Usage of Alternative, Environmentally Acceptable Materials – Experience from Eastern Croatia

I Barišić¹, M Zagvozda¹,² and S Dimter¹
¹Faculty of Civil Engineering, Drinska 16a, 31000 Osijek, Croatia
²To whom any correspondence should be addressed.

Abstract. The concept of sustainability should be the main guiding principle in the construction industry today. It mandates conservation of natural resources and thus lower impact on the environment. In road construction, part of construction industry that consumes largest quantities of natural materials, sustainable building and maintenance of roads is possible trough application of secondary materials. Usage of industrial and construction waste presents energy, ecologically and financially effective alternative. Republic of Croatia, even as a new member of the European Union, still lags behind the well-established practices of the application of alternative materials in different European countries. The reasons for this can be found in the current legal and technical regulations for alternative materials. In this paper, the existing regulations for alternative materials and the impact they have on the application of these materials in practice in the region of eastern Croatia will be shown.

1. Introduction
The concepts of sustainability should be the norm in all aspects of human development today. In construction industry, this mandates conservation of natural resources and lower impact on the environment. Application of secondary “alternative materials” in road construction as one of the biggest exploiters of natural materials presents a more rational, economically and ecologically suitable solution. The term ‘alternative material’ covers all materials except natural virgin materials, and usually refers to construction and demolition waste and a variety of industrial by-products. In the countries of the European Union a wide range of such materials is widely used as a substitute for standard building materials for a number of years. For these materials to be applicable, they should meet certain criteria, show a satisfactory level of performance and be cost-effective when compared to traditional materials. As EU Waste Framework dictates the aim for 70% of all construction waste to be recycled, re-used or otherwise recovered by 2020 [1], many universities, institutes and government organizations have been involved in research and development of secondary or recycled materials. The
European Commission supported two such projects, ALT-MAT and COURAGE [2], which gave insight into the application of these materials and helped in creating the legal framework.

In Croatia, traditionally used natural materials still present the largest share of materials used in road construction. As a large proportion of the planned road network has been built, the amount of reconstruction and maintenance works is increasing rather than the construction of new roads. Therefore, recycling of existing pavement courses and construction waste should be a prevailing solution. According to Sherwood [3], encouragement towards application of alternative materials should be done through development of the new or supplement of the old standards and technical requirements, development of guidelines that should inform about the possibilities of application of those materials, various administrative measures (such as taxes on natural materials or waste disposal), as well as using domestic and foreign examples to educate and change attitude towards alternative materials.

In this paper, the current state of regulation concerning alternative materials in road construction is shown along with the research that has been done and the discussion of the state of application in road building practice of eastern Croatia.

2. Legal framework

The first step towards systematic waste management, reduction of waste amounts and the number of landfills, with the aim of protecting the environment and natural resources, which also implies application of alternative materials, was done by passing Waste Management Strategy for the Republic of Croatia [4]. It establishes a concept without landfills, which encompasses avoiding the generation of waste, reduction of waste amounts and waste recycling. In order to implement the Strategy, a legal framework is necessary that deals with creation and recycling of waste as well as technical regulations for the application of such recycled materials in construction projects.

Construction waste is defined by the Regulations on construction waste management [5] as waste generated during the construction, reconstruction, removal and maintenance of existing buildings, and waste generated from excavation material, which cannot be used for construction without prior recycling. It was common practice for this construction waste to be disposed of in landfills, but the Waste Management Plan [6] defines that those materials that can be reused have to be separated and sorted from such waste. The emphasis on recycling is specially given for the waste from road construction, such as crushed asphalt or concrete, as it is necessary to take it into asphalt mixing plants to be recycled. Waste Act [7] allows contractors to reuse their own waste as building materials on the building sites where it was generated, but only if it complies with the Technical regulations on construction products [8] and the given norms.

