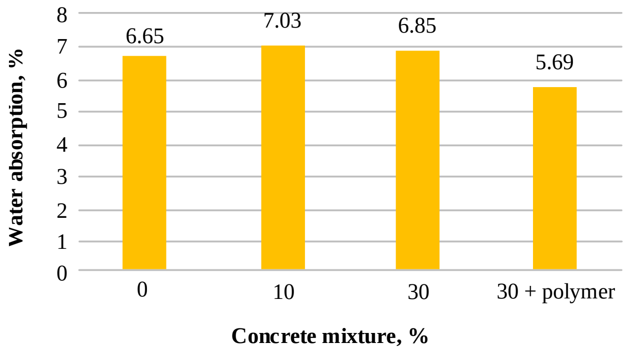

Fig. 6. Water absorption in 24-hour period.

The water absorption of hardened concrete increased when 10 % of sand was replaced by CGW. A test of specimens with 30 % of sand replacement by CGW showed that the flexural strength decreased in comparison with 10 % sand replacement, but still, the water absorption was higher compared with concrete specimens without any aggregate replacement. Despite the significant increase in water absorption during the last period of immersion (from 4 h and 24 h), the best result of water absorption is shown by specimens with 30 % of aggregate replacement by CGW and 25 % of water content replacement by polymer blend.

4. MULTICRITERIA DECISION MAKING ANALYSIS

The list of alternatives was created according to the different concrete mixtures and is shown in Table 7.

TABLE 7. ALTERNATIVES OF CONCRETE MIXTURES

No.	Alternative
1	0 % sand replacement by CGW
2	10 % sand replacement by CGW
3	30 % sand replacement by CGW
4	30 % sand replacement by CGW + synthetic polymer

List of criteria (Table 8) has been created in accordance with important properties of concrete that have been investigated experimentally in this paper.

TABLE 8. CRITERIA FOR CONCRETE QUALITY

No.	Criteria	Criteria definition	Units
1	x_1	Slump flow	Cm
2	x_2	Compressive strength	MPa
3	x_3	Flexural strength	MPa
4	x_4	Water absorption	%
5	x_5	Price	EUR/kg

The identification of weights is a non-objective evaluation because it is individual for each person influenced by personal feeling, experience and opinion. Therefore, in order to obtain more objective information, a survey of experts was created. The survey data was processed and based on the survey results, the weighting of criteria was determined. The selected weights for each criterion are shown in Table 9.

TABLE 9. WEIGHTS OF CRITERIA

No.	Criteria	Criteria definition	Units	Desired properties	Weight, %
1	x_1	Slump flow	cm	Higher is better	14.7
2	x_2	Compressive strength	MPa	Higher is better	27.3
3	x_3	Flexural strength	MPa	Higher is better	16.0
4	x_4	Water absorption	%	Smaller is better	18.0
5	x_5	Price	EUR/kg	Smaller is better	24.0

After processing the data, it is clear that two criteria have become priorities: compressive strength (27.3 %) and price (24 %).

Application of TOPSIS method was used to solve the concrete mixture selection problem, summarising the possibility of CGW use substituting the sand in concrete mixture by different amounts and adding a polymer blend.

According to the first step of the TOPSIS procedure, the decision matrix was created (Table 10). After this, the normalization of the decision matrix was performed and a normalized matrix was created (Table 11). Then, weighted normalized matrix was obtained, and the best and worst alternatives were found (Table 12). The distance between alternatives and the positive ideal solution and the distance between alternatives and the negative ideal solution were calculated (Table 13) and similarities to the positive ideal solution were expressed followed by the creation of the preference order (Table 14).

TABLE 10. DECISION MATRIX

	x_1	x_2	x_3	x_4	x_5
0 %	15	36.2	4.86	6.65	38.69
10 %	15	39.3	5.49	7.03	40.28
30 %	16	33.8	4.11	6.85	40.4
30 % + polymer	17	9.07	2.36	5.69	50.42
	max	max	max	min	min
Weights	0.15	0.27	0.16	0.18	0.24

TABLE 11. NORMALIZED MATRIX

	x_1	x_2	x_3	x_4	x_5
0 %	0.47553	0.56676	0.55667	0.50567	0.45303
10 %	0.47553	0.61529	0.62883	0.53457	0.47164
30 %	0.50723	0.52918	0.47076	0.52088	0.47305
30 % + polymer	0.53894	0.14200	0.27032	0.43268	0.59038

