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Improving the strength properties of recycled asphalt aggregate concrete

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HIGHLIGHTS

- Increase in recycled asphalt replacement results in further reduction in strength.
- Lower ultrasonic pulse velocity is obtained by the use of recycled asphalt aggregate.
- Rebound number decreases with the percentage increase in recycled asphalt aggregate.
- Roughening the aggregate prior to mixing increases the strength of recycled asphalt aggregate concrete.
- Roughening up to 2 h can have a small influence of increasing the ultrasonic pulse velocity.

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ABSTRACT

The querying of aggregate, for use in the manufacture of concrete, can have adverse environmental and ecological effects. The replacement of gravel aggregate with recycled (reclaimed) asphalt would help in the reduction of these effects. It can also help in reducing the quantity of recycled asphalt obtained from road re-surfacing that would otherwise be disposed off in landfill sites. The applications of concrete containing recycled asphalt have been very limited due to its low strength. This study investigates the feasibility of improving the strength of recycled asphalt concretes. This would increase the potential for using this type of concrete as an alternative to normal concrete, especially where medium strengths might be required. Concrete strength improvements would be achieved by changing the surface characteristics of recycled asphalt aggregate. This has been sought by using two methods; mechanical roughening and chemical solvent etching. It has been possible to improve the strength of concrete containing recycled asphalt to values similar to that of normal (gravel) concrete, by applying the mechanical roughening technique. Chemical etching has no effect on strength improvement of the concrete. The concretes have also been tested using non-destructive methods in the form of ultrasonic pulse velocity and rebound number. The effects of replacing gravel with different percentages of recycled asphalt on the strength, pulse velocity, and surface hardness of concrete are considered initially. The inclusion of recycled asphalt at 25% has resulted in the reduction of strength. The strength decreases further with an increase in the percentage (up to 100%) of recycled asphalt. All investigations were performed on early age concrete (1–28 days).

1. Introduction

Concrete is still one of the most popular and widely used materials in the construction industry, due to its high strength and versatility. It is made from a mixture of aggregate (normally sand and gravel), water and cement, with increasingly some cementitious or chemical admixtures. The demand for concrete puts pressure on the resources of the naturally available materials that go into its manufacture, such as fine and coarse gravel. In a typical year around 200 million tonnes of aggregates are quarried in the UK [11], from some 1300 quarries. Therefore, and for many years, attention has turned towards finding and using alternative aggregates to replace the use of quarried materials. In addition, the introduction of the aggregates levy tax in the UK and a number of other European countries has made the use of alternatives to natural aggregates, where possible, more cost effective than quarrying.

Some of these alternative aggregates are manufactured, such as Lytag (lightweight aggregate), expanded slags, and expanded clay [19]. Others take the form of recycled materials obtained from the engineering industry, for example recycled concrete aggregate

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(RCA), recycled asphalt, and recycled glass. Some of these are already in use in the construction industry, particularly recycled concrete and Lytag aggregates.

This paper considers the use and application of recycled asphalt as an alternative aggregate to gravel in concrete. Recycled (or reclaimed) asphalt is mainly obtained from removed old asphalt surfaces destined for landfill that are crushed to size and used as aggregate.

1.1. Recycled asphalt aggregate

Asphalt is used in many applications including motorways, road surfaces, airport runways, parking areas, coastal protection, canal linings, reservoirs, footpaths and cycle paths, and sport and play areas.

Asphalt is produced by mixing bitumen with granular aggregate materials, such as gravel, rock, or limestone. Asphalt as paving material consists of 95% aggregates mixed with 5% bitumen, which binds the aggregates together [10].

In the year 2007 there were 4000 asphalt production sites in Europe, which produced 435 million tonnes of asphalt per year. The rest of the world produced 1165 million tonnes per year, with USA production being similar to that of Europe [10].

