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7889 DISCUSSION

Some notes on significance of form in bridge engineering

B. J. ALLAN

I would like to comment on two more aspects of form, namely 'truth to materials' and 'unity'.

45. I have already quoted Henry Moore on the subject of symmetry and I would invoke him again with regard to 'truth to materials'. Henry Moore is a representative of the school of thought which believes that the natural characteristics of the materials should be reflected in the work created from them. Their potentialities should be exploited and limitations should not be artificially overcome or ignored. He recognizes the importance of the material in which he works, thinking and creating in this material... understanding and being in sympathy with his material so that he does not force it beyond its actual constructive build, producing weakness. This is a sentiment of considerable potency which may be equally applicable in the creation of bridge form, with an additional qualification that there is an economic penalty to be paid for forcing the material beyond its constructive build in the design of bridges.

46. Of the major constructional materials concrete is most versatile in the creation of an almost limitless variety of shapes. Apart from examples used in the Paper Fig. 18 may demonstrate the graceful response of concrete to the creation of curved shapes. When the curvature is large, as in this case, it permits the use of structural ornament of rough boarded imprint. However, when the use of rough boarding would be impracticable due to very tight curvature, textural treatment may be used to emphasize form as seen in Fig. 19.

47. If the 'truth to materials' is acceptable as a guiding principle in the design of bridges, it is acceptable only within an even more important principle, which is 'unity'. 'Unity' is the quality inherent in all good design and it can be achieved by harmony as well as harmonious contrast of form, colour or texture. 'In a perfect work of art all the elements are inter-related: they cohere to form a unity which has a value greater than the mere sum of these elements.'

48. Two-level interchanges catering for curvilinear divers movements are complex structures as far as unity is concerned, but nevertheless, the problem may be solved satisfactorily, even using precasting as seen in Fig. 1 (an example of 'truth to materials' and 'unity' combined).

49. The validity of Herbert Read's statement on 'unity' and Henry Moore's on 'truth to materials' and their applicability in the sphere of bridge engineering, could not be illustrated more appropriately than by a study of some of the magnificent large river crossings achieved by means of suspension bridges.

Mr P. Russell, Cement and Concrete Association

I have long admired Mr Allan's work in the new town that is world famous for its bold, creative thinking. Concrete has been my life in Scotland for the past 30 years, across a

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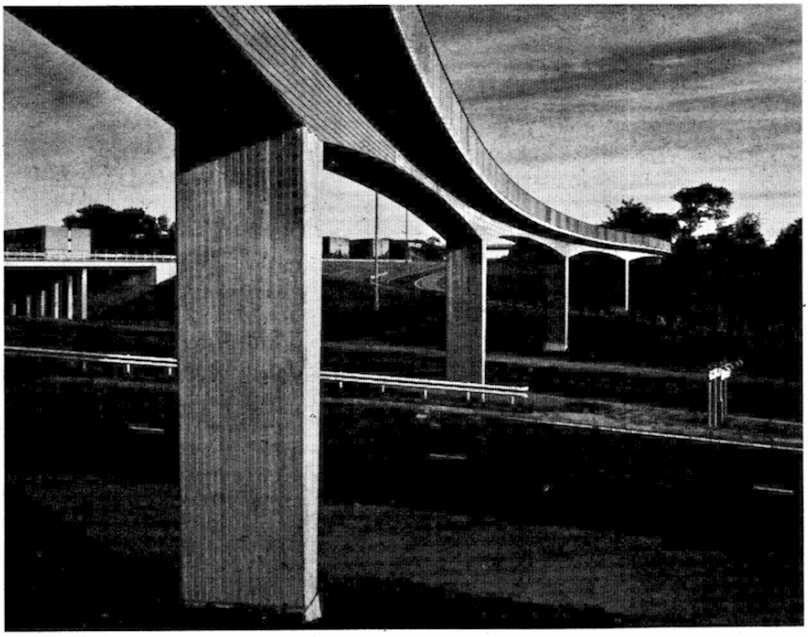

Fig. 18.

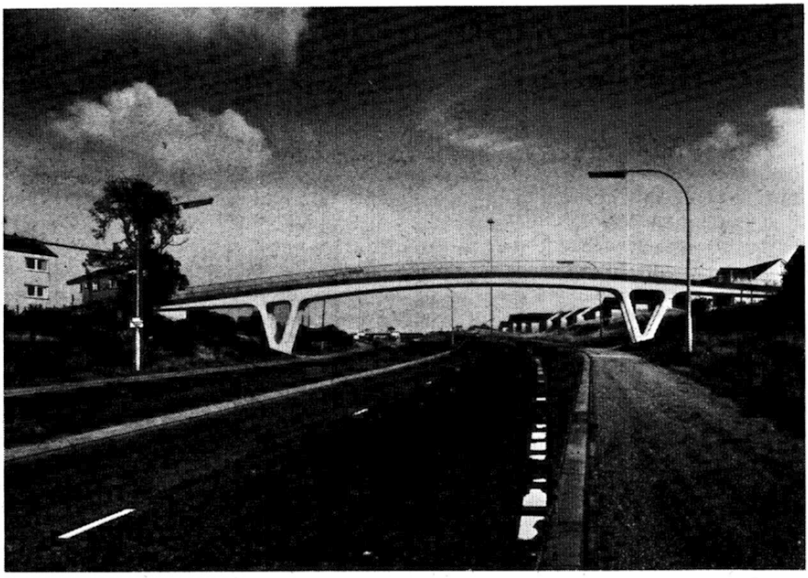

Fig. 19.

generation first of power from hydro-electric dams and now from oilfields with their platforms under construction at Kishorn and elsewhere. Just as interesting is the building of bridges in their infinite variety, and so abundantly exemplified by the Author, whose alliterative language has struck a responsive chord in the most unlikely of us.

51. Mr Allan has referred to the sayings of famous men and it is tempting to quote again from Ruskin who described my own city of Edinburgh in phrases that fit Cumbernauld equally well: 'a daily influence in forming taste and kindling the imagination of all who live within its view. Nobly arranged and forming curves at once majestic and harmonious.' The comments of Wordsworth are also clearly apt: 'guarded by the sober powers of science and sense', and of Carlyle with his 'marvellous entity and handsome competence—a sign of civilization'. Such would have been the judgment of those discerning men of letters if they had seen the other city that now takes Glasgow's overspill.

