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Waste Additives In The Production Of Building Materials: A Review Of The Academic Studies Conducted In Turkey

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ABSTRACT

Industrial production is increasing rapidly in parallel with such factors as increased population and consumption and advances in technology while energy resources are dwindling and the amount of waste is increasing. In this process, making use of waste, which is the main cause of environmental pollution, has become one of the important and priority issues. Furthermore, construction activities, which play an important part in countries' economies, have led to an increase in the production of construction materials. Every new production means more consumption of energy resources and raw materials. This, on the one hand, leads to a reduction of the limited natural resources and on the other hand increases building production costs. Yet, many kinds of waste materials in the world can be used in the production of building materials, and the idea of sustainable architecture makes this a necessity. In this context, the aim of this study is to examine and review the academic research done in Turkey looking into the use of waste products in the production of construction materials, and to present the results as a guide for the producers and consumers of construction materials. Within the scope of this study a scan was made for the keyword "waste" on the "Google Akademik" and "Dergipark" databases, and the 56 scientific papers that were obtained were examined and reviewed in the context of the research questions that had been generated. According to the results of the research, the waste products of different sectors can be used either directly or with processing in the production of various building materials and parts such as cement, bricks, tiles, cement pipes, briquette and aerated concrete. Various recycling alternatives can be used in transforming waste products into construction materials. Adding certain waste products to construction materials can have a positive effect on that material's properties. Waste products should be seen as having economic value. The use of waste products in building material production can reduce environmental pollution, energy use and building production costs.

Keywords: Building Material, Waste, Sustainability, Recycle, Turkey

INTRODUCTION

Industrial production is increasing due to factors such as the increase of population and consumption, and the development of technology. Increasing industrial production reduces our energy resources and increases the amount of waste. Recycling of waste has a great importance in the fight against environmental pollution. Construction material production is increasing with the mobilization of construction sector which is one of the leading sectors in the country's economy. Each new production causes more raw materials to be consumed. With the increase of raw material usage, our natural resources are reduced and production costs are increasing. By contrast, the use of resources can be reduced by using waste from different sectors in the production of building materials. This is required by the sustainable architecture.

Re-utilization of waste takes place in the form of recycling, recovery, reuse. The purpose of the re-utilization of waste is to minimize waste production, to protect natural resources and to contribute to the economy by using secondary materials. While recycling is a process in which waste is used as a raw material and converted into a new material, recovery is defined as the recycling of a new product through processing (Gurer et al. 2014). The use of wastes without treatment means reuse. With all these methods, the re-utilization of waste will solve the environmental problems and contribute to the economy of the country (Murathan et al. 2013).

In this study, academic researches related to the re-utilization of the waste of different sectors have been analyzed in terms of content. The aim is the investigation and evaluation of academic research done on the use of waste materials in the production of building materials, in Turkey, and to elucidate the results that will guide the producers and the consumers. In the study, "Google Academic" and "Dergipark" databases were scanned with the keyword "waste" and the available scientific publications were examined, evaluated, and the resulting findings in the context of the created research questions were presented.

MATERIAL AND METHODS

The method used in the research was applied in four stages. In the first step, as the result of the literature review with the "waste" keyword at the "Google Academic" and "Dergipark" databases, the scientific publications that were to be reviewed and evaluated have been reached. In the second stage, 56 publications were analyzed and classified in terms of type of publication, publication year, number of authors, faculty and division, data collection method, analysis method, national and international resource usage. In the third stage, content analysis has been conducted and the answers to the following questions have been searched:

- What are the types of waste material and discussed this waste belongs to which sector?
- How many tons of waste can be acquired per year?
- Are the wastes being treated before joining the building material content?
- Are recycling methods applied to the wastes to be used in building material production? If so, what recycling methods should be used?
- Are the wastes added as raw materials in the building material content? If so, in the content of which building material these wastes added?
- Does the waste change the properties of newly produced building materials? If so, to which direction?

In the last stage, the findings were interpreted with the help of charts and graphs.

RESULTS AND DISCUSSION

When the types of publications covered in the research are examined, it is seen that 80% is published as an article and 20% as a paper (Figure 1).

