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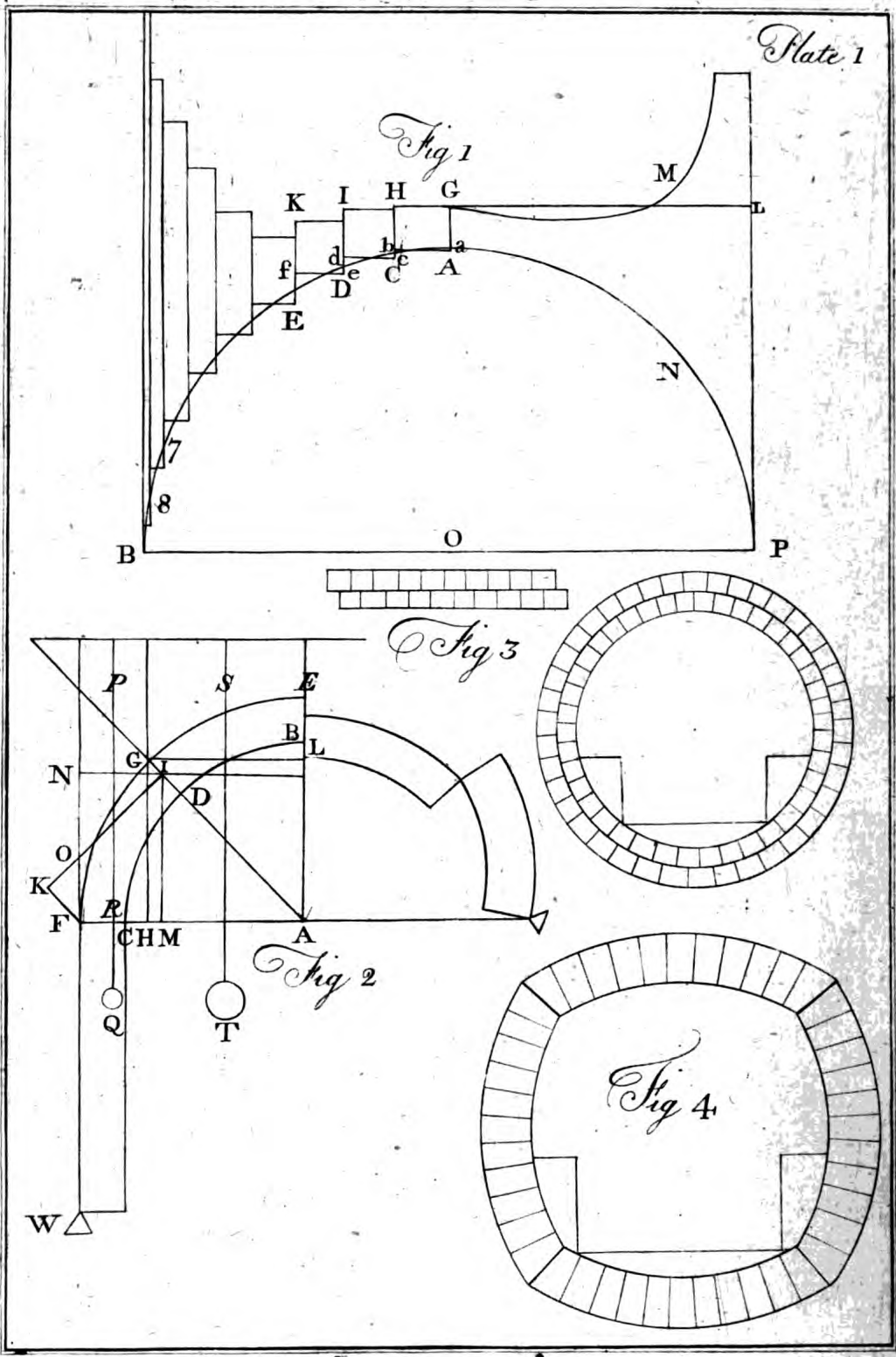
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OBSERVATIONS
ON THE
INTENDED TUNNEL
BENEATH
THE RIVER THAMES.



OBSERVATIONS
ON THE
INTENDED TUNNEL
BENEATH
THE RIVER THAMES;
SHEWING
THE MANY DEFECTS
IN THE
Present State of that Projection.

BY CHARLES CLARKE, F. S. A.

HAUD INSCIA, AC NON INCAUTA FUTURI.—Hoi

GRAVESEND;

PRINTED BY R. POCOCK; AND SOLD BY MESSRS ROBINSONS, PATERNOSTER-ROW;
AND J. TAYLOR, HOLBORN, LONDON.

1799.



INTRODUCTION.

EARLY in the month of June last, accident threw in my way Mr. DODD's first report on the *Gravesend Tunnel*, then in Circulation through the Counties of Kent and Essex. While a certain greatness of idea was very striking, and that it might be extensively useful, was not less evident, it was impossible not to discover a degree of inaccuracy in arrangements materially affecting the probability of existence, and obstructing the purposes for which it was designed; arising as it was clear from a want of that information in the projector, which must form the basis of every practice in building, to render it just and effectual. From long habits of acquaintance with works on architecture and the art of the Engineer, as well home as foreign, having myself been at an early period designed for the first of those professions, I was not to be informed that the most eminent men had upon the results of theory adjusted every performance of magnitude, and that the specimens of art we now behold with pleasure as the ornaments of the land we inhabit, derive all their stability from the scientific knowledge of their constructors. But leaving what was done in the early and middle ages, if we approach toward the times we live in, and go no further than this nation: if the pains taken by so able a mathematician as the excellent *Sir Christopher Wren*, for discovering the best forms of vaulting, and the position and quantity of the

piers in his great work St. Paul's, at London, are worthy imitation; or those of *Mr. Labelie* for the security of that fine structure Westminster Bridge; in the present undertaking of not less hazard, whose failure, from the singularity of the attempt, will draw with it a certain portion of ridicule on the Nation itself, it was not unreasonable to hope, to discover an equal degree of precaution, founded on the better rules possessed in these more modern times. Thus destitute, from upright motives was it, that certain moderate strictures were offered to the consideration of the Tunnellist, through the extensive medium of the Gentleman's Magazine, not a word was let fall on the authorities for the amendments proposed, they must be well known it was imagined to the projector of such a work as the Souterrain, every allowance became due to a hasty sketch and a first report, and although it has otherwise happened, it was hoped the author would have found cause for obligation to that attempt at correction, managed as it was; the points on which those corrections turned, were, First, a due regard to the curvature of his arch; Secondly, the disposition of the Vouffoires; Thirdly, the shape of the thing itself as it was designed, as a means of extensive traffic. For the sake of avoiding mathematical apparatus, half a circular arch with its bounding wall when kept in equilibrium was copied from the celebrated little work, "The Principles of Stone Bridges, by *Dr. Hutton*," well known it might be supposed, to every arch builder, and other references made to the same book.

On the 18th of July following, Mr. DODD exhibited a picture of the project at this place; it was too late to recede upon the motives suggested in the magazine, which did not appear till August. This exhibition was succeeded by a Pamphlet, in which were given a representation of the Tunnel, the superincumbent River, a View of the surrounding Country, with Plans and Sections, a fair Report in addition to the first, and certain pages of information deemed pertinent to the subject. It was then thought proper to assert, that an accession of strength could not be obtained by any attention to curvature or equilibration, and that its shape and construction were every way answerable to the end proposed, *et spargere voces in vulgum*. But difficult as may be the problem on the mechanism of arches, and deduced as are the methods of determination in particular cases, from the higher Geometry, I hope to shew in a very few words, to every one acquainted with the use of figures and a pair of compasses, that an attention in this way is of the highest moment in the present case;—this with the conclusions

clusions deducible, are intended to serve as *Lemmata* for illustrating the succeeding observations, designed as a Review of Mr. DODD's Projection and Pamphlet.