52. It is not a difficult step from the stone pillars of Auld Reekie's classical facades to the concrete pillars of Cumbernauld, nor can we dismiss from our thoughts the Union Canal that roughly joins the two brilliant concepts, planned in part by Rennie and Telford before the motorcar, and the solution by Mr Allan's colleagues of the problem of segregation.

53. The new town's topography is one of gentle sloping hills, and every effort has been made to blend into the landscape. On the other hand, there are dark and uninviting underpasses enlightened by white concrete in its precast form, and the very practical use of prefabrication in these fluted collonades, only second in quality to the remarkable cross of St John on Iona, perhaps the ultimate in concrete craftsmanship. It is good to know that the first ever site practice award of the Concrete Society was given to the contractor responsible for the work at Cumbernauld, and Mr Allan himself has won many prizes, itself a mark of approval and appreciation.

54. The only comparison with other Scottish bridges is that of the Perth–Inverness road 50 years before, when the Findhorn and other rivers were crossed by concrete structures that reflected the same forward thinking in their skilful use of light and shade in the facetted integration of abutments, wing-walls and parapets. Their successors now under construction are equally impressive and not only for their size. Appreciation of the same basic material is seen both in 'Concrete Bob's' reinforced bridge of the 1880s, still straddling the Road to the Isles, and in these sophisticated yet functional structures of the present day. Here I have a personal interest in the Institution's endeavours to catalogue the historical past and have long studied Wade's progress through the Highlands 250 years ago.

55. Concrete can be a mundane material lacking in form and finish, although certain blemishes may be tolerated and, indeed, add to the character of a bridge. But the surface itself is important, and here the choice is wide. Ribbed, fluted, bush-hammered, panelled, textured, board-marked, the last perhaps a particularly realistic approach to a large mass in that the mechanics of pouring and containment are quietly emphasized. One of the great merits of concrete is its mouldability, and it is here that the Paper is so relevant, showing how to avoid the commonplace at little extra cost but with much forethought. Cumbernauld's bridges come alive, and in a technical sense I sometimes think that engineers have a certain advantage over the layman in knowing just how much a slender deck owes to its prestressed or post-tensioned anatomy—pent-up energy indeed, stretched throughout its life to give the most slender form possible and to cope with any load.

56. I would suggest that all engineers should look at Mr Allan's structures one day, for only then will they fully appreciate his contribution to the science of serenity in this rather turbulent age.

Sir Donald Liddle, Cumbernauld Development Corporation

I am not an engineer, but I have studied the Paper, and I think it is extremely exciting.

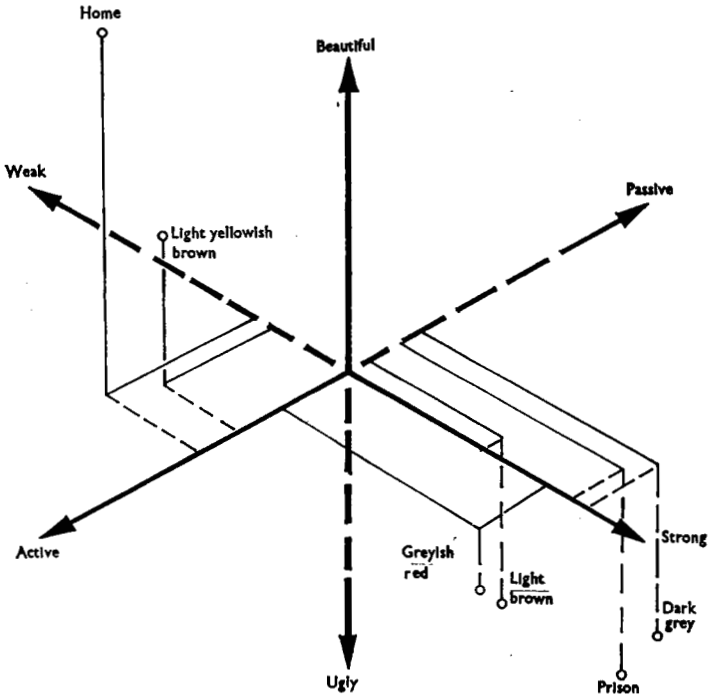

Fig. 20. Osgood's semantic space

I happen to be the Chairman of the Development Corporation with which the Author is associated and I would like to place on record our sincere thanks and appreciation for what we have derived from the skills and applied engineering of Mr Allan and his team.

58. The Author has recorded in his Paper that the policy in the new town of Cumbernauld has been for the maximum safety of pedestrians and motorists alike. Of course, this was no easy task. As Mr Russell has said, Cumbernauld is built on a very hilly area. Our original designated area was something like 4000 acres, and in 4000 acres of undulating ground, with some very steep slopes, there was a considerable problem. From the outset Cumbernauld had been designed for safety; and to be the safest town in the UK on a hilly site—as we are—calls for bridges and underpasses. Indeed, there are something like 40 underpasses and 54 bridges, including considerable variety of designs. Mr Allan's designing ability in concrete and in other materials has been widely acclaimed, and our people get real pleasure in traversing these bridges. They do indeed appreciate the line and the design and in particular their relationship to the environment.

59. This is one of the features which I think is extremely interesting in Mr Allan's work. It may be that in time it will be the thing to come and see Allan's bridges in Cumbernauld.

