Institution: University of Dundee

Unit of Assessment: UoA 14 - Civil and Construction Engineering

a. Context: The Unit's research is targeted primarily at end users in the construction and manufacturing industry sectors, local and national government (including non-departmental Public Bodies responsible to government), regulatory and monitoring agencies and technical standards bodies. The research has economic impact, impacts on practitioners and professional services and impacts on the environment. All impacts are achieved by utilisation by industry, government and non-departmental public bodies of outputs and services from the Unit's research programmes in concrete technology and construction, fluid mechanics and geotechnical and earthquake engineering. This leads to the implementation of commercially-profitable improvements to existing products and services, the adoption of beneficial technical changes to engineering practice, the introduction of new, updated or enhanced technical standards and the achievement of societal benefits through improvements in safety and environmental health.

b. Approach to impact. Impact is achieved by (i) disseminating to the non-academic user community information on the research expertise and infrastructure available within the Unit, (ii) targeting research areas that are attractive to industry and that reflect governmental and research council strategic priorities, (iii) engaging key senior practitioners as specialised advisors, (iv) identifying and collaborating with non-academic partners in research projects that benefit industry and/or government agencies, (v) inviting experts from outside the academic research community to participate in Advanced Research Workshops and specialist conferences/symposia addressing applied problems requiring research solutions and (vi) serving on and providing research advice to committees and specialised technical boards convened by non-academic bodies.

Since 2008, the Concrete Technology Unit (CTU) has undertaken a wide range of research investigations commissioned directly by large multi-national companies (HeidelbergCement, Atkins, Skanska, AMEC, BASF, Balfour Beatty), numerous SMEs and industrial consortia (*e.g* CEMBUREAU, the European Cement Association and the UK Quality Ash Association, the representative organisation of the cement industry in Europe). In 2012, a £800k grant was awarded to **Jones** from the Gulf Organisation for Research & Development in Qatar (i) to investigate the recycling of demolition waste as aggregate material for new construction and (ii) to develop a new generation of low energy, sustainable "green" concrete products for use by the construction industry in the Gulf and worldwide. In addition, the CTU secured a £250k grant in April 2013 from the Technology Strategy Board's KTP scheme to collaborate with Pelamis in reducing costs (and improving the performance) of wave energy generators. The Waste & Resources Action Programme established by the Department of the Environment has awarded the CTU research funding totalling £300k since 2008. The Impact Case Studies provide further evidence of strong, directly-funded research impact with non-academic end-users. For example, the Construction Management Research Unit (CMRU) has undertaken extensive commissioned research for large companies (Skanska, Atkins) and has been the leading academic partner in the Scottish Construction Centre (SCC). Similarly, **Vardy**'s worldwide participation with industrial companies (e.g Haerter AG, Sohatsu Systems Laboratory, Paradigm Flow Solutions) in the design and operation of rail tunnels and the location of offshore pipeline blockages have achieved enormous impact. The impact is described and quantified fully in the relevant Case Studies.

The Unit's research programmes in Fluid Mechanics, Concrete Technology and Geotechnical Engineering achieve societal impact in the areas of environmental health and safety, sustainability and the protection of the environment. For example, **Dong** has been commissioned since 2008 by Angus Council to develop and implement its coastal management strategy and the CTU has undertaken research funded by the Scottish Environment Protection Agency into recycling of glass waste. The impact of the Unit's research on environmental monitoring and regulation is exemplified by the representation of the Environment Agency on the External Advisory Board of **Davies**' EPSRC grant (2010-2013) on the discharge of industrial brine into coastal waters. Throughout the assessment period, research projects commissioned by offshore support companies (*e.g* Technip, Acergy, Subsea 7) have enabled the Unit's Geotechnical Engineering research group to exploit its specialised expertise and equipment (the Geotechnical Centrifuge) by providing data on sea floor

pipeline behaviour to the subsea engineering sector.