General technical requirements for road works [9] that have been in use since 2001 define the conditions for works in road construction and provide the requirements for materials. According to these requirements, the contractors can apply alternative materials if they:

a) possess the same quality or properties;
b) are of similar quality and properties in accordance with the recognized technical rules (norms);
c) meet the essential requirements for buildings according to Construction Act.
### Table 1. Possibilities of application of recycled asphalt aggregate [10].

| Recycled asphalt aggregate origin | Application of recycled asphalt aggregate in asphalt courses |
|----------------------------------|----------------------------------------------------------|
|                                  | Wearing course | Binder course | Base course | Base-wearing course | Poured asphalt |
| Wearing course                   | Yes            | Yes           | Yes         | Yes               | No             |
| Wearing + binder                 | No             | Yes           | Yes         | Yes               | No             |
| Binder course                    | No             | Yes           | Yes         | Yes               | No             |
| Base course                      | No             | No            | Yes         | No                | No             |
| Base-wearing course              | No             | No            | No          | Yes               | No             |
| Poured asphalt                   | No             | No            | No          | No                | Yes            |

General technical requirements do not give the possibility of application of recycled asphalt aggregate in production of new asphalt mixture, so for research purposes regulations for conventional materials had to be used. Therefore, from 2010 to 2012 new technical regulations for asphalt pavement layers [10] were being developed. Recycled asphalt aggregate, that is a product of milling of asphalt courses or crushing of asphalt slabs, is now allowed to be used as part of different bituminous mixes prepared by both hot and cold methods. Table 1 shows possibilities of application of recycled asphalt aggregate in different layers of pavement depending on their origin.

New regulations also define requirements for recycled asphalt aggregate to be used in new asphalt mixtures in terms of grading, proportion of bitumen and softening point of bitumen separated from the recycled aggregate. Before application, recycled aggregate has to go through testing defined by norms: sampling to assess homogeneity (HRN EN 932-1), bitumen extraction (HRN EN 12697-3 or HRN EN 12697-4), determination of bitumen softening point (HRN EN 1427), proportion of bitumen in reclaimed asphalt aggregate (HRN EN 12697-1), granulation of recycled asphalt aggregates (HRN EN 12697-2).

Beyond recycled asphalt aggregate, the possibility of application of fly ash from coal combustion as a filler and different types of slag (steelmaking, other metals) as an aggregate is mentioned for bituminous mixtures.

### 3. Research into application of local alternative materials for road construction

Research on the application of alternative materials in Eastern Croatia is mostly related to Faculty of Civil Engineering Osijek, independently or in collaboration with few companies that are aware of benefits of such materials and want to improve their technology. A short overview of local research into the application of alternative materials for road construction is presented below.

#### 3.1. Unbound aggregate base

The first instance of construction waste application in Croatia was done for unbound base courses in 2004 in Zagreb area [11]. Construction waste that was created in the course of demolition of existing buildings was crushed, sorted, sieved and then applied as unbound aggregate for transportation areas at the same location. Testing of compressibility modulus proved that this material is a sufficient substitute for natural aggregate both as a surface layer in construction stages and as a subgrade layer of the finished pavement.
3.2. Cement stabilized aggregate base

Research on cement stabilized base was done using alternative materials either as an aggregate or a binder. First research was done in 1996 with fly ash from the thermal power plant nearby Hungarian town Pecs. The research showed that cement stabilized mixture made with Drava River sand and 7% of binder complies with Croatian regulations when maximally 25% of the cement is replaced with fly ash [12].

Researches of cement stabilized base with slag aggregate were done in order to define the optimum composition of the mixes that give great economical and resource savings [13] and to examine the suitability of 100% slag aggregate for base courses of pavement for heavy traffic [12]. First research showed that increase in slag content gives higher strength in mixes with low cement content and that mixes with 2 and 4% of cement fulfill strength class criterion, respectively. Second research confirmed that slag can be used for base courses of pavements for heavy traffic loads even though it requires more binder and water and develops lower compressive strength.

3.3. Asphalt courses

Research into application of alternative materials in asphalt layers in eastern Croatia is mostly done with recycled asphalt aggregate. Application was tested for asphalt base courses as partial replacement of both crushed stone aggregate and bitumen, as well as for the wearing course [14]. The first research justified application of 20, 25 and 30% of recycled aggregate from an economic and environmental point of view. While for the second solution a trial production with 10, 15 and 20% of recycled asphalt was carried out and trial road section was constructed to see the behavior of this mixes under traffic load and environment over time.

