Heliports in urban areas

by

H. P. Finch, O.B.E.,

and

Structural tests on an experimental helicopter platform

by

R. J. Mainstone, M.Eng., A.M.I.C.E

Mr H. J. B. Harding (Past President) said that in 1957 he had become involved in the subject of heliports when he was able to give Sir Eric Mensforth some advice about the Port of London Authority requirements for building in the river, and on soil conditions at Battersea. The heliport was built as it was the only way in which Westlands could develop their helicopter business. Unless there was somewhere from which to work there was no way of getting the experience, both from the public and the Government points of view.

2. The heliport was to be built on a non-profit-making basis, for the prestige of the British helicopter industry, for export work and for exploration. The different authorities had wanted an assurance that it could be built in such a way that it would be possible to demolish it eight years later.

3. The choice of Battersea was made because John Brown & Co. had bought land in that area for another purpose and consequently owned this piece of ground by the river.

4. The slab itself extended out to the river with a 125-ft frontage and a depth of 50 ft. Then there was another approach to land 65 ft wide and 50 ft long. The land area was 200 ft × 200 ft, and of that 3000 sq. ft were available for parking three helicopters.

5. Before this came about there was a public inquiry, in 1958, at which various companies put up various suggestions. A platform floating in the river was suggested, but people would have had to get ashore.

6. The heliport at Battersea was only a miniature one compared with a major airport, yet it embodied in miniature many of the same problems. Negotiations were necessary with the Ministry of Housing and Local Government, the Ministry of Aviation, the Port of London Authority (who had to be assured about how far into the river the platform would extend and whether the piles could be removed if required by the Authority), Battersea Borough Council (for reasons of planning, sewerage and drainage of petrol), and London County Council (fire services, etc.), all for this quite small heliport. In the case of one of the size Mr Finch mentioned, all these things would be necessary on an even greater scale.

7. In § 27 of his Paper Mr Finch had set out the main elements to be considered: landing and take-off pads and turn-round parking area. A floating platform with a 15-ft range of tide would not have been of much use for getting ashore for parking, hence the piled flat-topped jetty leading to the parking area.

8. Mr Finch mentioned the unobstructed sector of air space for taking off, landing and loading. The Air Ministry issued a handbook of instructions for helicopter usage, defining angles of flight and a number of other matters.

9. A certain amount of building had been required for passenger handling, customs, etc. Even for a small heliport there had to be full treatment of air control by radio and, of course, the usual waiting rooms, weighing machines and customs facilities. There also had to be access for a rescue boat and for anybody wanting to arrive by river. The Architect decided that the most economic arrangement was to have a prefabricated but purpose-designed building with cedar board outside and cheerful colours, which contained the usual offices and an area for customs and passengers, etc. The petrol and oil stores had to be underground, with all the necessary precautions for draining off.

10. This small heliport allowed for the parking of only three helicopters and Mr Finch had pointed out the much larger number required for a commercial service.

11. He had only made one helicopter trip from one airport in Chicago to another. The helicopter appeared to be only a few hundred feet up but there seemed to be no restrictions concerning flying over built-up areas of the city. In London, on the other hand, flying was restricted to the area along the river, with equipment provided in case of emergency. Whether these regulations in Britain would ever be lifted he did not know. On the other hand, the noise problem was considerable. If large numbers of executives took to flying by helicopter in London, life would become unpleasant for many people working there.

Mr G. W. Rooke (Lewis & Duvivier), referring to the Paper on the structural tests, said that he would limit his remarks to the loading for which they were instructed to design the landing platform at Battersea. The heliport there was wanted in a considerable hurry and it was essential to have instructions without delay about the loading for which the platform was to be designed. They were in consequence greatly helped by the fact that their Clients were able immediately to stipulate the maximum wheel loading for which the structure was to be designed, namely 15 tons, including the dynamic effect. This was stated to be the maximum impact loading to be expected from a helicopter such as the 39-seater Westland Westminster landing on its two main wheels simultaneously. Such a plane would have a static wheel load of $7\frac{1}{2}$ tons, and adding a dynamic load factor of 2 would give an equivalent static wheel load of 15 tons. It was understood that this was considered adequate to cater for an approach speed of 10 ft/s.

13. A helicopter, however, would seldom, if ever, land simultaneously on both wheels, but with the wide transverse spread of the wheels relative to the body it seemed unlikely that the first wheel to touch down would transmit more than half the total load since the other half of the plane would still be falling freely, or rather as freely as the uplift from the rotors would permit. If, of course, the helicopter had a very severe list, it would seem that the force exerted by the first wheel to touch down might be substantially more than half the total load, but this might perhaps be regarded as an extreme emergency.