Let A B (*Fig. I.*) represent the half a circular arch, and let it be divided into any number of equal parts, suppose into nine, A C, C D, D E, &c. on the points of division, let the perpendiculars A G, C H, D I, &c. be raised, and the lines a b, c d, e f, &c. be drawn. If then on every division, an equal quantity of weight, or what amounts to the same, of matter of the like density, be placed, as shewn by the small incumbent parallelograms, the pressure on every one of the indefinitely small lines, a b, c d, e f, &c. must then be equal, and it is evident as they become the more narrow, their heights, must reciprocally increase; for each being formed to contain the same superficies, as their breadths become less, the greater will be their altitudes. But because those parallelograms are not incumbent on horizontal bases, but on the curvature of the arch, the following consideration will be necessary for obtaining a nearly complete idea of their true heights. Let the points of division, A C, C D, D E, &c. be joined by right lines, and the curvature will become a series of inclined planes, now having assumed the quantity on the plane A C, it will be evident, that the pressure may be rendered equal on the next plane C D, which has a somewhat greater inclination, the weight or height of the D H, must yet undergo an increase above what was found on the first consideration; for the greater the inclination of the plane, the less resistance does it make to the descent of the weight along its surface, and proceeding in this way downwards it will be evident that planes 7 8, and 8 B, from the greatness of their inclination will cause the height of the incumbent parallelograms to be increased to an exceedingly great degree.

Let now the series of planes in the circumference be conceived as infinite, and a curved surface will immediately present itself to the mind, on which being placed by means of a general theorem obtained from these or other suitable considerations, a height of walling in every point of the arch, it would then be in a state of equilibration, and appear as in the other half of the figure freed from the lines necessary for investigation, and have no more tendency to burst in any one part than in another. But it will be immediately alledged, that in practice no arch can possibly be allowed to be secured by such form of walling placed

placed above it, but must be terminated by an horizontal line, as GL , by which the portion of weight above ML being removed, the scheme NA , becomes too heavy for the hances NP , and the arch bursts about the point N , which is a constant effect, and it is thence named the weakest part of the arch.† It will further follow upon inspection alone, that it is only the scheme of the circular arch which can be admitted with any propriety in a work where much strength is required, as the termination of the weight laid upon this part when the arch is in equilibration, differs not very much from an horizontal line, and that the hances in arches of this kind should be wholly omitted when under a like termination of matter as having so great an aberration from a state of equipoise and depending wholly on abutments for stability.

That we may be enabled to shew the propriety of these deductions, obtained from an exact theory, let us now endeavour a little more palpably to approximate the consequences of Mr. DODD's construction at about thirty feet below the bed of the river, with seventy-two of water incumbent at the greatest depths, and exposed to a pressure of above two tons weight on every square foot. Thus placed, it is evident that the water exerts a force along the scheme of the arch, from G to E , (*Fig. II*), which by the most evident property of gravitation, has a tendency to thrust it downwards along the line GH , and by its action upon the lower part or hance, FD , endeavour to force it to turn upon the fixt point or fulcrum, F , till the whole shall have arrived in the position represented in the other half of the figure, which would be the precise moment of destruction. This can only be prevented by the resistance of the hance beneath its load of matter pressing downwards in a column, whose base is equal to FH , it will be now necessary to compare the force and resistance together, and this shall be done on the properties of the wedge and lever, as most familiar. Let us now imagine that the lines PQ . and ST , as passing through the centers of gravity of the respective columns, and their whole weights united in P and T . It will be readily also conceived, that the whole scheme of the arch has the likeness and

† This will be further increased when it is remarked the stone of the arch is about twice as heavy as the chalk with which the spandril or space $GBLA$ above it is to be filled, the specific gravities or weights of equal volumes of these substances being as 2,500 to 1,793.

properties of the wedge GLA , of which it forms a part; and acted upon by the weight T , the direction of its efforts for overturning the hance, will be at right angles to its side GA ; the hance is further to be considered as a lever, draw IK , the direction of the force T , and on account of its obliquity to FD , its length as a lever will be reduced to KF , a line at right angles to KI , at the point F ; again FR , the distance of the point F from the line passing through the center of gravity PQ , is also to be considered as a lever acted upon by the weight Q , and thus resisting the effort of T . Now the weight of a cubic inch of seawater is, 0372530 decimal parts of a pound avoirdupoise; this drawn into 1728, the cubic inches in a foot, is equal to 64,3731 lbs, which again multiplied by 72 the number of feet in 12 fathoms, the greatest depth in extraordinary spring tides, produces 4634,8632 lbs, or 2 tons 154 lbs the pressure on every horizontal square foot on the Tunnel, for above 150 fathoms in length. This then exerts a force on the half scheme of the arch GE , equal to 7,071 the feet in GL , drawn into 4634,8632 lbs equal to 14,6308 tons in the direction ST . Again by the property of the wedge the power is to the force it exerts for splitting the arch, as GL its head is to its side GA ; we have then this analogy as 7.071 is to 10, so is 14,6308 to 20,691 the force exerted in the direction IK ; this, to find its whole effort against the point F , is to be multiplied by KF , which is thus found. From AF 10 feet take MA , 6,36 feet half the side of a square inscribed in a circle of 9 feet radius, viz. that of the Tunnel added to half its thickness, it leaves 3,64 or NC , this again taken from 6,36 or NF , leaves 2,72 for OF ; then because the triangles OKF , and GLA are similar, it will be as GA 10 is to GL 7,071, so is OF 2,72 to KF 1,923, this drawn into 20,691 gives 39,7887 for the force exerted by the scheme. But this is resisted by the hance of the arch FD , its effort is thus discovered and compared. From AF 10 feet, take AH 7,071, its remainder 2,929 is equal to FH , the breadth of the column of water insistent on the part of the arch FG ; this drawn into 4634,8632 and divided by 2240 gives 6,0605 tons, this again multiplied by 1,464 FR its correspondent arm of the bent lever KFR taken equal to $\frac{1}{2} FH$, produces 8,8735 tons, its whole force for resisting the action of the upper part, and therefore subtracted from 39,7887 leaves 30,9152 for the excess of the pressure above the resistance arising only from the force of water. But the chalk immediately about the arch has a claim to our attention. The specific gravity of this

this substance is 1,797 the weight of a cubic foot 112 lbs, and estimated at 30 feet above the tunnel, and proceeded with as before, will produce a further excess of lateral pressure of about 19 tons, and added to the former it becomes 50. This is frequently to be opposed by the matter surrounding the hances, while twice daily must a drift of 45 or 46 tons be contended with, and never less than nearly 37 at the lowest tides.

Thus we see the consequence of neglecting the equilibrate arch, in which the force and resistance would in every point have destroyed each other, let us then endeavour to point out what may be expected to follow; First, the clay which is to surround the tunnel for the space of 12 inches must yield to so much force, it being impossible by any known method in so small a space to give it an equal degree of compactness; hence the four hances giving way for several inches its apex and lower part will shoot in as their supports are driven off, with the danger of fractures to the arch stones at the ends, and a general weakness to the whole. Secondly, Should it be led through a stratum of clay, loose sand, or other compressible matter, the same effect in a greater degree must be evident; as it must also from fissures, chasms, or other vicinal circumstances of the same nature far from improbable immediately beneath the bed of the river, although unforeseen by the confidence of Mr. DODD, or touched by his plumbet or boring engine. And lastly, The direction of the pressure is the worst for stability possible, it being perpendicular to the lowest part of the arch, along the line A G, against the bottom of the river, while the resistance opposed by the water is much diminished on account of its obliquity, and the swamped chalk giving way with not much greater difficulty than the water itself; while had it been placed on a pier or upright wall the center of motion must have been removed to W, and the direction of its force horizontal and incalculably strong, and if not from accidents in the way, it could with ease be rendered sufficiently so. But it may yet be supposed, and I know it is asserted that the chalk will not only support itself, but also the water above it in the lowest part of the river, and thus the tunnel can feel no effect whatever from that vast superincumbrance. What this substance may do thus posited I will not pretend to affirm, I know it will yield under less efforts beneath high hills; and earth does not press generally like a fluid in a column of its whole height.

If

If then there is any thing like truth in the deductions here offered, the foundations of the desired passage beneath the Thames are neither laid in profoundness of thought, nor the depth of professional talents.

Ordnance-Office, Gravesend

Dec. 20th, 1798.

OBSERVATIONS

OBSERVATIONS, &c.