Figure 1. Publication Distribution by Publication Type

It is seen that 60% of the 56 publications covered in the research are written between 2010-2017 and 40% between 2001-2010 (Figure 2). The increase in the number of publications in recent years indicates that there is a growing scientific awareness on the importance of the issue.

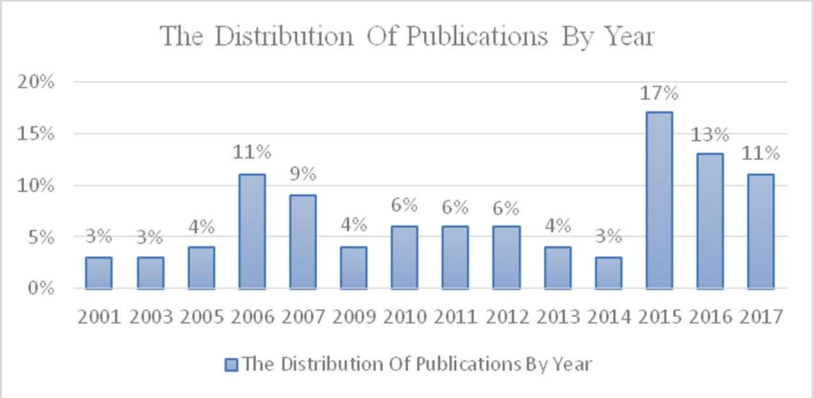

Figure 2. The Distribution Of Publications By Year

When the distributions of the publications covered by the research are examined by the number of authors, it can be seen that 43% of the publications are written by two authors, 27% by three authors, 18% by one author, 5% by four authors, 5% by five authors and 2% by six authors (Figure 3).It is observed that the largest number of publications related to the subject are authored by two people, and in general multi-authored publications are dominant. This indicates the importance of team work in producing research and publications related to the subject.

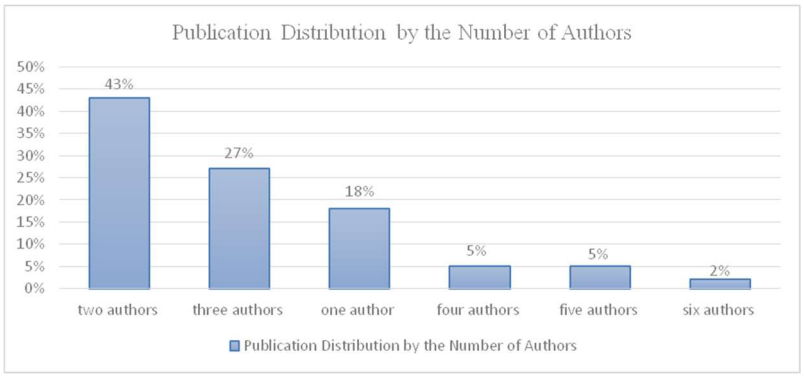

Figure 3. Publication Distribution by the Number of Authors

When the universities to which the authors of the publications covered in the research are affiliated are examined; it is seen that the studies are authored by the members of the following universities, respectively; 13% of KahramanmarasSütçü İmam University, 12% of AfyonKocatepe University, 12% of Gazi University, 8% of Fırat University, 7% of SüleymanDemirel University, 6% of Atatürk University, 4% of DokuzEylül University, 4% of Tunceli (Munzur) University, 4 of ZonguldakKaraelmas University (BulentEcevit University), 3% of Gaziosmanpaşa University, 3% of Kirklareli University, 2% of AbantİzzetBaysal University, 2% of Gebze Technical University, 2% of Hitit University, 1% of Adıyaman University, 1% of Aksaray University, 1% of ArtvinCoruh University, 1% of Balikesir University, 1% of Batman University, 1% Bozok University, 1% of ManisaCelal Bayar University, 1% of Cumhuriyet University, 1% of Düzce University, 1% of EskişehirOsmangazi University, 1% of Istanbul Technical University, 1% of Istanbul University, 1% MuğlaSıtkıKoçman University, 1% of NiğdeÖmerHalisdemir (Niğde) University, 1% of Selçuk University, 1% of Trakya University, 1% of International University of Cyprus (Figure 4).