14. He noted from the report of the then Ministry of Transport and Civil Aviation on planning of air stations for single-engined helicopters published in 1956, that the static wheel loads given were multiplied by three in order to arrive at the equivalent static load, making due allowance for the dynamic effect, but this higher factor did not appear to have been called for in the case of the Battersea heliport. Their Clients were good enough to say what must be done, and it was done without further argument, as they had every confidence in their Clients' figure. The question of the response loads of the structure itself was not considered. It was a heavy type of structure, very plain in design, and seemed to have performed its function well for a period of seven years, although it had probably never been subjected to anything like the load for which it was designed.

15. The drag loading at wheel hubs giving horizontal loads at tire contact with the ground was considered as being up to 0.3 of the up-load. At a figure of 15 tons for the latter the drag load would therefore amount to $4\frac{1}{2}$ tons. In actual fact with

such a structure over water, supported on long piles, and decked with a thick reinforced concrete flat slab, loads of this order did not present any difficulty since the design was governed rather more by practical considerations in deciding the spacing of the piles in conjunction with the minimum thickness of the deck, and a limited number of raking piles had of necessity to be included in order to provide this relatively tall structure with the necessary lateral stability. These were more than adequate to cope with any likely drag load.

16. It was, however, readily appreciated that where landing platforms had to be constructed on buildings and such similar bases, it was most important that the research which Mr Mainstone had carried out should be brought to its full conclusion so that the maximum landing loads liable to be encountered might be known by the designers of such structures within the closest practicable limits.

17. The construction of the Battersea platform was perhaps worthy of some comment. There was considerable discussion in the early stages of the project as to whether it should be a floating platform or a fixed one, a point already covered by an earlier speaker.

18. The platform as constructed was 120 ft long $\times$ 53 ft wide, with a 65-ft wide neck for the tractor to draw the helicopters to the parking area and bring them back when they were ready to set off again. The direction of the platform was more or less north-east/south-west, in the direction of the river at that point. The decking consisted of a heavy reinforced concrete slab some 21 in. thick, with the beam reinforcement concealed within its depth, as was so commonly used in jetty construction, supported on piles at 10-ft centres in the direction of the river and at 12-ft centres in a direction at right angles.

19. The piles were generally 14 in. $\times$ 14 in., prestressed up to the maximum of 55 ft long, but under the neck Rendhex Section III steel box piles were used as it was felt that with their open ends they would cause less vibration when being driven in the close vicinity of the old river wall than the heavier, solid-section concrete piles. The strata comprised fairly dense ballast to depths of $7\frac{1}{2}$ ft below bed level, underneath which lay clay of moderate stiffness.

20. Driving was therefore rather difficult since the piles had to be hit very hard in their weakest condition, i.e. as pin-jointed columns with their toes in the top of the ballast, and hard hitting had to be continued through to the clay. The thickness of the ballast was considered insufficient to ensure fixity for the lower ends of the piles which, with this unbraced form of construction, was considered necessary. When, however, the ballast had been penetrated, some difficulty was encountered in getting the specified set on the piles in the clay, which was rather surprising. One would have expected a greater frictional resistance from the ballast, which was very dense at the surface.

21. The Contractor (rightly, in the speaker's opinion) decided to pitch and drive the piles by means of a derrick running on a track behind the river wall. The heaviest piles weighed approximately 5 tons, and those furthest out from the river wall had to be pitched at a distance of about 110 ft from the centre of the derrick track, so that a relatively high-capacity derrick had to be used.

22. Four steel box piles were provided under each half of the platform raking at 1 in 3 in the direction of the river in order to give the necessary lateral steadiness, and also to cater for the highest drag or braking loads which might be encountered during the landing of helicopters. Four similar piles were provided at the outer end of the neck in order to ensure lateral stability in the opposite direction.

23. The Contractor used prefabricated columns standing on the top of the ballast with horizontal members in pairs spanning between them to build up a grillage at two levels forming holes at each point where piles had to be driven. The piles were then pitched by dropping them into their respective holes and applying a Delmag No. 12 hammer by means of the derrick. The hammer had a helmet combined with it which was lowered to receive the pile head with the hammer fixed to it. Once the combination was dropped on the piles the derrick bonds could be released and it

could be transferred to another job of work. As soon as the hammer was fired it worked without requiring any attention until the pile was driven to its set or penetration, whichever was the governing factor in each case.

24. Telescopic steel forms were used for the soffit shutter of the deck slab, their ends being supported on pairs of longitudinal timbers clamped to the sides of the pile heads, these timbers being in addition supported off the top of the ballast by means of light steel tubular columns with screw jacks at their upper ends.

25. Timber fendering with fender piles at 10-ft centres was provided along the face of the platform and returned half way round its ends in order to protect the structure from possible impact by river craft.

