The Properties and Uses of Roman Cement

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INTRODUCTION

During at least the first half of the nineteenth century mortar meant a mixture of lime and sand, cement meant Roman cement, and concrete at least in terms of buildings was a mixture of fine and coarse aggregate with lime.

Roman cement, which was patented by James Parker in 1796, was an important addition to the constructor's armoury. It was an hydraulic binder, which set in the presence of water, it set quickly, and was waterproof. Previously only some of these characteristics could be obtained by the addition of a puzzolanic additive to lime. It is not now generally appreciated that most Roman cements set in a matter of minutes, so it was not a straight replacement of lime as used in mortar, render or concrete, nor could it be replaced in all respects by Portland cement. New techniques needed to be developed for using it and novel applications were found for it, such as Charles Fowler's tile creasing for floors and roofs. Its use continued after it had been largely superseded by Portland cement because of its quick setting, its waterproofing properties and its superior adhesion to iron and steel compared with nineteenth century Portland cements.

This paper cites contemporary references from the nineteenth and early twentieth century, supplemented by personal observations, to show how Roman cement was applied and used, and for what purposes. The references suggest that it was used more widely than is generally recognised today. The paper concentrates on bond, waterproofing, mortar, concrete and similar uses, because Frank Kelsall[1,2] and Ian Bristow[3] have written on stucco and render. The paper relates to work in the United Kingdom but it is thought that cements with similar properties were used in the mainland of Europe and in America.

In 1838 the distinguished royal engineer Charles Pasley[4] told his readers that a vast quantity of Roman cement was now employed in and near London[5] and John Weale's *Dictionary* of 1849-50 says "a very great consumption of this cement takes place in London".[6] It can therefore be expected to be encountered in nineteenth century buildings and deserves to be more widely recognised and understood. Pasley's *Observations on Limes and Calcareous Cements* was basically about Roman cement, its manufacture and properties, because it possessed "an infinite superiority over all other hydraulic mortars, not excepting puzzolana". He had no doubt that had it been available Smeaton would have used it for the construction of the Edystone Lighthouse.[7] A.J. Francis confirms that without the assistance of Roman cement "a considerable number of the great engineering projects of the early nineteenth century could not have been carried out whilst the progress of the Industrial Revolution would undoubtedly have been retarded." [8] Pasley also mentioned that "the proper mode of preparing and of using cement could not have been understood in France," [7] particularly by Vicat and Treussart; to the extent that the former predicted that "although a vast quantity of it is now used in and near London, it will be gradually disused as soon as the hydraulic limes shall be better known and appreciated in England." [9] He could not have been more wrong.

Roman cement set particularly quickly and it set under water, but it was only effective if used neat or as a very rich mix, with no more than one or at most one and a half parts of sand. Any mixes leaner than 1:1½ simply did not set. "Cement is always weakened by the addition of sand, whereas

every kind of lime is improved by it".[10] Roman cement was not generally suitable for making concrete, because of its speed of setting and its inability to perform in any but very rich mixes, which made it difficult to use and disproportionately expensive, but nevertheless in spite of these shortcomings it was used in river and tide work.

The exceptional waterproofing properties of Roman cement and its bond to brick, tile and iron, but not to its hardened self, also made it indispensable to 19th century engineers, architects and builders. The specifications in T L Donaldson's *Handbook of Specifications* of 1859 show the extensive use of Roman cement by leading architects at a date when it would have been expected to be being eased out by Portland cement. A typical example is Thomas Cundy's specification for No. 19 Grosvenor Square, dated 1855. This mentions both Roman and Portland cement, and includes a number of clauses requiring cement, presumably of either type at the discretion of the builder, to be used for jointing salt glazed drainage, and for brick vaults and tile arches. However it specifically requires Roman cement for arches over openings in walls, as bond courses in all walls, and for waterproof rendering, as follows: [11]

- "*Turn arches* in Roman cement over all the external door and window *openings*, and over such of the internal openings and arches as are so directed by the drawings, the ends of the lintels being splayed off to spring the arches from the brickwork."
- "To build the brickwork in Roman cement, entirely through the thickness of the walls at the level of the several floors, 2 feet deep on the ground and one-pair floors and 18 inches on the floors above."
- "*Basement Cement work* - Form in Roman cement, to a height of 4 feet, the walls of the whole of the basement and kitchen offices, except those of the Housekeeper's and Butler's rooms;"
- "Form in Roman cement the splayed jambs to the openings of the bridgeways for light."
- "Form in Roman cement the whole of the door and window jambs not intended to have linings or shutters."
- " Form in Roman cement the angles and jambs of all the archways also the angles of the chimney breasts."
- "Roman cement skirting, 1/2inch projection and 7 inches high round the Housekeeper's and Butler's room."