SOCIETY to which we stand indebted for the advantages derived to us from education and civil life, is not without its evident claims in return upon the exertions of every individual, be the abilities in possession confined or extensive, that a combination of efforts for the preservation and benefit of the whole may be attained; and it becomes not less a duty to unite for mutual defence, or to preserve the body from evil, than it does to aim at laying open and discussing obscurities calculated for leading the mind with confidence in error. Impressed with these sentiments, the withholding whatever might in itself contain a possibility of good, by exciting a spirit of inquiry with desire for determining on an adequate basis apart from a reliance on private and untried authority, could appear in no other light than that of an essential failure. To this end are directed the succeeding observations on a recent and popular project, as it was shewn in the Town-hall of this place, and has since by its devisor been set forth in a Pamphlet, entitled, "Reports with Plans and Sections, &c. of the proposed Dry Tunnel, or passage from Gravesend in Kent, to Tilbury in Essex; demonstrating its practicability and great importance to the two Counties, and Nation at large, &c. by R. DODD, Engineer." They arose upon the inspection of the scheme of this object of hazard and expence, now matured for the public eye, and comparing it with the principles laid down by writers of eminence on the affair of engineering and
theoric

theoric building. To the engravings it is however that these strictures will be chiefly confined, with references occasionally to the accompanying work. Its author professes to avoid all elegance of style, and unnecessary ornament and technical terms; he has kept his word: yet had the technicals of the coal-pit not been substituted for those by which the well-informed in every profession have found it requisite to convey with precision their ideas, it might have been a present more worthy the Nobility and Gentry of Kent and Essex, for whose comprehension in this way the author could not possibly entertain any serious alarm, while it would not have detracted from the merit of the performance, had it carried with it something a little more like demonstration. From the writings of *Vitruvius* we learn it to have been the custom of his predecessors in the art of building, to admit nothing into their works whatever perfection it might seem to bestow, not deduced from the properties of nature, and could not be defended by well founded and just arguments; and the reason he assigns is, because they knew that whatever was not established in truth could never exist, however the eye might be carried away by appearances in a model or picture.^a Had this rule been every where extensive as it ought and invariably continued, many failures in building had been avoided, and had it been valid in the opinion of the Projector, or had he known it, we should not in the present advanced state of mathematical and physical knowledge, when every thing of worth and even curiosity has been submitted to the test of investigation, have discovered an Engineer who proposes to unite art with science, but must have possessed that attention to the form of the arch, the most prominent feature of the great work he so earnestly presses forward as a public good, that on secure and fixt principles it must have been best suited to all the purposes of strength and convenience, and so far have stepped out of the beaten track as to have quitted the circular for another, uniting at once those valuable properties.^b But far from observing in the project now in possession of the public

(a) Ita, quod non potest veritate fieri, id non putaverunt in imaginibus factum, posse certam rationem habere. Omnia enim certa proprietate, et a veris naturæ moribus, traduxerunt in operum perfectiones: et ea probaverunt, quorum explicationes in disputationibus rationem possunt habere veritatis.

M. VITRUVII de architectura, Lib. iv. c. ii.

(b) The longest practice without theory is not sufficient for the just construction of vaults. In this affair the oldest practice is but the oldest ignorance, subject to be deceived let the case but have a variation ever so trifling, says Mr. Frazier, in his great work, "La Theorie et la pratique de la coupe des Pierres a l'usage de l'architecture."

public and this submitted to its arbitration, any portion of that light which after the labours of so many able men who have directed their pursuits for the general advantage, and it costs but the pains of looking into their works to be able to do well, ought to have illuminated its inmost recesses we find, printed and reprinted the same specious absurdity,^a or is any thing discovered beyond what might be expected from the usual portion of practical geometry in every ones hands, and which *Mr. Emerson* has long since observed generally makes the only mathematical endowment of those who have the conduct of public undertakings. Likely the projector may esteem information thus founded unworthy the pursuit of the man of business and design, and with the late *Mr. Riou*,^b affect to laugh at what is usually termed the vagaries of the mere theorist; far from a singularity as this may be with men of his profession, he must be sensible that nature is not without her invariable modes of impulse, and that the greatest skill in the conduct of every operation like the present, consists but in forming the best arrangement subordinate to the end proposed, in conformity with her laws, by which the merit of every project may be appreciated. But as the limits prescribed to this paper do not permit such reasoning to be brought forward as might convince otherwise than already treated, which it is trusted an attentive perusal will enable every description of readers to comprehend, I shall content myself by referring to *Dr. Hutton's* work on the Principle of Stone Bridges, he may then learn if he has already imbibed those mechanical informations which should be the foundation of his every practice, what an arch of equilibration is, how important in works of eminence, what to avoid in the use of arches, and what to trust to;— that except the ellipsis on its shorter diameter, the complete circle presents the worst figure of a tunnel in the precise situation of the one proposed, as departing
most

And as the choice of the arch is of so great moment, let no person either through ignorance or indolence prefer a worse arch because it may seem easier to him to construct, for he would very ill deserve the name or employment of an architect, who is incapable of rendering the exact construction of these curves easy and familiar to himself.

HUTTON'S Principles of Stone Bridges, p. 6, Newcastle 1772.

(a) "I should recommend the form of this passage or tunnel to be cylindrical, wholly made of KEY stones, therefore the greater the pressure the stronger will be the work." DODD'S Pamphlet, p. 3. This ergo is truly unfortunate! as will appear to any one who may consult the works here after noted, and knows any thing of the composition and resolution of forces.

(b) RIOU'S Architecture of Stone Bridges, Preface p. viii. and p. 19. Where the Mathesis is not concerned, this little work is ingenious, entertaining and even useful. Its author has also published a work on critical architecture.

most from a state of equipoise where it is most wanted ; it will also teach him how to construct an arch perfectly equilibrate, whose upper line or extrados shall be horizontal, it possesses this valuable property, it may at pleasure be increased in height or width on a given span or elevation, the reader of intelligence will find sufficient to content him on the score of demonstrative evidence. This arch is now without any thing like inuendo as it was before in "A Word to the Wife," heartily recommended to the Tunnelist and his Friends.^b

But

(a) It appears that none but the arch of equilibration can admit of an horizontal line at top, and that no other with a horizontal line at top can be equally strong in all its parts, and therefore ought to be used in all works of much consequence. HUTTON'S Principles, p. 79.

If any architect or builder of churches or bridges shall please to make use of this curve for the form of the arch, they will find it the strongest arch possible to be made for these given dimensions. And where many thousand pounds are laid out for building a single bridge, it is certainly worth the pains to seek after the form of an arch which shall be the strongest possible, and it is very surprising that nobody has attempted it, instead of that all people have contented themselves with constructing circular arches, not knowing that different pressures against the arch in different places require different curvatures, which does not answer in a circle where the curvature is all alike : a circle it is true is very easily described, and that may be one reason for making use of it.—EMERSON'S Mechanics, 262.

A circle or any other curve when the curvature is not properly adapted to the weight sustained, is not capable of sustaining so vast a weight, but must in time give way and fall to ruin, except the mortar happens to be so strong as to keep it together ; on the contrary the arch sustaining every where a quantity of pressure proportional to its strength, will never give way so long as the piers which are its basis stand good, but by virtue of its figure will stand firm and unshaken.—IBID.

(b) The problem on the construction of arches deemed one of the most difficult in the Mechanics has been treated by the following writers, and their works comprise all that has been written directly on that affair.

The History of the French Academy for 1704 explains the subject ; and Mon. de la Hire in the Memoirs of that body for 1712, p 91 and 101, has published a Treatise sur la Construction des voutes dan les Edifices et sur la poussée des voutes, he is followed by Frazier in his work on forming the arch stones. Le Theorie de la Maçonnerie et de la Mécanique des voutes, par M. Belidor ; and Mr. Muller's Treatise on Arches, in his course for the use of the Royal Military Academy at Woolwich, are full on the same subject. But these only relate to the discovering the Piers sufficient to resist the lateral pressure or drift of the arch ; this was at all times a desideratum in architecture, yet never ascertained with precision till 1724 by M. Belidor, for De la Hire : and our Sir Christopher Wren (Parentalia 356) include the height of the pier in the calculation, without considering that it increases in solidity and at the same time resistance as it ascends. The quality of equilibration as conducing to the internal strength of the arch appears not to have struck the mathematical world till about 1704, when Dr. David Gregory, published his properties of the curve, called Catenaria, wherein he affirms they formed the only genuine arches, and that an arch of any other figure is only sustained because a catenaria is included in the thickness of it. This seems to have excited a spirit of inquiry ; the
Gentlemen

But if an error arises from the quality of the adopted curvature, not being chosen on the grounds of an intelligent, and well-digested Theory : certainly the shape of the thing itself, is as illy fitted for the purposes of traffic; a road 13 feet 10 inches, and some decimal parts in width, out of which is to be taken a banquette or foot-path, with a vault over head 12 feet high at an apex, and declining but too rapidly on either hand, presents many inconveniences to a merely superficial observer. But in this Souterrain intended to “*serve all the purposes of a bridge for horse, foot, and carriage passengers,*” “*which embraces two great objects of importance, the uniting for commercial (why not all?) purposes, the great east parts of the kingdom.*” “*To open extensive roads into the Counties of NORFOLK, SUFFOLK, ESSEX, KENT, and SUSSEX.*” “*To save the necessity of passing London Bridge, and thus avoid a circuit of FIFTY miles.*” Will not allow a stage coach to pass within its vault, unless its outside passengers dismount, or at any rate one to pass another, or even without danger two post-chaises to run abreast. “*Which is to afford opportunity for various establishments* and

Gentlemen of the French Academy applied themselves. and Mon. Parent discovered the chief condition of equilibration. Whether Mr. Emerson in his Fluxions, or my ancient friend and instructor Mr. Samuel Clark in his introduction to the theory and practice of the mechanics, first wrote on this point theoretically in our language, I am uncertain ; it appears in their works, and by the first all the usual curves are tried, and what he has delivered in his Fluxions is reduced to practice in his mechanics, though not sufficiently. The next writer on this subject, so necessary to security and saving expences in building was Dr. (then Mr. Charles) Hutton of Newcastle, and here is found included whatever may be necessary for instruction or even curiosity, on whose principles, the observations here given, are designed to be founded. And lastly, Dr. Young has rendered this problem less difficult, in his well-written article “*The Theory of the Gothic Arch,*” published in the transactions of the Royal Irish Academy, for 1789.