26. Mr Rooke understood that the relatively close spacing of the piles had caused some little surprise. He had himself always preferred close pile spacing, partly in order to make the shutter supports as light as possible. His firm had designed a number of structures in this type of construction without any bracing, fixing the head of the pile in the slab and the lower portion of the pile in the ground, and the particular design was very fully dealt with in a paper he had submitted to the Institution in 1949¹. It might appear 'rough and ready' but in fact was remarkably economical, and the cost of this platform, small though it was, and hence requiring quite a lot of plant for a very small area of structure, worked out at £2 5s 0d/sq. ft of deck area, which must be a record for the decade in which it was constructed. Even at that time one would have expected it to cost at least £3 10s 0d or £4 0s 0d/sq. ft.

27. Safety netting had to be provided around the perimeter of the platform. On the occasion of a visit to the heliport when the traffic was fairly brisk he had heard the criticism that instead of the platform with a single deck it would have been rather better to have arranged its shape differently in order to permit the helicopter traffic to circulate. The suggestion was that it would have been better to have two decks, one on each side of the platform, which would thus have been U-shaped instead of T-shaped. Craft landing could then have been drawn ashore by tractor for refuelling and parking along one side of the 'U' whilst the other side would have been left clear for drawing planes out on to the platform again immediately prior to setting off.

28. Mr Rooke mentioned that some hair cracks had developed in the concrete piles probably due to the hard hitting by the hammer on the full 50-ft length of the pile acting as a long pin-jointed column. These were effectively treated afterwards and as far as he knew there had not been any harmful effect on the structure.

Mr E. H. Lewis-Dale (Ministry of Public Building & Works), speaking in a private capacity, said that as far as the future was concerned he felt that it would be a very good idea if helicopter manufacturers and other vertical take-off aircraft manufacturers could give some idea of how these were going to come down. It would also be very useful if the tests could be extended with heavier loads. These, of course, would have to be simulated in some way.

30. He was a little diffident in saying that he disagreed with Mr Mainstone's conclusions, because the Author was obviously very much better qualified than himself, but he had two slight doubts on the matter. The first concerned the validity of the overriding load factor of 1.5, if the aircraft were reputedly to be designed for less or if the loads were unknown. If the loads were unknown, since aircraft manufacturers or their clients tended to increase the loads further and further, he would have thought it advisable to overstate rather than understate the case.

31. Mr Mainstone had said that the failing loads on the gears were in principle to be equated to the ultimate strength of the platform. He had a feeling that the statement might suggest to a young designer that he should try to equate the ultimate load in this way. A most unpleasant design, possibly using high tensile steel reinforcement or something of that sort, might result. He did not say that high yield point steel should not be used but misuse could be a very bad thing.

¹ The references are given on p. 371

32. He wondered which was the worst case, landing on four wheels, three wheels, or two main wheels in the case of an aircraft which landed on the main wheels only. If a helicopter was long enough for one set of wheels to come down on one slab and one on another when landing, could not the worst case be that of one set of wheels coming down on the slab, causing downward flexion on that slab and upward on the adjacent slab, with the other set of wheels coming down at a critical time? With the slab used by Mr Mainstone and using the same central support, this case could be simulated on a small scale and it might be possible to prove an electrical analogy, which could be fed into an analogue computer and extended over a very wide range of structures.

33. With regard to Mr Finch's Paper, in § 19 he mentioned particularly the safety factor in licensing for public use. As had been pointed out, there were many people concerned with licensing future heliports, whether roof-top or otherwise. Regarding roof tops only, there were, of course, the local authority, the planning authority (which might not be the same body), and all the others, but the primary factor in roof-top landing was not only the safety of the aircraft but that of everyone inside the building. This might demand some additional security over and above a slab which was fundamentally strong enough, in case there were a crash.

Dr A. J. Dutt (Greater London Council) said that he would like to raise a few points on the structural aspect of the helicopter platform. Mr Mainstone had used the same platform for experimental investigation for different support conditions. In practice the positioning of the reinforcements in the slab would be different, depending on the support conditions, i.e., free, fixed and slab with central column. As such there would be variation of modes of vibration and natural frequencies which would alter the dynamic load factors to a large extent. This situation was likely to be significant in the case of a platform having a central support. He felt that the test on the platform having a central support could have been conducted on a separate platform in order to have a better simulation of the actual condition. He would be glad to know if the platform had been designed as a flat slab or some other type.

35. Would the Author give an idea of the intensity of rotor downwash load during the landing of the helicopter? This would set up an initial vibration of the platform. Could he also say whether there was any possibility of the dynamic load from the helicopter acting in phase with the initial motion of the landing platform?

36. Would there be any dynamic amplification during the take-off of the helicopter?

37. What were the protective measures used for the strain gauges attached to reinforcements and load cells? For the free drop condition of the helicopter the loading should be considered as a rectangular pulse load.