Mr M. B. Leeming, Mott, Hay & Anderson

I was greatly impressed by what I saw in Cumbernauld and I am sure the local people appreciate what Mr Allan has done there. Also I congratulate the Cumbernauld Development Corporation for allowing him free rein for his ideas in producing an

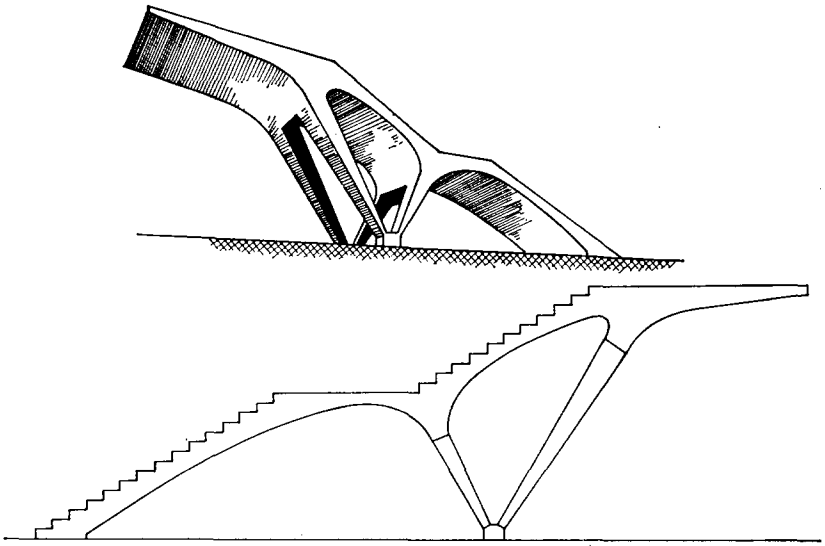

Fig. 21. Staircase at Palazzo dello Sport, Rome (Nervi)

excellent environment. My main disagreement with the Author is on the question of movement, which his structures do not fully express.

61. Vague and woolly explanations of what lies behind form and aesthetics in civil engineering mean nothing. However, Grimm[7] has recently attempted to put the whole question of aesthetics on a rational and quantitative basis. He has used Osgood's 'semantic space' where the meaning of words is expressed in three major dimensions.[8] These are the evaluation dimension, the activity dimension and the potency dimension. The evaluation dimension is beautiful–ugly, cheerful–sad, good–bad. Activity he has expressed as active–passive, tense–relaxed, fast–slow. Potency is expressed as strong–weak, hard–soft, masculine–feminine. Meaning can be evaluated in these three dimensions about a norm.

62. Grimm has placed structures in Osgood's semantic space (Fig. 20). 'Home' is active, slightly weak and beautiful. At the other extreme he has placed 'prison', which is strong, ugly and slightly passive. He postulates that all things in aesthetics can be placed in this space, and also suggests that various colours have their places too. Perhaps all houses should be a soft browny yellow, and all prisons a dark grey.

63. In fact, people throughout the ages have always tried to explain aesthetics, particularly proportion; among those who have put forward these ideas are Pythagoras and Le Corbusier with his modular theory. Maybe Grimm's theory is not perfect but it is a thought process which clarifies the mind in deciding what impression a structure should express and as a result the curves, texture, proportions, colour, etc. can be matched to convey that impression.

64. I do not know where Grimm places a bridge, but would suggest it is active, strong and beautiful. This activity is the point that Mr Allan misses to some extent in his structures. Perhaps Nervi's staircases at the Palazzo dello Sport (Fig. 21) have been Mr Allan's inspiration for his staircases up to his footbridges. Nervi's structure has movement. The eye takes a bound and a leap up onto the higher level and my only quarrel with this structure would be that perhaps the movement is too fast for a rather steady progress up the steps. Mr Allan's staircase on the other hand (Fig. 15) I would

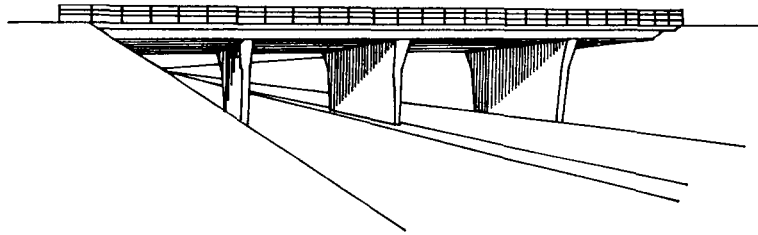

Fig. 22. Bridge, Doncaster Bypass

not quite describe as a 'galloping giraffe', but more as an outsider in the Grand National who has taken a leap and a bound and somehow hit the fence, and only the rider has been catapulted over. If the Author had resisted the temptation to put in the curved knee brace on to the column, his structure would have been superb.

65. In the matter of detail, I feel in one or two places he has gone to great lengths, but in fact the detail is rarely seen in closeup. The 'Greyhound' bridge (Figs 4 and 5) sits on a pedestal which is well proportioned, and the sets round about are beautifully detailed, but they will never be seen in quite that proximity by people crossing the bridge or in the cars rushing underneath. In Fig. 12, Mr Allan shows a V-legged pier to a bridge, which I think is fine and delicate. But then he says it will not withstand traffic impact, and has had to protect it with a pedestal which spoils the total effect.

66. Finally, I do not like circular columns to bridges. Again it is a question of movement. A bridge should express the activity of traffic going underneath and across the bridge. In this case, the eye trying to go through the bridge is arrested by the first column, goes up and down that column before going on to the next, then finally through the bridge. I consider here that a more solid type of wall is preferred, and would be better proportioned as in some bridges on the Doncaster By-pass (Fig. 22) where the eye goes straight through and the whole effect is one of unity.

67. I know that the Author's first comment will be that a wide bridge produces considerable darkness underneath, which has the effect of arresting the eye. In these cases,

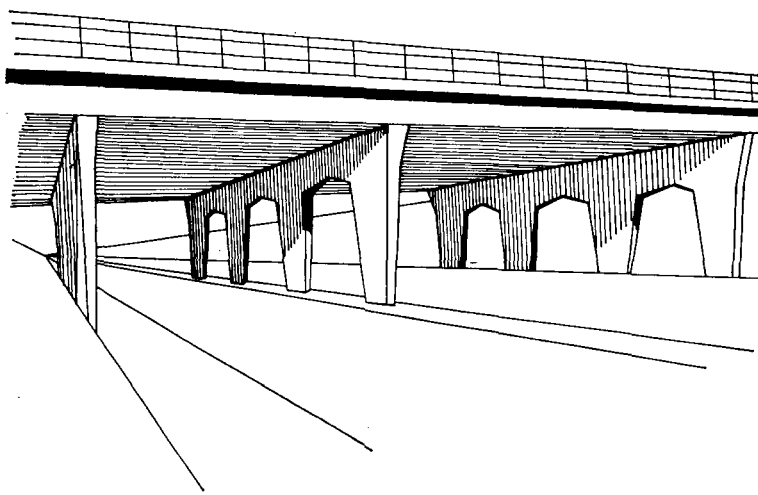

Fig. 23. Bridge, Maidstone Bypass

if the piers have suitably proportioned holes through them (Fig. 23) the movement of the eye can be maintained without deep shadow.