(a) In page 11 of the Pamphlet, we as usual rencontre Mr. DODD in a way peculiar to himself, affronting the common sense of his readers, “*and the width will be on the carriage way*” his own words, “*nearly 16 feet,*” the vertical section is referred to for proof. But twice the square root of the product of 4 drawn into 12, the lower and upper segments of his diameter where intersected by his road, is 13 feet 10,272 inches, its exact breadth, take 2 feet his allowance for a foot-way (See his Plan) and it leaves 11 feet 10,272 inches, is this a carriage-way of nearly 16 feet, or is it 4 feet 1,728 inches short of that breadth ? In the next page this demonstrating gentleman proceeds upon the practicability of his novel and interesting scheme, but here an incorrect section of the river and questionable assertions play a game into each others hands for mutual support. We are next in the depths of the coal-pit entertained with an irrelevant discourse on airs, fixt, and inflammable ; tops of candles brown and blue ; of sprents, styth, and brattishes ; by whose assistance with material fire as a helpmate, all fulminating vapours are dispersed. A note in page 15 lets us into an interesting adventure of a cow, who got, the relater knows not by what means, without hurt among

and agricultural improvements," "To improvements in commerce and agriculture, and opening new roads," Will not permit a loaded harvest-cart to enter beneath its roof. "Which is to serve as a military pass at this momentous crisis,"—Denies admittance to a baggage-waggon. In all this increase of population, of business, of improvement, new roads, and God knows what; and Mr. DODD's Tunnel is to be the exciting and efficient cause to it all. When a carriage enters a bell is to be rung by Mr. Collector, this is a sign, his colleague at the other extremity now knows a vehicle has began its progress, and he lays a prohibition on the progress of every other, till the first emerges. Little urgent must be the business and patient must be the driver, should a second or third enter the same way; or if a baggage-waggon presuming to stray beyond the limits of the Counties, or a harvest cart heaped in the Kentish fashion should present themselves; for then the upper tier of loading is to be clapt into a little cart, which like an esquire in days of yore, is to wait upon these waggons errant during their adventures in those subteraqueous abodes. Weak as these compromises between inadequacy and cupidity may appear, they were permitted to pass as sufficiently explaining away objections, as they arose on a point wherein every person present was competent to decide; and unanimously was it Resolved, That it is the opinion of this meeting, such a communication would be highly desirable and of most important national advantage. !^a And such has it remained since its picture was exhibited on the 18th of July, in the Town-hall at Gravesend, when the first meeting was held; and extensive traffic, and commerce, and agricultural establishments must submit, because

among the pitmen in Wylam Coliery; and how the horned animal was driven through the drift or Tunnel under the Tyne; one of Mr. DODD's Prototypes; then hoisted to DAY, BANK, or PIT-HEAP in perfect safety.—We do not find just here the Q E D of the demonstrator, but suppose it is meant to be fixed somewhere here about.

(a) The following question and response of the Tunnellist is given as a specimen of the happy facility enjoyed by that Gentleman in solving difficulties.—Q. Do you not think it (the tunnel) too low for baggage waggons, harvest carts, &c.—R. It is too low for a baggage waggon or harvest cart as loaded in this County; and for a stage coach. But here arises no objection, since they can take off the top, and a little cart can go before; and into Newcastle no large waggons are suffered to pass, and ONE AT A TIME WILL BE SUFFICIENT. As the projector is excellent at conclusion, it is imagined; that because for certain just causes thereunto moving, the Magistrates of Newcastle, no large waggons are permitted to enter that town: it is a just inference that neither harvest cart or baggage waggon should be suffered to pass from Kent into Essex.

Since the 18th of July Tunnel Meetings have been no longer held in the Town-hall, whether Mr. DODD has inscribed the room in the East Street where they now assemble, with "Procul o Procul este profani," I have not yet heard; Dr. Graham, a celebrated quack in medicine, did so.

because its author cannot or does not think proper to contrive any thing more suited to all the purposes of a bridge for horse, foot and carriage passengers. But then a corner of the fair report makes it known that a second tunnel the reverse of the first would not be without its public advantages.^a

Mr. DODD has yet the credit of conceiving a Souterrain placed but thirty feet below the bed of one of the deepest and broadest rivers in Europe ; it has not on the authority of his own work, a like in our Nation ; for those already noted by him are constructed beneath high hills, for giving passage to Canals, while the drifts much further depressed below the Tyne,^b occupied as they are by carts, horses, and pitmen, and once by the visit of a cow, who arrived in safety by the aidance of her horns to the bottom, differ in nothing from ordinary coal-mines.^a Thus, Mr. DODD, by shewing us a number of perforations under ground, and
affuring

(a) However sufficient this structure may be in width, and width alone is noticed in Mr. DODD'S papers, Its failure in height little appropriating it to the purposes it is designed to answer ; its devisor aware of objections, produced a scheme for another four feet less in diameter nearly capable of every service to be obtained from the one he then exhibited and now sanctions : the hint was in a slight sketch given, he informed the Meeting by Colonel Twiss ; and it was presented as a perfectly cylindrical tunnel, (See fig. 3) its disposition has its advantages, that of security by raised banquettes is peculiar to it, and those who have met a dray or other ponderous vehicle while passing under West Gate Canterbury, or been abreast with two stage coaches in the narrow part of Rochester Bridge, of 15 feet in breadth, without want of headway, must see the necessity of this arrangement. But from a gentleman of veracity I am told it was intended to consist of four circular arcs of about 60 degrees each ; it is in fig. 4 fairly represented, and in it may be traced the hand of a maffer.

(b) Let us hear Mr. DODD'S account of those coal mines, qualified by him constructions, and passes for canals, &c. this will shew how nearly they approach the thing proposed at Gravesend. Wylam Coliery under the Tyne is 192 feet deep, for so far fell the cow. Saperton Tunnel is through a solid rock. Kenton Tunnel through a hard rock. Hair Castle Hill Tunnel 210 feet below the surface ; not a coincidence discoverable : are we then to conclude because tunnels have been successful at those vast depths, a fortiori one must be so but 30 feet below the deepest part of the Thames : The reverse is the just conclusion. Had the proposed tunnel as those in the adduced specimens been placed so far beneath the water, or led through a high hill or solid rock, these observations had never appeared ; thus situated the arch need not be so nicely adjusted, for keeping the eye fixed on the upper and lower parts, the first is pressed down not by a column of the whole height above it, as the weight of earth generally lies in a certain highly curved arch, which may be seen formed by the hand of nature, upon the falling of any excavation, as when it presses down the head-way of a chalk-pit, while the second to fly off must remove the earth about it, in its direction to the surface. But the circular arch like an established nostrum is to continue to be applied, as it ever has ; to every case and constitution, by Gentlemen "seriously and perhaps interestedly impressed" who have not one symptom of despair, when the possibilities of art combined with science, are presented for the purposes of vast advantages, public and private.