William Tite specified Roman cement for bond courses and other sensitive locations in the construction of the new Royal Exchange in 1841[12] and Charles Barry required its use in "such parts of the brickwork or arches as may be directed" in his specification for the new Houses of Parliament.[13]

These quotations confirm that the special properties of Roman cement were appreciated and used by architects at a date when most modern authorities wrongly report that it had been almost entirely superseded by the Portland variety. Many of the following references confirm that its use survived for particular purposes to the end of the nineteenth century and beyond. The inclusion of strength requirements for Roman cement, alongside Portland cement and hydraulic lime, (tensile strengths of 200, 350 & 60 lb/sq in respectively) in the Glasgow Building Bye-Laws in 1892 indicates it was still in common use at the end of the 19th century.[14]

VARIETIES OF ROMAN CEMENT

Roman cement is made by burning cement-stones, or septaria, in a kiln "with a heat stronger than used for burning lime" as described in the Patent specification.[15] The cement-stones used by James Parker in 1796, and which were the subject of his Patent, came from the coast at Sheppey. They occurred naturally on the beach from whence they were gathered. Latterly they were dredged from

the seabed. It was also known as Parker & Wyatt's Cement, because it was promoted by Parker's partner Charles Wyatt and possibly also the more famous Samuel Wyatt after Parker emigrated to America.[16] Large accumulations of cement-stones were found where London clay bordered the shore, from the alum-shale on the coast of Yorkshire [17] and also elsewhere.

Varieties of Roman cement were generally known by the name of the manufacturer or by the location of the cement-stones. The principal brands were:

Harwich or Frost's - several mills listed by Thurston[18]
Francis or Grellier's - made at Millwall[19]
Atkinson's or Mulgrove's - from Whitby in Yorkshire
Calderwood - from Glasgow
Medina - from Hampshire and the Isle of Wight[20]

Francis lists a number of other manufacturers in London and elsewhere.[21] In his important paper on early Portland cements, Sir Alec Skempton explains the chemistry and the difference between Roman and Portland cements and includes contemporary reports of comparative strengths.[22]

Wilfred Kemp in his *Practical Plasterer* said that Medina might be considered as a superior quality and that it was of a somewhat lighter colour[23]. Millar said "it is stronger than Roman" and "sets a light brown colour, and very rapidly - almost as soon as it leaves the trowel." [24] This indicates further confusion because some writers distinguish between Roman cement and other brands of what was a very similar material, as shown by the prices in Laxton:[25]

Roman CEMENT, (best) per bushell	2s 6d
Ditto, Parker & Wyatt's, best of all Sheppey stone	4s 6d
Harwich or Frosts cement	2s 2d

which infers that Parker & Wyatt's was significantly superior. Peter Nicholson insisted that Atkinson's was "a much superior article". It is, he said, "a little higher in price, but will bear a great deal more sand"; it " is of a more delicate stone colour, and for situations exposed to the actions of water, not to be surpassed by any cement now in existence." [26]

Cement-stones were discovered in Boulogne, also in Burgundy and Russia.[27,28] Roman cements were also manufactured in America, and particulars were given in Rivington's *Notes on Building Construction* (1910).[29] Draffin gives details of natural cements used in America, which were still being manufactured in appreciable quantities in 1940.[30]

Roman cement mortars seen in south-east England can be recognised by their pinkish brown colour. It is possible that Roman cements from elsewhere may not be similar in colour.

QUICK SETTING

Roman cement's main characteristic, which contributed to its initial success and was the reason it continued in use, albeit in small quantities, until the 1930's was its speed of setting. Millar said "Roman cement is an admirable material where great rapidity in setting is required, and is very useful for repairing jobs", and "its quick-setting properties necessitate a great deal of skill and attention on the part of the workman, and it must be applied as soon as gauged." [31] Nicholson's *New Practical Builder* recommended that "the composition should be used as quickly as possible, and not a moment lost in floating the walls, which will require incessant labour, until the cement is set, which is almost instantaneous." [32] This characteristic, mentioned in almost every reference, meant that it was not particularly easy to use, and was unsuitable as a direct substitute initially to lime, with or without a puzzolanic additive, or latterly to Portland cement. When stuccoing with Roman

cement, it was applied worked up and finished in a single coat, because the bond to set material was poor,[33] as opposed to its bond to brickwork which was exceptional. Presumably plasterers working on stucco had an assistant on the scaffold with them continuously mixing small quantities for immediate use.

