Proc. Instn Civ. Engrs, Part 1, 1989, **86**, June, 531–537

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Offshore platforms: design of two southern North Sea jackets

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Mr D. Appleford, *Goodfellow & Associates*

What are the costs for a jacket of this nature compared with the costs of the top side. Abandonment is mentioned in the Paper. What would the costs of abandonment be as a percentage of installation costs, and how does the design cater for it?

Dr P. Blair-Fish, *John Brown Engineers & Consultants*

During the design of these platforms how many design iterations were used on the jacket construction design? Why were the jackets designed with a separate infill deck support frame at the top rather than as a single piece? Why not have extended legs on the jacket and short legs on the topside? That way, the fabrication, transportation and installation of the topside are much easier. For the jacket in its in-place condition what boat impact criteria were considered and were, for example, the 820 mm dia. braces required to resist boat impact in any way?

57. What redundancy or post-damage analyses were performed? What sort of sea state for transportation was considered? Was any analysis done of the possible effects of the jackup on the pile foundation? Was all the drilling of these fields straight vertical drilling or was there any directional or slant drilling? If the field were being developed today, might a smaller number of platforms be allowable by the use of directional drilling?

Mr R. Webb, *BP International Ltd*

It is many years since the first platforms in the Leman field were installed in 1967. Other structures have been installed there over the years. Can the Authors identify the specific design improvements included in this latest structure over previous designs in the field?

59. The work, as described in the Paper, included a comprehensive conceptual design phase. How suitable would such conceptual design be for graduate training and submission for their Professional Examination?

60. For the shallow water Leman G structure the Authors determined that a breaking wave condition applied in the extreme storm. To what detail did the Authors go during the design to satisfy themselves that the breaking wave was of the spilling type rather than, perhaps, a surging or plunging breaker? Were directional effects taken into account by a refraction analysis, or by other means, during the investigation?

Paper published: *Proc. Instn Civ. Engrs*, Part 1, 1988, **84**, Feb., 21–41.

Mr J. M. Dawson, *Rendel, Palmer and Tritton*

In the presentation the Author's slides included the computer program SPLINTER for the interactive solution of the jacket and foundations. The text of the Paper suggests that a more conventional approach was in fact used with the jacket and piles analysed separately. Using our own program RESPIN we have found in certain cases significant differences between the linear non-interactive and non-linear interactive approaches. Have the Authors checked the original design results against the newer approach, or made similar comparisons on other jackets?

Mr A. C. M. van der Stap, *Shell UK*

I understand that the design wave, the 100 year wave, is approximately 15 m. Why is the bottom of the topsides still at a relatively high level above the waterline? Have there been other criteria which governed this level?

63. No boat-landing was adopted, to reduce the wave loading on the platform. However, both fenders (boat fenders around the legs) and walkways are still included in the design. Would the Authors incorporate these in new designs, considering the current cost-cutting environment?

Mr D. E. Glyn-Woods, *Fellow*

Can the Authors expand on the time scale of these operations. How long was spent on design, construction and installation?

Mr D. R. Carruthers, *Taylor Woodrow Offshore Limited*

The platforms were designed shortly after the Authors' company had finished the design of the Morecambe drilling platforms. Morecambe also had problems with breaking waves. How much more accurate do the Authors think that the calculations of breaking wave loads on these jackets were, as opposed to the calculations for Morecambe, especially DP3? Has this any significant effect in terms of forecasting the actual life expectancy of the Morecambe jackets? What was the ratio between the maximum compression load in the piles and the maximum tension load?

66. At Morecambe breaking waves occur. The fetch for wave formation stretches from somewhere off Florida to Morecambe, if exactly the right line south-south west is envisaged. Additionally the sea bed slope is in line with that fetch.

Mr Laver, Mr Barltrop & Dr Middleton

There are three questions posed by *D. Appleford*. On the question of costs, the total project cost was £87 million including jackets, topsides, piles and installation, but excluding drilling. The materials for the jackets and piles, which were purchased by Shell and supplied to the fabricator, cost £3·5 million. The fabrication of the two jackets cost £7·1 million. The topsides cost about £20 million and the installation about £3·0 million.