affuring us that what has been done may be repeated, proves what has not been held as a doubtful case ; while by the similarity in appearances to the present project, the mind is misled and rests satisfied in a conclusion which is not necessarily connected with the question. This is an often practiced and well-known sophism. It appears again in the likeness of indeterminate expressions, as, " about 20 feet" for the breadth of the excavation necessary for admitting the stone work and clay, although it is certainly 21 feet 6 inches, or 22 feet ; this diminishes our fears for its falling beneath its load. The like is to be noted of the section of the river where no sudden fall, here named the Cant appears. If this management does not betray the influence of the *auri sacra fames*, it does of incapacity or want of care.^a In the present case as in every great undertaking due precaution is to be allowed on the score of security, yet the choice of the cylindrical tunnel which renders two-fold the defects of the circular arch, seems to have been directed, by confounding the notions of wet with what the title contradistinguishes dry tunnels : it is an admitted fact that a stratum of chalk is to be passed through, and as chalk is in all places in possession of the same properties, whatever could be desired for abutment or foundation is obtained, it might then be constructed with a low arch of equilibration fixed on upright piers, and the expansive quality of the vault itself so difficult to contend with on other occasions, may be here rendered in resisting a supposed lateral pressure inwards, of the greatest utility.^b I have further to relate that the great cisterns at
Dunkirk

(a) To this may be referred the inaccuracies of the section and depths of the river on the scale and allowances of the Tunnellist himself while the dimensions of the first report are reprinted and repeated in the second. Apply but the compasses with the longest sounding marked 10 fathoms along the section, for lines so marked are of different lengths, and instead of 900 yards from one extremity to the other, it will be found to be 510 fathoms or 1020 yards ; if about 5 be added for deflection from a straight line, it makes 1025, or 125 at 13l. per yard, or 1625l. above his estimate : but these errors are trifling and amply rectified by an allowance for contingencies, it is supposed or it must be otherwise unnecessary of 14,005l. (on the 23d of November at the Crown and Anchor, when 30,000l. was to be raised,) above the original price of the undertaking 15,995l.; independent of 3,141l. for excavated chalk reported of excellent quality. Yet those concerned in the lime trade on the banks of the river affirm that the chalk dug at a level lower than its bed is so swamped as to be unfit for the kiln, and that water drains into the excavation. Whether it will be less so under the river is a question of no difficult solution. But a stratum of clay, or rather a loose loam mixed with sand perfectly well saturated with water is to be ascended. Hic labor hoc opus. Yet this is excellent, as well as the " fine rich mould a few feet deep" that covers it, and every thing Mr. DODD encounters in the way of his tunnel ; they look also well in a neat engraving. But " Nimum ne crede colori," says the poet on eye-catching and pretty things.

(b) If we condescend to take nature as a guide, an excellent model of a Souterrain will be found in
the

Dunkirk and Calais esteemed *chefs d'œuvre* in their way, sunk in a marshy soil of 108 English feet in length, and 12 under ground, with no vast impending force to stay the lateral pressure of their sides, are thus made, and the water kept in, as is that from the land withheld by a nice application of bricks and terras. Thus amended in height and the figure of its vault, a pass might be had capable of realizing all the exaggerated good noted in the pamphlet, and that such it should be is the true interest of those who venture a portion of their effects upon it, as its share-holders.

As I should be happy had I seen these observations in the hands of a man of mathematical abilities joined to experience in actual construction, qualities so seldom united, so I could willingly at this place conclude my remarks, and should do so, did I not perceive an error merely practical in the disposition of the Vouffoirs within the work of the thing itself. These are Mr. DODD's KEY-stones equally pressed on all sides from the circumference of his cylinder to the center, by some he knows not what property of gravitation, for the sake of rendering the whole the stronger the more it is burthened,^a although in any scheme of gravity it can never be true, for every arch like every beam must have its maximum of strength, unless as it is affirmed in that Gentleman's book, he can so form a tunnel beneath a river, that when the entire circle is by the workmen completed, "*it will be in strength superior to the original bed of chalk passed through*" At credat Judæus Apella non ego. And I leave this point to be settled between him and the knowing in those branches of science from whence he should have deduced his *demonstrations*, or no promise of demonstrating should have appeared in the title. Upon an inspection of the
vertical

the chalk caverns at Chesilhurst in this County; from them a design and precepts for carrying it to maturity might be deduced. They are of two parallel drifts of more than a furlong each in length, with perforations through the pier, besides passages leading off to circular apartments, in some of these the chalk has given way and the earth fallen in a highly arched dome. No weight is here caused to occupy a larger base by the intervention of the counter arch, although a vast weight is sustained, yet they have existed for ages. Nor are counter arches admitted by the best architects, but in bad foundations; or are they necessary unless they are affirmed of use to preserve the tunnel from water.

(a) But since the materials of which arches are constructed are not of infinite strength, there must be a certain degree of pressure, which would rend even an arch in perfect equilibrium.

Dr. YOUNG's Theory of the Gothic Arch, Transf. of R. Irish Academy, 1789—76.

vertical section of the tunnel, it will be seen that it is formed of two unbonded courses of Vouffoires; or it has in artificer language a straight joint: this method a long habit has functioned, and it seems to owe its rise or at least the extensiveness of its use, to a name no less than that of *Count Vauban*. To this arrangement objections worthy attention are started by an Engineer of eminence, "Formerly says this author vaults of brick ^b were composed of several vaults one upon the other, each one brick thick without any bonding between, but it has been discovered that this practice is ill founded; for if there happen an opening of the lowermost for a brick or two, the rest soon separate, and the repair becomes very difficult, for want of the means of uniting the new with the old work; and frequently has it happened shortly after the finishing, the first vault has separated and been detached entirely from the rest.^b It is also an axiom in building, that the distinct parts duly jointed and cemented are to be considered as forming one solid whole; and hence arises another defect, for from the experiments made by the same author on the strength of timber, and the relative degrees of strength in other materials may hold nearly the same proportion: we learn that the weight a beam would sustain, was to that sustained by one twice as broad of the same length, thickness, and kind, as 406 to 805; when its thickness was exposed to the action of the force, but when its broadest side as 406 to 1580; by which it is proved that beams of the same length and equally thick, have their strength in the ratio of the squares of their breadths;^d and we may rest pretty well satisfied till it may be thought worthy to make a course of experiments immediately to the purpose, that an arch of two bricks thick, unbonded, is but twice as strong as an arch of one; and of three, but possessed of three times that strength: whereas
if

(a) Such a word as bricks should not have appeared in this paper had their use not been functioned at the Town-hall the 18th of July, when the Tunnelist assured those present, bricks would do very well for building his project, BECAUSE THEY WERE SO HANDY TO WORK WITH!—He added, and something was necessary to suit bricks to the taste of his hearers. There is in this County a vitrified Brick,—May he not be told there is in every County and in every clump arising from circumstances in the composition and burning, what is called half run bricks? but then they are generally so distorted, that with all the vast durability attributed to them they are admitted no where unless in foundations, and for the rudest purposes.

(b) Science des Ingenieurs.

(c) *IBID.*—That is in the language of Mr. Emerson, (*Mechanics* 93) The lateral strength of any piece of timber whose section is a rectangle, is directly as the breadth and the square of the depth; and this he assures us (*Page* 110) is equally applicable to any solid bodies acted upon in like manner. It is here first applied to bonded and unbonded arches.

if bonded, the degrees of strength would be as the squares of those numbers, and be represented by 1, 4, 9. These remarks contain insuperable objections to this practice so beloved by the artificer, because it is *so handy to work up*. Its credit was not however very high with *Messrs. Adam*, who in the large brick arches of the Adelphi, exposed to a great weight of buildings, have thought proper to give them the advantage arising from the materials being bonded together. But we are told "the whole extent of the tunnel will be nearly if not absolutely water tight." "That the water will be locked and made water tight every 10 or 12 inches." Subserving to this water locking may Mr. DODD's KEY-stones be so disposed, and of like tendency seems the care taken in setting the under sides of the Vouffoirs of the superior vault against the joints of the lower.^a It must be however evident there yet remains on account of the upper and lower tiers of joints crossing each other, a course of interstices through which the water can at once penetrate the thickness of the whole; and were it not for this circumstance which no human invention could obviate, an accumulation might be made between the two vaultings, and to conceive its effect in that situation needs no uncommon share of sagacity. It is not so that M. Belidor *water-locks* his Cisterns and Souterrains. But had not the denomination been confounded with the Vouffoirs and its properties, we should have heard nothing of the artificer term KEY-stone,^b whose effect on the mind of the projector is detailed, and their making an arch the stronger the more it is burthened without regard to relative position, to the direction of pressure, or the load to be sustained: the same confusion of ideas has induced that Gentleman to talk of water-locking by the same method, with counter-arches for keeping out water, and springs, which rise but against a point with no vast impetus, because arches sustain a force diffused along their circumferences; and thus avoiding the convenience of upright sides, persist on the counter-arch with the expence attending, an expence from whence no advantage can arise: for if the water is immiffible it must be through the interstices or joints, and whether these are upright, or horizontal, or declining, it makes but little or no difference to the action of a fluid.^c

Annexed

(a) See Fig. 3, for this management of key-stones and joints.