The incorporation of the Unit's research into new Technical Standards is illustrated by **Jones**' appointment to CEN (European Committee for Standardization) and BSI (British Standards Institution) committees on concrete durability and aggregates for concrete, respectively. **Davies** has served since 2009 with Marine Scotland and aquaculture practitioners on the Scottish Government Ministerial sub group *Containment in Aquaculture*, preparing a Scottish Technical Standard for aquaculture. The Geotechnical Engineering research group's expertise in foundations and ground anchors is included in the *Engineering Solutions* theme of the industry-led Scottish Aquaculture Innovation Centre.

The Unit is well-served by senior external advisors. Professor Tom Harrison (Technical Director, British Ready Mix Concrete Association; Chairman, BSI concrete committee), together with Professor Peter Hewlett (Director of Research & Development, David Ball Group) and Professor Pal Chana (Executive Director, MPA Cement) constitute the Industrial Advisory Board for the CTU, meeting biannually. All have served the Unit as Industrial Visiting Professors during the assessment period, together with Professor Richard Whitehouse (Technical Director, HR Wallingford Ltd) and Professor Tim Broyd (Halcrow Group Director of Technology Innovation & Sustainability, 2008-2012). The Unit's Industrial Advisory Boards identify new, industrially-relevant research areas and opportunities requiring timely investigation. Impact achieved through the participation of non-academic users in research conferences hosted by the Unit is illustrated by the regular international conferences mounted by CTU since the late 1990s. The 7th and 8th in the series (2008, 2012) each attracted 200 delegates, with 50% participation from industry and non-departmental Public Bodies.

Membership of industry-led bodies provides opportunities to interact effectively and achieve impact with end-users. **Jones**' membership of the BSI Concrete committee has led to the incorporation of CTU's research on the use of recycled concrete aggregates (RCA) into the present British Standard BS 8500 *Specification for Concrete*. Similarly, **Davies** has served (2009-2013) as a Director of the National Subsea Research Institute (NSRI), an industry-led research centre operating as a partnership between industry and academia to develop and lead a co-ordinated research strategy for the UK subsea sector. This has provided **Davies** with access to the NSRI Subsea Technology Advisory Group, consisting of 16 industrial representatives (including Aker Solutions, Total, Chevron, BP, Wellstream, Atkins, Technip, Fugro, Cameron, Shell, Talisman, J P Kenney) advising on long term future technology requirements of the UK subsea sector.

All Unit researchers are made fully aware of the benefits of incorporating partnerships with non-academic users in grant proposals to the Research Councils. This maximises impact through the involvement of partners in identifying applications of the academic research and influencing the direction of the projects to optimise impact. Recent examples of EPSRC grants held with collaborative partnerships are EP/E031749/1 (**Brown**; Partner; BRE), EP/J010359/1 (**Dong** & **Davies**; Partner: HR Wallingford Ltd), EP/G066124/1 (**Davies**; Partners:Jacobs & HR Wallingford Ltd), EP/G068925/2 (**Vardy**; Partner:Brinker Technology) and EP/D041821/1(**Dong** & **Davies**; Partners: Black & Veatch, HR Wallingford Ltd). The *GeoWave* FP7 project coordinated by **Knappett** has 5 industrial partners (Wavebob Ltd, Cathie Associates, Lloyds Register, Seaflex, Deep Sea Anchors AS) undertaking industry-specified research on a new generation of offshore anchors and mooring components for wave energy devices.