The property of setting quickly was the reason Roman cement survived well into the twentieth century, particularly for repairs and for running mouldings. Verrall in 1930 preferred Portland, but still found Roman cement "easier to run mouldings than in Portland cement, because no driers are required". Also, "it can be followed on by painting" which no doubt made it useful to have small quantities handy for repairs.[34] Millar found it very useful in repairs, because it set rapidly and could be painted immediately. [35]

Speed of setting was also the reason Roman cement was useful for tide work as described below.

USE UNDER WATER

Tide work of course also required a hydraulic material that would set under water. This was the property of Roman cement for which Parker's Patent claimed, in the title - "A certain Cement or Terras to be used in Aquatic and either Buildings and Stucco Work". It was the property cited in the letter from Thomas Telford quoted in Thurston. This letter was written on 12 April 1796 to John Mackenzie, Secretary to the British Society for the Fisheries, and told of experiments Telford had made for the Society, concluding that as a consequence he was "fully justified in recommending to the Directors to use Mr. Parker's Composition in the place of Dutch Terras, in constructing of the Pier at Lochbay in Skye." [36] This experience of the properties of Roman cement prompted Telford to use it to joint the stones forming the sides of the trough of Chirk aqueduct, and for the outer joints of the wharves at Aberdeen constructed in 1840.[37]

Thomas Martin recommended Roman cement "as of great utility in dock works"[38] and similar recommendations were made in Nicholson,[39] Sutcliffe[40] and Mitchell:[41] it is interesting to note that Rivington's expanded the description of this instance of its use in the later edition.[42,43,44] Henry Reid is one of the few authorities who mentioned Roman cement concretes, which were frequently employed "where much running water prevents lime or Portland cement concrete from setting quickly enough for such works."[45] Roman cement was used to point the joints of the masonry of the Bell Rock Lighthouse,[46] and of the lower parts of the piers of the Menai Bridge to prevent erosion of the lime mortar. "In short", said Pasley, "no substance with which I am acquainted, excepting cement, is capable of resisting the violence of the waves or of running water." [47] Rennie found Roman cement useful at Grimsby Docks.[48]

The property of natural (Roman) cements responsible for their continuing use at the end of the nineteenth century was their ability to set in a few minutes: hence they could be used where a slow setting cement would be washed away.[49] Indeed the Royal Engineers continued to use Roman cement into the 1880s for marine works because its quick setting properties allowed work to be done between tides.[50]

Swan quotes *Specification* for 1918, in which the Municipal Engineers' section recommends the use of Roman cement particularly where its rapid set gives it an advantage over Portland cement, such as in underwater works and tidal situations as a covering for Portland cement while it sets.[51]

ROMAN CEMENT CONCRETE

The speed of set meant that Roman cement was not easy to use for concrete. Robert Smirke[52] carried out a trial at the New Custom House, in 1826, "in which he grouted two equal parts of gravel, the one with Dorking lime, the other with Roman cement, it was found that the latter would not answer at all, for, instead of becoming harder, the mixture fell to pieces".[53] Laxton gave prices

for brickwork in Roman cement mortar and in lime mortar, but concrete for foundations was composed of Dorking lime and gravel, indicating that Roman cement concrete was not in general use. [54]

In 1869, Henry Reid described the use of Roman cement concretes for tide works, but it was seldom used for general concrete purposes because "it cannot be used with a large proportion of aggregates" and hence was more costly. He also warned that "... its quick setting properties requiring great care in avoiding the danger of disturbing its induration after the initial set has been accomplished." It should be mixed dry with not more than four parts of aggregate and then carefully wetted with a spray of water. "Roman cement concrete should not on any account be rammed, as the action of the rammer would disturb the indurating action which speedily sets in." [55] Reid also said that the Americans used natural cements for concrete, and sometimes with lime, and their experience of such a combination was most satisfactory.[56] It appears that American natural cements were more finely ground and set more slowly than British natural cements.

Roman cement concrete was used in the construction of the floors of the Rainbow Tavern in Fleet Street in 1860 but it is probable that this was as much for bedding the 7 ft. x 3 ft. slabs of slate forming the floor finish as for filling the haunches of the brick arches spanning between the cast iron beams[57]. The use of Roman cement for tile bedding was mentioned by Sutcliffe.[58]

In 1838, Pasley said cement should never be used for making concrete because it would not set if leaner than 1:2 whereas lime concrete could be 1:7 or 8 and even then would be no better, so the vastly increased cost was not merited.[59] Medina cement was however evidently found suitable for a leaner mix, as in the pair of cottages built in 1:6 concrete in the Isle of Wight in 1852 described in the *Civil Engineer and Architects Journal*, and for no fines concrete military huts.[60]

BRICKWORK IN ROMAN CEMENT

Before the twentieth century, most brickwork in buildings was built in mortar made from lime and sand, which took some time to set. There was a consequent risk of small movements whilst the mortar was still soft and longitudinal or bond timbers were built into walls "to prevent those partial settlements to which new brickwork is always liable".[61] Courses of brickwork laid in Roman cement mortar were introduced as an alternative to bond timbers, and Roman cement mortar was used in other locations such as arches, where movement could result from squeezing out of the still soft mortar.