38. A further point worth considering was the dynamic effect of wind on the supports of the elevated platform when situated over the rooftop of a skyscraper. When a helicopter platform was situated on a river site the impact of wave action on the support needed consideration. Perhaps this combined dynamic action could be studied in a future investigation.

Mr D. H. Little (Messrs Walter C. Andrews & Partners) said that the conclusions he drew from Mr Mainstone's Paper were that the impact devices on helicopters were designed to produce a momentary load about twice the weight of the helicopter, so that if this weighed 10 tons the maximum reaction in the spring would be 20 tons and there would be a build-up from 0 to 20 tons with a maximum normal approach velocity of 6 ft/s. Above that velocity the 20 tons remained constant but moved sufficiently to absorb the energy arising from an approach velocity of 12 ft/s, and then crumpled up. The impact effect of all this on a foundation or platform which had a frequency of 6 c/s was to double that load. Hence with a helicopter weighing 10 tons there could be a spring reaction of 20 tons, which because this was applied suddenly to the platform could become 40 tons. However, if the frequency of the platform was

increased to 20 c/s there was no multiplying factor, and the 20 tons in the spring remained 20 tons.

40. From Table 1 it appeared that frequencies could be increased and the multiplying factor of 2 eliminated by applying restraint to the slab either by fixing the ends or shortening the span. It would seem that a 12-in. thick slab on a grid of 20 ft $\times$ 20 ft, allowing for the continuity, would have this frequency of about 20.

41. Was the rigid slab the right answer? Should not the whole slab go up and down? In the case of ships, in very round figures, 1000 tons moving at $\frac{1}{2}$ ft/s had a kinetic energy of 50 tons/in.; 10 tons moving at 6 ft/s was 75 tons/in. which was not very difficult to handle; and 10 tons moving at 12 ft/s was only 300 tons/in. He would have thought it possible to drive piles at wide spacings and have a greenheart timber decking, instead of reinforced concrete, which would absorb the kinetic energy of the vertical approach of a helicopter, just as vertical fendering on a jetty dealt with the horizontal approach of boats.

42. He thought the accident factor was very important psychologically. If an aeroplane made a bad landing it stood a better chance of survival if it did so on a runway than if it came down in a wood or field. But if a helicopter had to make a bad landing it would be better for it to do so in a soft field rather than on a rigid concrete deck such as that described in the Paper. Somehow this seemed to indicate a fundamentally wrong principle in the design of the landing platform.

The Chairman (Mr Neville Borg) said that, taking a sober view of heliports of any sort and their establishment and operation for civil traffic on any normal economic basis, if his own experience in the last 10 years was anything to go by he would have said they had no future at all. All enquiries at any time seemed to lead to the conclusion that the commercial future of the heliport was always about 20 years in the future. They were operable for military or emergency purposes or for purposes with a high element of 'social benefit' but in terms of normally generated traffic for civilian purposes (whether pleasure or business trips) the costs were relatively high and operating precautions, including those arising from conflicts of safety zones as between airport and heliport, relatively severe. If there were an airport handling fixed-wing aircraft within 10 miles of a heliport, the heliport might be adversely affected. All these factors seemed to militate against the establishment of commercial helicopter routes.

44. However, he wondered whether all the ground work would prove to have been done, not for the benefit of the helicopter, but for that of the variable-geometry or vertical take-off plane. Perhaps at some time the operational conflict would be removed by the use of airports for both large and small vertical take-off aircraft operating trunk and local services respectively.

45. On experience so far, there was little justification for reserving a heliport site for 25 years, particularly if it sterilized valuable adjoining land. At the same time, one had a strong feeling that in the future there might be good reasons for one.

Mr R. W. S. Thorley (Westland Aircraft Ltd) said that he agreed to a very large extent with the last speaker's remarks; the helicopter had always been regarded as an interim machine to V.T.O.L. aircraft. But a few months previously Westland had brought off another 'first' with the introduction of the first twin-engined helicopter with civil certification in Europe, and the advent of multi-engined helicopters must surely have a very great bearing on this question.

47. So far as Westland's interest in the heliport was concerned, it was quite definitely a private venture, and with no thought of profit. Obviously they had a vested interest in helicopters, but apart from that it was very useful from a development point of view. They wished also to show to the appropriate authorities that they believed that at some time in the future a major heliport suitably situated in Central London should be built.

48. Mr Finch had rather depressed him by enumerating various sites that had been considered and apparently rejected for one reason or another. He was not quite clear as to the basis of measurement, whether it was mileage from a central point such as Marble Arch, or the time it would take by car or some other method of public transport to get to a predetermined point, but he would have thought that anything south of the river would not be particularly satisfactory. Under normal conditions Parliament Square could be reached in 12 to 15 minutes from Westland's London heliport but most people wished to go further than this, and as soon as the journey extended to Oxford Street or to the City the time was considerably increased, even in the easy times of the day.

