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A study for the understanding of the Roman pavement design criteria

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ABSTRACT

The authors present the suggestive hypothesis that Romans possessed specific and specialized pavement design criteria, from which the most appropriate construction techniques and the majestic road infrastructures descend. From a back-analysis of some road pavements, it emerged that there is a good correspondence between thicknesses and materials selection used by Romans and those arising from the calculation by analytic methods introduced only in the modern age. In this paper, some considerations, from the point of view of road engineer, were presented; these could be usefully shared with the researchers in the fields of cultural heritage and archeology in order to identify both soils and road pavement materials sampling and classification systems for a new perspective of scientific speculation.

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1. Introduction

Roads represent the emblem of Roman civilization and perhaps the constructive element that more than others has allowed the military art development and the maintenance of political power, establishing the economic and cultural primacy. This immense horizontal architectural heritage has effectively outlined those that still are the commercial and infrastructure networks of Europe and North Africa, and the terrestrial connections with the Middle East [1–6].

Archaeological investigation and more generally research in the field of archaeological and cultural heritage preservation have come to delineate and provide significant contributions regarding Roman roads, essential basis of ancient topography and advanced material analysis for restoration purpose. Much attention has been placed on the analysis of construction techniques, especially in the road layout, giving greater attention to platform functions, pavement wearing course, urban context, transport functions and transport devices.

With specific reference to sections of these infrastructural works, that is to say all the layers of stone materials built to form the structure that in road engineering is defined as road superstructure or pavement, the several information inferable from ancient texts and from descriptions of the archaeological finds have not led to a complete understanding of the design process that is upstream of the construction technique.

In the perspective of a road engineer, the considerable wealth of information on archaeological finds of road pavements not easily leads to scientific possibility of systematize on a large-scale a back-analysis process of Roman roads, in order to determine their design criteria. This difficulty is a result of the provenance of the available data from scientists belonging to different disciplines and cultural background and consequently there is a use of non-uniform terminology that is also accentuated by translation of scientific papers to the English language.

The aim of this paper, as a contribution by authors from road engineering field, is to present to scientists of cultural heritage some considerations about the classification of materials used and about the quantification criteria of a dig depth for the construction of Roman roads; among these there are suggestive decision-making, maybe real calculations, operated by Roman *architectus*, with predetermined service life expectations.

2. The misleading narrative on the Roman road paving

Romans were the first to transform the old paths, already born in prehistory, into real built roads, both in terms of layout and superstructure. For this purpose, the *architectus* was operationally helped by a surveyor (*agrimensor*) and a leveler (*librator*), while the soldiers were the real builders [1,2,5].

Many authors, including the ancient ones, have tackled the description of the construction techniques of Roman roads: among many others, the poet Statius (Silvae VI, 3) with reference to the construction organization of Via Domitiana, or Pliny, which was a careful observer of roads and related buildings.

According to what has been learned from ancient texts [1,7–10], Roman roads can be distinguished from a constructive point of view

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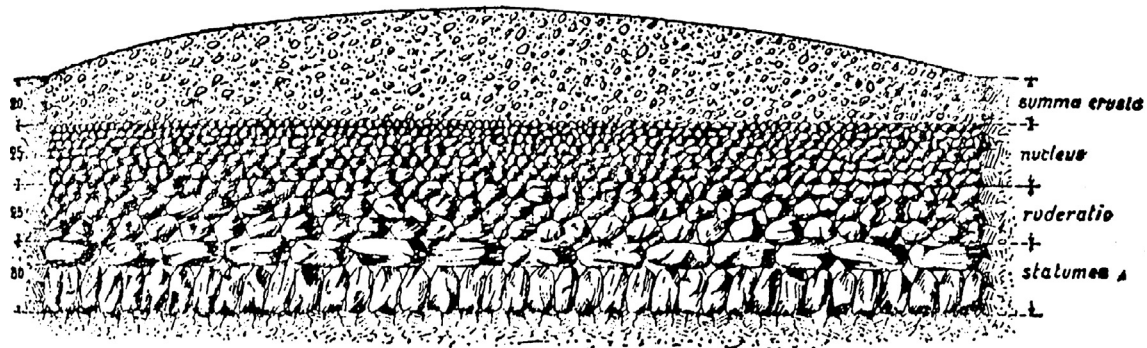


Fig. 1. Paradigmatic Roman roads pavement [5].

in *viae terrenae*, i.e. “dirt roads” or constituted by selected natural soils which were placed within a dig, *viae glareae*, that were constituted by unbound aggregates, and eventually *viae silice stratae* which were coated with polygonal and unequal stone slabs having structural, functional, decorative and hygienic roles and gave monumental expression of power.

