CONCRETE STRENGTH AND BOND BEHAVIOUR IN CHEMICALLY AGGRESSIVE ENVIRONMENTS

BY

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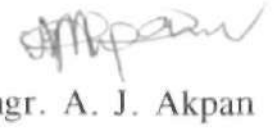
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THESIS DECLARATION

I hereby decleare that this thesis has been composed by myself and that it is a record of my own research. It has not been accepted in any previous publication for a higher degree.

All quotations are distinguished by quotation marks and the sources of information are specifically acknowledged by means of references.



Engr. A. J. Akpan

CERTIFICATION

We hereby recommend that the thesis prepared under our supervision by ANTHONY JOSEPH AKPAN titled "Concrete Strength and Bond Behaviour in Chemically Aggressive Environments" be accepted in fufillment of the requirement for the award of a DOCTOR OF PHILOSOPHY in (Structural Engineering) of Ahmadu Bello University, Zaria. NIGERIA

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14. My father, Chief J. Akpan

DEDICATION

THIS THESIS IS FULLY DEDICATED TO THE BLESSED MEMORY OF THERESA JOSEPH AKPAN (1931-1983)

AND

TO ALL MY STUDENTS, PAST, PRESENT AND FUTURE.

ABSTRACT

The results of pullout and compression tests of concrete subjected to a simulated aggressive chemical environment is presented. About one hundred and tour pull out test specimens and one hundred and fourteen cubes were tested for ultimate local bond strength after curing for one hundred and eight days in different aggressive media.

Two of the simulated environments were acid based while the third was caustic. The cubes cured in the acid based environment namely, Sulphuric and Hydrochloric acids showed a remarkable strength loss for the grade 30 and 40 concrete used. The caustic medium, Sodium Chloride solution did not show any convincing strength loss.

A natural occurring material, Rubber Latex (Poly 1- 4 Isoprene) for coating small diameter bars in "light" structures was examined. With an appreciable Bond Ratio range of 0.97 to 1.05 the material is found acceptable as a coating medium for concrete reinforcement bars.

The simulated aggresive media had volume fractions restricted to 2 percent for the Pullout test and 3 percent for the Compressive Strength Test. It was observed that for Local Bond requirements to be controlled, higher grade of concrete may be necessary depending on the nature of the aggressive environment and the bar diameter. It was also observed that the limiting volume fraction for maximum ultimate bond stress is a function of the bar size and the concrete grade. Thus for grade 30 concrete, the limiting value is between the range of (0.57 to 0.74) percent for sulphuric acid simulated medium and (0.95 to 1.0) percent for hydrochloric acid simulated medium. That of grade 40 concrete in a sulphuric and hydrochloric acids simulated media are within the range of (0.95 to 1.45) percent and (1.10 to 1.20) percent respectively.

