

**“EFFECT OF SULPHATES IN CEMENT (CONTAINING 5% POZZOLANA)
AND IN SAND ON THE CORRELATION BETWEEN COMPRESSIVE
STRENGTH AND U.P.V. OF CONCRETE OF DIFFERENT MIXES”**

By

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ABSTRACT

Sulphates may be found in any of the raw materials of cement. Sand contaminated with sulphates is currently a local problem because of the difficulty in obtaining well-graded sand which could be used in concrete that has an acceptable sulphate content.

In this work, the effect of sulphates in cement, with 5% pozzolana, and in sand on the correlation between compressive strength and ultrasonic pulse velocity (U.P.V.) of concrete of different mixes such as 1:1.5:3, 1:2:4, and 1:3:6 is studied in order to assess the degree of the correlation of different mixes and its resistance to sulphate attack.

We can conclude that the U.P.V. seem to be a good method for assessing the quality and strength of the concrete specimens.

1. INTRODUCTION

Concrete is often liable to come into contact with substances which tend to react chemically with it. The seriousness of such reactions depends on the nature of the reacting substances and on their concentrations. Some of the most important causes of concrete disintegration are salts in general and sulphates in particular [1-4].

Many researchers have studied the effect of sulphate attack. Most of these studies were concerned with external attack, which is the exposure of concrete to sulphate solution from its surrounding. The other type of attack is internal and is due to the existence of sulphate in the materials from which concrete is made. Sulphate may be found in any of the raw materials of cement. They are also added as gypsum to the cement clinker to ease grinding and regulate the setting time of cement [1,4].

The main problem of locally available sand is its contamination with sulphates. These sulphates together with the sulphates already in cement may cause internal attack on cement. Therefore, an upper limit of SO_3 content in sand is specified. In Iraq at present it is 0.5% by weights of sand.

A possible solution to this problem is to reduce the percentage of SO_3 in cement. This is achieved by reducing the amount of gypsum added to cement clinker. Thus, enabling the use of greater sulphate content sand in concrete.

A study carried out by A.R. Shalal [5] shows the possibility of reducing the percent of SO_3 in cement, and its effect on physical properties of cement, mortar, and concrete. He shows that 5% pozzolana can be used instead of some gypsum as a grinding aid for the cement in order to reduce the total sulphate content in cement. He also concludes that, for cement with 5% pozzolana, the sulphate content of cement can be reduced and substituted equally by higher sulphate content in sand. Thus, the compressive strength and U.P.V. of concrete are mainly dependent on the total amount of sulphates in the mix. He also shows that the U.P.V. seem to be a good method for assessing the quality and strength of concrete specimens.

The above study is for 1:2:4 concrete mix. In this work the effect of sulphates in cement, with 5% pozzolana, and in sand on the correlation between compressive strength and U.P.V. concrete of different mixes such as 1:1.5:3, 1:2:4, and 1:3:6 may be studied in order to assess the degree of the correlation of different mixes and its resistance to sulphate attack.

2. EXPERIMENTAL WORK

A possible solution to the problem of internal sulphate attack may be to reduce the SO_3 content in cement. This is achieved by reducing the amount of gypsum added to cement clinker. An alternate material to gypsum is pozzolana. This material could be added to cement clinker at the grinding stage.

Ordinary portland cement clinker from AL-RASHED factory was used in this work. The chemical composition of cement, pozzolana, and gypsum are shown in Tables (1) and (2).

Table 1: Chemical Analysis of Ordinary Portland Cement and Pozzolana.

Item	Percentages O.P. Cement	Percentages Pozzolana
Silica (SiO ₂)	22.96	57.40
Alumina (Al ₂ O ₃)	5.100	14.00
Ferric Oxide (Fe ₂ O ₃)	2.800	1.600
Lime (CaO)	64.30	8.700
Magnesia (MgO)	3.400	3.400
Sulphuric Anhydride (SO ₃)	0.750	0.100
Loss on Ignition	0.200	12.50
Alkalies	0.850	2.500
Total Alkalies as Na ₂ O	0.940	—
Total	100.36	100.20

Table 2: Chemical Analysis of Gypsum.

