Journal of Archaeological Science 53 (2015) 12–18

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

A method for calculating soil pressure overlying human burials

Glenys McGowan, Jonathan Prangnell*

School of Social Science, The University of Queensland, Queensland 4072, Australia

A R T I C L E I N F O

Article history:
Received 13 May 2014
Received in revised form
15 September 2014
Accepted 17 September 2014
Available online 6 October 2014

Keywords:
Soil
Weight
Vertical load
Taphonomy
Burial
Exhumation
Cemetery

A B S T R A C T

While damage to the human skeleton due to vertical pressure exerted by overlying soil is a common observation at archaeological excavations, comparatively few studies have attempted to quantify the magnitude of this pressure. As part of a suite of taphonomic studies of a nineteenth-century cemetery located in Brisbane, Australia, a soil loading calculation equation usually employed in civil engineering is used to calculate soil vertical pressure at various depths for both child and adult graves. This cemetery was characterised by extreme vertical compression of coffin burials to the extent that human remains were sandwiched between the coffin base and lid to a thickness of just a few centimetres. Calculations determined that, because of their narrower grave shafts, the burials of children experienced between 40% (1.83 m depth) and 27% (0.91 m depth) less vertical soil pressure than those of adults buried at similar depths. Further calculations for different soil types showed that coarser grained soils such as gravel and sand exerted less vertical pressure than a similar volume of saturated clay due to the amount of air trapped between the coarser grains. It is anticipated that the equation utilised in this study could find widespread applications in the fields of archaeology, physical anthropology, forensic archaeology and cultural heritage management.

1. Introduction

The potential for vertical soil pressure to contribute to bone degradation was highlighted during a salvage excavation conducted at the North Brisbane Burial Ground (NBBG), a nineteenth-century cemetery in the centre of Brisbane, Queensland, Australia. Many of the burials had suffered damage due to extreme vertical compression (Fig. 1). In the majority of these the wooden coffin lid had fallen in and been pressed against the human remains and the coffin base. The sides of the coffins were deformed in response to soil movements, and had lost some of their vertical height, but still remained relatively upright (Fig. 2). Three wooden coffins with lead liners were generally more resistant to compression, with the sides showing inward buckling in response to vertical pressure (Fig. 3).

It is estimated that the NBBG received approximately 5000 interments between 1843 and 1875, in separate cemeteries according to religious denomination (Rains and Prangnell, 2002). The cemeteries were each located on dissected slopes of clay developed over phyllite bedrock (McGowan, 2008:197). Generally, bodies were buried in hexagonal wooden coffins covered inside and out with textiles (Prangnell and McGowan, 2013). There is contemporary documentary evidence that some burials were interred at quite shallow depths. In 1875, the Brisbane Courier (5/3/1875:2) reported that children's and adults' graves in the Anglican cemetery were only being dug to a depth of 3 ft (0.91 m), apparently upon instructions from the Trustees. After its closure, the Burial Ground became overgrown and neglected for a period of 36 years, before being redeveloped into parkland (Prangnell and McGowan, 2013). Low-lying parts were used as a municipal landfill and nightsoil disposal site from 1914 until the early 1960s (Prangnell and McGowan, 2009).

Earlier this century, the building of a new sports stadium on the site necessitated the excavation of 397 burials discovered during the preparation of foundations and service trenches (McGowan and Prangnell, 2011). Human remains, coffin wood, textiles and metal artefacts were found to be in a surprisingly poor state of preservation after only 160 years of burial, a comparatively brief time span by archaeological standards. By the time of excavation, 6% of coffin wood, 77% of textiles and 22% of metal coffin furniture had *completely disappeared* from the archaeological record (McGowan, 2008:364). Of the 397 burials excavated 54.2% contained only soil silhouettes, 29.9% contained highly compressed and powdered skeletons, 12.3% contained compressed and fragmented bones (Fig. 1), 3.4% had broken bones in anatomical position and one burial was well preserved with a complete but disarticulated skeleton (Fig. 3).

* Corresponding author. Tel.: +61 733652887.
E-mail addresses: g.mcgowan@uq.edu.au (G. McGowan), j.prangnell@uq.edu.au (J. Prangnell).

http://dx.doi.org/10.1016/j.jas.2014.09.016
0305-4403/

Fig. 1. An example of extreme vertical compression typical of most graves at the North Brisbane Burial Ground (Head and torso of burial F15 in the Anglican cemetery). Many burials at North Brisbane were compressed to a vertical height of just a few centimetres. Segments on the scale bar are marked in 25 mm intervals.