49. It was obvious why the over-station heliports were suggested, at Charing Cross or Waterloo, although even Waterloo was on the wrong side of the river, in his view, and he could not really see any adequate reason for siting a heliport, for example, near Tower Pier. Perhaps it could be argued that this would be adjacent to the City, but a great number of people using such a service would want to go to their hotels before going to the City.

50. Westland had recently acquired this site which they had leased for the last seven years. It was possible that it might be extended and that there might be secondary access to the pad, but it had never been their intention to provide a permanent heliport for London there. This was merely an interim heliport. Their hope was that as a result of this example the Government might one day provide what was demanded. He felt that the day was now very near, with the advent of multi-engined helicopters. Even this small heliport had done reasonably well bearing in mind that it had had no scheduled services. There had been 11 500 movements up to the end of 1965, and 14 000 passengers had been through. For a heliport of such a small size it was encouraging.

Mr G. S. Cooper (Ministry of Public Building & Works) said that, with regard to the question of aircraft and their alleged loadings, he had found in conventional airport runway design that a new aircraft always exceeded the load stated at the time of conception by over 20 or 30% when it became operational. If one received a series of loadings for an aircraft to be built in three years' time, or to be operational in three years' time, it was pretty certain that they would be grossly exceeded. While not suggesting that anyone should 'fiddle' with the loading factors so carefully set out in Paper 6921, he felt that designers ought to try to persuade their clients to aim at much higher loadings at the ordering point than they thought their aircraft was going to reach.

52. With regard to down-draught from the rotors, this in itself was not significant on the platform from a loading point of view but he had seen quite remarkable effects on buildings near heliports or near take-off points and wondered whether Mr Finch would like to give any views in this connexion.

Mr G. N. Coulter (Deputy Borough Engineer, Lambeth) said that he had an interest in the Nine Elms site. He was not employed by the Authority at the time that Nine Elms first came to the fore as a possible heliport site in the London area but he gathered that at that time his Council expressed some alarm, particularly at the question of noise. Mr Finch had dealt admirably with this aspect in his Paper. He did not know whether at that time the figure of air traffic movement of 25 each hour, which Mr Finch mentioned, was appreciated, but at a recent meeting of the Transportation Engineering Group, when a similar subject was being debated, the speaker said that if air traffic were to be as heavy as this throughout the whole of the day he was not surprised that the borough engineer was greatly concerned.

54. This was not the proper forum at which to argue the pros and cons of Nine Elms as a site as against others, but there were two important points which had occurred to him in this context. Mr Finch had mentioned the provision of car parking accommodation on the site. But once one got out of the immediate confines of

the heliport there was always the difficulty of dealing with the traffic generated by the heliport. A heliport designed as a major heliport for the whole London area would be a considerable generator of traffic, and one of the factors militating against Nine Elms would be the proximity of Vauxhall Cross, a major road intersection, which was already being troubled, not least by the current Government proposal to introduce Covent Garden Market into the area. Would the probability of the introduction of Covent Garden Market into the area have any serious effect on the choice of the site for a heliport?

Mr G. A. Weeks (Building Research Station) said that the impact factors quoted in Fig. 19 of Paper 6921 by means of which it was suggested that design loads could be obtained from the appropriate wheel loads, were related to the fundamental frequency of that part of the landing platform in the vicinity of the touchdown. This precluded any direct approach to the design of the slab since, until the slab was proportioned, its natural frequency characteristics could not be precisely assessed. This same problem arose in more acute form in the design of the experimental platform itself. Lacking the data now available in Fig. 19, the simple analyses on which Figs 1 and 2 were based were taken as a guide, and gave partly intuitive estimates of the slab frequencies which were then checked by simple model tests. These might indicate a possible approach in cases where analysis proved difficult. In the tests the slab was represented by a perspex sheet 20 in. square. This was held in a special frame by means of which both the free and fixed support conditions proposed for the prototype could be reproduced at a number of different spans.

56. As shown in Fig. D1, the rotation over the supports was prevented by steel pads which were screwed down onto the perspex sheet. When these steel pads were not in contact with the sheets the support conditions corresponded with the simple ball support conditions on the prototype structure.

