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7692 DISCUSSION

Drax power station

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Mr B. G. R. Holloway, Rendel Palmer and Tritton

When designing the steel frames for 2000 MW power stations, commencing with Eggborough in the early 1960s and followed by Ironbridge, Fawley and Pembroke (the latter two being oil-fired), it was considered that the design experience and codes used for the smaller 240 MW station steel frames in the early 1950s could not be extrapolated linearly as these larger stations were past the limits of previous engineering experience, and all design assumptions were therefore reviewed. The design parameters evolved were considered by some at the time to be ultra-conservative, and it is therefore more than gratifying that Messrs Judson and Morris have arrived, apparently independently, at most of the same conclusions.

57. With the relatively light cladding on these stations, compared with brick panels, wind loadings and the resulting deflexions are an important factor. When the boilermaker was asked to specify the maximum horizontal deflexion which could be tolerated at the top of the boiler for Eggborough power station his first reaction was to indicate that no deflexion could be tolerated, but eventually he agreed limits of ± 2 in. It was found that a portal design, even with the then low cost of high yield steel, could not unless grossly uneconomic reduce the deflexion to this amount. Consequently a braced structure was adopted, and this arrangement was also followed at Ironbridge and Fawley stations, with resulting problems of plant installation. In the case of Fawley the foundation conditions, with possible differential settlement of the column bases, would have presented added problems had a portal design been adopted.

58. For Pembroke, the boilermaker permitted a horizontal deflexion at the top of the boiler of $\pm 3\frac{1}{2}$ in., and this relaxation coupled with good foundation conditions and general agreement to avoid the use of high yield steel because of delivery and lamination problems, made it possible to provide an economic portal design. Drax had the advantage of a bunker bay to assist in restricting deflexion but it would be instructive to know if any economies were lost in achieving a portal structure with a horizontal deflexion limited to ± 2 in.

59. *In the calculations for Eggborough, etc., the effect of the cladding was neglec*ted, but it has been shown that the cladding can reduce the deflexion by as much as 20%. This, however, would apply only in the longitudinal direction and only partially transversely to the two end boiler frames.

60. It has also been determined theoretically that the wind loading on a partly clad structure is greater than on a completed building. To confirm this, wind tunnel tests were arranged by the CEGB and carried out by Scruton:[1] the increase in wind loading over that of the completed building was shown to be about 50%. This information does not, however, appear to have been made available to the designer of

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Drax. This enhanced wind effect necessitates the addition of a considerable amount of temporary bracing during construction.

61. It was also theoretically determined that there would be a considerable up-upward and downward wind pressure on the turbine house roof, and that, should a portal structure concept be adopted, there could be a gauge change of the crane rails of approximately ± 1 in. This would be resisted by friction or propping from the crane wheel flanges unless a pendulum leg design was adopted for the crane. Consequently, the columns were made as cantilevers, with the roof members simply supported and arranged so as to give the appearance of portals. It is not clear from the Paper whether this arrangement was adopted at Drax and it would be useful to have the Author's comments on this aspect of the design.

62. The boiler suspension girders for Eggborough and Ironbridge were also supported on rockers at the lower flange, but at Fawley and Pembroke they were of box type, and the support was arranged at the neutral axis of the girders, thus eliminating the spreading effect. This was achieved by haunching the girders up at the ends. The girders were also split horizontally, thus halving the weight to be lifted. The sections of the supporting columns were arranged so that the shortening under boiler load was uniform, thus limiting distortion of the boiler.

63. At Eggborough the boiler structures surrounded one of the horizontal members and assumptions were made regarding the heavy bending stresses in the stiff box columns induced by the heating up and expansion of this member, although shortening due to the reactive force was taken into account. This led to consideration of the effect of a temperature gradient from the superheater floor to the firing floor. Assumptions made were subsequently measured and confirmed at operational stations. These agreed with the figures given in § 31.

64. As a result of the low extra-over price for high tensile steel in the early 1960s considerable use was made of this material at Eggborough, Ironbridge and Fawley, but there were delivery, welding and lamination problems. As a result Pembroke, like Drax (§ 33), was built almost entirely in mild steel, which also reduced the hazard of brittle fracture.