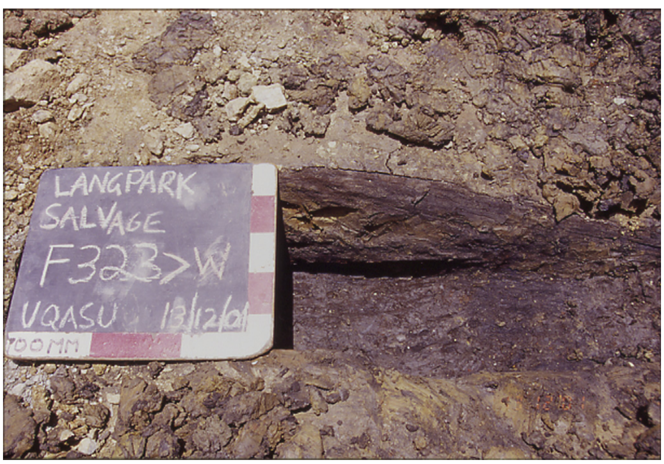

Fig. 2. Burial F323 in the Anglican cemetery showing the coffin lid compressed onto the base, with the sides deformed and shortened but still upright.

It was noted that, in some places, burials were covered with overburden of more than 7 m of landfill waste (McGowan, 2008:212) (Fig. 4). Previous research into the taphonomic conditions at the North Brisbane Burial Ground has demonstrated that soil temperature (Prangnell and McGowan, 2009), soil pH (McGowan and Prangnell, 2006), fluctuating groundwater levels (McGowan, 2008), high soil salt content (McGowan, 2008), chemical attack from landfill leachate (McGowan, 2008) and ongoing microbial attack (McGowan and Prangnell, 2006) are factors involved in the degradation of human remains and artefacts at the site. Considering the extent of overburden and the heavily compressed nature of the remains a method of quantifying soil vertical pressure was also sought as part of this broad analysis of site taphonomy aimed at determining the critical factors leading to the extreme degradation observed.

2. Method

While there have been a multitude of studies published in the archaeological and forensic literature focussing upon the taphonomic effects of plant, animal, and microbial activity on human bone preservation, as well as the modifying effects of waterlogging and extreme heat, less attention has been devoted to the effects of soil physical and chemical parameters such as pH, chemical contamination, soil temperature and soil pressure. Crist et al. (1997) appear to be the only authors to attempt to quantify the weight of soil overburden on cemetery burials by modelling grave fill as a prism of earth sitting on the roof of the coffin and quantifying the weight of this soil prism based upon its volume. They calculated that for 4 ft (1.22 m) of soil cover in a grave shaft of dimensions 6 ft (1.83 m) by 3 ft (0.91 m), the volume of the grave infill would be approximately 72 ft^3 (2.03 m^3), and the total weight of this earth would be between 5,400 lb and 7,200 lb (2.45 and 3.27 tonne) based upon a unit weight of 75 lb (34.02 kg) to 100 lb (45.36 kg) per cubic foot of soil. However, engineering research conducted by Marston and associates found that the load on a buried linear object is not the same as the weight of the prism of earth above the object, and is in fact either greater or lesser than the weight of the fill itself, depending upon the rigidity of the buried object, the compactness of the soil and the method of trench construction and infilling (Liu, 2003:362–363).

Fig. 3. Inward buckling and breakage of the wooden sides from lead lined coffin burial F206 in the Roman Catholic cemetery in response to vertical soil pressure.

A coffin is essentially a long narrow object buried in a trench which is also long and narrow-a situation similar to that of a buried pipeline. With this analogy in mind, a mathematical equation used in industry to calculate the pressure exerted by fill over buried pipelines was used to determine grave fill pressure in cemetery burials. The load on a conduit (or a coffin) is made up of the weight of the prism of earth fill above the top of the conduit pressing down, less the counteracting upward force of the total frictional or shear forces acting on the trench sides as the fill settles (Spangler and Handy, 1982:730). The degree of consolidation of the trench/grave fill is also important. When loose material is used to backfill the trench/grave, it settles downward under its own weight, while the surrounding rigid walls act to hold the fill