FIG. D1: MODEL USED IN TESTS

57. Since similitude requirements could not be met by adopting different horizontal and vertical scale factors, perspex sheets of a nominal thickness of $\frac{1}{8}$ in., $\frac{3}{16}$ in. and $\frac{1}{4}$ in. were used. The model was excited by means of a small vibrator mounted directly over the centre of the slab. This was actuated by the signal from a variable frequency oscillator and by varying the frequency the forced vibration could be adjusted to coincide with the fundamental frequency of the model. Resonance indicated when the amplitude of the vibration, which was picked up by an accelerometer mounted on the underside of the slab, reached the maximum value for a given energy output of the oscillator. The pattern of the vibration was studied in more detail by viewing the model with the aid of a stroboscope flashing with a frequency very near to the resonant frequency of the slab. The general pattern of vibration could be seen quite clearly and it was also possible to examine the behaviour of the slab at harmonic frequencies.

58. From the results of these tests it was possible to verify the original analytical estimates and also to predict more closely the natural frequencies of the experimental platform. Confirmation was obtained later by vibrograph and other tests carried out on the actual platform.

59. Although, as suggested in the Paper, it might be possible to include in design specifications tables of impact factors for slabs of normal proportions, he thought that model tests of this kind would allow a designer much greater freedom if he were dealing with cases involving slabs of irregular shapes.

Mr H. P. Finch, replying to the discussion of Paper No. 6858, said that Westland's Heliport at Battersea indeed fulfilled a very useful function. It was the only provision in London for helicopters since the temporary South Bank heliport, but he was sure that Mr Harding and Mr Thorley would be the first to regard it as an interim provision. No one would like to think that the future of London's helicopter transportation was limited to this site.

61. Mr Harding had mentioned a floating platform and indeed there had been several proposals on this basis. A floating platform could, however, only be associated with relatively small-scale use, since it was unlikely that the large parking areas associated with very busy heliports could be provided by this means. In the case of the proposals that had been made, the limitation on intrusion into the shipping fairway meant that the floating platform had to be so close to the river bank that direct flight in a relatively straight line on take-off could not safely be accomplished.

62. The interesting suggestion had been made (and no doubt it would have been quite practicable had this proposal been followed up) that the normal approach would be along the axis of the river and then by air taxi-ing onto the floating pontoon, which would be regarded merely as a parking place for the helicopter. In this way a certain amount of traffic could have been handled, but the space could not have been afforded for more than two helicopters at any one time.

63. A point had been made concerning the safe flight paths needed for single-engined helicopters and the fact that in Chicago this did not seem to be treated as an absolute requirement. The Americans seemed to regard railway tracks as constituting a safe flight route and providing emergency landing areas, an idea he himself found very difficult to accept. Track use on suburban and city lines in London was far too heavy for this philosophy to gain general acceptance.

64. Mr Lewis-Dale had mentioned the safety of people occupying the upper floors of buildings where a roof was used as a helicopter landing pad. Where a structure was specially created as a heliport, the upper floor would be very adequately protected in construction and would probably not be used for general occupation. An adequate buffer would always be provided between the under-side of the landing deck and any occupied space. He had attempted to make the point in the Paper that, in general, buildings which were not densely occupied were preferable as the bases for heliports.

65. Mr Little had mentioned the possibility of flexible decks, and it might have been expected that the current intense activity relating to the provision of decks for helicopters on oil rigs would have brought about some study of this problem. Mr Finch was, however, unable to say whether there was any flexibility in the comparatively light platforms which existed at some places.

66. He did not share the pessimism which had been expressed as to the future of the helicopter. As Mr Thorley had remarked, the introduction of the multi-engined helicopter was a very distinct step. The next development would probably be something on the lines of the S65, which would have a greater weight and passenger capacity, and, it was hoped, would be better from the economic point of view.

67. The extent of the area which had been examined in search for a London heliport had been mentioned. Time rather than distance was involved, and there were two possible datum points: the City of London and the hotel area of the West End. The latter was judged to be the more important, but since the number of sites from which a selection could be made was so limited by general planning considerations, some attention was given to those sites which existed at the eastern end of the Central London area.

68. Mr Cooper had suggested that down-wash might have some effect on buildings. Tests had been carried out, and Mr Finch did not think there was any evidence that the type of building likely to be provided at a heliport would be very much affected. There would, however, have to be some limit placed on the approach of pedestrians. There would also be the question of dust. A 50-ft buffer outside the extent of the actual landing and take-off pad would probably provide sufficient protection against these particular hazards.

69. Mr Coulter had discussed the anticipated movement rate and its derivation. Mr Finch believed that 25 movements per hour were about the maximum to be associated with a single landing pad. This had not been tested but the figure referred to a peak operating rate in bad weather, possibly in non-visual conditions.