68. It is often said that beauty is in the eye of the beholder, and this axiom gives rein to a great deal of undisciplined excesses. Aesthetics becomes the whim of the individual: 'I shall do what I like'. If however it can be based on a rational idea of what one is trying to achieve, the environment will benefit to everyone's advantage.

Mr J. Murray, Superintending Bridge Engineer, Lancashire Sub Unit, NWRCU

In § 31 the Author compares modern sculpture with bridge design, and asks whether the footbridges shown in Figs 13–15 had succeeded in making public property 'art-full'. He also says '. . . the artist compels the viewer to an intellectual exercise leading to an endless variety of images'. Surely the artist is trained to do this, and the bridge engineer is not. It is not the bridge designer's brief to make an intellectual exercise out of design as this leads to gimmickry, as it has done in much of modern sculpture and in the footbridges shown in Figs 13–15.

70. The Author refers to this problem again in an important quotation from Herbert Read in § 39, part of which reads '. . . where functional forms are equal in operative efficiency . . . then it is possible to choose between them to select the most beautiful'. In Figs 13–15 the choice of sloping and curved supports does not fulfil this basic criterion of operative efficiency. This condition would require the provision of vertical supports for the footbridge and the staircases. The use of a mixture of sloping, vertical and curved supports makes the structure look contrived and not in harmony with the buildings which form the background to it.

71. In Fig. 6 vertical supports are provided throughout. They fulfil the basic criterion of efficiency and harmonize with the tall buildings behind. It is therefore a most pleasing structure.

72. The 'Greyhound' footbridge (Fig. 4 and §§ 14 and 15) is not a successful structure. The triangular frame double support is fussy and shows confusing shadows on the rear frame. This could be avoided with a simpler support. The deck curve is not smooth enough in the centre, and the deck fascia is a little thin at the ends.

73. In Fig. 5 the very small pedestal spoils the base detail which would be better without it. The base in Fig. 13 is of much more satisfactory shape and size.

74. In § 22 the Author says that the deck of the Bridge of Sighs 'dips down gracefully'. In fact Fig. 7 shows the left hand side of the deck coming down too sharply. The double V supports are unnecessarily cumbersome for the size of this bridge. Shadows on a deck of varying thickness appear to suggest twisting of the fascia on the right hand side. Most of these adverse effects could be avoided if the deck and supports were of a simpler type.

75. The proportions of the footbridge in Fig. 8 are wrong, because it is too tall for its length and a different solution is required.

76. The bridges shown by the Author in Figs 1, 10, 16 and 17 have the greatest appeal because they are in a natural setting, surrounded by hills and trees. Nature's imagery is much more beautiful than man's and engineers must therefore remember to keep man's imagery in a low key.

Mr W. R. Varley, North Eastern Road Construction Unit, DoE

I should like to make a few comments dealing with the philosophical aspects of the Paper. I do not accept one of the very early statements concerning the Platonic ideal—that there is a perfect truth existing independently of man. Each man has his own standards, and along with it, if he has any humility at all, an awareness of other people's standards. One's own standards are based on some allegiance to what is loosely called the consensus of informed opinion. One's judgment is based on precedents. Each decision one makes in arriving at a solution to one's own aesthetic problem adds to the collection of judgments, and each decision changes slightly the centre of gravity of that consensus of informed opinion.

78. The Author has with a wealth of expression illustrated the qualities of form and shape which he regards—and I do not dissent from the collection he displayed—as being good. But with this wealth of example and the fortunate circumstances of life that the Author has had in being able to work with continuity and support in the locale and environment which he has come to know intimately, I wish he had investigated and tried to make, some objective evaluation of the principles which influence aesthetic quality.

79. It is quicker, cheaper, and looks cleverer because it is more mystical, to handle the whole of the aesthetic side in one gut-busting heave of inspiration based on experience. I do not believe that it is the best way, for the designer has to foresee the future standards of informed opinion as well as his own. There must be some systematic approach to this evaluation.

80. Mr Leeming has described an approach suggested by Osgood which is valuable. I liked all the examples that Mr Allan displayed for they showed that the engineer can do what he wants provided it is done with a proper respect for the right scale and order of things, and this Mr Allen has got right. He has the scale right, and I think it is adherence to this rather than to the Platonic ideal and absolute truth independent of man which accounts for the success of Mr Allan's bridges at Cumbernauld.

Mr R. J. M. Sutherland, Harris and Sutherland

The real difficulty with even the smaller highway bridges in towns is not their appearance—important though this is—but their scale, which is too big for the domestic scene. Further, in towns the large areas of concrete surface, inevitable with most highway structures, soon tend to become foul due to atmospheric pollution. The problem is how to make such structures less dominant.

82. In America, and in particular in California, some success has been achieved by growing creepers up columns or on retaining walls. Maintenance becomes a little more difficult and often the conditions are not ideal for plant growth, but when my firm tried this in England even the cheapest plants were simply stolen. I wonder whether the Author has tried this type of planting and if so with what success.

Mr B. Forster, Union International Co. Ltd.

Mr Allan suggests that for a civil engineer, a feeling of social responsibility is a powerful motivating factor and this is reflected in his appreciation of the importance of the visual impact of the environment on people. I would suggest that it is not a motivating factor to have a feeling of social responsibility. The idea of social responsibility has been sold to engineers because they are not terribly good at creating agreeable forms. It is a pressure which has been brought to bear on engineers to try and stop them making ugly objects. I think a very powerful motivating factor is a desire to shape things. The Author talks about sculpture, and it is quite obvious that he has joy in shaping things, so I put forward this as a major motivating factor in a designer.