(b) Vouffoirs the stones which immediately form the arch, the middle one is the key-stone, the rest should increase in size all the way down, the more they increase the better, as they will better bear the great weight which rests upon them without being crushed, and also bond firmer together.—Principles of Stone Bridges, 102.—By this process may a circular arch be made equilibrate; it was devised by M. De la Hire, and the method of performance may be seen in Mullar's Works. It was adopted by Mr. Labelie for rendering his arches in Westminster Bridge secure throughout their lengths; it might also have been imitated in a recent offering to the public.

(c) See Note at the end of the work.

Annexed to the Tunnel will be a Steam-Engine with its Apparatus ; but by what application of its powers the drainage is to be exhausted through a pipe which occurs in the engraved sections of the tunnel, declining it is said at four inches in the yard for about 510 yards together, is not laid before the public. Yet this is a point in which the public is heartily concerned. It is no less concerned on the score of ventilation, as we are told "there will be a current of pure atmospheric air passing through the tunnel, without the aid of machinery, as experience teaches us that air like water rushes most into confined passages." Valuable as are the teachings of experience, yet we all know that there are in these cases certain existing circumstances determining to those effects ; whether they are found about the thing proposed, is a problem which demands a better solution than an ipse dixitism.^a

If then as a man impressed with a strong regard for works of art in architecture, conducted upon principles legitimately scientific, I have presumed to discover defects and point towards their amendment, that this may with every human probability be secured, I shall here bring to the notice of those, appointed for the carrying into execution this hazardous project, the first step taken by the committee engaged for the management of the affairs of Black Friars Bridge. The architect was caused to lay his designs before the late eminent *Mr. Thomas Simpson*, and submit to his correction ; a vast saving was the consequence, and security

(a) Air being a fluid has a right to be considered equally subject as water to the laws of hydrostatics ; and the more palpable effects of the latter may be offered in explanation of certain properties of the first. Let there be conceived two equal vessels fixed at some distance apart on a horizontal plane with a tube of communication as much like Mr. DODD's tunnel as possible. If the first be supposed filled with water and the tube opened, it would rush into the confined passage to the other which is in this respect comparatively a vacuum ; this is Mr. D's case, but he should have gone a little further ; let water be continued to be poured into the first vessel and it will rise in the other always at equal heights till they are full ; or what is the same suppose the whole space above the tube now occupied by the water to a certain height. What has become of the rushings into confined passages of the Tunnelist ? It is a well-known fact that the water above presses on that in the tube, every point of which feels a weight equal to a column of the perpendicular depth of that point from the surface, and in this case air will act in the same way ; and Mr. D. to gain full ascent to his position should prove a greater rarefaction of air in the County of Kent than in Essex, or the reverse. Did he ever see air rush down one shaft of a coal-mine and up another ? down both he might for supplying the consumption below ; and this is the usual determining circumstance. And is it not rather to be supposed that the depths of the tunnel unless ventilated, will become a reservoir of mephitic damp ?

security and permanency might be the effect of a like interposition of the skill of his yet eminent successors in mathematical celebrity.^a Far from resting on a presumed immunity from error with my mind, *Ne sperarem ibi fractum gratiæ ubi non meruisssem*, ready to conviction and prepared for acknowledgement, I conclude these remarks on the project of the Gravesend Souterrain, knowing as a motive, neither interested view, nor personal enmity, nor the esprit du corps, nor any but that natural love of country I trust we all feel, as well in its lesser as its greater concerns; this has induced me to aim at recollecting what I might at an early period have possessed relative to such subjects, and to oppose with a view towards general advantage, abuses universally rooted, and false opinions universally embraced.

(a) The author of the Principles of Stone Bridges, so often noticed along these remarks, having already bestowed a portion of his labours upon a subject so intimately connected, appears not the least likely for giving salutary directions to the Tunnellist.

(Note c, Page 21.) After having endeavoured to shew the defects of the project as it now exists, it may be expected something beyond mere hint should be offered in amendment; but although every man has on a public work a right to manifest his opinion, and being no professional builder or engineer I may decently withdraw from that task; I have yet a desire to rescue the preceding observations from any stigma which might be a traverse in their way, should it be a wish to any gentleman they had never seen the light. They are then to meet condemnation as the theoretical reveries of a man unpracticed in habits of laying bricks and stones, of perforating beneath the surface of the earth, who had never tried the abyss of a coal-pit, knew nothing of puddling canals; or had seen to a demonstration either on the Continent, or in America during the war, the necessity for a complete system of TUNNELISM. It is then with becoming diffidence I submit a design, the result of some meditation though not as I could wish it, complete. It is intended to unite convenience with security, its description as it relates to those conditions is, First, In the clear it is 16 feet and a $\frac{1}{2}$ wide by $13\frac{1}{2}$ to the springing of the arch, and thus admits two stage coaches, waggons, or harvest carts to pass each other; it has besides a range of iron posts 6 inches square at their bases, supporting a gallery about 20 inches wide, and thus two passes are provided in the least possible space for the convenience of travellers on foot for whom no retreat could be found upon the breaking down a carriage, restive horses, or oxen the animal most frequently crossing in the ferry-boats: and thus what may be necessary for fulfilling the first point is arrived at. Secondly, The chalk being depended on for abutment, the side walls are only taken sufficiently massive for sustaining the perpendicular pressure, they rest on a basement projecting about 12 inches on either hand, nor can any clay be allowed to intervene between them and the original chalk, and some other method may be found without danger for restraining the ingress of the water: from below it may be resisted by a pavement of large stones or a course of masonry fixed in clay, above it a stratum of bricks and terras, as shewn by M. Belidor, and the road relaid, which although less expensive than counter-arching, and less subject to injury from position, that prejudice may meet nothing of violation, an arch is placed

placed for that purpose. || The roof which is to be secured from the action of the water by a suitable application of terras, &c. is the low arch of equilibration continually recommended, its curvature is discovered from considering the different densities of the stone of the arch itself, the chalk and the water above it, and bringing them to the height they would be at if wholly of the first. The question is now reduced to the discovery of an equilibrate arch beneath an horizontal extrados, of the given span, elevation and thickness above the vertex; and then certain lines about the curve are calculable for its description, and this I take to be that grand and precise point in this affair whence certain hopes of any thing like stability alone can be derived, although I am sensible an allowance is made on account of tides, which demands a further consideration. For the length of the key-stone (the upper Vouffoir is meant) 20 inches is allowed by M. Gautier in Belidor's tables on common occasions, but the weight to be sustained being that of a fluid thus void of tenacity, and every particle of its base pressed downwards in a column of its whole height, a greater degree is requisite, and 3 feet may not be in excess. The length of the rest of the Vouffoirs increase as they proceed downwards, by which they are more and more enabled to resist without crushing beneath the great incumbrance, and will unite with greater firmness. The direction of the whole force of the arch exerted against the pier is declining along the dotted line, by which it has a tendency to give solidity and resistance to the lateral pressure of its sides inwards if any can exist, and least the lower vouffoir should slide upon the impost, or that immediately below it, and the chalk alone directly opposite be depended on for abutment, they are indented as are all the courses beneath; this though rather pertaining to the art of the carpenter than the mason is not without its use, it was employed as an incastratura or mortise for securing the seats in the amphitheatre of Titus, &c. by it the stones will be prevented from sliding, and the centre of motion must be thus fixed to the lowest part, and a height of chalk of 23 feet instead of 7 will oppose as abutment to the same force divided along the pier and acting in an horizontal direction, or should on account of the vast lateral pressure, a higher arch than that in the figure by which it would be diminished be less objectionable, the problem will still subsist without affecting any position on which this construction depends. The catenaria also seems to have valuable and untried properties for an arch sustaining a great load upon the vertex. The section here given (Fig. 5) is supposed of dimensions requisite for the greatest depths, it would necessarily decrease in solidity and expence as such a work proceeded upwards under a weight continually diminishing, it would also require a greater excavation than 22 feet, but this with suitable precautions relative to depths of water, strength of headway, &c. becomes no circumstance of terror; and that it may with its lights and smoak have an appearance less like the Descensus Averno, a vertical entrance with becoming fronton and inscriptions should be formed with stairs leading to the upper and lower banquettes designed as passes reversing each other. If instead of a Souterrain of a single road 16 $\frac{1}{2}$ feet wide, it was diminished to 10 or 11 feet, and another of the same dimensions placed immediately adjoining with arched communications through the pier, and uniting with the foot ways of two feet wide, it would afford a course of recesses from danger, while one set of lamps would serve for illuminating the two; and this double Souterrain it seems likely could be executed with less hazard than the first of these projects. This disposition for suitableness and excellence in its way became forcibly striking shortly after my hearing of the proposal for a road beneath the river. I had learnt from the elaborate work of Nardini the *Roma Antica*,* that the gates of Old Rome, and of some modern cities were for ease to an extensive traffic
thus

(||) Whenever a counter arch is applied by an architect as a basement in a bad foundation, its spandrils are worked up with masonry. An application of them as in the vertical section of the tunnel, was devised by Leoni Baptista Alberti, a learned architect of the 16th century, but never made use of. See *L'Architecture Pratique de Bullet*, 180. But if in a passage through a swamped loam, a counter arch should be found requisite as a basis to the whole, then the superior vault inverted presents the best form; and other arrangements may be needful, which it is unnecessary here to point out.