TABLE OF CONTENT **PAGE**

Title page i

Declaration ii

Certification iii

Acknowledgement iv

Dedication vi

Abstract vii

Table of Content viii

List of Tables xi

List of Figures xiv

List of Plates x

CHAPTER 1

1.0 INTRODUCTION 1

CHAPTER 2

2.0 LITERATURE REVIEW 4

2.1 Bond Slip Characteristics in Reinforced Concrete 4

2.2 Bond between Concrete and Steel 29

2.3 Anchorage Bond Length -B.S.8110 Recommendations 31

2.4 Local Bond Stress 36

2.5 *Corrosion of Reinforcement* 40

2.6 Concrete in Aggressive Environment 42

2.6.1 Sulphate Attack 44

2.6.2 Attack by sea water 44

2.5.3 Acid Attack 46

2.5.4 Alkali Attack 47

CHAPTER 3

3.0 EXPERIMENTATION 48

3.1 Water Analysis 48

3.2 Reinforcing Steel Rods 50

3.3 Odinary Portland Cement 52

3.4 Cube Strength 54

3.5 Cage Fabrication/Basic Test Procedure 54

3.6 Experimental Set Up And Testing Procedure 59

3.6.1 Rubber Latex 62

CHAPTER 4

4.0 **ANALYSIS AND DISCUSSIONS OF RESULTS** 82- 67

4.1 Reinforcing Steel Bar 82

4.2 Compressive Strength Test 84

4.2.1 Sulphuric Acid 84

4.2.2 Aggresive Effect of Sulphate Ions 84

4.2.3 Hydrochloric Acid 86

4.2.4 Aggresive Effect of Chloride Ions 87

4.3 Failure Load and Maximum Slip 89

4.4 Bond Ratio 91

4.5 Local Bond - Slip Curve Trend 95

CHAPTER 5

5.0 Mathematical Modelling of Results 115

5.1 Bond Stress Slip Curve Model 115

5.2 Bond Stress Slip - Volume Fraction Model 122

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.0 Conclusion 127

6.1 Recommendation for further research 132

REFERENCES 133

LIST OF APPENDICIES 142

LIST OF TABLES

			PAGE
TABLE	1	Tension anchorage lengths	23
TABLE	2	Tension anchorage lengths	23
TABLE	3	Ultimate Local Bond Stress in Beams	34
TABLE	4	Concentration of salts for the sites analysed	42
TABLE	5	Test Results on Reinforcing Steel Bars 1	43
TABLE	6	Test Results on Reinforcing Steel Bars 2	43
TABLE	7	Physical Test Results of OPC Used	44
TABLE	8	Chemical Test Results of OPC Used Oxide Compounds	45
TABLE	9	Chemical Test Results of OPC Used Main Compounds	44
TABLE	10	Compressive Strength Test Result 1	47
TABLE	11	Compressive Strength Test Result 2	48
TABLE	12	Compressive Strength Test Result 3	49
TABLE	13	Compressive Strength Test Result 4	50
TABLE	14	Compressive Strength Test Result 5	50
TABLE	15	Maximum Pull Out Failure Load 1	58
TABLE	16	Maximum Pull Out Failure Load 2	59
TABLE	17	Maximum Pull Out Failure Load 3	59
TABLE	18	Maximum Pull Out Failure Load 4	60
TABLE	19	Maximum Pull Out Failure Load 5	60
TABLE	20	Maximum Pull Out Failure Load 6	61
TABLE	21	Maximum Slip Results 1	62
TABLE	22	Maximum Slip Results 2	62
TABLE	23	Maximum Slip Results 3	63
TABLE	24	Maximum Slip Results 4	63

TABLE 25 Maximum Slip Results 5 64

TABLE 26 Maximum Slip Results 6 64

TABLE 27 Maximum Bond Stress Results 1 76

TABLE 28 Maximum Bond Stress Results 2 77

TABLE 29 Maximum Bond Stress Results 3 77

TABLE 30 Maximum Local Bond - Slip Approximations 1 101

TABLE 31 Maximum Local Bond - Slip Approximations 2 106

TABLE 32 Maximum Local Bond - Slip Approximations 3 106

TABLE 33 Maximum Local Bond - Slip Approximations 4 106

TABLE 34 Bond Stress - Volume Fraction Model 107

TABLE 35 Cube Strength - Volume Fraction Model 108

TABLE 36 Limitting Value of Volume Fraction 110

Fig. 21 Bond Stress Vs. Slip Curve 6 90

Fig. 22 Bond Stress Vs. Slip Curve 7 85

Fig. 23 Bond Stress Vs. Slip Curve 8 86

Fig. 24 Bond Stress Vs. Slip Curve 9 87

Fig. 25 Bond Stress Vs. Slip Curve 10 88

Fig. 26 Bond Stress Vs. Slip Curve 11 89

Fig. 27 Bond Stress Vs. Slip Curve 12 91

Fig. 28 Bond Stress Vs. Slip Curve 13 95

Fig. 29 Bond Stress Vs. Slip Curve 14 96

Fig. 30 Bond Stress Vs. Slip Curve 15 97

Fig. 31 Bond Stress Vs. Slip Curve 16 98

Fig. 32 Regressed Local Bond Slip Curve 1 102

Fig. 33 Regressed Local Bond Slip Curve 2 103

Fig. 34 Regressed Local Bond Slip Curve 3 104

Fig. 35 Regressed Local Bond Slip Curve 4 105

LIST OF FIGURES

		PAGE
Fig. 1	Section through reinforcing bar and concrete showing separation that occurs near primary crack	6
Fig. 2	Geometry of bar deformation	7
Fig. 3	Tensile Stress Rings from Tepfers	7
Fig. 4	Prepared Pre cracked specimen	8
Fig. 5	Bond/Slip curves versus reduced bar slip	9
Fig. 6	Bond stress - Vs slip curve	13
Fig. 7	Linear Bond Slip Law Approximations	15
Fig. 8	Non Linear Bond Slip Law Approximations	16
Fig. 9	Arrangement for the measurement of slip	21
Fig.10	Relationship between pull - out load and slip at free end for twisted rods	23
Fig. 11	Influence of Sodium Chloride on Bond Strength	25
Fig. 12	Bar anchored into a block of concrete	28
Fig. 13	Forces and stresses acting on an elemental length	32
Fig. 14	Corrosion Cycle (Idealised)	36
Fig. 15	Molecular Structure of Natural Rubber	65
Fig. 16	Bond Stress Vs. Slip Curve 1	80
Fig. 17	Bond Stress Vs. Slip Curve 2	81
Fig. 18	Bond Stress Vs. Slip Curve 3	82
Fig. 19	Bond Stress Vs. Slip Curve 4	83
Fig. 20	Bond Stress Vs. Slip Curve 5	84