Item	Percentages
Silica (SiO ₂)	6.500
R ₂ O ₃	1.260
Lime (CaO)	32.26
Loss	21.26
Sulphuric Anhydride (SO ₃)	37.92
Total	99.20

Effect of Sulphates in Cement (Containing 5% Pozzolana)

Pozzolana was added with gypsum⁽⁵⁾ to cement clinker so as to increase the efficiency of grinding. The level of SO_3 in cement clinker was changed by adding different amounts of gypsum to give calculated levels of SO_3 in cement of (1,1.5,2,2.5,2.8) percent by the weight of cement. The maximum level of SO_3 in cement was limited to 2.8% which is specified according to Iraqi standards [6]. The minimum level of SO_3 in cement was limited to 1% so as to produce cement of desired setting time. Cement with less than 1% SO_3 content have a very quick set. The above levels of SO_3 were chosen so as to study the effects of different amounts of SO_3 content in cement on different physical properties of different concrete mixes such as 1:1.5:3, 1:2:4 and 1:3:6. The percentage of pozzolana that was added with gypsum simultaneously, were fixed at 5% by the weight of cement.

U.P.V. and compressive strength of concrete as mentioned above were performed in this work. The compressive strength test was conducted according to the (B.S. 1681-1970) and the U.P.V. test was conducted according to the (ASTM-C-597).

The level of SO_3 in sand, used in concrete, was changed by washing and adding natural sulphates to give calculated SO_3 in sand of (0.2,0.5,1.0,1.5,2.0) percent by the weight of sand. These levels were chosen so as to study the effects of high percentage of sulphates in sand on the compressive strength and U.P.V. of concrete and compare them with the maximum allowable amount of sulphates which is accepted to be used in concrete here in Iraq at the present time. The grading of sand and gravel used in this work are in agreement with the (ASTM-C-33) specifications.

3. RESULTS AND DISCUSSIONS

The results of the variation of U.P.V. with the percentage of sulphate content are shown in Figures (1) to (3). Each of these points represents the average of three measurements of U.P.V. of three concrete cubes for the various percentage of sulphates for all mixes as shown. These results were determined by measuring the pulse velocity for each specimen at various ages (7,28, and 90 days) which is then tested to failure by crushing.

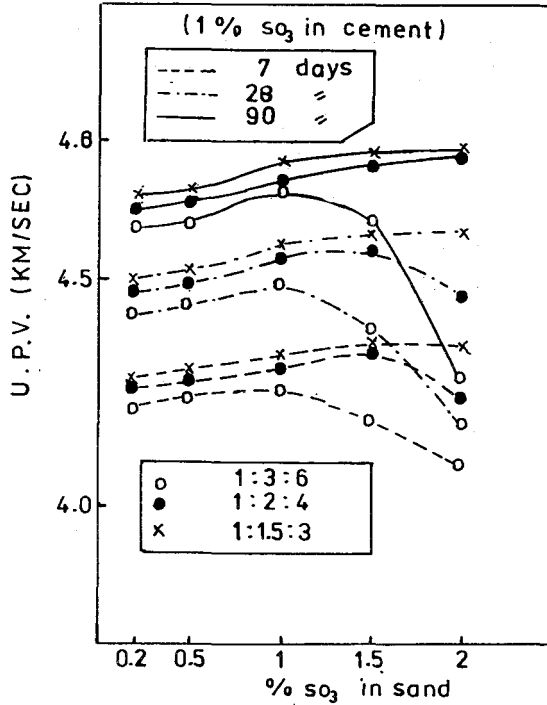


Figure 1: Relationship between U.P.V. and SO₃ Content in Sand.

As shown in Figures (1) and (2), for (1, 1.5, and 2) % SO₃ in cement, the U.P.V. increased with the increase of amount of sulphates in sand up to an optimum and then it decreased. The optimum sulphates content in sand giving maximum U.P.V. for the above sulphate content, ranges from 1% to 2% and it depends on the curing ages and percentage of mixes i.e. the optimum total sulphates content in concrete mixture giving maximum U.P.V. ranges from 3.5% to 5%. A large decrease in U.P.V. was observed for cement containing sulphates more than 1.5% with sand containing sulphates higher than 1%, or for cement containing more than 1% with sand containing sulphates higher than 1%, specially for early ages. In figure (3), for (2.5, and 2.8) % SO₃ in cement, a large decrease in U.P.V. was evident with the increase of amount of sulphates in sand.