Nineteenth century price books give rates for brickwork in Roman cement[62, 63, 64] as well as for brickwork in lime mortar, but not for Portland cement mortar, implying that Roman cement and lime were in common use for general building work, but Portland cement was not. Comparative costs per rod in various price books were:

1839 (Laxton)	Stock brickwork in Thames sand and stone lime	£13. 16. 6
	Ditto in Roman cement	£17. 6. 0
	Ditto in Harwich cement	£16. 14. 0
1862 (Skyring)	Stock brickwork in mortar	£14. 0. 0
	Ditto in Roman cement	£17. 0. 0

Robert Smirke used Roman cement for bonding courses as an alternative to chain bond timbers (bond timbers placed in the centre of a wall) in the construction of the new County Court House at Maidstone in 1826. The handsome stone fronts of the building were generally backed with bricks and rubble stone, interrupted at intervals with three or four courses of bricks laid in Roman cement[65] He also incorporated brickwork in Roman cement in the upper part of the underpinning to the London Custom House (Fig. 1).[66]

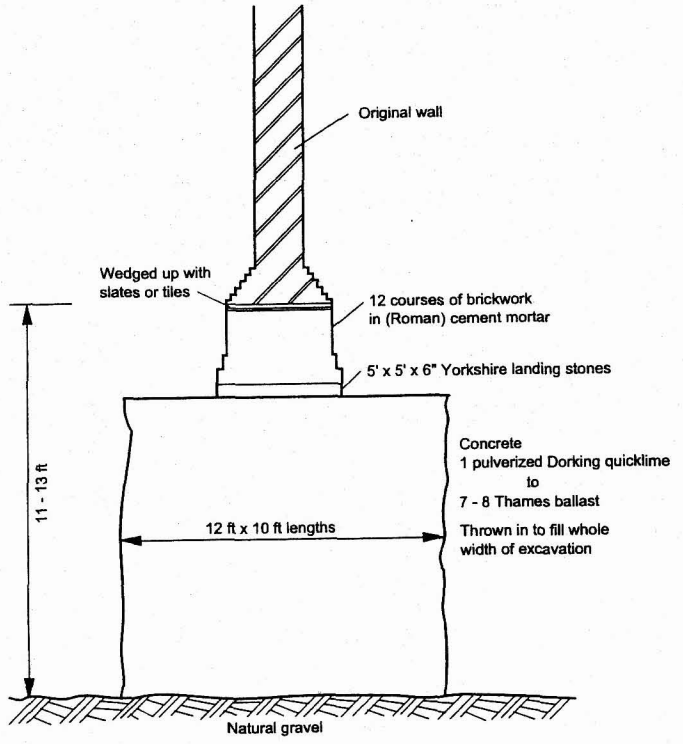


Figure 1. Robert Smirke's underpinning of the London Custom House 1825 as described by Pasley.

The walls of the tank for the gasholder constructed by Mr John Aird in 1858 at the Independent Gas Works at Haggerstone "were built with (lime) mortar, with rings of brickwork in (Roman) cement introduced at intervals for the purpose of strengthening them, and enabling them to resist the treacherous movements to which the London clay is subject." Similarly Mr Methven incorporated six courses of brickwork in Roman cement in every five feet to strengthen his 145ft diameter 55ft deep tank for one of the gasholders at King's Cross (Fig 2.).[67] During alteration works on St John's Lodge in Regents Park, when stucco dating from c.1830 was removed from an external wall, Roman cement mortar bedding to the flat arch and the reveals of a door opening were revealed, the remainder of the wall being laid in lime mortar. Roman cement was used in these critical locations presumably because of its speed of setting, superior bond, and strength. It is also interesting to note that the wall was wholly built of place bricks, except for the flat arch and any brick in the reveals that had to be cut, which were yellow stocks. The bricklayers clearly knew that the poor quality friable place bricks would shatter if struck with the trowel to cut them and could be less than satisfactory under pressure in an arch, and so turned to the more expensive stocks to avoid problems in these locations.