TABLE 25 Maximum Slip Results 5 64

TABLE 26 Maximum Slip Results 6 64

TABLE 27 Maximum Bond Stress Results 1 76

TABLE 28 Maximum Bond Stress Results 2 77

TABLE 29 Maximum Bond Stress Results 3 77

TABLE 30 Maximum Local Bond - Slip Approximations 1 101

TABLE 31 Maximum Local Bond - Slip Approximations 2 106

TABLE 32 Maximum Local Bond - Slip Approximations 3 106

TABLE 33 Maximum Local Bond - Slip Approximations 4 106

TABLE 34 Bond Stress - Volume Fraction Model 107

TABLE 35 Cube Strength - Volume Fraction Model 108

TABLE 36 Limitting Value of Volume Fraction 110

LIST OF PLATES

		PAGE
PLATE 1	Fabricated Steel Mould Used	52
PLATE 2	Cured Steel Bars positioned in basin after the Cleansing Treatment	54
PLATE 3	Test Specimen in Test Rig	56
PLATE 4	Digital Monitor Used	57

CHAPTER 1

1.0 INTRODUCTION

Concrete can be produced in a variety of forms with strength ranging from 15N/mm^2 up to 155 N/mm^2 and density from 500 kg/m^3 to 4000 kg/m^3 /26/. However where durability is concern it is suggested that there are four main options for protecting concrete /22/. These are; ordinary-crete, coated-crete, efficient-crete and coated rebar - crete. Coated rebar-crete is designed to satisfy structural requirements and is used only where protection of reinforcement from corrosion is required. In contrast to coated-crete the reinforcement itself is coated. The close control that can be exercised during the coating process gives rise to more confidence of the in situ performance of concrete.

Organic coatings are used to protect bars embedded in concrete from corrosion /22/. These coatings include epoxy coatings ,paints, bitumen, cement slurry, resins, and cashew nut shell liquid /22/. Chemical aggression has been known to produce distressing effect on concrete. Two principal sources of chemical aggression is usually acknowledged by researchers. These are:

(1) The natural sources which include sea water and soils which are rich in sulphates, nitrates, carbonates as well as chlorides and

(2) The artificial sources which include chemical manufacturing industries, daries, fertilizer manufacturing companies and industrial effluents. The presence of these corosion agents acting in a collective or singular sense, results in the reduction of the

strength of concrete thereby weakening the bond between the concrete and reinforcement.

In recent years efforts have been dispensed by researchers and engineers towards examining ways of enhancing satisfactory performance of concrete in aggressive environments. These efforts ranges from simulation of time dependent study of aggression as it affect reinforced concrete, electro chemical examinations of corrosion as it afects concrete and development of reccomendations and mathematical models for optimal performance of concrete structures in these environments in order to satisfy both safety and durability requirements. Most of the research findings have been documented in the prevailing codes of practice. Much as the codes of practices has given much recognition to corrossion as a negative factor in reinforced concrete technology, there exist some salient facts about corrossion that has not been been clearly defined. These include accertaning the degree of damage inflicted by the causative agent, the degree of corrossion and the tolleratable [limiting] values of the corrossive radicals in terms of concentration. Most of codes tie their reccomendations to the concrete cover and grade. The acceptability of coating substances for the protection of reinforcement rods and its effect on the bonding is not explicitly spelt out in the codes. This short comming partly promted this research work.

The work is specifically aimed at examining the deteriorative effect on the compressive strength of concrete subjected to a simulated chemically aggresive environment. It will as well assess

the bond performance of two kind of ribbed bars (diameter 12 and 20mm respectively) in the simulated enviroments. The acceptability of Poly 1 - 4 Isoprene as a coating material will be examined.
The research is designed to produce results that will serve as a basis of developing a mathematical model that will relate the volume fraction of the aggressive medium to the compressive strength and the ultimate bond stress of the grade of concrete use namely grade 30 and 40. It will equally serve as a basis of establishing the functional relationship between the ultimate bond stress and their corresponding slips.
This research work is limited to two grades of concrete as well two bar diameters. The results and coclusion were generally drawn on the simulated enviromnets namely Sulphuric acid, Hydrochloric acid and Sodium Chloide solutions.

Chapter one of the thesis gives a sumary of the aims and objectives of the research work as well as the limitations.
The review of some previous works done in the area of corrossion and bond strength is discussed in chapter two.
Experimental details are presented in chapter three. These include analysis of water obtained fron the case study sites, analyses of the reinforcing bars and cement.
Chapter four presents the experimental results with the discussons.
The mathematical models developed are presented in chapter five follwed by the conclusions and recomendation for futher research in chapter six.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 BOND SLIP CHARACTERISTICS IN REINFORCED CONCRETE

The very concept of "bond" in reinforced concrete is indistinct and "bond stress" is extremely difficult to measure and define. The term bond stress means different things to different research workers depending on their terms of preference. One of the earliest documented works on bond between reinforcement and concrete was by Johnson et al /40/ who came to a conclusion after examining the properties of High Yield Point Steel and Tension Reinforcement in beams that the bending moment under flexural members are dependent primarily on the total yield strength of the reinforcement. The findings by Johnston et al /40/ also led to the investigation at the National Bureau of Standards to determine the effect of magnitude of these stresses on the bond of deformed bars. The study was supported by the committee on Reinforced Concrete Research of the American Iron and Steel Institute. The test procedures used in the study were essentially those recommended by A.C.I. Committee 208 /5/.