68. The second question relates to abandonment costs. None were formally made at the time, but in the southern North Sea they are predicted to be relatively small. The platforms are fairly easy to remove because it just requires cutting the piles at mud line and, because of the water depth, diver access is easy with no

saturation diving requirements. An estimate of abandonment costs would be £1 million.

69. With regard to the design for abandonment, it should be remembered that the southern North Sea structures are fairly small and they are well within the capability of heavy lift semi-submersible crane vessels (SSCVs). There are no special requirements built in, apart from the fact that the piles have to be cut and one would have to put back, in some form, lifting attachments which were cut off post-installation.

70. In answer to *Dr Blair-Fish*, the number of design iterations on the platforms was fairly small, partly because there was a limited amount of time and partly because there is not a great saving to be made by going round and round the loop many times for southern North Sea structures. To be more specific, for Leman G there were two separate stages of design. The first was the conceptual stage in which were determined the breaking wave forces and pile sizes. A major problem was the large amount of scour and sea bed movement which results in the piles supporting the jacket clear of the sea bed, rather like a portal frame. That determined the pile and leg size, from fairly simple calculations, without having to do an iteration on the jacket as a whole. Once the pile sizes had been determined, it was then a question of running through the analyses listed in the Paper to see whether the Authors' initially estimated brace and leg sizes were satisfactory. In the end, they probably performed three or four overall iterations in the conceptual and detail design phases.

71. The question of how best to fill the gap between the top of the jacket and the deck was the subject of a separate study during the conceptual design. Several different means of filling this gap were investigated; even bringing the top of the jacket right up to the deck underside, which is the suggestion made by Dr Blair-Fish. There were advantages and disadvantages of each arrangement. However, the scheme chosen provided a top-of-jacket walkway at an appropriate level and allowed, at least for Leman G, one-piece piles. The resulting scheme was the best for Shell's requirements, and the design installation vessels; however, the design was being conducted in 1983–84, and the now accepted use of SSCVs in shallow water could result in a different optimum solution.

72. The boat impact criteria was a 2500 t supply boat with two impact speeds. The first impact speed was 0·5 m/s. For this case, any damage to the structure would be very localized; for example, denting of an impacted leg was acceptable, but permanent deformation of other members was not acceptable. The second impact speed was 2 m/s. For this case the jacket was required to be standing after the collision. The Authors accepted considerable damage, particularly to the main chords. The amount of deformation was in excess of 0·5 m with the second type of impact, but the overall structure was capable of taking the impact and the deck would still be supported afterwards. It was necessary for the deck designers to be aware of the consequences of a boat impact, and to design their structure to resist formation of a plastic hinge at a deck support point. The 820 mm braces were not particularly required for boat impact. Obviously they helped protect the conductor area, but their diameter was determined by fatigue requirements.

73. Redundancy and analysis of post-damage strength is best illustrated by Fig. 12 which depicts triple lines where structural members were considered to have suffered some form of damage. They were in turn considered structurally non-effective, and it was demonstrated that the jacket would nevertheless be structurally adequate due primarily to its triangular framing. The members were selected