84. The second point is that the word 'organic' is used, and it is put forward in the Paper as a principle. It is not very clear to me exactly how this should be taken. When I read the Paper, I think Mr Allan is trying to reflect in an artificial structure a natural growth out of the ground, but because it is not a natural structure, he is trying to reflect in some way the spirit of the natural landscape. However, I do not think the underpass shown in Fig. 2 is particularly organic in its principal form. It is basically a rectangular culvert which people walk through, but it does have an attractive surface. In the Paper there is a proposition that organic form is the most appropriate for civil engineering structures because these structures generally appear in a natural landscape. However, most of Mr Allan's work is sited and fits quite happily in a suburban context of small-scale buildings. So when Mr Allan argues that things ought to be organic, I do not think that it is necessary to say that it is because they are sited in a natural landscape.

85. In § 17 there is a statement that symmetry equals cliché, and destroys any dynamic characteristics that the structure may have had. There are, however, several struc-

tures which rely largely on symmetry for their stability, e.g. the suspension bridge. I agree that one should not contrive to make things appear to be symmetrical. To illustrate that some structures do demand symmetry I would refer to Ove Arup's footbridge across the Wear, which is largely symmetrical. The deck slopes because of the difference in the heights of the banks; but if the banks had been the same height, I think it would not have looked any less attractive.

86. I agree entirely with a general principle put forward later, that one can succeed if one treats the major form of the bridge as a solid which has to be moulded to give light and shade.

Mr C. H. Wilshere, John Laing & Son Ltd.

I am delighted to see Cumbernauld with so many wonderful bridges. It would be pleasant to learn that they cost less than normal bridges, but I fear they will have cost more.

Mr D. T. Yeomans, University of Liverpool

There is an apocryphal account of a conversation between a bridge engineer working for a county council and a member of the Ministry of Transport. 'How much money are we allowed for aesthetics?' to which, of course, the reply was 'None'. Aesthetics is not something stuck on afterwards, but part of the structure when it is formed. So it is difficult to attribute any costs to aesthetics. The engineer showing me his bridges said 'It is all aesthetics. That is how we decide what the shape will be.'

89. The Author suggests that what he wants to do is to look at the thought processes which are involved in designing these bridges. In reading the Paper I was disappointed, because that was not the message that came across. Indeed, I had no idea when I had finished the Paper what the thought processes were. I was not sure, taking an almost facetious example of the 'galloping giraffe', whether he began by saying 'Let us have a galloping giraffe and make the bridge that shape', whether as he began to form the bridge he said it was beginning to look like a galloping giraffe so let us push it in that direction, or whether he stood back at the end and said what name shall we give this, and then added 'It looks like a galloping giraffe'.

90. The question I still want somebody to answer is how do engineers take account of aesthetics when designing something like this? At what stages is it done? How does it affect the thought processes? I imagine the answer will be 'that engineers think about it all the time'. But I want a more detailed answer than this even if it is not something that can be answered simply.

Mr D. S. Thistlewood, University of Liverpool

I applaud the Author for the enthusiastic way he speaks about aesthetic quality in his bridge design. However, I am left with two feelings—one of slight confusion and one of some disappointment.

92. The confusion I think orginates from the fact that the Author uses the two traditional disciplines of aesthetic judgment, namely, the classical and the romantic: he seems to take liberally from either to suit his own purpose, and constructs arguments which I think could justify almost any situation.

93. I have a feeling of slight disappointment because in making his exposition, he does so from a position of privilege. Quite literally, all the illustrations were taken from privileged positions, that is, positions of trespass, grass verges, banks, and so on, from vantage points which are not available to most people who would have to use these bridges. His justification was presented almost entirely in visual terms. I think this is wrong. I was looking for some justification of his designs in other than aesthetic terms, and the privileged images would be meaningless to members of the public who have to experience aesthetically these bridge designs, not with so much their eyes, as with the soles of their feet.

The Chairman (Mr Bartlett)

I should like to ask the Author whether he sees any merit in more architects being trained as engineers, and more engineers being trained as architects. He might give me quite a short answer on bridge works, so I would ask him to try and extend his opinions on that subject into other fields.

Mr H. N. Ginns, Past President, Institution of Highway Engineers

I wish to congratulate the Author on his Paper referring to Cumbernauld new town bridges. I enjoyed his 'aesthetic' design approach and feel that the Paper should help young designers to apply to their bridgeworks something more than the simple putting together of the necessary pieces. There is a genuine movement in the UK for 'quality of appearance' of bridges and the Paper will take its place in that movement.

96. I must explain that I have more than a general interest in the Author's work for the reason that as a Deputy Chief Highway Engineer in Scottish Home Department in 1958–59 I had much to do with the early planning of the new town of Cumbernauld and sought to encourage grade-separation for traffic and segregation for pedestrians in the face of the usual pressures for cheap standard 'on-the-level' designs and layouts.

97. This early work, done in conjunction with the planners and the new town staff, has born fruit in making Cumbernauld the safest city in the world, road-accident wise. Thus, indeed, the Paper gave me much personal satisfaction as it represented the culmination of work done some 17–18 years ago.

98. May I also congratulate the Author and his staff on their achievements on the ground. The ultimate satisfaction for an engineer is to be able to *see* his own creations in being and in use: the new town engineers must be contented people. They can take to heart some words of Henry Moore: 'To be obsessed by some vision and to have the continuous opportunity of working to realize that vision could be looked upon as God's greatest gift to anyone'.

Mr D. B. Storrar, Engineer, Scottish Development Department

In his intriguing Paper, the Author analyses some thought processes associated with, in the words of the introduction, 'the creation and selection of form in bridge design'.

100. An engineer is accustomed in the design of bridges, to exercising his engineering intellect. That is, he is able to meet the mathematical challenge of a technical problem, and can put a cost to its solution. This may be an over-simplification, but, it is an outline of a process with which an engineer is familiar, and for which training has prepared him.

101. However, when an engineer comes to exercise his aesthetic judgment, he is on much more difficult ground, having had no formal guidance in this direction. This seems a surprising omission when one considers the importance of form. After all, the impact of the inevitability of the form of a bridge will continue to enhance, or detract from the landscape long after the mathematical intricacies of its design and the cost of its construction are forgotten.

102. Mr Allan draws to our attention the place which consideration of form has in bridge engineering, and it is a subject to which he has devoted a great deal of thought. I would be grateful therefore if he could perhaps give his views on the nature of training or guidance which he considers engineers could receive to enable them to tackle more knowledgeably and authoritatively the problems associated with the appearance of bridges.