Clifton et al /22/ also confirmed the findings as documented by Johnson et al /40/. Bars of two sizes were used at several of embodiment lengths. The nominal yield strength of the reinforcement was 690 N/mm^2 [100000 psi]. The tensile reinforcement in the pull-out test consisted of 12 mm and 25 mm deformed bars. A 3 ft [915 mm] length of each bar was tested to rupture in tension and the stress-strain relationship studied.

The concrete was made from a mix of cement, sand and gravel approximately 1:3.5:4.4 by weight. Pull out specimens were of square section with a size of 254mm. The rods were tested in a 200000 lb. [890 kN] capacity universal electromechanical testing machine. Slip of bar was measured with 0.001 in [0.0254 mm] micrometer dial gages and estimated to 0.0005 in [0.0127 mm]. A C I Committe 208 /5/ observed that the bond strength was found to decrease with increase with increase in the length of embedment of a bar of a given size. The bond value also decreased in the bar diameter for a given diameter ratio. Two criteria were used to define the critical bond stress . These were a loaded end slip of 0.01 in [0.254 mm] and a free end slip of 0.002 in [0.05 mm], which ever occurred first. The value of $U_c/2$ [critical bond stress] for all the 12 mm bars were greater than 350 psi [2.415N/mm^2] which is the maximum allowable bond stress specified in A.C.I. 318-56 /5/. The values of $U_c/2$ were less than 350 psi [2.415N/mm^2] for all the 25 mm bars except the bar which had an embedment length of 7 ins [117.8 mm].

The Mechanics of Bond and Slip of deformed bars was examined by Luth et al /43/. They /43/ stated that the action of bond forces and the associated slip and cracking were examined for all bars with various surface properties . Bond according to Luth et al. can be thought of as the shearing stress or forces between a bar and the surrounding concrete. the force in the bar is transmitted to the concrete bond by shearing. Bond, they opined, is made up of three components. These are

(a) Chemical Adhesion

(b) Friction and

(c) Mechanical interaction between concrete and steel.

Bond of plain bars between concrete and the immediate steel depends on the first two elements although there is some mechanical interlocking due to the roughness of the bar surface /43/. It was equally their view that deformed bars however depends on mechanical interlocking for superior bond properties. This according to the researchers, does not mean that friction and chemical adhesion is negligible. These properties are however secondary, they opined. Figure 1. illustrates a section through a reinforcing bar as suggested by the same group of researchers /43/. This figure shows separation that occur near primary crack. It is a section through part of the concrete and half part of bar diameter showing what happens at near primary crack.

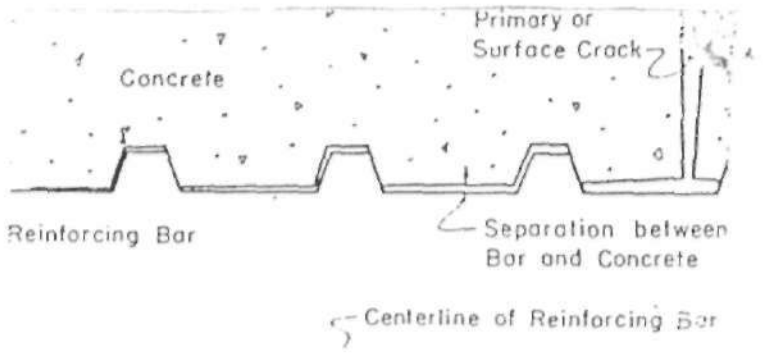


FIGURE 1 Interface Seperation at primary crack
[after Luth et al. /43/]

Luth et al /43/ also observed that bars having ribs with steep face angles (larger than 40 degrees with bar axis) slip mainly by compressing the concrete wedge formed in front of the bar rib. Figure 2 illustrates the geometry of bar deformations with radial tensile stresses acting normal to the concrete interface as viewed by them /43/.