70. Certainly any major heliport would have to solve its own car parking problems and also take account of problems of access by road. With regard to the site at Nine Elms, the committee which had made the recommendation with regard to safeguarding the site took fully into account the additional traffic which the heliport would generate and the necessity to provide car parking space. There was little he could say concerning the co-existence of a transferred Covent Garden Market and a large heliport. As far as he was aware the two would be adjacent rather than on the same site, and from what little he knew of the scheme for the market it would not interfere with the heliport in presenting unacceptable obstructions. He would have thought perhaps the only conflict would arise when both were seeking to secure a riverside space, as this was indeed limited. The heliport would need it for access for single-engined helicopters, and the Market might need it for shipment of produce by river. If so compatibility might perhaps be secured by the use of different working levels.

Mr R. J. Mainstone, replying to the discussion on Paper No. 6921, said that, since the instrumentation of the experimental platform and the techniques of observation and analysis were considered elsewhere^{D2}, he would concentrate on the comments that had been made and the questions that had arisen on the broader aspects of the Paper.

72. Both Mr Lewis-Dale and Dr Dutt had questioned the representative nature of the platform or of the landings made on it, while Mr Little had suggested, more radically, that its design was fundamentally wrong in principle.

73. The soft deck or the very flexibly supported deck advocated by Mr Little were, indeed, attractive from the point of view of reducing the landing impact on the helicopter. From this point of view, though, it must be remembered that, to be effective, the deck surface should deflect wherever the undercarriages touched down by at least

several inches in about 0.1 s. It hardly seemed possible to achieve that with the type of greenheart timber deck suggested, however widely spaced the piles. Some kind of double deck system seemed the only answer and it was difficult to see any overall economy or other advantage in this over the normal practice of equipping the helicopter with sufficiently flexible and resilient landing gears to cushion the landing shock on any relatively smooth surface. From the point of view solely of economy in the construction of the heliport structure it was difficult to see the advantage of any form of soft deck. Certainly the very flexible single deck, even if it had some advantage from the point of view of the helicopter, would have a low natural frequency. This would be associated with large dynamic amplifications of the landing loads and with an increased risk of resonance with any pitching or rolling motions of the helicopter on its undercarriages. The investigation had, therefore, been restricted to fairly rigid hard decks and Mr Mainstone thought this had been the best procedure.

74. Such decks might in practice take a variety of forms and Dr Dutt had correctly pointed out that, if they were of reinforced concrete, the positioning of the reinforcement would vary according to the support conditions. By far the most important parameter governing the dynamic amplification of the imposed loads was, however, the natural frequency excited by a landing impact, and the positioning of the reinforcement influenced the amplification only indirectly through this frequency. The testing of a single slab, with a single pattern of reinforcement but supported in a number of different ways, had given a slightly different range of the relevant natural frequencies from that which would have been obtained if the slab had been redesigned for each new support configuration. This had meant that the frequencies for which dynamic amplifications were plotted in Fig. 19 were not as evenly spaced as he would have liked. But it meant no more than that. He was sure that the same shape of curve would have been obtained if a large number of different platforms had been built.

75. The deck was a flat slab and had been designed as such. The main problems in design were first to estimate, on the basis of the theoretical analysis represented in Fig. 1 and Fig. 2, the effective loadings for different natural frequencies, and secondly to select proportions, spans and alternative support details to give a suitable range of frequencies. The support details had to allow easy and controlled moves from one configuration to another and the fact that it seemed essential to have four rather than three supports called for particular attention to the dimensional tolerances which had to be observed in constructing the slab and the diagonal bearing walls. He had found these aspects of the design of the platform among the most interesting in the whole investigation and was grateful to Mr Weeks for giving some further details of the procedure. So that the need to estimate frequencies in order to arrive at design loads should not be regarded as more onerous than it really was, it might be added that both the initial, partly intuitive estimates of the slab frequencies and the values derived from the model tests agreed closely with those finally measured on the experimental platform itself.

76. The scope of the tests on the platform had also been restricted, but he did not think that they would have learnt much more if they had extended them, as suggested by Mr Lewis-Dale, to heavier loads. He would have expected precisely the same amplifications of the loads, provided that the undercarriages loads themselves or their simulated equivalents varied with time in the same way as those of the Westland Whirlwind and he understood that this was so for all helicopters now flying.

77. Most of Dr Dutt's remaining questions had already been answered indirectly in the Paper but he would deal with them briefly. The curves in Fig. 10 showed a residual rotor lift shortly after touch-down in the live landings of about 40% to 70% of the helicopter weight. The corresponding downwash would, at this time, act largely on the platform, but it was not, like the wheel loads, a load which increased rapidly from zero, so it induced no vibration in the platform. In fact, in the test landings from a low hover, there was little change in the downwash on the platform

since initially, while the helicopter was hovering, the total downwash, though greater, was more widely distributed beyond the confines of the platform. In an actual landing from a greater height, the downwash would increase gradually from zero as the helicopter approached, but even in an 'emergency' landing at 12 ft/s, its rate of increase would be well below that needed to initiate a significant vibration in any likely practical structure. The second question in § 35 did not, therefore, arise. During take-off there was merely a gradual transference of load from the undercarriages to the rotors, concentrated loads at the former giving way to the widely distributed load of the rotor downwash which gradually reduced to zero as the helicopter gained height and moved away. There was no possibility of dynamic amplification here. Essentially the free drops differed from the live ones only in the absence of rotor lift and rotor downwash. As could be seen from Figs 8, 13 and 14, the loading was no more a rectangular pulse than in the live landings. Had it been so, the dynamic amplification factor would, of course, have been 2 for every free drop, whatever the support configuration.