Mr W. K. Mackay, Partner, Jameson Mackay and Partners

Almost 30 years ago the National Academy of Sciences coined a term 'the complete highway' which was deemed to incorporate the qualities of utility, safety, beauty and economy. Utility was defined as 'the ability to serve the categories of traffic for which

the highway is built'. Safety was embodied in 'the orderly movement of vehicles and pedestrians'. Beauty was defined as 'the harmonious integration of engineering and landscape', and economy was defined as 'a combination of effective design and pleasing appearance at a reasonable cost for construction and maintenance'.

104. Mr Allan in his Paper is right to remind us that our choice of structural form, and particularly finish and detail, is not totally prescribed by considerations of utility, safety and economy. An adventurous and imaginative designer can ally to those qualities a variety of form and treatment in order to produce a 'harmonious integration of engineering and landscape'. What this approach does demand, however, is an almost individualistic approach to each structure within its own particular setting. This is a counter-movement to standarization of bridge designs according to loading, span and skew. It does not, however, mean that there is no place for standardization and the economies which are assumed to stem therefrom. Standarization of components and erection techniques is compatible with variety of finished structural form. It is this combination of standardization with individualism which distinguishes the road bridges of Cumbernauld. There is a basic unity deriving from the prefabricated columns and flush beam soffits which is then removed from uniformity by the visible response of each structure to the particular dynamics of the traffic which it carries and to the environment within which it is set. In footbridges the functional constraints are much less definitive so that there is, or might be, more scope for imaginative form. The fact that many of the footbridges in Cumbernauld have been given local nicknames, such as the Snake, the Greyhound, the Dinosaur, the Galloping Giraffe and Ben's Dragon, are indicative of the local interest in these structures and suggest that the citizens consider them a form of civic sculpture.

105. There is a real danger of tending to excuse mediocrity by blaming the constraints of economy, utility and safety—all words which have unadventurous, unattractive overtones. This Paper should stimulate all engineers to regard each structure as a fresh challenge to creativity.

106. President Johnson, in a message to the American Congress in 1965, said: 'I hope that, at all levels of Government, our planners and builders will remember that highway beautification is more than a matter of planting trees or setting aside scenic areas. The roads themselves must reflect, in location and design, increased respect for the natural and social integrity and unity of the landscape and communities through which they pass.' There has been a remarkable improvement in recent times in the aesthetic quality of road and bridge design but the movement has seldom, if ever, been so eloquently expressed in words and examples as in the Paper and works of Mr Allen.

Mr Allen

Before commenting in detail on individual contributions I would like to refer to an article by Will Howie which I think relevant to the Paper.[9] Under a bold headline 'Will engineers become underlings or architects of the New Jerusalem?' he was reporting on the British Association meeting in Stirling when Sir Misha Black, Professor of Industrial Design at the Royal College of Art said that 'No longer would engineers have to be content with the role of underlings to architects but they would be on terms of equality provided they had the capacity to do so'. According to Will Howie 'if the professor is right in asserting that the essential elements of creativity and expressive symbolism must exist before anything can be considered a work of art, it is clear that most engineering falls outside art. Few would dispute that it does.' I claim to be amongst those who would dispute this statement.

108. There is a historical dichotomy of very long standing between the so called fine art which has an ideological or symbolic function of representing our mental perceptions in a material form and applied art which has a utilitarian function of making objects which satisfy practical needs. I consider that bridge engineering can be included under the heading of applied art.

109. According to Herbert Read the function of applied art is wider than merely

finding a practical solution to satisfy practical needs. Such a solution will be in conflict with other and essential instincts if it does not at the same time provide an aesthetic solution. The totality of the human being includes an aesthetic impulse as well as various practical impulses, a concern for the form as well as for the efficiency of the instruments of production or use. Unless this instinct for form is satisfied at the same time as the functional need, a disturbance will be set up within the social totality. The pattern of the culture will not be integral.

110. He in fact considers the constructive engineer as an abstract artist as long as he manages to reconcile his functional aims with ideals of proportions and vitality. Commenting on individual contributions I am extremely grateful to **Mr Russell** not only for his favourable comments on my work but also for his appreciation of the broader philosophical principles involved in the Paper, which unfortunately were missed by some contributors to the discussion. Mr Russell's comments are very pertinent and expressed in elegant language which is rare in the world of engineering. Few engineers are able to emulate his eloquence or to equal his expertise as far as concrete is concerned.

111. **Sir Donald Liddle**'s generous comments are perhaps the most significant to me, as Sir Donald is the genuine representative of the people of Cumbernauld. I appreciate that in matters of function and of taste, the community is the final arbiter. Its comments are spontaneous expressions of acceptance or otherwise. I am pleased to record that the desire to use the footbridges in particular is demonstrated long before such structures are complete. People attempt to cross the footbridges even though they are still under construction, which the Contractors find rather inconvenient.

112. I appreciate **Mr Leeming**'s thoroughly prepared and well-illustrated contribution. However, studying as I have for some time the philosophy of aesthetics, I have come to realize that it is indeed full of vague, woolly and contradictory statements, starting with Aristotle contradicting Plato more than 2000 years ago, Kant contradicting Piero della Francesca (a friend of Leonardo and the foremost mathematician of his day), the western aesthetic theory completely at variance with the Chinese ancient philosophy of aesthetics which is reflexion of embodiment of the Tao conceived as a quasi-moral order of the universe: how more woolly can you get, Mr Leeming may say? But he is doing his best in this respect in § 61. All this may indeed be alien and incomprehensible to the 'bolts and nuts' mentality of most engineers, who look for straightforward rules and regulations to guide them in their work and thus end up as underlings to architects in matters of aesthetics and are generally unappreciated by the public in this field. I am not familiar with Grimm and Osgood's work, quoted by Mr Leeming, but certainly now I have the details of their publications I will make an attempt to study their views, which may be the latest additions to the countless futile attempts made throughout history to rationalize aesthetics and the creation of beauty. I am somewhat sceptic if Grimm and Osgood are likely to be less woolly than Plato and Kant.

113. However, meantime I am content to follow Herbert Read's statement 'that the question of form in art—even industrial art is not a simple one. It cannot be solved by a rule of thumb. If the Golden Section or some other canon of proportions were made compulsory for all industrial design, I have no doubt that the whole standard of production would be improved, but only at the cost of a profounder and more essential vitality' (woolly?).