TABLE 12. WEIGHTED NORMALIZED MATRIX CONTAINING IDEAL AND WORST SOLUTION

	x_1	x_2	x_3	x_4	x_5
0 %	0.07133	0.15302	0.08907	0.09102	0.10873
10 %	0.07133	0.16613	0.10061	0.09622	0.11319
30 %	0.07609	0.14288	0.07532	0.09376	0.11353
30 % + polymer	0.08084	0.03834	0.04325	0.07788	0.14169
Ideal	0.08084	0.16613	0.10061	0.07788	0.10873
Worst	0.07133	0.03834	0.04325	0.09622	0.14169

TABLE 13. SEPARATION MEASURES

	d_{ib}	d_{iw}
0 %	0.02384	0.12793
10 %	0.02114	0.14294
30 %	0.03844	0.11304
30 % + polymer	0.14390	0.02066

TABLE 14. RELATIVE DISTANCES TO IDEAL SOLUTION AND PREFERENCE RANK RESULTS

	s_{iw}	Rank
0 %	0.84294	Second
10 %	0.87117	First
30 %	0.74622	Third
30 % + polymer	0.12555	Fourth

According to the relative distance to ideal solution calculation, the study demonstrates that the concrete mixture containing 10 % of CGW replacement of aggregate (sand) appears to be the choice. The relative distance to the ideal solution of concrete mixture containing 30 % of sand replacement by CGW and 25 % of water content replacement by polymer blend is significantly low (0.12555) compared with the remaining three alternatives and it is because of low compressive and flexural strength. The multicriteria analysis showed that there is no big gap between the first, second and third place in preference order, and this shows the sensitivity of results – even a small change in raw material price (natural aggregate or CGW) could influence the rearrange in results.

5. CONCLUSIONS

1. After performing the analysis of the mixed colour CGW eluate parameters, it can be stated that leaching is insignificant and it is expedient to use this waste as a secondary raw material (for example in construction industry) while reducing the use of natural resources;
2. The experiment of fresh concrete flow was performed to estimate the consistency of each mixture. Flow remains the same (15 cm) in case of control mixture and mixture containing 10 % sand replacement by glass waste. When the replaced amount of sand increases up to 30 %, the flow rate increases as well (16 cm). In case when 30 % of sand was replaced by CGW and 25 % of water was replaced by the polymer blend, the flow rate increased even more (17 cm);
3. Tests on hardened concrete flexural strength showed the best results (5.49 MPa) in mixture containing 10 % of sand replacement by CGW. The second result (4.86) was for the control specimens containing no glass waste. A test of specimens with 30 % of sand replacement by CGW showed that the flexural strength decreased even lower (4.11 MPa) compared with the concrete without sand replacement. Specimens of mixture with 30 % of sand replacement by CGW and 25 % of water content replacement by polymer blend showed the worst results (2.36) and the decrease of flexural strength was significant in comparison with all three remaining mixtures;
4. The best result of compressive strength (39.3 MPa) was obtained in specimens containing 10 % of sand replacement by CGW. The second result (36.2 MPa) was for the control specimens. When the replaced amount of sand was increased up to 30 %, the compressive strength decreased (33.8 MPa). The worst result (9.07 MPa) was shown by specimens containing 30 % of sand replacement by CGW and 25 % of water content replacement by polymer blend;
5. The water absorption of hardened concrete increased when 10 % of sand was replaced by CGW (7.03 %) compared with the control specimens (6.65 %). Test of specimens with 30 % of sand replacement by CGW showed that the flexural strength decreased (6.85 %) in comparison with 10 % sand replacement, but still, the water absorption was higher compared with concrete specimens without any aggregate replacement. The best result of water absorption (5.69 %) is shown by specimens with 30 % of aggregate replacement by CGW and 25 % of water content replacement by polymer blend;
6. In this paper, the multicriteria decision-making based on TOPSIS method is applied to solve the problem of decision on CGW use in concrete tiles production, where four alternatives were compared in accordance to five criteria. Weights of criteria were calculated in accordance to the survey of experts;
7. The results of the analysis show, that the first ranking among the different concrete mixtures based on the mechanical and economic properties belong to the concrete

mixture with 10 % of sand replacement by CGW, second mixture contains no sand replacement, third mixture is containing 30 % of sand replacement by CGW, and fourth mixture is the one that contains 30 % sand replacement by CGW and 25 % water content replacement by polymer blend;

8. Result sensitivity was found – while there is no big gap between first, second and third preference ranks, even a small change in raw materials price (sand or CGW) could lead to rearrange in results;
9. We conclude this study by stating that the results met our expectations. The application of waste glass in concrete is the promising direction for waste glass recycling and the study indicates that TOPSIS can be used as a decision-making model for making the most effective mixture selection choice.

Acknowledgement

This research is funded by the Ministry of Economics of the Republic of Latvia, project "Assessment and analysis of energy efficiency policy", project No. VPP-EM-EE-2018/1-0004.

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