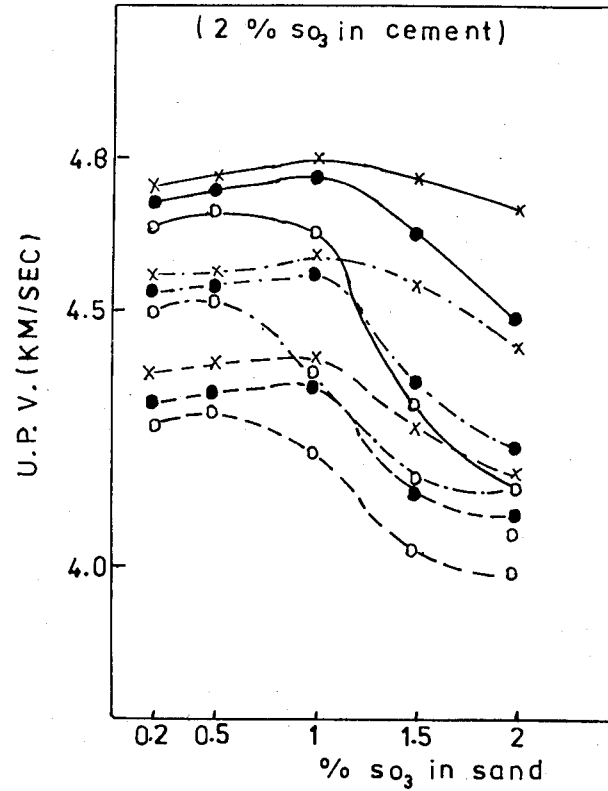
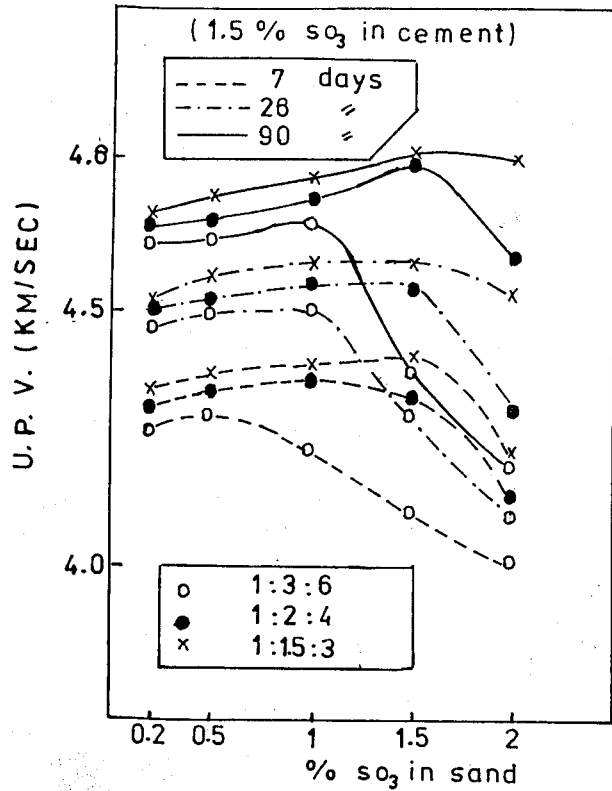


Figure 2: Relationship between U.P.V. and SO_3 Content in Sand.

