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Exploring the effects of geotextiles in the performance of highway filter drains

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ABSTRACT

Highway Filter Drains (HFD) are one of the most utilised drainage systems for roads, being considered as an environmental solution for sustainable drainage in transport infrastructures. However, little research has been done to understand their performance, representing a significant knowledge gap. This article therefore determines the hydraulic and clogging response of 3 different HFD designs in the laboratory; one standard design with British Standard Type B aggregate, and 2 new designs including a geotextile located at 50 mm and 500 mm depth from the surface of the HFD structure in order to assess the effect of the geotextile. The laboratory models were initially subjected to 9 rainfall scenarios with 3 rainfall intensities (2.5, 5 and 10 mm/h) and 3 storm durations (5, 10 and 15 min). Subsequently, the equivalent of 2-years' worth of pollutants were added to test possible clogging issues under the highest intensity rainfall event, corresponding to a 1 in 1 year return period for the West Midlands, UK. No clogging issues were found in any of the models although the majority of the sediments were concentrated in the first 50 mm of the HFD profile, with higher percentages ($> 90\%$ of the sediment added) in those models with an upper geotextile. Location of the geotextile significantly influenced (p-value $= 0.05$) the hydraulic performance of the HFD.

1. Introduction

Vehicle traffic in the UK has increased dramatically since the 1950s to more than 300 billion vehicle miles in 2014 (UK Department of Transport, 2015). To cope with this high volume of traffic, the UK has a road network of nearly 1.8 km road/km^2 of land area with a total length of 419,596 km, of which 3674 km are motorways and 49,040 km are main roads (Nicodeme et al., 2013).

The Strategic Road Network (SRN) (including motorways and A roads) (UK Department for Transport, 2012) and local road networks are England's most valuable infrastructure asset, valued at approximately £344 billion and as well as the roads, includes other infrastructure such as bridges, embankments and drainage systems (House of Commons, 2014). In 2012–2013 public spending on maintaining England's roads was £4 billion, divided between the UK Department of Transport, the Highways Agency (Highways England since 2015) and Local Authorities. The operation, maintenance and improvement of the SRN, which represents 2% of the total road network (7080 km), is the responsibility of The Department of Transport through Highways England (House of Commons, 2014).

Road drainage systems are therefore a vital asset in transport infrastructure, contributing to the safety of road users by removing surface runoff, improving visibility and mitigating environmental problems to receiving waters. Hence, they are an important part of the maintenance programme developed by Highways England (Ellis and Rowlands, 2007; Coupe et al., 2015).

Filter Drains (FD), kerbs and gullies connected to pipes below ground and surface water channels along the pavement edge, are the main methods of dealing with surface runoff (DMRB-UK, 1997a). FD, also known as 'French Drains', are not only one of the most used drainage systems in the UK, but are also an historically important engineering technique across the world. FDs when used on highways are defined as Highway FD or HFD, terminology which will be used hereinafter. Approximately 50% of the SRN in England (in total about 7000 km accounting for traffic flow in both directions) uses HFD as their main drainage technique (Coupe et al., 2016).

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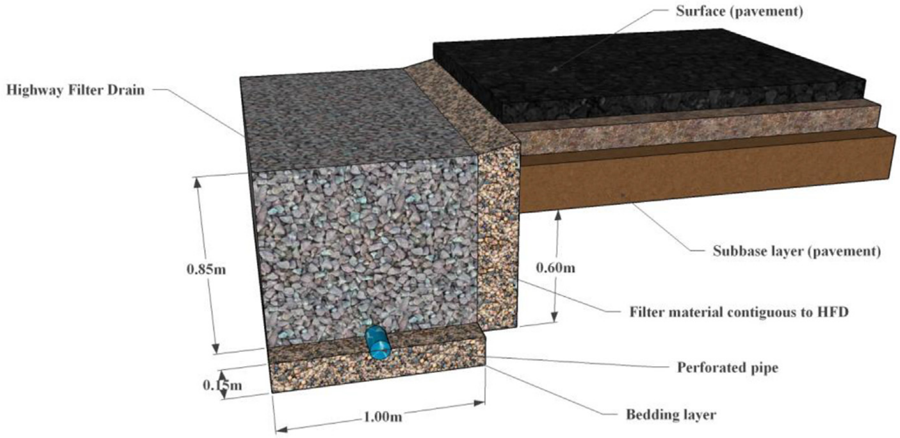

Fig. 1. Standard HFD design and detail of its position relative to the edge of the highway.

HFD are designed to cope with a wide range of storm events, to avoid flooding problems. Thus, the Design Manual for Roads and Bridges (DMRB-UK, 2004), Volume 4 Section 2 (Drainage), stipulates that highway drainage systems should be designed for high intensity events over a few minutes (short durations) with return periods of 1 year (with no surcharge of piped systems or road-edge channels) or 5 years with no flooding on the carriageway.