The Unit's approach aligns with the University's *Strategy to 2017* transformational plan to distinguish the University through innovative and effective knowledge exchange and to translate research outputs through knowledge exchange to address societal challenges. To effect this alignment, the Unit exploits fully the resources within the University's Research & Innovation Services (RIS), working with a dedicated Business Development Manager to draw on expertise in identifying new funding opportunities with non-academic partners and research outputs with commercial potential. The RIS "Innovation Portal" has been used extensively to access the SFC-funded Innovation Voucher scheme that funds collaborative research projects of benefit to SMEs and the Scottish economy. The CTU has undertaken 6 such projects since 2011; for example, with

a Knowledge Exchange Partnership with Moock Environmental Solutions Ltd to investigate the effects of including spent-printer toner ink in concrete to improve water resistance. The scheme has also funded **Jones**' research into the role of concrete in hydrogen storage, undertaken on behalf of the Scottish Hydrogen and Fuel Cell Association - the body bringing together Scottish Enterprise and Scotland's specialised fuel cell and power generation companies, energy consultants and councils with an interest in Hydrogen & Fuel Cells.

c. Strategy and plans: The Unit's academic strategy has impact at its core. In consequence, its goals are to maximise the impact of its research by (i) continuing to undertake research of international quality with non-academic end-users having a need for the results of this work and (ii) disseminating widely the results of the work to the non-academic community in the UK, the EU and overseas. The Unit will continue to consolidate its existing research collaborations with non-academic users (particularly those such as **Vardy**'s that are formalised through University spin-out companies), identifying new individual or consortium research partners and utilising university social media to publicise research achievements.

The Unit will increase its cross-disciplinary research (particularly within the University's Offshore Renewables Institute (ORI)) to expose new areas in which non-academic impact can be realised. The ORI, formed in 2013, is a key vehicle for achieving impact. It will offer consultancy, services, industry contracts, industry-research collaboration opportunities and skills training. It will have a Business Development Manager who will spend all his/her time on the ORI; the ORI is essentially industry-facing and has been set up in that way. Dundee is close to around 3 offshore wind farm sites off the East coast of Scotland, putting it at the heart of a growing industry. Significantly, the University has already made a substantial capital investment (£1.2M) in the *Wind & Marine Renewables Test Centre for Concrete Materials and Foundations* component of the ORI, resulting subsequently in an £833k award for the Centre from ERDF after the assessment period. This Centre will become an integral part of the Scottish Energy Laboratory network, offering industry, client bodies and regulators advanced test facilities and enabling whole life performance and cost assessments for high-repeatability production to be undertaken. The ORI is placed ideally to exploit collaboration opportunities associated with the newly-established, industry-led TSB Offshore Renewable Energy Catapult, based in Glasgow. The specialised research interests of the ORI and the Catapult are complementary and the forging of close links between the two bodies is a high priority. In this regard, the Unit is also ideally placed to benefit from its involvement in the successful bids for the industry-led SFC Innovation Centres in *Aquaculture*, *Sensors* and *Construction*. Engagement with these Centres will be pursued urgently.

The Unit will continue to work closely with its Industrial Advisory Boards, to benefit from the expertise and insight of the members and the external networks to which they provide access. An Impact Network committee will be formed, composed of leaders of the 3 research sub-groups, the College Business Development Manager, a representative from RIS, all Industrial Visiting Professors and nominated representatives from each of the SFC Innovation Centres (Aquaculture, Construction, Sensors). The Committee will coordinate translational research activities, identify and exploit new research opportunities outside the academic sector and disseminate widely its research expertise. Not least, this innovation will allow the Unit will take advantage of the University's recent initiative to raise the profile of research-based consultancy activities. The Unit will continue to work closely with the University's RIS office via the dedicated Business Development Managers and will continue to make full use of the RIS Innovation Portal (see §(b)) to collaborate with SMEs .

d. Relationship to case studies: The Case Studies illustrate the success of the Unit's two-way approach to achieving impact by (i) responding effectively to demands from non-academic end-users for access to the specialised research expertise within its research groups and (ii) disseminating widely the Unit's research expertise via industry-led committees and events attended and supported by the non-academic community. Both Impact Case Studies are characterised by (i) the recognition by industry and government of research excellence in the Unit and (ii) the adoption of the Unit's research products and services by the end-user for subsequent utilisation and exploitation for commercial benefit and societal improvement.