operations described in the report, but without a more physically based derivation the engineering implications of the method cannot be assessed.

The results of the comparisons between the finite strip method and that of the report give the user a method of making a rapid evaluation of the accuracy of the report method, though it is not always possible to separate dead and live load effects. The more detailed results of the Appendices are necessary if a full appreciation is required. In fact, the Appendices are necessary if any part of the report is to be understood at a level which would make it a working document for a design engineer. The report and the extensive Appendices show clearly that 'simple' engineering theories are not at all simple. They contrast strongly with finite element methods for

which powerful computers are necessary for the very large numbers of arithmetic operations, but which are simple in concept and as readily accept a multi-cell beam with a complicated cross-section, as a single I-beam.

It would be difficult to produce a fully automatic computer program to cope with the method of the report in a general way which would avoid an uneconomic amount of pre-processing of data. It is perhaps more likely that programs could be written for specific types of cross-section which could be calibrated against finite element solutions. Once sufficient detail is defined, however, less complex models may be suitable for the degree of accuracy required. Consequently the physical insight given by the report is perhaps its most important attribute.

BRIAN RICHMOND

Pressure on vertical formwork when concrete is placed in wide sections

T.A. Harrison

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The importance of an accurate knowledge of the pressure of concrete on formwork is well known. In fact the very first report of the Civil Engineering Research Association, dealt with this subject in April 1965. CIRIA used the data obtained from CERA Report No. 1 to produce graphs for site use to estimate concrete pressures. Site personnel found the graphs difficult to use and CIRIA produced a revised form of presentation with tables. This is the current information used by the industry in calculating the pressure, but it specifically excludes the use of concrete with cement replacement materials or admixtures and only refers to concreting of parallel-sided formwork. The only other method of calculating formwork pressure is the ACI method, but this is not in general use in the UK.

The publication of Dr Harrison's research report has been long awaited. His new pore-water pressure theory explains simply and concisely the mechanics of concrete pressure applied to formwork. The report explains the basis of the earlier theories and goes on to explain in simple terms the theory of pore-water pressure in concrete. The difference between placing concrete as a continuous fluid member and the site practice of placing in layers is also explained. There are essentially three areas in the construction industry where pressure of concrete on formwork needs serious consideration: firstly in walls on building

contracts, secondly on civil engineering contracts (for large foundation walls and abutments etc.) and thirdly for slender columns and piers. This report is intended only for civil engineering wall applications. On building contracts, walls tend to be relatively thin and this introduces other parameters in the interpretation of the theory; also concrete pressure in single-storey height buildings would rarely exceed 55 kN/m². With regard to pressures on columns, these are a unique case and require separate consideration owing to the higher rates of placing and because the two-dimensional restraint of the section may cause arching and particle support to reduce the concrete pressure. The civil engineer wishing to update his understanding of concrete pressures on a large contract would be well advised to read Dr Harrison's report.

The new theory postulates that the particle structure and the permeability of the formwork (to allow dissipation of the pore-water pressure) are two significant factors in concrete pressure on formwork. In considering the effects of admixtures, plasticizers and cement replacement materials upon the particle structure, the report admits to being inconclusive. Some guidance, though, is given for the use of water-reducers and plasticizers and air-entraining agents, but on the effect of superplasticizers and cement replacements, no conclusions are reached. Perhaps

these results have been prematurely released in this report pending completion of the additional work now being carried out.

The section on permeability of formwork provides the main clue to future economies in formwork design by allowing a face material to influence the final design pressure. It was disappointing to read that only one type of face contact material had been used in the tests. The presentation of results using Douglas Fir plywood is good and there is adequate test information: the height of wall, though, is not stated and we must only assume that it was a significantly high section of wall used on each test. If permeability to reduce pore-water pressure is critical, then the position of joints in the formwork should also be critical. For example, an impervious steel face of formwork would provide no allowance for water to dissipate but, if it had joints at regular, say 600 mm, centres, then this might affect the final pressure. The possible effect of joints is not discussed. A corollary not discussed in the report is the effect of drilling holes into an impervious face, thus allowing the pore-water pressure to be relieved. If we consider the formwork with holes in it, the effect of them blocking up by cement paste should also have been analysed. The practical man would ask the question "Does re-use affect the pressure?" If you plot the results given of site pressure measurements and identify the number of uses of the formwork, there is a tendency for the results to show that, after three to four uses, the reduction in pressure due to porosity of the face is reduced, owing presumably to the face porosity being reduced. More research is necessary.

The report concentrates on vertical parallel-sided formwork. Many civil engineering applications will be using sloping faced forms of either parallel or varying section. Neither case is referred to in this report. Future work should apply the theory to such non-vertical forms and comment on the likely effect

upon the pressure. Since CIRIA discontinued the use of the 'K factor' of stiffening time of the concrete in published pressure tables, there has been no up-to-date method of assessing pressures on walls of varying cross-section with varying vertical rates of rise of the concrete.

When considering the long-term practical use of this research report, the end user must be considered. The economics of formwork are such that reduction in design pressure will result in economy by reduction in material and/or labour content of the formwork. The designer needs to know the effect upon his design of the chosen form-face material to predict the concrete pressure for his calculations and this will also require a knowledge of his mix design in advance. In contrast, the site personnel will know the mix design and the stated pressure and need to work back to obtain a rate of placing. These two opposing viewpoints both need information and the final end product of the research should aim to provide information for these two conditions. Ideally upper limits of pressure need to be assessed for the other commonly used formwork face materials for use with the CIRIA method, and possibly some reduction factors based on the CIRIA method to provide economy over all the range of pressures, related to the face material.

The important warning about concreting under water, in certain conditions and the considered maximum limitation of concrete pressure when unsealed Douglas fir plywood is being used are only the start of what should be a long-term research programme by the C&CA. It is obvious from the amount of data plotted in the report that such research work is very costly and time-consuming. Certainly at only £3.75 the report is worth reading and will provide some initial information until further results are available.

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