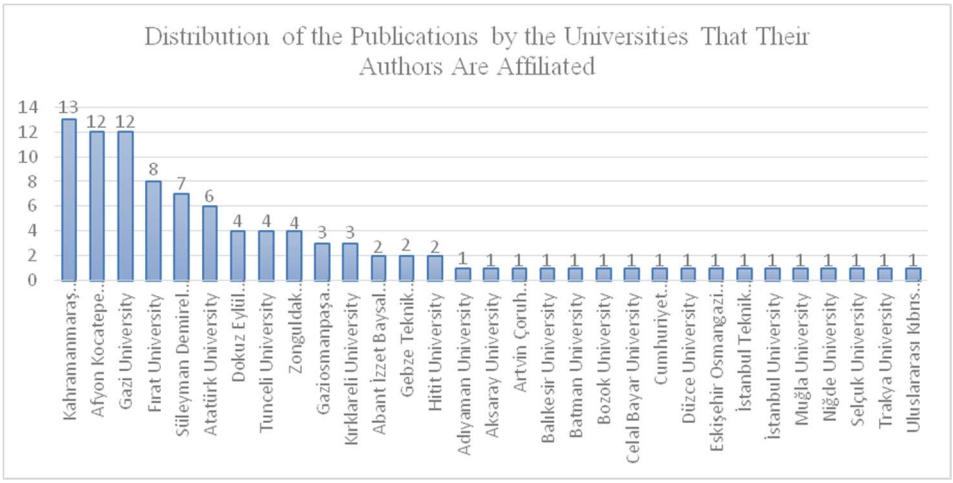

Figure4. Distribution of the Publications by the Universities That Their Authors Are Affiliated

In 11% of the publications covered in the research, the affiliated faculty information of the authors was not reached. Among the authors with faculty information available, it can be seen that 27% of these authors are working at Engineering Faculty, 18% at Technical Education Faculty, 12% at Vocational High School, 11% at Technology Faculty, 9% at Faculty of

Architecture and Engineering, 9% at Faculty of Agriculture, 3% at Faculty of Arts and Sciences, 3% at Faculty of Science and Literature, 3% at Faculty of Economics and Administrative Sciences and 1% at Faculty of Forestry (Figure 5).

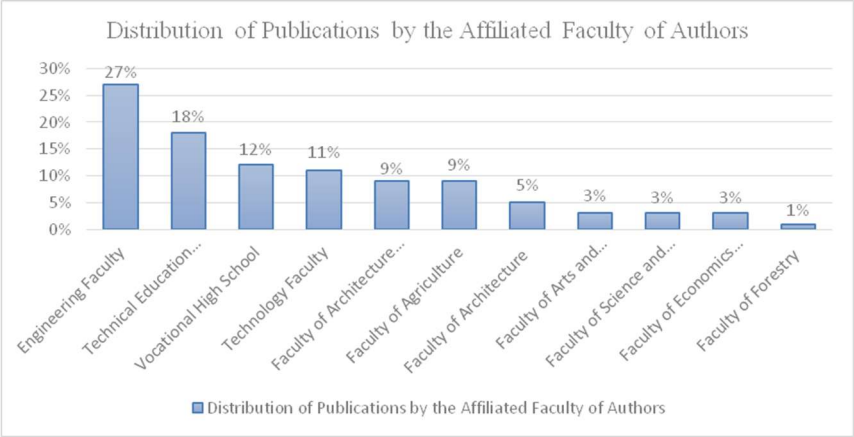

Figure 5. Distribution of Publications by the Affiliated Faculty of Authors

In the 16% of the publications covered in the research, the information of the department to which the authors are affiliated, cannot be reached. It is seen that a significant majority of the publications reached to the information are produced in the Department of Civil Engineering. In addition, departments such as Mining Engineering Department, Building Training Department, Architecture Department, Chemical Engineering Department and Agricultural Structures and Irrigation Department are noticed among the departments where these studies are conducted (Figure 6).