(*) Page 37 his words are "Donde certa congettura puo caversi, che delle porte di Roma, alcune fussero cosi doppie di Gianì, forse per commodita di carri o di some."

thus formed. The thing itself became at least in my eyes of National Credit, and it seemed desirable that executed by a few individuals, with but the benefits conferred by the honest advantages of their country, it should emulate the greatest performances of that people with all their arts and the spoils of a ruined world.

If then the project here offered, is, as I trust it will be found conformed to the circumstances to be encountered, with due regard to an apposite theory, was built with the largest manageable blocks of Scotch Granite, † (they might be cut to moulds in the quarries and imported on the spot) the whole set in terras, ‡ with clamps of copper, § it might one day, like another Stone-Henge, be a cause of wonder to a new race, to whom our language, our manners, and ourselves might be wholly forgotten, or but conjecturally known.

(†) The volume or space occupied by two bodies is in the inverse ratio of their specific gravities; if the specific gravity of granite is 4,000, of water 1,000, the first will be in the space it takes up 4 times less than the other; and by knowing those of chalk and sea water the height of granite above the apex of the arch will be found of equal weight, above 31 feet. If instead of an equilibrate arch it had been taken a part of a circle of but 60 degrees, then if the height of wall above every point had been at the cube of the secant of the arch in that point. it would still be kept equilibrate, that is as 3 times the radius of the tables 30,00000 is to the logarithm of 31 feet 1,4913617, so is 3 times the logarithmic secant of 30 degrees 30,1874082 to 1,678699 the logarithm of 47 add 2,22 feet the height of such arch to 31, and take the sum from 47 it leaves 13,78 feet for the height of walling above the horizontal line over the spring of the arch necessary for sustaining it in equilibration, when the whole is of granite this would be near 50 of water, &c. had the arch been of 90 degrees the height of granite above the horizontal line over the spring had been 52 feet, or it must have been near 200 feet in water, &c. this falls in with the purposes of the introduction, and ought to be a caution to Tunnel-makers beneath a river; for proceed but to one of 120 degrees, and the aberration from equipoise is inconceivably great, the effect must be evident.—See Notes from MR. EMERSON, whose labours for the service of mankind in the just construction of arches were rewarded with the contempt of those he designed to oblige,—*nec tempora mutantur.*

(‡) In Campini Vetera Monumenta is an oleose composition used by the Mosaic painters for setting their lapiduli and pieces of coloured glass; many of their performances have lasted near 2000 years, and it is not unlikely this as a cement might be better than terras Salmon also in his polygraphics gives a plaister mixed with oil of everlasting duration.—M. Gautier thinks the ancients preserved the courses of their buildings from water, by cutting the stones so smooth as to exclude even the air, and recommends it to practice: its effects might be more certain than of any cement, to the weak alliance of which, great blocks are superior.

(§) From ancient buildings it is discovered that iron decays and spoils the stones by its rust,—effects noted by L. Bap. Alberti. *Sed nos ex veterum operibus intelleximus ferrum corrumpi et nequicquam durare. Æs vero durare et prope æternum esse, quin et ferri rubigine marmora commacerari et circumrumpi adverti.*—This and part of the last from the erudition of Mr. R10U.

POSTSCRIPT.

POSTSCRIPT.

THE force of the preceding observations depending chiefly upon mechanical principles, the ensuing remarks possessing a claim to much regard, could not be wrought up. They were obligingly communicated by a gentleman in the vicinity of Rochester, of so much intelligence and weight in society, that a presumption of rectitude may be inferred from a coincidence in sentiments.

It certainly must follow of course, that by expending a large sum of money, a very large and long hole may be bored under ground. But in this case, the expences of completing this work do by no means end, the moment its bricks and stones are laid. Toll-houses must be erected; toll-keepers employed; lamps must be constantly burning at a very considerable expence;—when to the interest of the capital expended these further additional yearly charges are annexed; there seems to be no reasonable expectation of its turning out to be a work that will pay for itself. The interests of the shores of Kent and Essex can never be deeply engaged in a trading point of view with each other, by this or any other new channel of communication. Their market is the Metropolis, and the surface of the Thames the cheapest road to it. Essex possesses no one commodity which Kent wants. The only trade now existing between the two Counties is, for the chalk which Kent sends to Essex; and as long as a barge can swim, it will always be cheaper to convey bulky commodities from shore to shore, on the surface of the water, than by land under it. It has been said aloud and much relied on, that where a new communication is made from one part of a County to another, that it is a fresh channel in which a new trade will run.^a When this happens,

Mr. DODD who as we learn from his book receives so much honor from the continual application of his mind to projection for the public good, has known in less likely places an increase of business five fold in consequence of a new communication. But the present profits of the ferry not of 900l. but 5 or 6, reduced 1-3d, as proposed by him and taken as a datum, it will require a seven or eight fold increase to be brought by the magic of a tunnel to do much better than the funds for subscribers at 30,000l. when expediture for lamps, toll-men, and indemnity to the holders of ferry-rents if suppressed

happens, it must arise from one part of the country being in possession of a saleable article wanted by the other; and for the passing of which this new channel is opened. Now this tunnel when completed except for the passage of troops, is only preparing two roads, one under that river in addition to one where a passage over it is established, and confining it purely to a pecuniary remuneration of its own expences, it must remain a doubt whether the public will prefer the passage of the tunnel to that of the boats; and in proportion as the public is divided in opinion and preference, in such proportion must the future produce of the tunnel be increased or injured.

is withdrawn. Yet this is raked from five Counties, and golden eggs are marshalled in parade; improvements in agriculture, commerce, population become now dependents on tunnel influence, by the opening new roads even beyond the Counties; and Mr. DODD, unqualified in his expressions as usual, assures us a fifty miles circuit will be saved by this narrow medium, in avoiding London Bridge. Yet if they are, it must be to those who reside at Gravesend and Tilbury, or at places on or near the shores of the Thames, lower than those spots: but for them what the river has never prevented the tunnel will never promote; in every other position as it recedes from those bounds, Mr. DODD's fifty miles will continually lessen till it is not worth bearing the fatigue and inconvenience of cross roads not every day passable, for their sake, much more the waste of lands and expences occasioned by opening new ones. Let a journey be instanced between two Eastern points of the Counties Harwich and Hythe, at 145 miles apart through London, a saving by the tunnel of 22 miles is only made, or about 1-7th: between Yarmouth and Rye, at 186 miles, but 11 or 1-17th: but can any due motive of commerce exist between those parts which could be refrained by these inconsiderable additions, while agriculture, as it is the general interest, and as we find it, is nearly at an unimprovable height. And thus this blaze of distant influence, when viewed through the prospective of the most obvious calculation, becomes but a mere BOUGIE; and its dependents, improvements in commerce, agriculture, &c. seem not less evanescent. It is not however pretended that to a vicinage of very many miles within the Counties, (and so far it is that rational expectation ought to rest satisfied) it may be of no advantage, on the contrary it is likely to be extensively of use, and merit the solicitude necessary for bringing it to maturity, at those hands whose patriotic zeal induces them at an ordinary remuneration to hazard on it as a great work, and evidently a public good, an inconsiderable portion of the wealth obtained from public favour and encouragement. But it is yet proper to try the colour of every man's complexion and temper; so necessary says Mr. Addison for the right understanding him as an author, whether of British growth or of Laputa.