Pasley reported instances of spalling of bricks in walls laid in common (lime) mortar and pointed with cement[68]. It is interesting to note that the implications of this practice were recognised nearly two centuries ago, but many individuals working on old buildings still fail to know about it or

understand it today. Brunel used Roman cement for the remarkable reinforced brick cantilever semi-arches he built near the entrance to the Thames Tunnel[69] and Pasley proved with his tests on reinforced brick beams that Roman cement could perform tasks for which lime mortar could not (Figs. 3-4).[70]

Roman cement walling was useful for alteration or repair, because of its quick setting, or when in a hurry. For example it was used for the temporary houses for the Lords and Commons "finished in a dry wholesome state ready for use, in the short space of three months after they had been destroyed by fire in 1834, although the work was executed in a very unfavourable season".[71] It appears likely that brickwork in Roman cement was used throughout much of the nineteenth century in sensitive locations to provide bond and strength in walls of buildings, and possibly also as an alternative to bond timbers, but because it is concealed behind stucco or plaster it has passed unrecognised.

TENACIOUS BOND

The extraordinary bond of Roman cement to bricks was demonstrated by the tests carried out by Francis, White & Co. at their cement works in Lambeth, and also by the Royal Engineers at Chatham. In these tests a pier was built out horizontally from a wall using neat Roman cement (Fig. 5). The cement was mixed, applied to one face of the first brick and the brick held against the wall by the bricklayer holding the point of his trowel firmly against it. He then mixed the cement for the next brick, applied it and similarly held it for two or three minutes. Using an average quality cement 18 or so bricks could be stuck out from the wall before the pier collapsed and Messrs. Francis, White & Co. repeatedly stuck out 29 bricks in this way, (to form a cantilever about 7 ft. long).[72] Skempton says that practically every cask of cement used in construction the Thames Tunnel from 1825 onwards was tested in this way.[73] Subsequently Pasley used direct tension to compare different cements and their bond to bricks and stones. He also demonstrated this tenacity

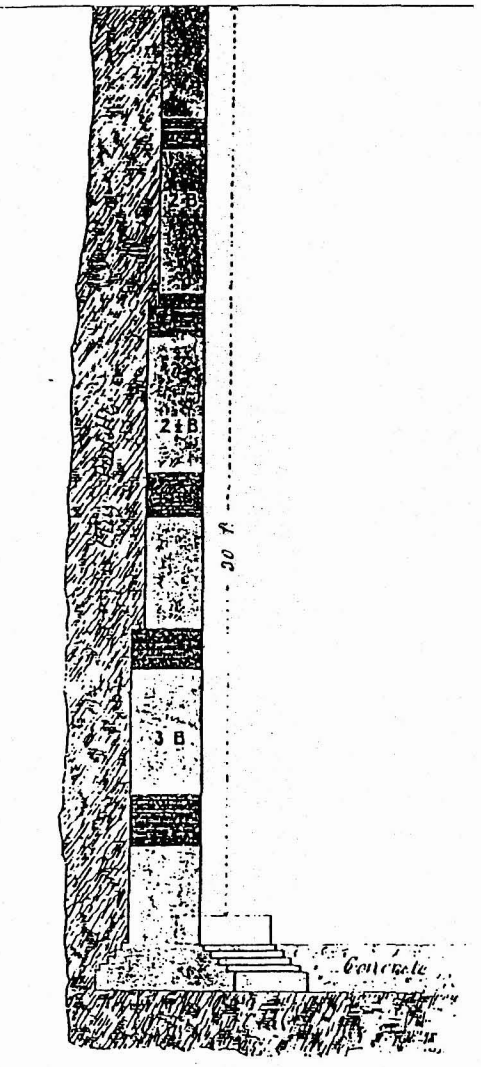


Figure 2. Gasholder tank walls incorporating Roman cement bond courses 102ft. 5in. diam and 30ft. deep (from *Clegg, Treatise on the Manufacture and Distribution of Coal Gas*, 1866)

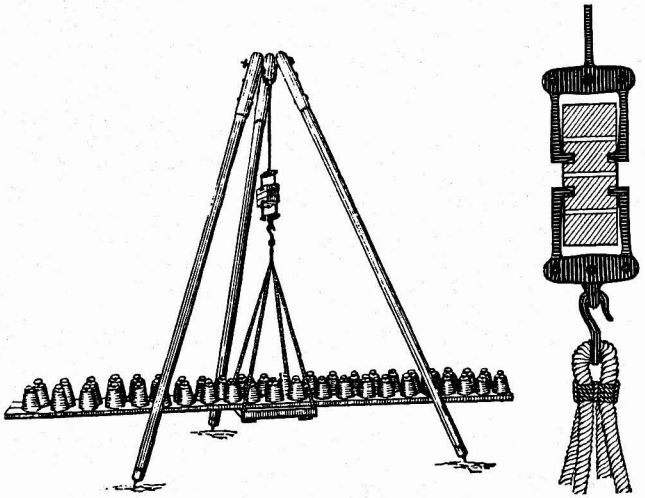


Figure 3.
Pasley's tesion test for cement and lime mortars (from *Pasley, Observations on Limes...*, 1847).