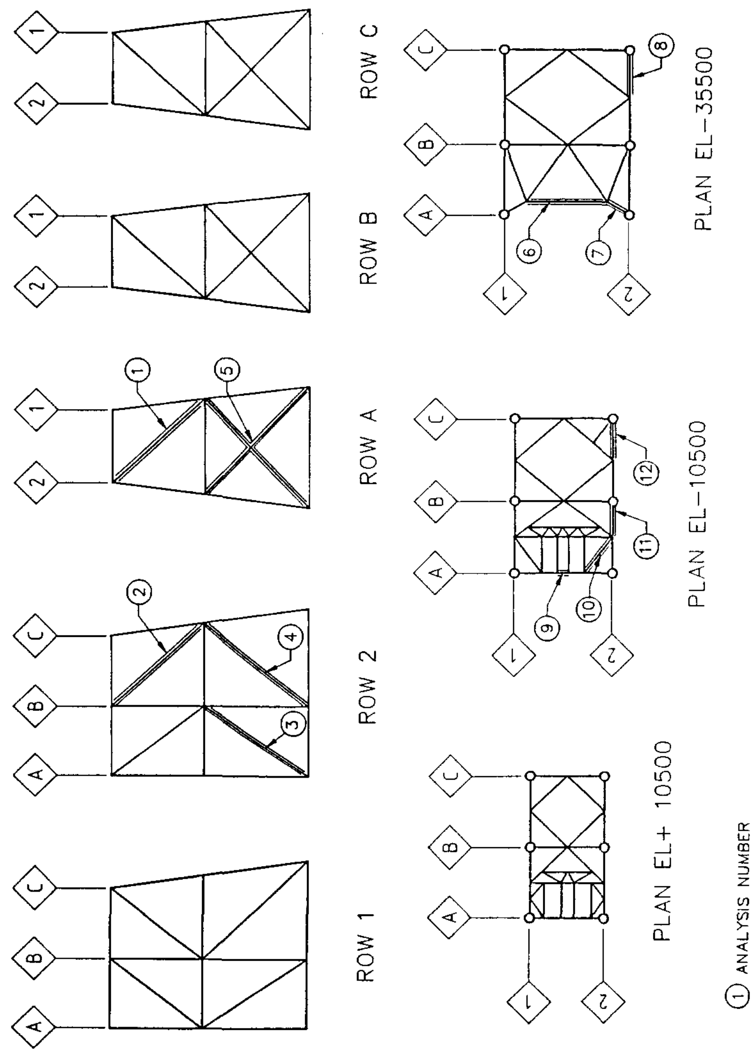

Fig. 12. Damaged members for post-damage analyses

on the basis of their susceptibility to damage and the results of the in-place analysis utilization checks against the codes of practice. As a result, a total of 12 different members were considered non-effective.

74. An illustration of *R. Webb's* point can be given by reference to the 1967 design of Leman BD compared with the 1984 design of Leman F. A typical frame in BD comprised 12 joints and 23 members with four bracing levels. A similar frame in F comprises fewer joints and members and spanning is increased to allow only three bracing levels. Furthermore, the 36 in piles of 1967 have made way for the 54 in piles of 1984 now that larger pile hammer capacity is available. Indeed, there is now the potential for 96 in piles. The overall result of such design changes is a more transparent structure with fewer, possibly larger diameter members that makes for a more efficient use of steel.

75. The question of graduate training is not that distant from the Authors as two of them have just that responsibility. For graduate training, conceptual design is frequently better than detail design work; detail design of a jacket is very computer orientated and analytical, whereas the conceptual stage offers a better opportunity to apply the principles of design. However, the detailed design is good in terms of training to take some responsibility for producing drawings which have to be converted into hard steel. Areas of particular interest are not in the main jacket but on riser guides, conductor guides and the appurtenances which can form a neat package as a part contribution to PE1.

76. The type of wave breaking, as shown by Fig. 13, is dependent on the sea bed slope and the steepness of the wave in deep water. At the Leman G site the combination of sea bed slope (1%) and deep water wave steepness (0·1), resulted in a spilling breaker. The spilling breaker was modelled approximately as a regular wave using ninth order stream function theory. This was considered acceptable because a spilling breaker is similar to a limiting height regular wave and the results were a reasonable approximation to a separate limiting height wave model, from J.R. Chaplin of Liverpool University. Similarly, in answer to *Mr Carruthers*, if the Morecambe Bay platforms, which also had shallow sea bed slopes, were designed using an adequately high stream function theory, the Authors would anticipate that the loading should represent that from a spilling breaking wave (this would also require the ratio of wave height/water depth to be about 0·78).

77. Mr Carruthers also asked whether the pile design was dominated by tensions or compression. By chance the maximum pull-out load of 10 MW and the maximum compression of about 30 MN both required a pile penetration of 45 m.