According to DMRB-UK, 1997b, UK HFDs should be a minimum of 0.6 m below the pavement sub-base in order to prevent groundwater entering the pavement structure. Including the full depth of the road structure, the typical depth for an HFD is up to 1 m with a width of approximately 1 m (Fig. 1).

A perforated pipe is located at a depth of 850 mm in a full-sized HFD, details and recommendations such as its diameter, the type of aggregate used for the bedding layer and the main body of the HFD are all given in the Design Manual for Roads and Bridges (DMRB-UK, 2001) and the UK Highways Agency Manual of Contract Documents for Highway Works (MCDH) (2009).

After a long operational life, often 30–40 years of service, some HFD may need maintenance and in order to judge this, their performance is monitored using high-speed non-intrusive Ground Penetrating Radar (GPR) surveys, specifically SMARTscan both on verges and central reservations (Carnell, 2015). However, there is a lack of comprehensive understanding of the hydraulic processes that take place in HFDs and how resistant and resilient they are to flooding and clogging.

The impact of this research is wider than just the UK as HFD are used in other countries across the world such as the Republic of Ireland where a visual inspection carried by Bruen et al. (2006) on the Irish dual carriageways and motorways found that more than 40% of them had HFD as their main drainage system. Also in Ireland, issues around clogging have been commonly addressed by the use of a geotextile as a barrier to fine material ingress (Bruen et al., 2006; Desta et al., 2007) whilst still allowing water to flow through and into the drainage material and pipe. Other international drainage techniques similar to HFD also use geotextiles such as the so-called “edge drains” in the U.S.A (Kearns, 1992; Koerner et al., 1996) and Canada (Raymond et al., 2000); and also in Spain (Castro-Fresno et al., 2013; Andres-Valeri et al., 2014; Sañudo Fontaneda, 2014; Sañudo-Fontaneda et al., 2014a; Sañudo Fontaneda et al., 2016) where there are specifications including the use of geosynthetic products in drainage structures (AENOR, 2001; Bustos and perez, 2007).

Despite the fact that geosynthetics have been included successfully in the structure of other SuDS such as Permeable Pavement Systems (PPS) in the UK (e.g. Pratt et al., 1999), their utilisation in association with HFDs is still viewed with scepticism by some engineers due to concerns over possible blockage of the aggregate layer and/or the pipe, leading to a reduction in infiltration capacity. In order to address these issues, there were 2 aims of this research:

1. To determine the effects on HFD hydraulic performance of the inclusion of geotextiles due to its water retention characteristic (WRC). This concept is described by Chinkulkijniwat et al. (2017), who also highlight the lack of knowledge of geotextile WRC.
2. To determine the influence of the geotextile on the potential for clogging for short return periods.

2. Materials and methods

2.1. Experimental preparation and materials

Ten plate-glass rigs were set up: 4 replicates of the Standard HFD, and three replicates for each HFD model containing geotextiles at 2 different depths in the profile (50 mm and 500 mm respectively). The rigs had 5 mm thick walls and measured 215 mm × 215 mm x 650 mm, thus their volume was 0.030 m^3 and surface area was 0.046 m^2 (see Fig. 2). No lower pipe was used, since the aim was to analyse the hydraulic and clogging performance of the aggregate and to isolate the influence of the geotextile layer on the general performance of the HFD, following the preparation method presented in Sañudo-Fontaneda et al. (2017). The outflow, used to build the hydrographs of performance for every HFD model, was measured using funnels placed at the bottom of

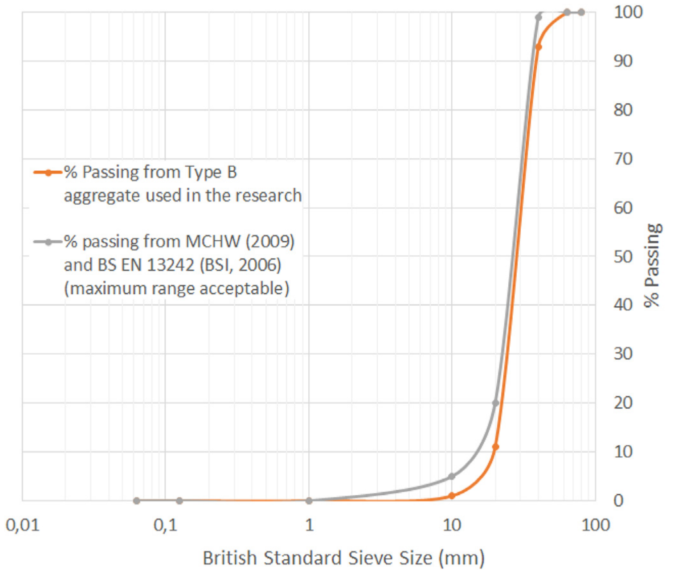

Fig. 2. Gradation curve for the Type B aggregate.