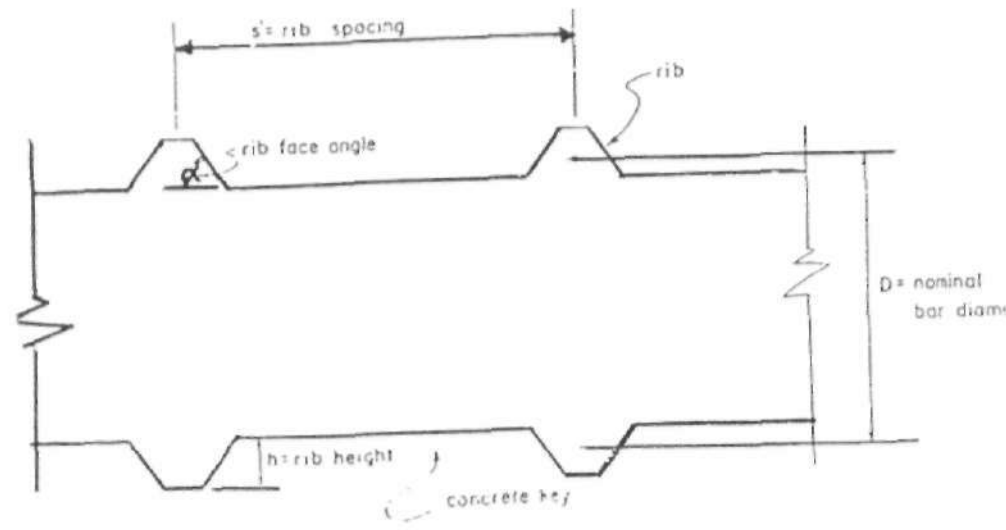


FIGURE 2 Geometry of bar deformations.
[after Luth et al /5/]

The views of group Luth and Gergerly /43/ is equally shared by Tepfers /67/, Door/28/, Gamborova et al /31/, and Abrishami et al /1/. Tepfers assumes that the radial component of the bond force (i.e. the confinement forces) are balanced against concrete " rings" in tension, which resist the tensile hoop stress /67/. Figure 3 illustrates this view.

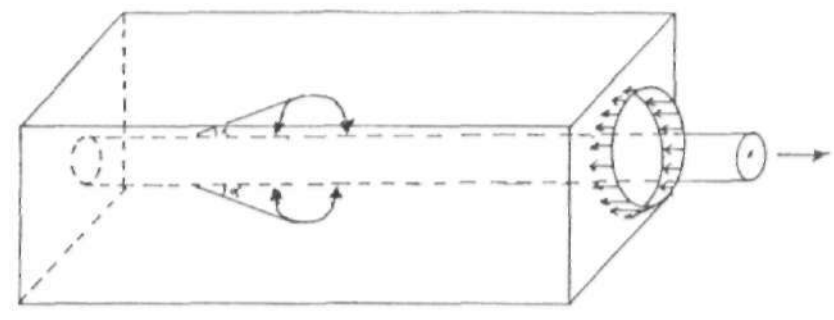


FIGURE 3. Tensile stress rings .
[after Tepfers /67/]

Gamborova /31/ analysed the mechanical interaction between a bar and surrounding concrete which is accompanied by the formation of splitting cracks. In order to study bond behaviour when bond is assured only by mechanical interaction between bar ribs and mortar he prepared several pre cracked concrete specimen with the splitting plane at right angle to the plane intersecting the ribs. This is illustrated in figure 4.

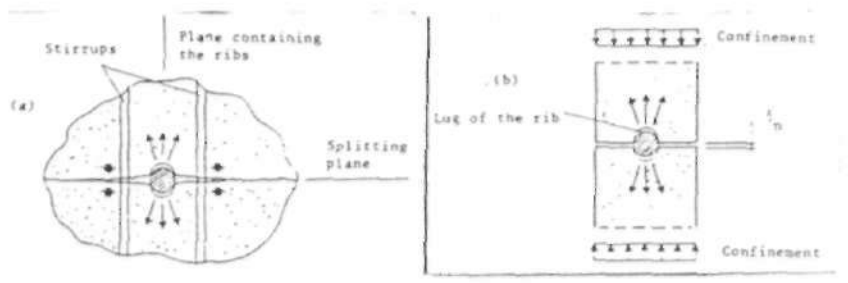


FIGURE 4. Prepared pre cracked specimen.
[after Gamborova /31/]

The test was carried out on seven specimen and in each case a pull out force was applied to the single reinforcing bar and the width of the existing splitting crack was kept constant through out the test .The variables measured by the authors /31/ were

average bond stress - τ

confinement stress - δ

bar slip - s

width of crack - d_n

The values of the bond stress τ and the confinement stress δ were obtained by Gamborova /31/ using the following equations:

$$\tau = \frac{V}{\pi D_b L} \qquad (1)$$

and

$$\delta = \frac{N}{\pi D_b L} \qquad (2)$$

where :

V = Applied Shear Force

D_b = Diameter of Steel Reinforcement

L = Embeded Length of Bar

N = Shear Force

A value K = τ/s the friction, coefficient was computed for all recorded values of τ and s.

The graphical plot of the bond - slip curves versus the reduced bar slip according to Gamborova /31/ is shown in Figure 5.