Page 18, line 9.—In Mr. DODD's section of the river (made from actual measurement) we find neither the cant so confidentially mentioned by every one, as extending the length of the Kentish shore nearly through Gravesend Reach, nor are the deepest parts of the water placed towards the same side, as might be expected from the current both on the ebb and flood tides setting along it, while the depths of the river seemed curtailed. This led to the taking a few soundings, they were made at low-water

water, and though not quite accurate in distances, may shew well enough the depths opposite the hemp-house in the rope-ground, the spot by common report assigned for the tunnel. For the first 24 or 5 fathoms, the depth was but 4, in the next 21, it increased to 10, this is the declivity called the cant, which is every where discovered more or less approaching towards a perpendicular: the depth then continued to about 1-3d the breadth of the river, at 10½ more or less, and gradually lessened till the Essex shore was gained. If the water be allowed to rise 15 feet in ordinary tides, it will make the whole depth at high water 12 or 13 fathoms.

THE END.

ERRATA.

In the Note, Page 6, for G B L A, read G L P A.

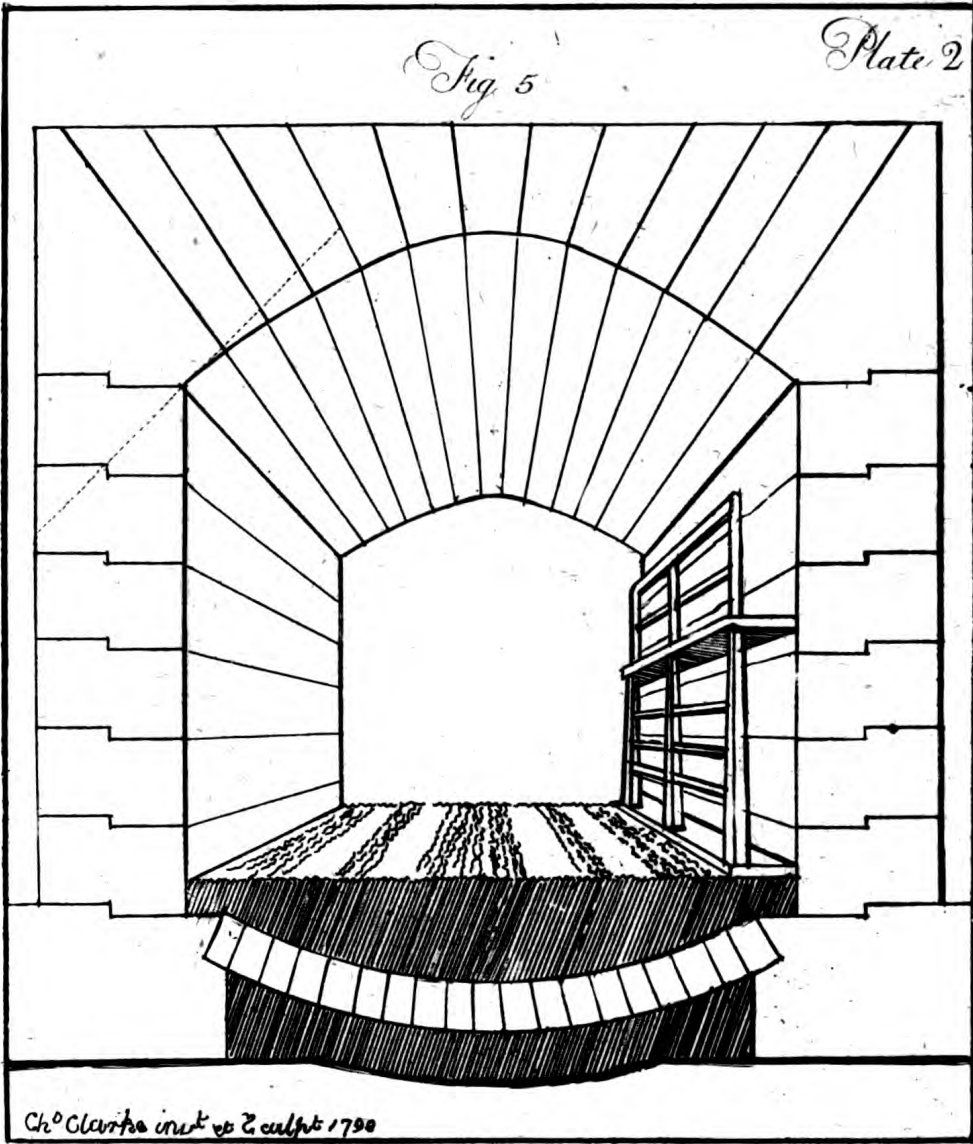
Page 6 second line from the bottom, for P and T, read Q and T.

Page 8 three lines from the top, for latual, read lateral.

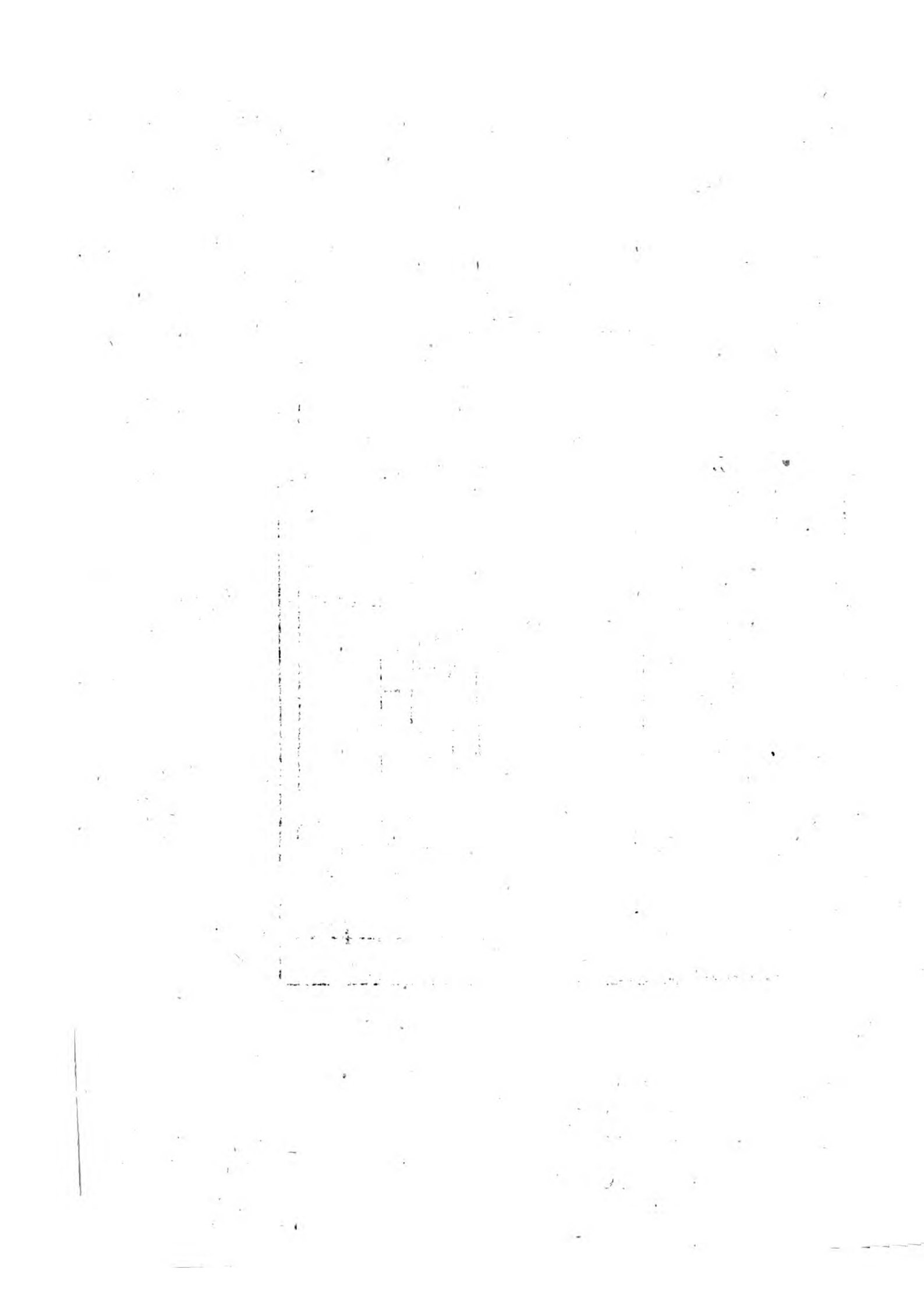
Page 14, ditto in the Note.

Fig 5

Plate 2



Ch^o Clarke inest et sculpt 1790



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