65. End moment connexions were a problem. The connexions consisted of large horizontal Ts with their stalks bolted to the flanges of the beams. The high loading from these was transmitted to the 'webs' of the box columns by means of heavy flanged diaphragms. These, although simple on the drawing board, led to weld distortion problems in the diaphragms, and as a result in subsequent tenders the diaphragms were highly priced. At Pembroke it was found cheaper to haunch the beams, thereby reducing the forces of the end couple which permitted simpler diaphragms to be used. Where end moment connexions were not required, the end detail consisted of shear pads with neutral axis connexions, thereby eliminating the effect of change of beam end slope under loading.

66. It is noted from § 36 that large diameter V quality HSF bolts were used throughout. Their use in the four power stations mentioned was minimal because they were considered then to be unsatisfactory under fatigue conditions.

67. The question of pattern loading from the floors to the columns merits consideration for economic column design. Individual floors must, of course, be designed for dismantled plant, etc., but the degree and pattern of loading from the floors to the columns must be realistic. Theoretically worst combinations could lead to heavy column bending. A 20% relief of floor live loading into the columns was agreed with the CEGB at Fawley and Pembroke. Did any such relief apply at Drax?

Dr D. W. Cox, Polytechnic of Central London

Variations of 4 ft head or 0·1 ton/sq. ft are reported in artesian water pressure at 50 ft depth, where the piles are founded in sand. The soft strata above have a low vertical permeability and hence any change in water pressure at depth will result in a similar change in effective stress at that depth.

69. Theoretically the pile end bearing capacity is directly proportional to effective stress. Recent field tests by the writer confirm this to be partially true in practice.

70. The effective stress below 50 ft of soft soil is about 1 ton/sq. ft. A change of 0·1 ton/sq. ft in water pressure and effective stress could cause a 10% change in ultimate pile capacity. A larger increase in artesian pressure, say 12 ft, could result in a 30% loss in ultimate capacity. Could this account for some of the variation between the initial and working pile capacities?'

Mr Judson and Mr Morris

Mr Holloway has raised the question of limiting in the most economical way the horizontal deflexion of the boiler supports. On Drax the initial design gave a calculated deflexion of 3·3 in. which was thought to be acceptable. Comparatively late in the design stage the limit was set at 2 in. The reduction was achieved by increasing the size of some the beams and by increasing the number of beams with moment connexions. The corresponding increase in the weight of structural steel work in the building was about 10%. It would really not have been possible to have introduced bracing at this time and we doubt whether it would have been possible to have had a braced structure, even if a decision had been made to do so at the start of the design. Some of the problems assocated with differential settlement of foundations for a rigid framed structure would equally occur with a braced one.

72. The information concerning wind loading on a partly clad building was, in fact, available to the Authors at the time of the design of Drax. The limitation on deflexion, however, only applied, of course, when the structure was completed. Therefore when erection conditions were checked it was found that only the design of some of the portal frame connexions was affected. A small amount of temporary bracing was also needed in the first bay of the bunker bay to suit the erection sequence.

73. The main lattice girders of the turbine hall are simply supported. The change in gauge of the crane rails under the worst conditions of crane, surge, wind, temperature and superimposed loading was calculated to be $\pm 0{\cdot}5$ in. which was considered to be acceptable.

74. We note the manner in which Mr Holloway dealt with boiler support girders on Fawley and Pembroke. On Drax the box girders carrying the 100 ft span suspension girders were linked together so that there was no spread of the supports under load.

75. We are not clear whether Mr Holloway would accept V quality bolts under fatigue loading now, but, in any case, on the connexions in which they were used at Drax the number of significant loading cycles was low.

76. **Dr Cox** has highlighted a fundamental principle of soil mechanics and we agree with his comments about the effect of changes in artesian pressure on effective stress and the consequent theoretical variation in a pile's end bearing capacity. However, the total capacity can be affected by variations in skin friction, in sand density, particle size distribution and angularity, and by a number of other causes. We should be interested to have more information on his field work which supports the direct relationship between end capacity and effective stress.

77. We believe that on Drax the main problem was the undulation of the upper surface of the water-transported sand and the failure to drive some piles into this sand; these therefore rested on the softer material above it.

Reference

1. SCRUTON C. The problems of estimating wind loads on structures with special reference to cooling towers. *Natural draft cooling towers—Ferrybridge and after.* ICE, London, 1967, 85–89.