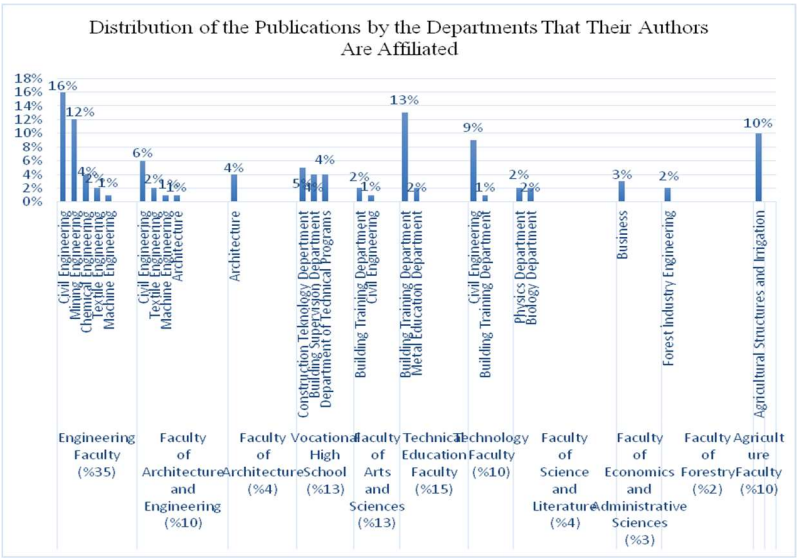

Figure 6. Distribution of the Publications by the Departments That Their Authors Are Affiliated

When the publications covered in the research were examined, it was seen that 82% of the publications employed the experiment method, 16% the literature survey method and 2% the interview method (Figure 7).

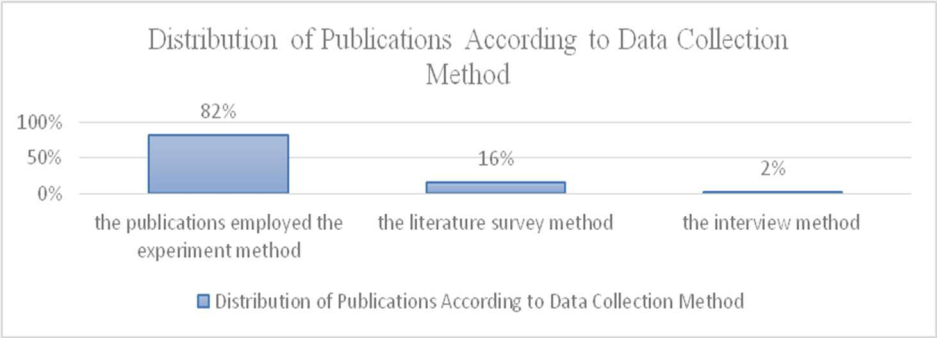

Figure 7. Distribution of Publications According to Data Collection Method

When the analysis method of the publications covered in the research is examined, it is observed that 78% used quantitative analysis, 18% is qualitative analysis and 4% used both qualitative and quantitative analysis (Figure 8).

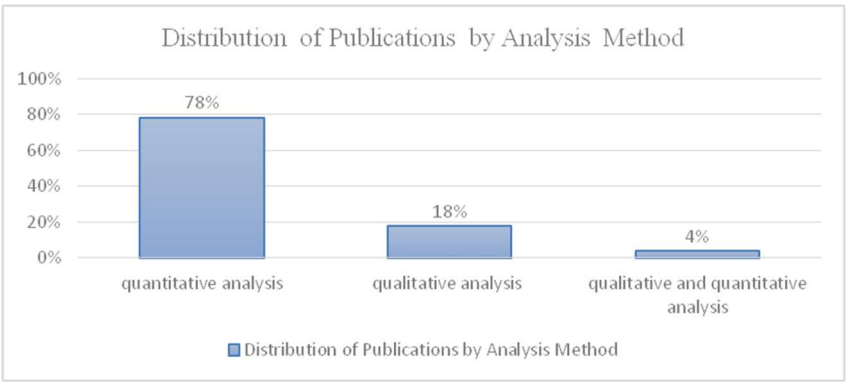

Figure 1. Distribution of Publications by Analysis Method

When the use of resources is examined in the publications covered in the research, it is seen that 57% of the total number of resources used in publications is national and 43% is international sources (Figure 9).