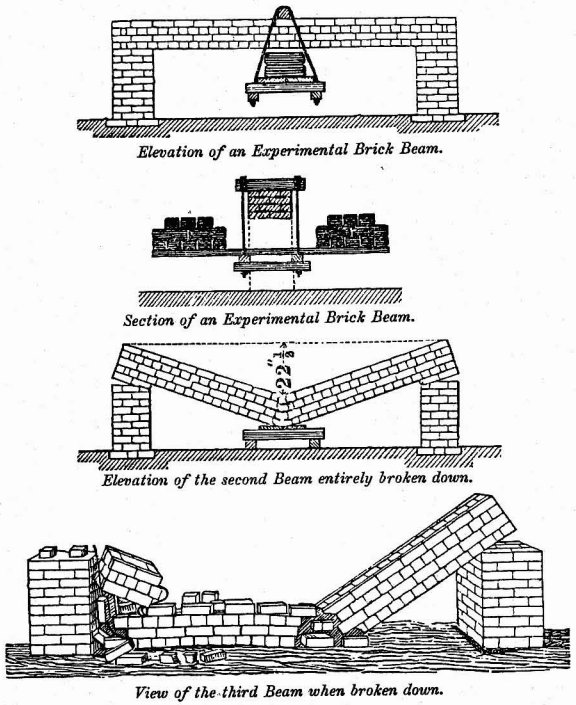


Figure 4. Tests on reinforced brick beams. Top- Roman cement mortar failed with 4532lb: bottom- lime mortar failed miserably with 742lb (from *Pasley, Observations on Limes...*, 1847).

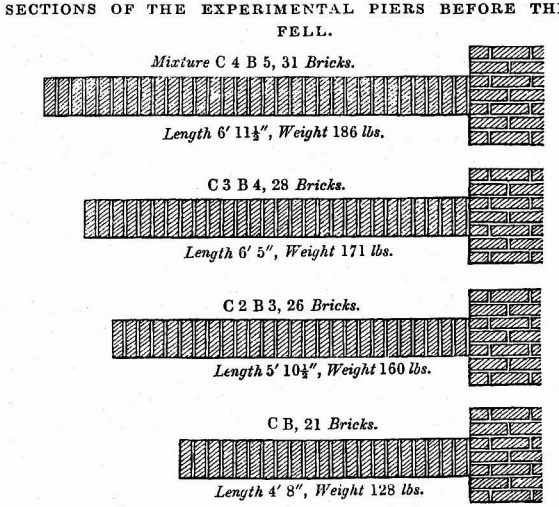


Figure 5. Horizontal piers built out from a wall to compare and test Roman cements (from *Pasley, Observations on Limes...*, 1847).

by building a small summerhouse with a pagoda roof and cantilever eaves, wholly of brick and tile laid in Roman cement (Fig. 6).[74]

TILE CREASING

Charles Fowler[75] took advantage of the tenacious bond of Roman cement to tiles in his tile creasing for terrace roofs. He used three layers of common plain clay tiles bedded and jointed in neat Roman cement, well bonded and rubbed down closely upon each other. In 1831 he adopted this construction for the flat roofs at Hungerford Market, where it spanned about 4'6" between cast iron beams, and sustained crowd loading. No additional waterproofing was needed because the Roman cement served this purpose, as well as providing the bond to ensure structural integrity of the construction. Because this construction was sensitive to slight movements which could cause cracks through which water could leak, he built the walls "in cement, to prevent compression".[76] I.K. Brunel also used this form of construction as the roof over a detached drawing office on the park side of his house at 18 Duke Street, Westminster (Fig. 7). The tile creasing spanned 5 ft. between cast iron beams and carried earth forming the garden.[77] Barry used tile creasing shallow arches for the intermediate floor in the roof over the House of Lords, presumably as a fire barrier.