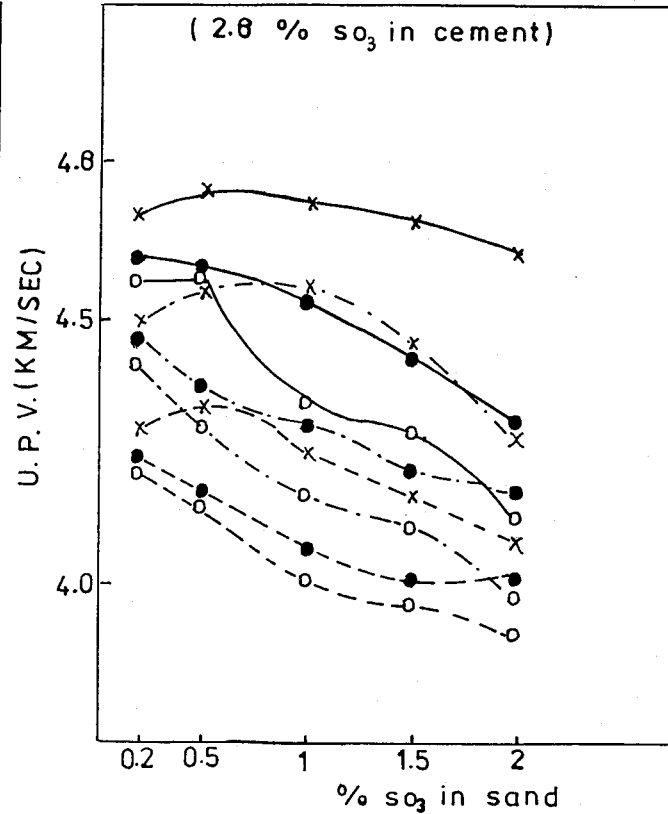
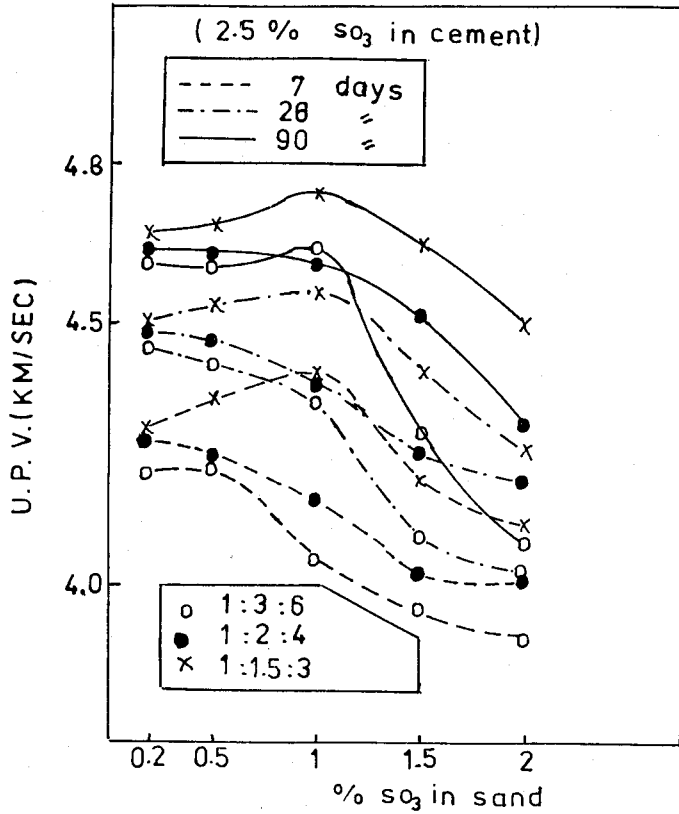


Figure 3: Relationship between U.P.V. and SO_3 Content in Sand.

Effect of Sulphates in Cement (Containing 5% Pozzolana)

It is concluded that the effect of source of sulphates on the U.P.V. is rather minor. Therefore, the sulphates content of cement can be reduced and substituted equally by higher sulphates content in sand. The increase in the sulphates content of sand is almost the same as the decrease on the sulphates content of cement. Thus, the U.P.V. of concrete is mainly dependent on the total amount of sulphates in the mix and not on the riches of the mix.

The velocity of ultrasonic pulse in the solid material depends on the density, and elastic properties of that materials [7]. Changes occurring in the structure of cement paste with time caused by either hydration or by agressive action of sulphates, are determined by repeated measurements of pulse velocity. Changes in pulse velocity are indicative of changes on strength [7]. In practice, the compressive strength – pulse velocity correlation has a great importance. Thus, one can correlate the pulse velocity of this research with the corresponding value of compressive strength (Figures 4 to 6).