114. Herbert Read is of course himself a follower of Kant, the German philosopher still considered father of modern aesthetics, who in his *Critique of judgement* said clearly and unequivocally 'It is impossible to find theoretical rules for the construction of beautiful objects'.[10]

115, Regarding § 65 I am able to assure Mr Leeming that details shown in Fig. 5 are seen by a great many people and what was originally a dump for local vandals, impossible to keep tidy, now seems to be treated with more respect. For construction, produce well executed details and in design apply broad philosophy is my recommendation and give the uninitiated, the onlooker, the man in the street some credit for perceptive powers. In § 66 Mr Leeming expresses firm dislike of circular columns; once more he is against the

ancient and modern trend in structural engineering and aesthetics. However, be that as it may, the use of circular columns in the bridges at Cumbernauld was largely dictated by their structural efficiency and ease of erection, for they are standardized and precast and as such superb in quality, while their graceful classic appearance (which seems to appeal to many observers) is purely incidental.

116. I find **Mr Murray**'s contribution particularly puzzling and somewhat at variance with my intention. When embarking on the Paper I intended it as a short philosophical essay. Mr Murray instead, and with considerable presumption, chooses to concentrate on the 'bolts and nuts' aspect of bridge design which was not the subject of the Paper. However, I am prepared to accept his somewhat detailed challenge. In § 72 Mr Murray makes a bold but unproven statement that the Greyhound footbridge (Fig. 4) is not a successful structure; very dogmatic, but ill founded. Mr Murray is obviously not familiar with high density urban development and the many constraints it imposes on the design. Coming down to 'bolts and nuts', the use of triangular frame enabled the reduction of bending moments in the deck of some 40%, reduced the deflexions, made the crossing feasible and achieved considerable structural and cost efficiency.

117. Similarly in § 75 he uses again his dogmatic approach, that is, without knowing the design constraints condemns the proportions of the footbridge in Fig. 8 as wrong. In this case he hoists himself by his own petard when he says that it was too tall for its length. The truth of the matter is that length was dictated by planning considerations and tallness by statutory headroom required, as a bridge engineer should know. The footbridge is structurally extremely efficient, if Mr Murray would realize that it is in fact a two-hinge arch, the structural implication of it being the fact that the sloping members or legs are able to carry a considerable thrust, thus reducing bending moments in the curved deck. The deck is curved for functional reasons and maximum slenderness is achieved throughout to harmonize with the environment. This bridge was a subject of many favourable comments from architects as well as local citizens. Mr Murray generally seems to have a 'thing' about sloping members; this is a somewhat undesirable rigidity of view in an experienced engineer. My philosophy is 'flexibility of design'—the 'horses for courses' principle—and this is amply illustrated by a variety of bridge forms at Cumbernauld. Anyway, philosophically speaking and more in the context of the Paper, the examples shown were selected on their suitability to illustrate a particular design principle which I would advocate. For instance, the Greyhound bridge illustrated the use of an assymetrical arrangement of structural elements; whether such principle may or may not be acceptable to other designers is another matter.

118. Regarding Mr Murray's statement in § 69 'that engineers are not trained in art', I would quote the German philosopher Novalis: 'A potter, no less than a poet, is born, not made'. Art is not entirely a matter of training. I reaffirm my belief that bridge design in all its aspects is very much an intellectual exercise or task, since intellectualism is a doctrine that all knowledge derives from reason,

119. It was with real pleasure that I examined **Mr Varley**'s contributions, very pertinent and appreciative of the philosophical aspects of the Paper rather than the details.

120. However, although I used a quotation of Plato extolling the merits of intellect over emotion, I did not express or indeed support a view that there is a perfect truth existing independently of man. This is why I follow those philosophers and writers such as Kant or Herbert Read who condemn as futile any search for rationally apprehended beauty; organic vitality is my aim, in search for beauty, beauty expressed not only by form but even more by visual rhythm, a most difficult aspect of beauty to perceive. (No rules of thumb offered!) I agree with **Mr Sutherland** that the scale of a highway structure is the most important single factor as far as environment is concerned. From this it follows that large spans so beloved by the real 'bolts and nuts' engineers, if used in the wrong context, may destroy environment more effectively than any form of structure.

121. Regarding planting in structural context, the only suitable element I feel is the

open crib-walling used instead of solid retaining walls. I have some experimental work in hand in this respect but it is too early to express any views on its suitability.

122. I have no quarrel with **Mr Forster**'s criticism and accept his robust statement on the subject of desire to shape things. Indeed, I consider it as complementary to matters discussed in the Paper.

123. I feel that I should elaborate a little on the term 'organic', and the associated expressions such as 'organic vitality', 'organic unity' and 'organic design'. By the term 'organic' I mean basically part of nature, part of the environment. The most characteristic single feature of organic design is the use of the organic curve which is always sympathetic towards nature, enhances its liveliness, expresses the joy of living and is symbolic of a vitalistic urge. But to express such sentiments an organic curve must be an unrestrained free flowing curve. Until the advent of the computer the use of such curves was an anathema to an engineer dealing with structures, for the simple reason that his intellectual armoury was insufficient to assess stress conditions in a complex three-dimensional curve. Even now, when the computer is accepted as essential hardware in structural design, there are comparatively few examples of structures such as the 'Dinosaurs' (Fig. 13) or the 'Snake' bridge (Fig. 6), both using freely flowing curves. I deprecate the present still extensive use of straight decks on footbridges which more often than not are non-functional and demand high embankment approaches which are costly and unsightly. The term 'organic' in the context of the Paper embraces not only structures but the immediate approaches and I am glad that Mr Forster notes that most of the works described in the Paper are sited to fit quite happily in a suburban context. However, he does not seem to realize that the 'context' itself is an artificial creation, also aiming at being organic. This may be difficult to discern but nevertheless it is true, particularly in the case of the Greyhound footbridge (Fig. 4), Seafar Landlands interchange (Fig. 1) and Village interchange (Fig. 16).