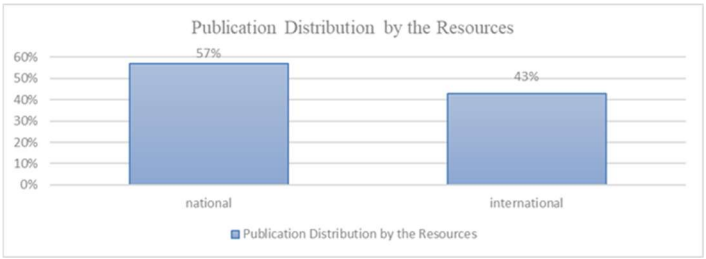

Figure 9. Publication Distribution by the Resources

It is seen that the wastes proposed to be used in the production of building materials in the publications covered in the research are very diverse. According to the results obtained from the examination of publications;

- Among the energy sector waste; fly ash, silica fume, bottom ash, lignite coal,
- Paper and paper products sector waste; waste paper, waste paperboard, vegetable waste,

- Among industrial wastes based on stone and soil; pumice, perlite, gypsum, glass, marble powder, stone powder, concrete,
- Among mining sector waste; vermiculite, zeolite, barite, phosphogypsum,
- Among the textile sector waste; waste cloth, waste wool, waste cotton,
- Chemical, petroleum, rubber and plastic industry waste; waste rubber and waste PVC,
- Among the metal industry wastes; blast furnace slag, has an important place.

In addition, industrial wastes such as industrial oils, and household wastes, such as plastic bottles, are other wastes that stand out in use in the production of building materials.

According to the literature, lignite coal waste is estimated to be 600 million tonnes per year worldwide, while structural waste makes 180 million across Europe. In Turkey, 13 million tons of lignite coal waste, 13 million tons of fly ash, 249.409 tons of textile waste, 100,000 tons of marble powder and 10 thousand tons of plastic waste are produced annually (AydinIpekci et al., 2017; Alyamaç and İnce 2007; Binici, 2016, Kozak, 2010, Yüksek and Kaya, 2017).

Within the scope of the research, it was identified that the wastes were treated before joining the building material content. According to waste type;

- Dimensional analysis for Fly ash,
- For paint waste, waste rubber and agricultural wastes; collecting, crushing, crushing, grinding, separating,
- For marble dust; drying in oven, crushing, sieving,
- For waste newspaper paper; pulping and drying,
- For waste fabric; hand lay-up,
- For phosphogypsum; drying and sieving,
- For bottom ash; sieving,
- for clay pulp and plastic bottle shards; sieving and grinding,
- for blast furnace slag; crushing and sieving,
- for phosphogypsum; cooking
- for Waste concrete; grain size analysis
- For glass dust; recycling methods such as grinding must be used.

Within the scope of the research, it has been determined that wastes can be added as raw materials in building materials. According to the data obtained from the publications covered in the research, waste can be used as raw material in many building materials such as brick, concrete, cement, fireproofing material, mud brick, briquette, composite material, chipboard, plaster mortar. Accordingly:

- Thermal power plant waste fly ash can be used in clay bricks, cobs, concrete, cement and composite material production,
- Industrial wastes can be used in concrete, insulation material and in cement production,
- Boron waste can be used in concrete production,
- Marble dust can be used in concrete production,
- Phosphogypsum can be used in cob production,
- Phosphogypsum can be used in cement and clinker production,
- Plastic wastes can be used in plaster mortar,
- Waste concrete can be used in the production of the thermal insulation materials.