Reclaimed asphalt aggregate has been mainly used in the production of asphalt pavement material to replace virgin natural aggregates. The percentage of recycled asphalt aggregate presence in asphalt mixes can be up to 30% for highway pavements applications. The bitumen of the recycled asphalt would also contribute towards the binding in the new mix; reducing the amount of bitumen consumption [2]. Other applications for recycled asphalt aggregate have been as loose sub-base material in road construction. There has been limited use for recycled asphalt aggregate in cement concrete production, due to the weaker strengths produced by recycled asphalt concrete in comparison to other conventional aggregate concretes. Delwar et al. [9] and Huang et al. [13] investigated the use of recycled asphalt aggregate in cement concrete as a replacement for natural aggregate. Although lower strengths than normal were produced by recycled asphalt aggregate concrete, it had sufficient strength for a number of concrete applications, such as barriers and driveways.

This paper investigates the feasibility of improving the strength associated with recycled asphalt concretes. This would increase the potential use of recycled asphalt concrete in civil engineering construction and further reduce the disposal of asphalt at landfill sites. Non-destructive testing (NDT) in the form of Ultrasonic Pulse Velocity (UPV) and Rebound Number (RN) have also been used to assess any improvements in recycled asphalt concrete during early age of concrete (1–28 days after mixing).

This study also establishes the use of non-destructive techniques (UPV and RN) in the assessment of concrete containing different percentages of recycled asphalt during the early age of concrete.

1.2. Non-destructive testing

Two of the most commonly used NDT testes were applied.

1.3. Ultrasonic pulse velocity (UPV)

The UPV of concrete is obtained by measuring the time (transit time) the ultrasonic pulse takes to travel between a transmitter and a receiver on opposite sides of the concrete. The velocity is the path length (distance between transmitting and receiving transducers) divided by the transit time. The transit time is measured using the PUNDIT, which is connected to the ultrasonic transmitter and receiver [1,15]; PUNDIT 2006). The transducers used for concrete testing were 54 kHz with 50 mm diameter.

UPV varies with the presence of voids, cracks and other defects. When a pulse reaches a crack or a void in concrete, it takes the route through the denser material, i.e. the pulse travels around the crack/void and not through it, hence taking longer time to reach the receiver. The measured UPV values would become reduced. This enables the use of UPV as a method for detecting areas of voids, defects, damage, or low quality in concrete.

1.4. Rebound number

The surface hardness of concrete has been used as an indicator of in-situ concrete quality. This is measured using the rebound hammer [8]. It relies on the principal that an elastic mass would rebound by an amount that is dependant upon the hardness of the surface it impacts [15]. Increase in surface hardness would result in bigger bounce of the rebound hammer, which is displayed on a scale as a dimensionless rebound number. The surface hardness technique can be used in the establishment of concrete quality and detecting areas of deterioration and defect, when compared to good quality concrete [20,18].

2. Materials and experimental method

2.1. Materials

2.1.1. Cement type

The cement used in all the mixes of concrete investigated was CEM I Portland Cement (PC) type 42.5 N, manufactured by Lafarge Blue Circle. This was a general purpose cement of a quality that complies with BS EN 197-1 [4] and carries the European conformity CE marking.

2.1.2. Mixing water

Ordinary fresh tap water was used throughout. This water is considered as suitable for use in concrete in accordance with BS EN 1008 [5]. The water was used at ambient temperature.

2.1.3. Aggregates- fine and coarse

All the different types of aggregate used in the manufacture of concrete were oven dried and allowed to cool before use. The concrete mixing water was adjusted for the absorption of different aggregates. The aggregates were allowed to absorb water for 24 h prior to mixing.

2.1.3.1. Normal (gravel) concrete. For gravel concrete, Thames Valley flint gravels (4/10 mm and 10/20 mm) and uncrushed river sand (0-4 mm all-in) were used throughout the experimental work. The fine aggregate particle sizes were found to have the grading proportions shown for sand in Table 1. The water absorption and relative density of the aggregates were measured based on a saturated surface dry basis as outlined by BS EN 1097-6 [6], and also shown in Table 1.

2.1.3.2. Recycled asphalt aggregate concrete. Throughout this study, recycled asphalt concrete is essentially normal concrete with the 20 mm gravel (10/20 mm) replaced with single size 20 mm reclaimed asphalt (10/20 mm). The 20 mm recycled asphalt aggregate was a Type I unbound mixture for sub-base asphalt, supplied by Tarmac Southern Ltd (Hayes). It has a relative density (saturated surface dry) of 2.46 and water absorption of 0.5%.