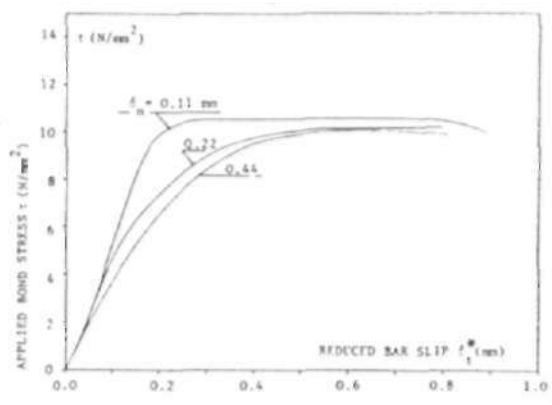


FIGURE 5. Bond slip curves versus reduced bar slip.
[after Gamborova/31/]

In the range δ_t = (0.4 - 0.6) mm to (0.7 - 1.0)mm where the maximum bond strength is reached the friction coefficient

K_1 is almost constant /31/. However this coefficient decreases at increasing values of the split within δ_n according to the empirical relation

$$K_1 = 0.20 \left(\frac{D_b}{\delta_n}\right)^{\frac{1}{3}} \qquad (3)$$

where :

D_b = Mean Bar Diameter

δ_n = Split Width

δ_t = Reduced Bar Slip

For values of δ_t larger than 2 mm ,the friction coefficient tends to become constant and the value of the friction coefficient K_1 is given as

$$K_1 = 0.13 \left(\frac{D_b}{\delta_t}\right)^{\frac{1}{3}} \qquad (4)$$

The works of Goto /35/, Reynolds et al. /57/ and Martin/44/ have a significant dimension in the bond strength study of deformed bars. Reynolds /57/ carried out test with induced bond failures of rectangular beams of cross section 200 mm x 100 mm deep. A lower bound estimate of bond strength can be obtained from the equation;

$$f_{bs} = 0.27\sqrt{f_{cu}\left(0.5 + \frac{C}{\Phi}\right)} \qquad (5)$$

where f_{cu} = Cube Strength of Concrete

c = crack width

ϕ = Bar Diameter

The use of this equation in designing according to Reynold et al. /57/ will require the introduction of a partial safety factor. Martin /44/ examined the bond performance of Ribbed Bars (Pull out test). He focused his test on the influence of consistency and concrete composition. The test was performed with three water - cement ratios of 0.50, 0.75 ,0.90, ; Three consistencies labelled c1, c2, c3,; and using three grading curves also labeled A16 , B16 ,C16. The reinforcing steel used was 18 mm in diameter. The test was performed according to the German Industrial Standard [DIN 488] (Deuthse Institute fuer Normen 488) and the guideline spelt out by RILEM DOCUMENT 128 /60/. The average bond stress values (averaged with a bond length of 5π, were calculated from :

$$\tau_b = \frac{V}{5\pi\phi^2} \qquad (6)$$

where;

τ_b = Average Bond Stress

V = Applied Shear Force

ϕ = Diameter of Ribbed Bar

After testing at the age of 28 days and the result analysed ,a mathematical relationship between the tensile strength and the compressive strength of the form in equation 7 and 8 was

derived ;

$$f_{c,t}=0.222 f_{cube}^{\frac{2}{3}} \tag{7}$$

$$f_{c,t}=0.35 f_{cube}^{\frac{2}{3}} \tag{8}$$

where :

$f_{c,t}$ = Compressive and Tensile Strength

f_{cube} = 28 - day Cube Strength

Consistency was observed to have no effect on the strength for Pull Out Test up to 10 MPa. It has been observed that the mechanical interaction between steel and concrete occurs within a slip range of 0.01 - 1 mm /44/. The range of chemical adhesion /44/ begins within a slip range of (0 - 0 .01 mm).The ultimate load range (slip range > 1 mm) Martin /44/ deduce that

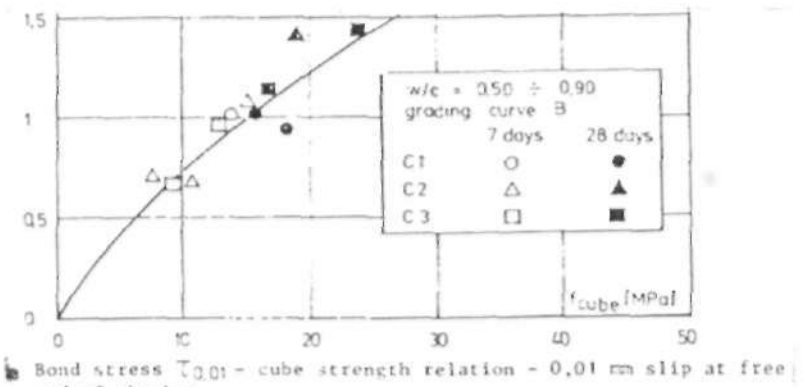
$$f_{c,t}=K_1 f_{cube}^{\frac{2}{3}} \tag{9}$$

where f_{cube} = 28 - day Cube Strength

K_1 = Regression Constant

As far as practical application of slip range is concern he suggested that 0.01 to approximately 0.05 mm should be an acceptable range of interest. He argued about the inclusion of averaged 1 mm displacement as a slip range for the computation of bond stress. According to Martin /44/ displacement of 1 mm are

no more relevant from the practical point of view .As a consequence only the bond stress value for 0.02 mm slip approximately corresponds to the average bond performance in the ultimate limit state. Figure 6 shows the bond stress versus slip value for average bond for 0.01 mm slip /44/.