The use of recycled asphalt aggregate to a greater extent occurred during the Second program of reconstruction of national roads (Betterment II) [12]. Within this program, road sections were reconstructed with cold recycling methods by using cement, “geocrete” (commercial name for a special hydraulic binder) and water or foamed bitumen, cement and water as binders. Application of the second method served also for testing the technology and for defining the technical regulations.

4. Alternative materials in road building practice

During the CONWAS project [15], it was concluded that 80% of construction waste can be recycled and reused, but it was estimated that in 2006 only 7% of construction waste was recycled [4]. Through implementation of different regulations on waste management in the recent years both percentage of reported construction waste and the amount it has been recycled has risen (table 2). As it can be seen, in 2013 almost 72% of the reported construction waste was recycled [16]. Even though there is a positive trend, this is still a small amount considering the estimation that 2.3 million tones of construction waste is produced per year in the period from 2006 to 2015 [6].

| Year  | 2010   | 2011   | 2012   | 2013   |
|-------|--------|--------|--------|--------|
| Reported construction waste [t] | 220,911.16 | 186,960.98 | 317,310.84 | 374,407.36 |
| Recycled construction waste [t] | 67,237.43 | 46,848.23 | 115,477.98 | 269,427.67 |

That state of the application of recycled materials in road building practice is still poor; it testifies the fact that according to EAPA [17] in 2012 only 2% of production of new hot and warm asphalt
mixes contained reclaimed materials. On top of that just 6 out of 55 asphalt plants in Croatia were fit for hot recycling.

Actual state in the application of alternative materials in road construction practice of eastern Croatia and reasons influencing such state were examined by a questionnaire survey. The survey was distributed to construction companies, which deal with road design, construction and maintenance [18]. It comprised 10 questions related to the experience in the application of alternative materials, reasons for usage of such materials and knowledge of technical regulations on this subject. In total 12 companies responded to the survey, 50% companies in the sample were engaged in construction, 22% in design and 28% in maintenance works.

When asked about the usage of alternative materials in their practice, 50% responded affirmatively, 33% do not use alternative materials and 17% of companies are still in research phases of possible application (figure 1). But the percentage of application of alternative materials in overall activity is quite low, because in almost 70% of companies alternative materials comprise up to only 15% of production (figure 2.). Other 23% of respondents that apply more than 15% of alternative materials in their work are in research only fields or that application is the usage of quarry waste in embankment/base layers.

Out of possible materials to be used in road construction, the respondents mentioned quarry by-products and by-products of aggregate dust collection in asphalt plants, crushed concrete and brick as well as recycled asphalt as the ones they do apply in their practice.

Figure 1. Application of alternative materials.

Figure 2. Representation of alternative materials in the overall production.
For a number of possible alternative materials, the respondents were asked to assess the possibility of whether those types of materials could be used in their field as is, whether more research should be done or whether their application is not possible. As is shown in figure 3, the greatest potential among all the materials already mentioned as being used is ascribed to different types of slag, construction waste and mullock, whereas shingles, plastics and sewage sludge ash do not have potential to be used or application is still in research stages.

Recycled asphalt is one of the most commonly used alternative materials in road construction that can be used as a wearing course, as aggregate in base and sub-base layers or as material for embankments. The survey showed that all of the respondents are familiar with different methods of asphalt recycling and 75% of them apply some method in their work (figure 4.).