Tile creasing was extensively used in domestic construction, for roofs over basement rooms and floors of entrance halls with tile finishes, where it can still be found. Sometimes it was arched and sometimes flat. Mr. Frost proposed a similar fireproof floor construction using extruded fireclay tubes, 2½" square, laid in two courses, at right angles to each other, jointed and grouted in pure cement, to span 8 or 10 ft.[78,79]

A recent collapse of a cast iron beam carrying a terrace at the rear of a house in Hyde Park Gardens dating from 1836 has revealed that the original waterproofing was non-structural tile creasing in Roman cement, laid on lime concrete infill above half brick arches spanning on to the bottom flange of a cast iron beam. The half brick arches were laid in Roman cement, were covered with a Roman cement screed, and had their soffits rendered in Roman cement.[80] The architect - Thomas Crake - was clearly concerned to ensure that water did not penetrate his construction by including three separate layers of Roman cement.

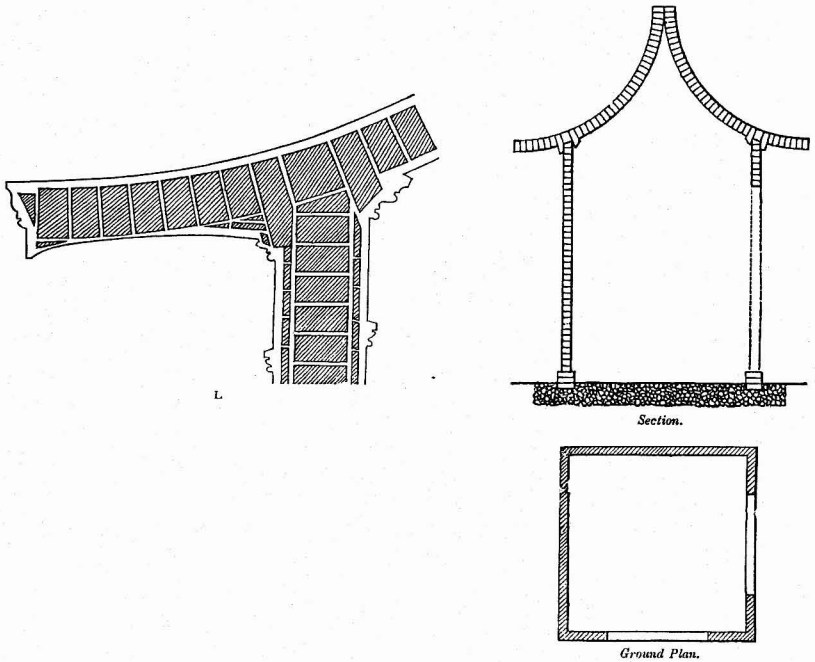
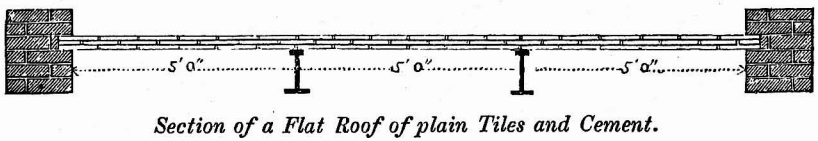


Figure 6. Summer house at Chatham built of brick and tile set in Roman cement mortar (from *Pasley, Observations on Limes...*, 1847).



Section of a Flat Roof of plain Tiles and Cement.

Figure 7. Tile creasing spanning 5ft. over I. K. Brunel's drawing office at 18, Duke Street, Westminster (from *Pasley, Observations on Limes...*, 1847).

WATERPROOFING

Pasley reported many instances of the use of Roman cement as a waterproof render or screed, and this was probably one of the reasons it was extensively used for stucco.[81,82] He used a Roman cement screed over casemates (rooms for storing ammunition), over arched roofs of basements, to ensure they remained dry, and for lining cisterns. Nicholson said it is "most extensively used for lining cisterns tanks, reservoirs, &c." [83] Roman cement waterproof render was used by Thomas Cundy in the basement of 19 Grosvenor Square, as quoted earlier and an old pinkish render was exposed recently on a damp basement wall in a building in Chesterfield Street in London, indicating that Roman cement was probably more widely used for this purpose too than is generally now realised.