Bond stress $\tau_{0,01}$ - cube strength relation - 0,01 mm slip at free end of the bar

FIGURE 6. Bond Stress Vs Slip Curve.
[after Martin/44/]

Martin /44/ among his conclusions recommended that for the purpose of comparison of bond stress in different test series, a simple bond test (e.g. pull out test) just as it is usual for the other properties of concrete which include tension and compression test should be carried out. Finite element methods has equally been used for obtaining an insight study of bond mechanism. The works of Nilson /50/ and Zienkiwicz /77/ documents this .

Linear approximation of the bond slip law have been proposed by

The linear approximation of the bond slip law is reflected in the CEB - FIP Model Code /20/. The assumption is that there exist a uniform bond stress between the steel bar and concrete. Consequently,

$$\tau_b = C \qquad (10)$$

where

τ_b = Uniform Bond Stress

C = a constant depending on bar - concrete interface.

This constant is usually connected with the tensile strength of concrete and the surface characteristics of the bar /56/. The greatest disadvantage of the solution with constant bond stress is that a slip independent steel stress distribution is obtained which is true only for plain bars /14/. This fact can be illustrated mathematically as :

$$\delta_s(x) = \frac{4}{\phi}\int_0^{l} \tau_b dx = \frac{4C}{\phi}\int_0^{l} dx = \frac{4C}{\phi} l_b \qquad (11)$$

where:

l_b = embeded bar length

τ_b = Bond Stress

C = a constant depending on bar - concrete interface

ϕ = Bar Diameter

$\delta_s(x)$ = Bar Slip

Balaz's et al /14/ consider the result of Rem /56/ and others to be a function of the relative displacement (slip) between the steel bar and the concrete sections. Owing to the differential relationship between the bond and steel stress , the steel stress also depends on the slip /14/ ;

$$\delta_s(x) = \frac{4C}{\phi}\int_0^l \tau_b[S(x)]\,dx \qquad (12)$$

where

τ_b = Bond Stress

C = a constant depending on bar - concrete interface

ϕ = Bar Diameter

$\delta_s(x)$ = Bar Slip

S(x) = Steel Stress

The bond slip law giving the relationship between the bond stress and slip is generally a non linear relationship of the form /14/;

$$\tau_b = f(s) \qquad (13)$$

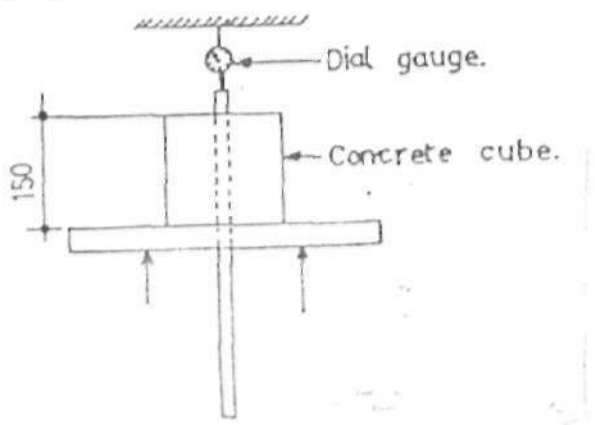
where:

τ_b = Bond Stress

f(s) = Slip Function

even if only the ascending branch of the bond slip law is considered. Experimentally the bond - slip law is obtained from the pull out force - unloaded end slip [F(force) - S_u(Slip)] diagram. The nominal bond surface is given as

reinforcement in concrete. In their study, a wide range of organic coating materials were used. These were paints, cement slurry, cashew shell liquid. Steel rods of length 70 cm and diameter 10 mm both plain and twisted were used for the pull out test. Each rod surface was cleaned using water, sodium hydroxide solution and sulphuric acid. The rods were then dried. Primary coat of polymer was applied on the rods. The second seal coat were given 18 to 20 hours after the application of the primary coat . The coated rods were embedded in concrete cubes of size 150 mm such that the projected length on one side measured 5 mm and on the other 545 mm (fig. 9)



Concrete mix of 1 : 2 : 4 with a water - cement ratio of 0.6 was used. The specimen were cured in water for 28 days. Test was carried out using a 40 tonne Universal Testing Machine. The slip in the reinforcement rod was measured with a dial gauge of least count 0.002 mm per division. It was observed the decrease in load after the peak value is found to be lower in the case of coated rods than in the uncoated cases. Rods coated with bitumen systems did not take much load. (Fig. 10)