Fig. 1 shows a paradigmatic representation of section of *viae stratae*, commonly reproduced in several texts, inferred from the description of Vitruvius: it is constituted by several layers structure which is realized as a filling of a dig that could reach 2 m depth or, in any case, until a more compact soil is achieved. As a matter of fact, it is safe to assume that this is an exception rather than a rule.

In this recurrent paradigmatic description the subgrade, i.e. the substructure, would be prepared using lime mortar to even out imperfections and to create a base for the subsequent layers [1,2,5,10,11]:

- the first layer, named *statumen*, was mainly constituted by large blocks, rocks or stones (*saxa*), with at least 5 cm size (not smaller than the capacity of the hand), arranged in a row and placed either horizontally or vertically and bounded by lime mortar or clay: the thickness of this layer was variable from 20 to 60 cm depending on the circumstances;
- the second layer, named *rudus* and having a thickness of about 25 cm, had a water drainage function and was constituted by crushed stones or by rubbles; also in this layer it was contemplated the presence of lime mortar;
- the third layer, named *nucleus*, was constituted by gravel, coarse sand or earthen fragments mixed with 1/3 of lime mortar: the thickness of this layer was of 30 cm at the edges of the road, and 45 cm in its center;
- the surface coating (*pavimentum* or *summa crusta*) was also constituted by polygonal and unequal stone slabs artfully cut to advantage the closest clamping.

It was merely said that there could be only some of these layers, as is often found, as a function of the in-site soil conditions.

From ancient text evidences and from archeological finds summarily analyzed until a few years ago, one cannot fail to recognize errors in the communication of information about the Roman roads construction techniques, the main of which is the stratigraphic composition that is more diversified and specialized as a function of in situ soil conditions, that today are named geotechnical characteristics. Clear and transferable technical-scientific information on subgrade conditions can almost never be inferred.

It is however more than likely that Romans followed construction rules, codified procedures of context analysis and materials qualification (along the road alignment and in its immediate surrounding areas), ordered construction and maintenance sequences,

etc. and that they considered the relationship between pavement and both surface and ground water.

The lack in transmission of construction and maintenance rules has worsened in the Middle Ages with the abandonment of road's care, with alienation, environmental degradation and dismantling of materials for other building purposes.

The fact remains that Roman road pavement are very diversified in the number of layers, particle size of aggregates used (that is described and almost never analytically determined), water susceptibility of fine fractions, use of natural or artificially broken materials, relationship between the subgrade level and the ground-water level, etc.

3. Classification of the main Roman pavement types

From the available archaeological sources a number of solutions adopted by Romans for roads construction, which are recognizable in the various territories and geographical areas, can be distinguished: the choice between these solutions was dependent on several factors including the ground conditions, the road function, materials availability, etc.

Everyone who wishes to undertake a systematic analysis through engineering approach of the descriptive data present in literature must face many difficulties. These difficulties are partly due to the almost total absence of formal material classification data, which are essential for a dialogue among competencies, and are further complicated by the use of vague or incorrect terms in the description of stone aggregates and soil in road constructions. Particle size, particle size distribution and shape of aggregates as well as the presence of crushed or rounded elements, of organic matter and many other indicators, affect mechanical properties and water susceptibility of subgrade and unbound aggregates.

Having said that, some Roman road pavements can be identified from several available sources.

3.1. *Viae glareae*

Via glareae is a Roman road pavement composed of granular stone materials and generally equipped with *crepidines* (kerb). First of all the ground was excavated to a depth variable from 20 to 70 cm and after that the dig was filled with aggregates: the coarser ones, which include both rounded and crushed elements, are generally placed at the bottom (Fig. 2a) [12]. In some cases, fine materials are placed under the coarser ones: these sections are often consequences of the overlap of different pavement structure, which were therefore realized in different times (Fig. 2b) [13,14]. *Glareae* are also the road pavements realized on embankments, such as the roads of centuriation [15], Spain [16] and Britain [17]. Only few information about embankments of centuriation are available: there are some examples in which the layers were composed of gravel, river pebbles

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