124. I agree with **Mr Wilshere**'s brief assessment: it is a fact of life that good things may cost a little more.

125. I also agree with **Mr Yeoman**'s comments in § 88. However, I am somewhat surprised that Mr Yeoman did not find the Paper up to his expectations as far as coverage of the subject is concerned; the very title with the first two words of the title 'some' and 'notes' makes it plain that only a brief and limited summary of the subject will be given. The Paper does not pretend to be a manual or a text book on the design of form.

126. Very likely the subject does merit a book devoted entirely to the subject of form in bridge engineering, but that is another matter. However, considering the Paper, together with the introduction, some of the discussion which followed and a study of the references quoted may have clarified the matter of form in bridge engineering a little. Perhaps this could be listed under the following headings:

(*a*) organic characteristics of form
(*b*) spontaneous use of asymmetry—or otherwise as required by (*a*)
(*c*) use of free flowing curvature arising out of proper interpretation of (*a*) and (*b*)
(*d*) use of ornamentation
(*e*) truth to materials principle
(*f*) unity.

These could be considerably expanded as chapters of a book on the subject, but obviously not within the limited context of a paper, and I feel Mr Yeoman's expectations are a little too high in this instance.

127. The captions given to various footbridges could be better described as nicknames—'the Snake' bridge, 'Ben's Dragon', etc., originated from the citizen's of the town long after the particular structure had been completed.

128. Regarding Mr Yeoman's demand for more detailed answers to his queries, these could only be provided in a book on the subject. However, I doubt if such a book is at the moment available.

129. I find **Mr Thistlewood**'s comments in § 92 very perceptive. I admit to the adoption of the classic and romantic philosophies of aesthetic treatment in appropriate cases.

130. Classic treatment is being displayed mostly in highway bridges, which are more disciplined structures by virtue of numerous design constraints, and they are of course at the service of the machine. While romantic, somewhat exuberant, treatment of form is given more scope in footbridges with their less onerous design constraints but with greater emphasis on the human element and environment, these examples of two different aesthetic treatments demonstrate the flexible, non-dogmatic approach in which I believe. However, I find Mr Thistlewood's comments regarding the illustrations being taken from privileged positions somewhat naive. Of course they were taken in such a way as to show the structures to the best possible advantage, but nevertheless they can be seen from other vantage points, particularly from the surrounding houses (Cumbernauld is a high density town) as even more attractive, so they are constantly under observation. Indeed all the views shown present deliberate attempts to capture moments of enchantment which I wished to share.

131. In § 93 Mr Thistlewood states that my justification was presented almost entirely in visual form. In this respect I would quote good authority, namely Harold Osborn, who in his *Aesthetics and criticism*[11] says 'No set of words can explain what a picture means, what a statue means or a dance or a song or a musical composition. Works of art cannot be described or explained. They must be perceived and the most the critic can do is to offer hints and direction for focussing the attention in the very difficult art of exercising and cultivating the skill to perceive.'

132. Should more architects be trained as engineers and more engineers be trained as architects? This is an interesting question posed by **Mr Bartlett.** My brief answer is a very emphatic no. I do not think that such training should be a matter of deliberate policy. Any crossing of professional boundaries could only be voluntary and of course such schemes would have only a very limited effect. But I do see the need for a closer educational overlap between the two professions. Perhaps during four years' study at a university both the architectural students and the engineering students should attend the same basic classes, embracing art theory and aesthetics on the one hand and basic sciences on the other hand for a period of, say two years. If some such scheme found acceptance, the Chilver Committee recommendations would of course be essential for its implementation.

133. Education generally is very relevant to the subject of aesthetics. Plato said 'We must necessarily attach supreme importance to that part of education which encourages the sense of rhythm and harmony—because rhythm and harmony sink most deeply into the recesses of the soul and take most powerful hold of it, bringing gracefulness in their train and making a man graceful, if he be rightly nurtured, but if not the reverse'[12]; even when it comes to reasoning, added Plato, the aesthetic approach will have been the best, because it will have given a man 'that instinct of relationship which is the key to truth'.

134. It seems that my comments on the question of engineering education posed by Mr Bartlett largely answer **Mr Storrar**'s question. I would emphasize at this point that the mathematical challenge referred to in § 100, which to some creative minds has always been a mere drudgery, has now largely disappeared with the advent of the computer. The engineer is able more than ever before to exercise his creative ability, natural or acquired, by study formal or extra mural. The engineer has now a chance of being a master builder, a constructor in Le Corbusier's sense; one who is concerned more with synthesis and creation rather than mere analysis and calculations. As a constructor he would develop a passion for order and order is harmony, is beauty.

135. According to Herbert Read[12] Plato said as the modern psychologists are saying that 'all grace of movement and harmony of living, the moral disposition of the soul itself, are determined by an aesthetic faculty; by the recognition of rhythm and harmony. The same qualities, he said, enter into painting and all similar workmanship, into weaving and embroidery, into architecture (therefore presumably into bridge architecture)

as well as the whole manufacture of utensils in general; nay into the constitution of living bodies and all plants, and the absence of grace and rhythm and harmony is closely allied to an evil style and an evil character whereas their presence is allied to and expressive of the opposite character which is brave and sober minded.'

136. I was especially pleased to receive **Mr Ginns'** contribution not only because he is well known for his untiring advocacy for better roads in the UK but also because in his vantage position with the Scottish Home Department he was able at the appropriate time to help the process of gestation, and later on witnessed the birth of the infant city. This was conceived as the first 'motropolis' in the world, but a city that tamed the motor car. He still retains his interest in the New Town of Cumbernauld, this youthful community now approaching its coming of age, a town which during its brief but exuberant growth made a mark in all aspects of design well known throughout the world.

137. I believe it most appropriate that the discussion should end with a contribution from **Mr MacKay.** Mr MacKay more than any other contributor captured the essence, the substance and the spirit of the Paper and in a brief but brilliant exposition summarizes philosophical aspects which previously escaped unnoticed. No observation in the whole discussion is more perceptive and gives me more satisfaction than his remark about 'this combination of standardization with individualism which distinguishes the bridges of Cumbernauld'.

138. This is a most succinct and apt summary of the ideas which I attempted to convey. I am especially grateful to him, who obviously as a well-known consultant with world-wide connexions has little time to spare on such non-profit making activities as an unrewarding discussion of a somewhat abstruse philosophical essay.

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