**Figure 3.** Potential of application of different alternative materials.

| Material                                      | Yes | No | Still in research stages |
|-----------------------------------------------|-----|----|--------------------------|
| Plastic                                       |     |    |                          |
| Glass and china clay waste                    |     |    |                          |
| Sewage sludge ash                             |     |    |                          |
| Waste tires                                   |     |    |                          |
| Roofing shingles                              |     |    |                          |
| Quarry by-product                             |     |    |                          |
| Municipal waste incinerator ash               |     |    |                          |
| Mullock                                       |     |    |                          |
| Foundry sand                                  |     |    |                          |
| Silica fume                                   |     |    |                          |
| Cement and limestone ash                      |     |    |                          |
| Blast-furnace, steel nad non-ferrous slag     |     |    |                          |
| Powerplant ash and slag                       |     |    |                          |
| Construction waste                            |     |    |                          |
| Crushed concrete                              |     |    |                          |
| Recycled road pavement materials              |     |    |                          |
| Asphalt plant aggregate deducting             |     |    |                          |
The biggest incentive for the usage of alternative materials can be found in ecological reasons and cost of these materials versus the cost of natural materials as the survey has shown (figure 5.). Respondents do not have good opinion with regard to the current state of law and regulations when application of alternative materials is concerned: only 38% are both familiar with the regulations and think it is sufficient for the field they are in, and the rest either are not familiar or do not think it is adequate.

When their own construction waste is concerned, even though it is allowed to reuse it as recycled material, only 27% do recycle, while others dispose their waste.
5. Conclusion
Even though Croatia recently became a member of the European Union, practice of application of more sustainable and ecological secondary materials still lags behind the well-established European practices. Some steps towards the improvement were made by adopting the Waste management strategy and its implementation. More construction waste is being reported and recycled every year and research is being done to support application of this materials. Research on recycled asphalt aggregate and its common application in other countries resulted in passing new technical regulations for asphalt courses. Such example of combining knowledge from alternative material research with experience from practice in other countries should be continued, since the main problem of application is presented in the lack of technical regulations, norms and criteria. The survey has shown that getting rid of that barrier should yield greater application of alternative materials as all respondents find them to be a better ecological solution and a possibility for financial savings.

6. References
[1] Directive 2008/98/EC on waste (Waste Framework Directive) [Available]: http://ec.europa.eu/environment/waste/framework/
[2] European Commissio 1999 COURAGE, Final report
[3] Sherwood P 2003 Alternative Materials in Road Construction, A Guide to the Use of Recycled and Secondary Aggregates Second edition (London: Thomas Telford Publishing)
[4] Waste Management Strategy for Republic of Croatia Official Gazette 130/05
[5] Regulations on construction waste management Official Gazette 38/08
[6] National Waste Management Implementation Plan for 2007-2015 Official Gazette 85/07, 126/10, 31/11
[7] Waste Act, Official Gazette 178/04, 153/05, 111/06, 60/08, 87/09
[8] Technical regulation on construction products Official Gazette 33/10, 87/10, 146/10, 81/11, 130/12, 81/13, 136/14
[9] IGH 2001 General Technical Conditions for Road Works, Book I: General Terms and Preparation Works (Zagreb: Hrvatske ceste)
[10] Rázrada Tehničkih Svojstava i Zahtjeva za Građevne Proizvode za Proizvodnju Asfaltnih Mješavina i za Asfaltne Slojeve Kolnika 2012 (Zagreb: Hrvatske ceste)
[11] Sanić A and Dimter S 2010 Application of recycled aggregates in pavement base courses Proc. of 1st Int. Conf. on Road and Rail Infrastructure CETRA2010 ed Lakušić S pp 291–297
[12] Dimter S, Netinger I and Barišić I 2012 Hrvatska iskustva u primjeni recikliranih materijala u cestogradnji Sabor Hrvatskih Graditelja 2012 Cavtat
[13] Barišić I, Dimter S and Rukavina T 2014 Strenght properties of steel slag stabilized mixes Composites: Part B 58 pp 386–391
[14] Dimter S and Androjić I 2014 Primjena recikliranog asfalta u proizvodnji asfaltnih mješavina Dani Prometnica 2014-EU Fondovi i Projekti Prometne Infrastrukture ed S Lakušić
[15] Primjena recikliranog agregata iz građevnog otpada [Available]: www.igh.hr/CONWAS/www/Primjena HR.pdf
[16] Agencija za zaštitu okoliša 2010, 2011, 2012, 2013 Izvješće o Podacima iz Registra o Onečišćavanja Okoliša
[17] EAPA 2012, 2013 Asphalt inFigures
[18] Zagvozda M, Dimter S and Dolaček-Alduk Z 2012 Alternativni materijali – novi trend i izazov u graditeljstvu Sabor Hrvatskih Graditelja 2012 Cavtat