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AUTHORS' REPLY

The writers thank the discussors for their interest in the article and their comments are appreciated.

The authors agree with the writers that Equations (5) and (6), derived using Dupit's assumptions, do not predict the true free surface in the case of gravity flow to a well and the pressure head predicted at the base of an aquifer by these equations is greater than the actual value. The fact that Equations (5) and (6) do not predict the true free surface for gravity flow is evident from Figure 5.

In the case of idealised aquifer, (Figures 1 & 2) Dupit's assumptions are valid in the entire region of confined aquifer. In unconfined aquifer, the equation derived from the above assumptions predicts true pressure heads at well radius, r_w , and at the radius of influence from the well, r_e . It is an accepted fact that Equations (1), (2), (7) and (8) are correct, though Dupit's assumptions are involved. Equations (1) & (2) and (Figure 1) lead to

$$\log_e L = \frac{2h(h_o - h) \ln r_w + (h^2 - h_w^2) \ln r_e}{2h(h_o - h) + (h^2 - h_w^2)} \quad \dots(19)$$

Equation (19) for L (Figure 1) and Equation (9) for L_c (Figure 2), derived from Equations (7) and (8), involve terms which are unaffected by Dupit's assumptions and hence these equations give the breakaway point correctly and are valid irrespective of the free surface profile.

The paper mainly indicates the method of approaches adopted by the authors and Muskat (1946) to analyse the problem of composite pressure head and gravity flow system. Equations (5) and (6) predict the free surface more closer to the actual one than that of Muskat's method (Figures 4 & 5).

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Araldite AZ 15 Impregnation of Kaolin

by

P.K. De

(1) K.S. SANKARAN AND D. VENKATESHWAR RAO**

The writers congratulate the author for the paper on impregnation technique by AZ 15 resin admixture on Kaolin. In the opinion of the

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** Associate Professor and Research Scholar respectively, Soil Engineering Laboratory, Department of Civil Engineering, Indian Institute of Technology, Madras-36.

writers, resin admixtures do not belong to suitable impregnating materials for clays (either saturated or partially saturated) for microstructural studies.

An ideal impregnating material to be used in clays should have the ability to replace the water phase in clays without altering the clay microstructure in any aspect. The water phase in clays consists of pore water and adsorbed water. This is possible only, if the material used for impregnation dissolves in water in all proportions, and the replacement should take place by diffusion process. On subsequent heating at low temperatures, say 55–65°C, the water phase in clay samples should evaporate. And on cooling at room temperature, the impregnating material should solidify by imbedding the clay particles without causing major changes in the general orientation pattern of the clay microstructure. Thus, the process should cause over all shrinkages uniform and minimum, if any. The impregnated samples should have sufficient hardness (but not brittle) either to yield good thin sections or to yield flat surfaces on grinding.

Polyethylene glycol compounds (Carbowax) with various molecular weights have been used by various research workers (Altemuller 1962, Barden et al 1970, 1971; Franklin 1964; Jongerius et al 1963; Martin et al 1970; Mitchell 1956; Morgenstern et al 1967; Sides et al 1970 and Willoughby et al 1969) successfully. Its major disadvantage is that it is suspected to react with the clay minerals, and cause shrinkage to some extent (Brewer 1964). Various chemicals have been suggested by different research workers, but they are not popular.

Several resin admixtures have also been suggested to impregnate partially saturated and saturated clays (Cent et al 1971; Franklin 1964; Jongerius et al 1963 and Singh 1967). The resin admixture, with araldite CY 212, Hardner HY 964, Monostyrene, Dibutylphthalate, Plasticiser DY 064 (Singh 1967), has been attempted by the writers on montmorillonite and kaolin clays. This admixture is found to be unsuitable for impregnation on clays for the following adverse effects experienced by the writers :

- (1) It is very sticky and viscous in nature, and do not flow through the fine pores of the clays even to a depth of 1 mm. Handling the clay samples in the resin admixture is very troublesome.
- (2) Even after addition of sufficient quantity of styrene, the viscosity of the admixture does not reduce less than 5 cps. It may be remembered that viscosity of the water is 1 cps (centipoise).
- (3) Therefore, the pore water inside the clay mass is entrapped by the surrounding resin admixture, while the clay sample is immersed. Thus, the effective replacement of water phase in clays does not take place, since the resin admixture does not dissolve in water.
- (4) During curing (even at low temperature 65°C) the entrapped water phase in clays escapes by scaling off or peeling off the clays, layer by layer. Thus, good impregnated clay samples have not been obtained. The author has also experienced similarly (P. 248). The reason for bubbling is due to the escape of pore water vapour on heating. Moreover, the temperature 105°C

maintained for curing by the author definitely might have affected the clay microstructure.

- (5) Longer periods, say minimum of 7—10 days, are required for curing the resin admixtures. It also requires great attention during curing as periodically some quantity of mixture of resin has to be poured over the sample now and then.
- (6) Resin impregnated clay samples does not offer good facility for the preparation of thin sections or flat smooth surfaces either for microscopic or X-ray diffraction studies. Carborundum powder (grade 600 or 800) particles used for grinding have been found to stick to the clay samples, and it is a difficult task to wash off the particles even by kerosene. The writers have observed the carborundum particles sticking to the clay samples even after washing with kerosene thoroughly, when observed under optical microscope.
- (7) Preparation of the impregnated clay samples by the resin admixtures on large scale is not convenient and costlier too.