78. *Mr Dawson* asked about the difference between separate analysis of the piles and jacket and the more rigorous technique of coupled soil–pile–structure interaction. Leman F and G piles were designed using separate pile and jacket models. Although this gives relatively simple models, it is not easy to match the two analyses. However, the more recent technique of using a coupled approach overcomes this problem. A retrospective analysis of Leman F using the coupled foundation program SPLINTER has not been done, but both Shell and AOGE are confident that the design is satifactory for the purpose. AOGE are using SPLINTER extensively to assess existing structures. It is quite useful in showing additional capacity by redistributing loading on the foundations. Some jackets which in uncoupled analyses were not very satisfactory are found to be satisfactory from the coupled analysis.

79. *A. van der Stap* had noticed a peculiarity with the Leman F air gap between the 100-year wave and the deck underside. Typically it is in the range 1·5–3·0 m,

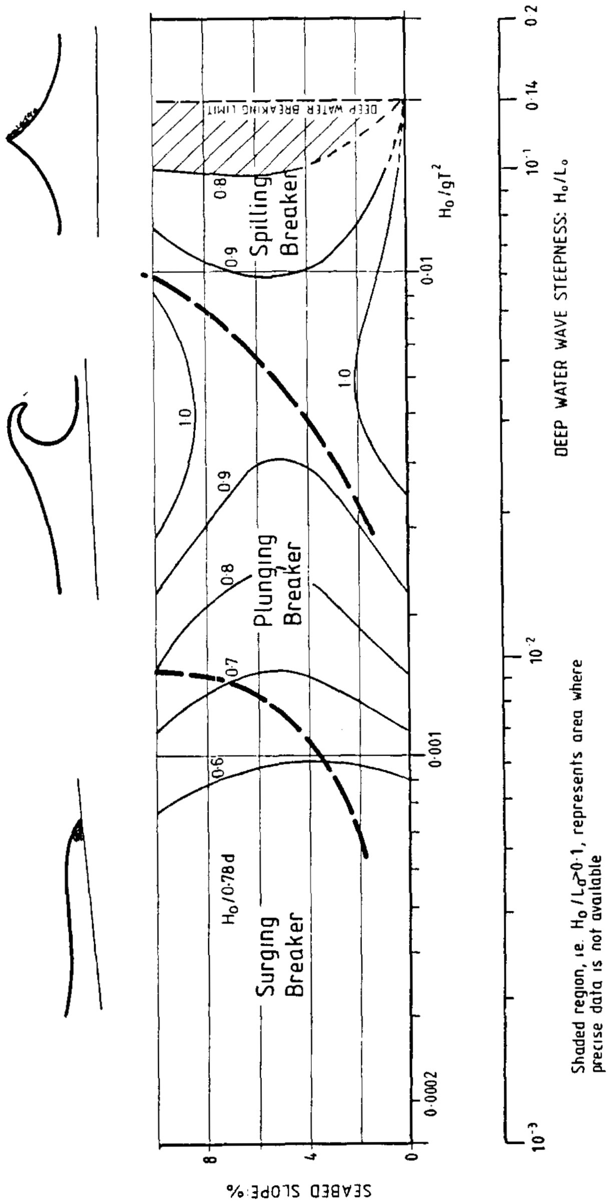

Fig. 13. Deep water wave height and steepness that will break at a given water depth and sea bed slope (after Iversen, 1953 and Goda, 1970)

but in this case the size of the make-up piece was meant to be similar to that on Leman E. It was for this reason that it was decided not to change substantially the design so the air gap came out fairly large.

80. There were no fenders as such provided. There was just a very small walkway and access down to the small boat area. A mooring hook is provided for supply boats. The Authors have moved away from providing fenders for the simple reason that if the jacket is struck, more damage can be done by a fender dropping off and hitting something on the plan brace below as it goes to the sea bed. It is better to leave the jacket clean as it is then much easier to maintain. Even with new designs, walkways are still needed at the installation stage. There is a case for partly removing them afterwards, and that is the current trend. However, an access to sea has to be provided to satisfy the regulations and that requires some walkway along the jacket.

81. With regard to *D. Glyn-Woods* question on time scales, the detailed design of Leman F was started in March–April of 1984 and AFC drawings were issued by August of that year. For Leman F the conceptual design was provided by Shell; the Leman G conceptual design began in May 1984, and the detail design was completed in November 1984. The construction phase was exactly a year, with a fabrication contract start in January 1985 and the jackets installed by Christmas Day that year.