78. He was grateful to Mr Little for his very clear and concise illustration of the main conclusion of the investigation which had been presented graphically in Fig. 19. He wished only to correct the assumption that the maximum undercarriage reaction remained the same for approach velocities of 6 ft/s and 12 ft/s. This was not normal practice nor was it desirable from the point of view of efficient undercarriage and air-frame design. It was preferable always to make the fullest use of the available undercarriage travel, thereby reducing the maximum load for any but the worst landings. This, of course, was advantageous also from the point of view of the landing platform and had been recognized in the distinction between the two landing cases in recommendations (a) and (b) (Paper 6921, § 46).

79. Since, on the basis of the dimensions given by Mr Rooke, the characteristic frequencies for the Battersea Heliport must be well above 20 c/s, there would, as Mr Little had pointed out, be virtually no multiplying factor and Mr Rooke had been perfectly justified, in this case, in working directly with the maximum impact loading as stated by Westlands. If he was correct in assuming that this loading had been considered as a working load on the platform, it appeared that the design might even have been unnecessarily conservative. He understood that the design load factor for the 'normal' landing on two main wheels for the Westminster was less than 1.5. If recommendation (a) was accepted, the equivalent static wheel load would therefore be about $11\frac{1}{2}$ tons instead of the 15 tons assumed.

80. The suggested load factor of 1.5 in the recommendation to cover both cases such as that of the Westminster where the design load factor for the undercarriages was less, and those in which, at the time the platform was designed, it was unknown had, however, been questioned by Mr Lewis-Dale. Some comment on the reasoning behind the suggestion therefore seemed desirable. The suggestion that it should be regarded as an overriding minimum was linked to a desire to make the working load, or 'normal' landing case the primary one for design purposes. This meant that the 'normal' landing load factor must not be taken as much less than the factor for the 'emergency' landing, which seemed always likely to be 2.0 or more. The suggestion that it should also be taken as the factor for the helicopters of the future, for which any permanent heliport must be designed, was based merely on the consensus of opinion of several large helicopter manufacturers. He had hoped that one of the Westland representatives would have commented on this aspect of the recommendations, but he trusted that their silence signified agreement. He felt that both Mr Lewis-Dale's and Mr Cooper's justifiable anxiety that future loadings should not be underestimated, should be met not by an artificial increase in the load factor but by a realistic estimate of the maximum size of helicopter to be accommodated by the heliport throughout its design life.

81. He could not accept Mr Lewis-Dale's objection to the principle of the recommendation (b). Any valid principle of design could be misapplied, but it was not

thereby made invalid. On the other hand, he readily accepted that the landing case described in § 32 could be a critical one and should, when it was likely to arise, be considered in design. Recommendation (b) of § 46 had not been intended to exclude critical cases other than those mentioned, but he was indebted to Mr Lewis-Dale for drawing attention to one which might otherwise have been ignored.

82. Finally he thanked the Chairman for his remarks on the future of the heliport. When the problem had first been put to the Building Research Station and they were planning the experimental investigation they had received much encouragement from his predecessor at Birmingham, Sir Herbert Manzoni. A country-wide survey of opinion at that time had also suggested that there would be a real demand for the results by the time that the investigation was completed. Since then, commercial helicopter services had developed steadily across the Atlantic and much had been achieved, but here interest had definitely waned. The potential nuisance from noise was, no doubt, one reason; yet he could not help feeling that the basic one was a different attitude to innovation. He had seen something of the operations of the four main commercial helicopter networks in the U.S.A.—in New York, Chicago, Los Angeles and San Francisco—and only in the case of the most recent operation of New York Airways on and off the PanAm roof, high above central Manhattan, had it appeared that some annoyance might be caused in the immediate vicinity of the roof. All proposals for a central London heliport of which he was aware had been modest when compared with the PanAm roof except in the matter of deck area, but the PanAm experiment was, no doubt, being watched closely by the responsible authorities here. If, in fact, the future did lie with some form of vertical take-off aircraft other than the helicopter, the investigation described in the Paper would be equally relevant, provided that there was no radical change in the design of undercarriages.

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