The results for each family of specimens (same level of SO_3 in cement) were studied alone. This is because the correlation is affected by many factors such as type of cement, type of aggregate, aggregate/cement ratio...etc. [7].

The equation of regression between the compressive strength and U.P.V. is expected as follows:

$$C = A + B \cdot U$$

where

$$C = \text{Compressive strength (MN/m}^2\text{)}$$

$$U = \text{U.P.V. (km/sec).}$$

$$A, B = \text{Constants to be determined.}$$

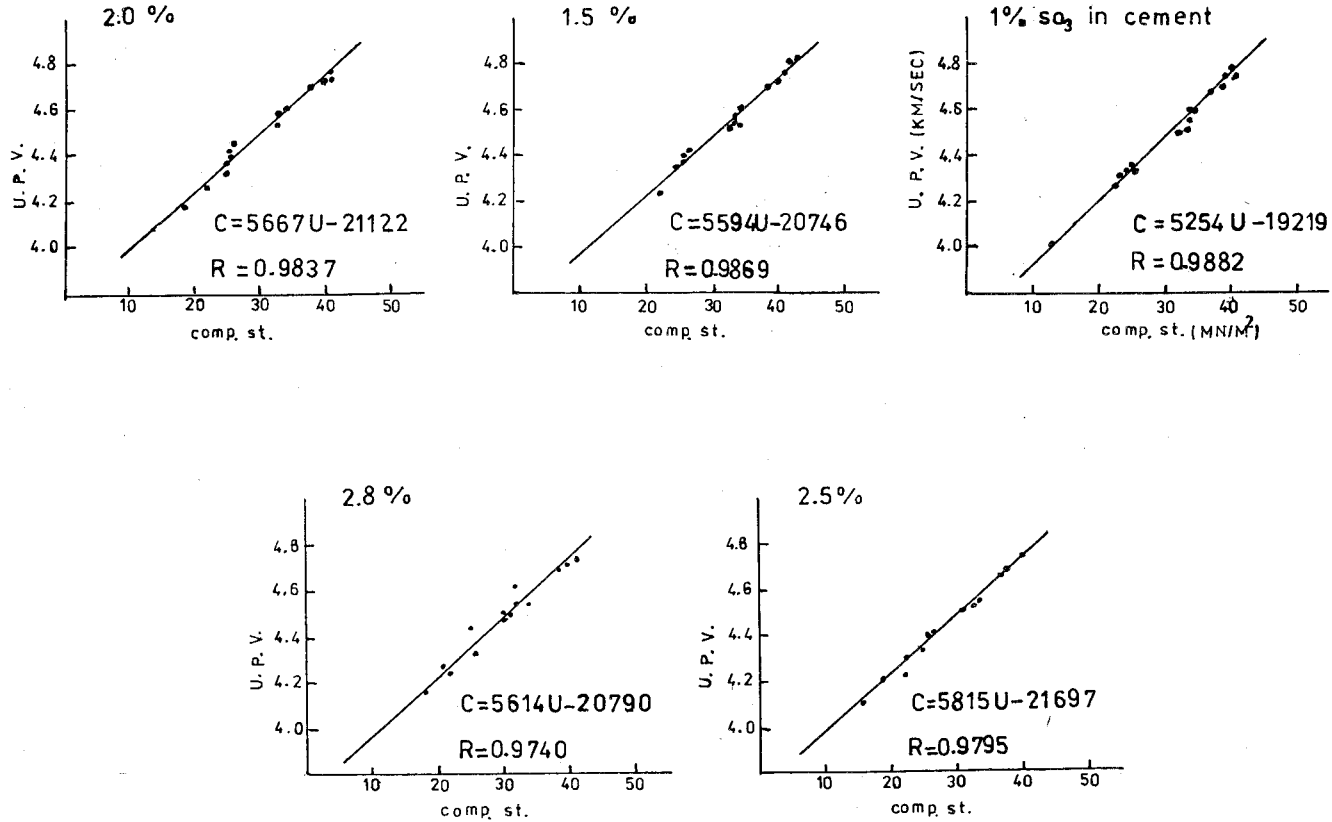
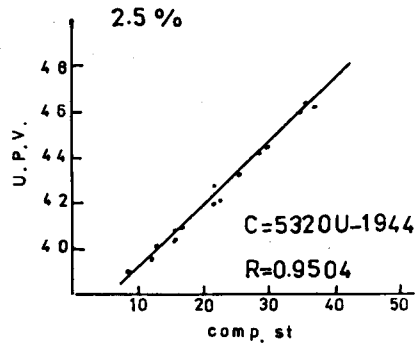
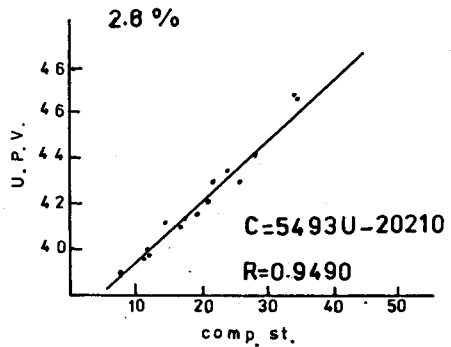
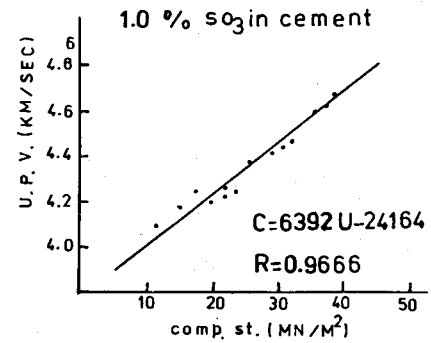
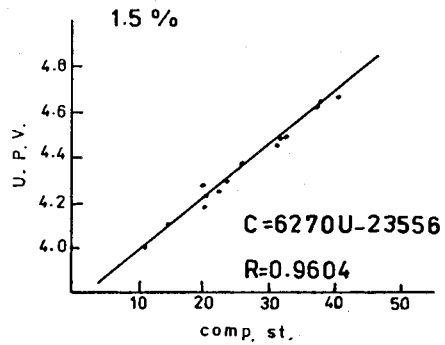
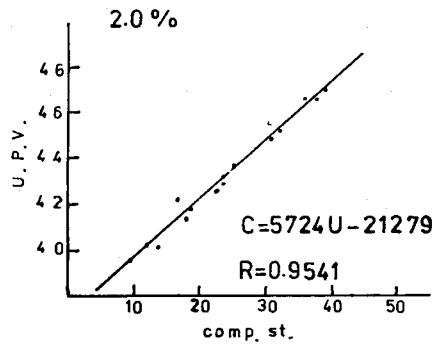