The writers feel that similar difficulties (as described above) have to be encountered in case of any type of resin admixtures for impregnating the clay samples. Therefore, the resin admixtures are not suitable for impregnating the clays. The writers also suggest that there is a need to search for better types of impregnating materials for clays to yield satisfactory results.

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(2) R.B. SINGH*

The author has reported comparison of the properties of Araldite AZ 15 with Araldite AY 18 alone with regard to the suitability for impregnation of kaolin. The writer has experience of working with Araldite CY 212 on clays of different mineralogical compositions including kaolinite clays, and details of his technique have been published (1967, 1969). While selecting Araldite CY 212, different relevant properties including hardness of set blocks of different grades of Araldite resins including AZ 15 had been looked into. Araldite CY 212 was found to be superior, because, in addition to having properties comparable with other suitable grades like AY 18 or AZ 15, it possessed the advantage of a lower curing temperature of 55°C. Araldite AZ 15 has a curing temperature of 105°C, which was the highest for the several grades tested. It is highly probable that high curing temperatures lead to permanent structural changes in the impregnated clay blocks, and hence any technique involving high curing temperatures cannot be relied fully for quantitative microstructural work.

An indirect indicator of structural changes due to the method of treatment could be taken to be the percentage shrinkage of the treated clay blocks. Greene-Kelly (1971), amongst others, has accordingly pointed out the desirability of achieving impregnation with as little shrinkage as possible. The axial shrinkage of impregnated clay blocks varies from 0 to 3 percent generally with a maximum of about 5 percent in pure montmorillonite clay for Araldite CY 212 treated clay blocks as reported by the writer (1969). It would be of interest to know the percentage axial shrinkage for Araldite AZ 15 treated kaolin clay blocks for the sake of comparison.

The author has reported occurrence of hair cracks in the Araldite AZ 15 impregnated kaoline blocks and occasional bubbling of the resin hardner mixture at the curing temperature of 105°C. Except for some difficulties of hair cracking with pure montmorillonite, no trouble was experienced with Araldite CY 212 impregnation. It is the writer's experience that the effect of disruption of soil microstructure due to high temperature curing becomes more pronounced with more active clays. Hence, experience with chalk impregnation at different curing temperatures as reported by the author can only be of limited applicability.

While emphasising the use of resins with lower curing temperatures for the impregnation of clays, the writer wishes to state, however, that sufficient original microstructural changes are preserved even after high temperature curing of impregnated blocks, especially, in the case of non-active clays like kaolin, as evidenced amongst others by the author's studies (1971).

* Professor of Civil Engg., Deptt. of Civil Engg., Institute of Technology, Banaras Hindu University, Varanasi-5.

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AUTHOR'S REPLY

(1) *The writer thanks Sankaran and Rao for their comments and interest in the paper. Unfortunately, they did not seem to appreciate the significance of resin impregnation, and they are presumably not entirely familiar with the technique of resin impregnation.*

An ideal impregnating material should have the ability to replace the water phase without altering the microstructures of a clay. The water phase in a clay system is a complex one and the replacement of this in practical terms would invariably result in some microstructural changes. Therefore, the problem is how to minimise the strain.

The writer suggests that Sankaran and Rao should try to carry out the exact procedure described in the paper for Araldite AZ 15 impregnation, so that they could confirm that the experience they had with Araldite CY 212 does not apply to the Araldite AZ 15 resin. The writer does not agree that curing at 105°C destroys the clay microstructure. Although some attention is required during the curing stage, it is not necessary to pour the resin mixture periodically, if enough is used in the first place to fully submerge the clay slices.

The difficulties experienced by Sankaran and Rao in regard to the adherence of carborundum powder to the resin impregnated samples may be eliminated by using water to wash the samples, instead of paraffin. The writer totally rejects the suggestion that resin impregnated clay samples do not offer good facilities for the preparation of thin sections, either for optical or electron microscopic investigations. It is considered that the opposite is the case. The resin impregnated samples provide opportunities for both kinds of investigations. The carbonwax 6000 impregnation only caters for inspection by an optical microscope.

(2) *The writer thanks Singh for his interest in the paper. The writer agrees that the experience with chalk impregnation at different curing temperatures can have limited applicability, but finds it difficult to accept that any technique involving curing at 105°C cannot be relied upon for quantitative microstructural work. He may be correct in his diagnosis that the effects of high temperature curing may be pronounced with active clays and thus the suitability of any technique does not depend only on the technique itself.*

Although it is often believed that the percentage axial expansion or shrinkage is an indirect indicator of the microstructural changes, it is surely simplification. The kaolin slices impregnated with Araldite AZ 15 had axial expansion of 1.17 percent normal to the direction of consolidation and 3.56 percent along the direction of consolidation.