Pasley advocated brickwork in cement mortar for sleeper walls supporting ground floor joists and also several courses of brickwork in cement mortar immediately above the level of the earth, as a damp proof course.[84] Telford used Roman cement in the foundation of the roadway on the Highgate Archway, and found it was easier to lay it insitu than precast.[85]

TUNNELS

Mr Gravatt said that 1500 casks of Roman cement were used in the brickwork of the Thames Tunnel,[86] neat in the arches, one to one half of sand in the piers and one to one in the foundations according to Reid.[87,88] Pasley also averred that "The tunnel would not have been built if this or a similar quality of cement had not been accessible" (Fig. 8). Francis provides further contemporary particulars of the construction of the Tunnel brickwork and the use of Roman cement.[89] This all confirms Pasley's statement, that: "if the use of this admirable material had not been discovered, the execution of the Thames Tunnel would have been impracticable, for if it had been attempted in the very best mortar, the pressure of earth would have crushed some parts of the brickwork before the mortar got consolidated, and in other parts the lime would have been washed out of the joints, as was the case in a new basin in Chatham Dock-yard".[90]

Robert Stephenson told Pasley that "he makes it a rule, deduced from experience, never to use lime mortar in the arches of tunnels, but to build them with cement exclusively." [91] Mike Chrimes has recently shed further light on the reasons for this statement. At the Primrose Hill tunnel on the London to Birmingham Railway when "mortar began squeezing out of the brickwork joints, and the inner edges of the bricks were crushed" by the forces exerted by the clay, he substituted 'paving' bricks set in Roman cement mortar for the London stocks in lime mortar.[92]

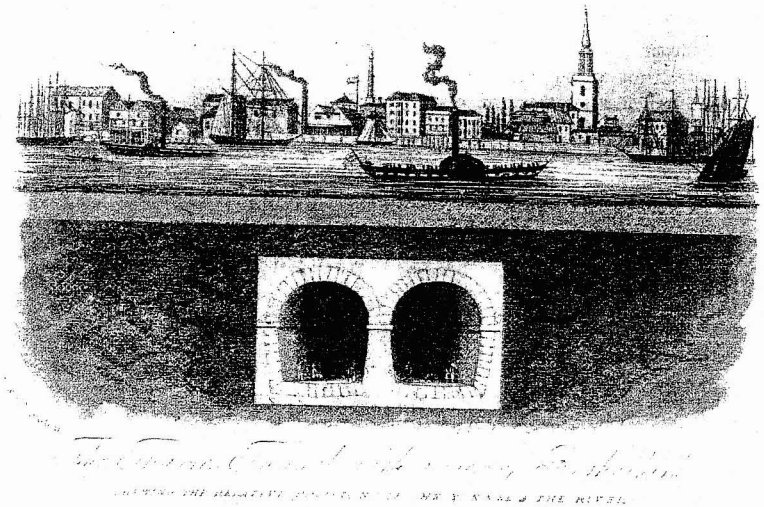


Figure 8. Section thorough the Thames Tunnel, which could not have been built without the tenacious bond and waterproofing properties of Roman cement.

OTHER USES

Messrs Parker & Co, the Patentee of Roman cement, advertised that they manufactured "Coping-stones, Window-Sills, Blocking and String Courses, Balustres, Gothic Ornaments, and other works of this nature", and Pasley [93] and Verall advocated its use for casting[94]. Generally cast items were made of Roman cement mortar packed with pieces of broken brick and tile, rather than Roman cement concrete. When the paint was removed from the external walls of St John's Lodge in Regents Park, components of the embellishments to the stucco could be seen to be the characteristic brown colour of Roman cement, and to be precast. Pasley mentioned precast ornamental vases, chimney pots and ridge pieces. [95] In the discussion at the RIBA in 1863, following the presentation of a report on artificial stone, the well known manufacturer of terracotta J.M. Blashfield mentioned a house built of Roman cement concrete blocks that he admired and described his efforts to make similar blocks.[96]

Iron reinforcement was used in the brick beams built by M. I. Brunel and Charles Pasley, but no references have been found that would explain the problems in the Holborn district of London in 1916, described by the District Surveyor in his paper to the Concrete Institute on dangerous structures: "In my district there are many parapets with balustrades of Roman cement containing iron cores which have rusted, bursting the balustrades so that pieces fall on to the footway." [97] It is suggested that these balustrades were precast, and needed iron cores for handling.

Henry Adams said Roman cement was used for setting coppers and parging flues, for which the quick setting and bond would have been useful,[98] as was probably found by Simpson when he recommended Roman cement for jointing pipes.[99] Bond was the reason that the late B.L. Hurst's notes (c1895) showed Roman cement render on the underside of the joists on the soffit of a filler joist floor, where he knew plaster would be unlikely to stick. Quick setting was no doubt the property appreciated when advocating Roman cement for tile bedding.[100]

CONCLUSIONS

The frequent references cited in this paper indicate that Roman cement was an important material in the British construction industry throughout most of the nineteenth century and that its use continued well into the twentieth century, particularly in the plastering trade for repairs. Its properties - quick setting, exceptional bond and ability to exclude or retain water - were well understood, and consequently it was used extensively where its greater cost over lime were justified and where its performance was superior to the Portland cements then being developed.

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