Figure 4: Relationship between Comp. St. and U.P.V. for 1:1.5:3 Concrete Mixes.



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Figure 5: Relationship between Comp. St. and U.P.V. for 1:2:4 Concrete Mixes.

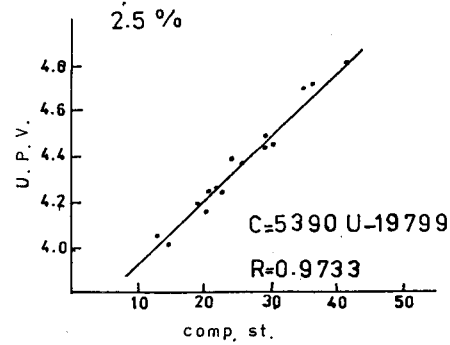
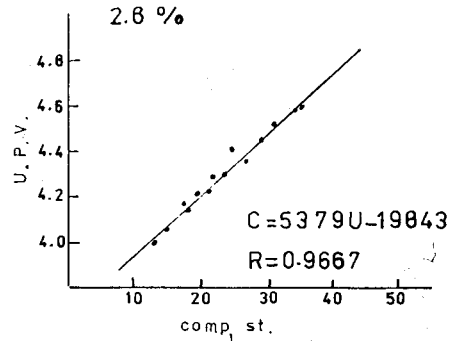
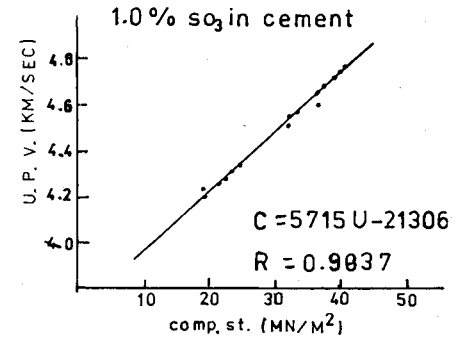
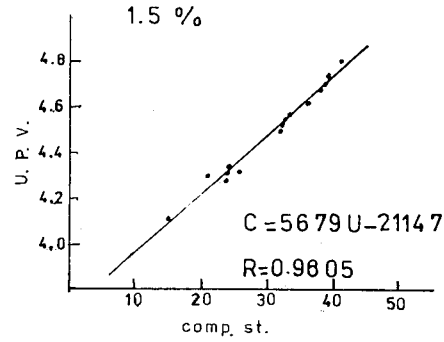
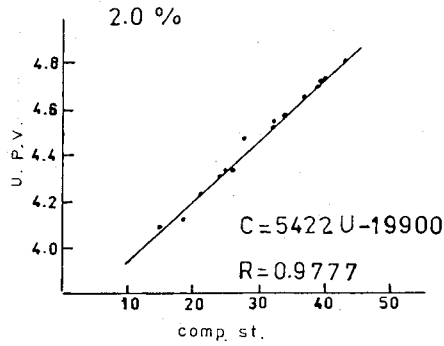


Figure 6: Relationship between Comp. St. and U.P.V. for 1:3:6 Concrete Mixes.

The constants (A) and (B) are determined using a least square method of fitting for the data obtained for each family. The correlation coefficient (R) was determined for each correlation. The results are shown on Figures (4) to (6). It can be seen all values indicate high positive correlation. These correlations indicate that for a specified value of U.P.V., one can find the corresponding compressive strength from the appropriate correlation. Such correlation was obtained from specimens having similar properties as that of compressive strength specimens.

The above results are in agreement with the previous literature such as work by Mansour [8] and Mahmoud [9].

Finally, it can be concluded that the U.P.V. seem to be a good method for assessing the quality and strength of the specimens throughout the experimental programme.

4. CONCLUSION

From this work, it can be concluded that:-

1. The effect of source sulphates on the U.P.V. is rather minor. Therefore, the U.P.V. of concrete, for cement with 5% pozzolana, is mainly dependent on the total amount of sulphates in the mix and not on the richness of the mix.
2. The U.P.V. seems to be a good method for assessing the quality and strength of the specimens throughout the experimental programme.

REFERENCES

1. Taylor H.F.W., "The Chemistry of Cement"; Volume (1); Second Printing; Academic Press; London and New York; 1972.
2. Neville A.M., "Properties of Concrete"; Second Edition; Pitman Publishing Limited; London; 1972.
3. Troxell, Davis, and Kelly, "Composition and Properties of Concrete"; Second Edition; McGraw-Hill Book Company; 1968.

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4. **Lea F.M.**, "A Study of Cement and Concrete"; Third Edition; Edward Arnold Limited; London; 1970.
5. **Shalal A.R.**, "A Study of Cement Retarders Related to Internal Sulphates Attack"; A Master of Science Thesis; University of Baghdad; College of Engineering; Sep. 1981.
6. **Special Committee**, "Report on the Standards of Iraqi Sands"; Baghdad; 1980.
7. **Jones R.**, "Non Destructive Testing of Concrete"; Cambridge University Press; 1962.
8. **Mansour M.H.**, "The Effect of Sulphate on the Physical Properties and Geometrical Changes of Concrete"; A Master of Science Thesis; University of Baghdad; College of Engineering; June 1976.
9. **Mahmoud T.K.**, "The Effect of Sulphates and Cyclic Wetting and Drying on the Physical Properties of Concrete"; A Master of Science Thesis; University of Baghdad; College of Eng.; June 1977.