If wastes are added to building materials in production, it can be seen that standards related to building materials have values close to the required values or that meet the mentioned standards.The use of fly ash as a thermal power plant in the construction of bricks can prevent the whitening (chalky surface) caused by the lime vomiting that occurs in the bricks (Kızgut et al., 2001). With waste cardboard, plaster, pumice, perlite, vermiculite and zeolite, higher fire resistance in the new material produced can be ensured (Binici, 2016). Heat insulation, sound insulation and bending strength values are increasing in building materials produced with cotton waste, fly ash and barite (Binici et al., 2012). By adding paint waste, waste rubber and agricultural wastes to concrete, strength properties of concrete, pressure and bending strengths are increasing (Gönen et al., 2012). The lignite coal waste has a positive contribution to the lightness of the bricks (Yüksek and Kaya, 2017). The use of waste newspaper paper in the production of insulation material increases the heat, sound and fire resistance of the material produced (Binici et al., 2015). The mechanical strength of cement increases with the use of boron waste in cement production (Demirel and Nasiroğlu, 2017). Cohesion and compressive strength of concrete increases with the use of marble dust in concrete (Gülan et al., 2016). The use of plastic bottle wastes in plastering reduces the number of cracks in the plaster and the thermal conductivity value (Memiş and Örüng, 2012). the heat insulation values of concrete increase and the amount of water absorption decreases, when PVC waste is used in concrete production (Şahin et al., 2007). If Phosphogypsum is used in the production of cement and clinker it is possible to produce high strength and fast setting materials (Demirel and Çağlar, 2015).

Some negative effects can also be caused by the use of wastes in building materials. When stone powder obtained from Ahlat stone is used in the production of concrete, the pressure and bending strength of the concrete decreases (Erdal and Şimşek, 2011). With the use of phosphogypsum in cobs, the water resistance of cobs decreases (Değirmenci, 2005). The use of bottom ash in the production of briquettes increases the void ratio and decreases the compressive strength (Yüksel and Kaya, 2006) The blend of blast furnace slag and fly ash reduces the workability of the cement produced (Topçu and Karakurt, 2007). When plastic bottle wastes are employed in the production of plastering; compressive strength, bending strength, unit and specific weight of the material and freeze-thaw durability rates of the plaster decrease, while the water absorption rate of the plaster increases (Memiş and Örüng, 2012). In concrete production, when waste concrete is used as aggregate, water absorption rate of the concrete increases (Demirel and Çağlar, 2015).

CONCLUSION

According to the results of the research, it is observed that the articles and the reports have begun being published after 2000 and an increase can be seen in recent years in number and variety of publications. The recent increase in publications has contributed to the development of environmental awareness in the construction sector. For this reason, existing studies should be taken further and researches for the use of different wastes in the production of different materials should be increased.

It is seen that a significant part of the publications examined within the scope of the research are authored by multiple authors. Civil Engineering, Mining Engineering, Architecture, Chemical Engineering, Agricultural Structures and Irrigation fields have been determined as the scientific fields that are standing out in the researches. However, it seems that the subject is not usually studied with interdisciplinary teams, and the teams formed by a large number of authors who specialize in a particular field are noteworthy. On the other hand, the nature of

the subject requires interdisciplinary work. Interdisciplinary studies on the subject should be made.

Within the scope of the research, it has been seen that the waste of different sectors can be used by being recycled in the production of building materials and parts such as cement, brick, concrete, concrete pipes and briquette. On the other hand, positive and negative changes in the properties of building materials come into play due to the use of wastes as raw materials after passing being treated by physical and chemical processes. It is important to carry out new research to solve the adverse effects.

It was also observed that new building materials could be produced by combining various wastes within the scope of the research. Obtaining a new insulation material by compressing waste newspapers is an important example of this. Heat and sound permeability coefficient of the produced material shows that it can be used as insulation material. It should also be possible to increase the efforts to assess the potential of various wastes in this sense.

In conclusion, obtaining building materials from recycled wastes will contribute to the reduction of natural resources and energy consumption, as well as reducing the production of building materials, and also to the prevention of environmental pollution. In addition, due to the use of waste, the cost of production of building materials can also be reduced. In the construction sector, where significant amounts of raw materials are needed all over the world, waste can be re-utilized and economic benefits can be achieved while environmentally friendly building materials that can meet the expected performance can also be produced. In this sense, it is necessary to increase the number of interdisciplinary studies and disseminate the applications.

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