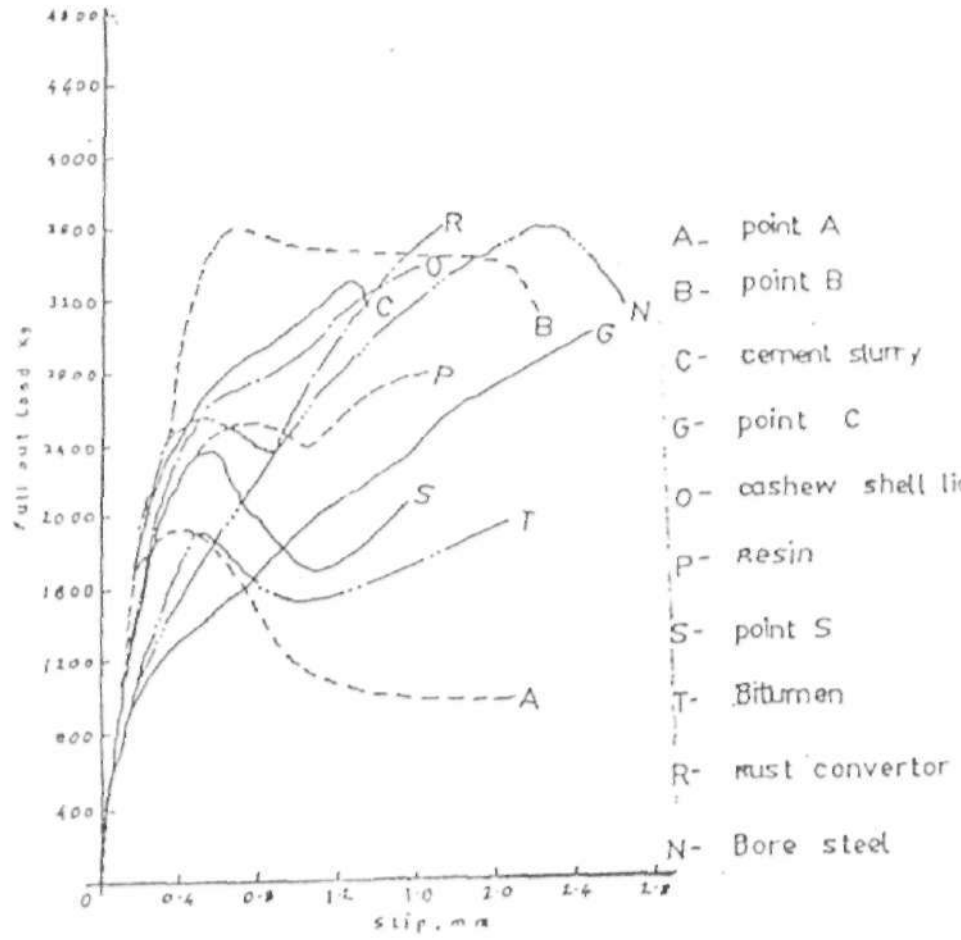
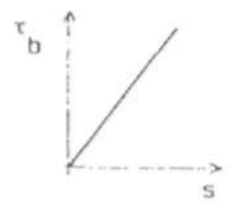


FIGURE 10. Relationship between pull out load and slip at free end for twisted rods. [after Pantil/52/]

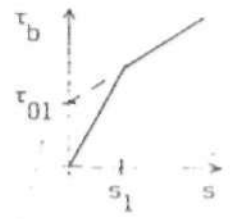
Rem /56/, Lutz et al /43/, Ngo et al /48/ , Edwards et al /29/ Venkateswartu et al /71/, Tepfers et al /68/, Guvriani /34/ and ,Balaz /14/. Their models are presented in figure 7(a - f). Some researchers are of the opinion that the bond slip law is of a non linear form. The models of non - linear behaviour are as proposed by Rem /56/, Nilson /50/, Houde /37/, Martin /45/ and Ciampi et al /21/ illustrates this and are presented in figure 8.(a - e)



$\tau_b = cs$

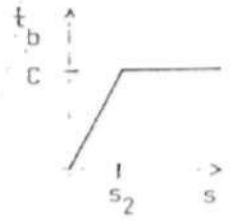
c_s is called slip modulus

Giuriani /7a/



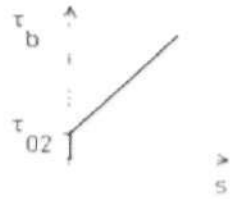
$$\tau_b = \begin{cases} cs & 0 \leq s \leq s_1 \\ \tau_{01} + \alpha_1 s & s_1 < s \end{cases}$$

Edwards-
Picard /7b/



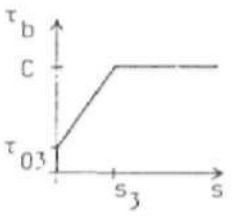
$$\tau_b = \begin{cases} cs & 0 \leq s \leq s_2 \\ C & s_2 < s \end{cases}$$

Tassi/
Balázs /7c/



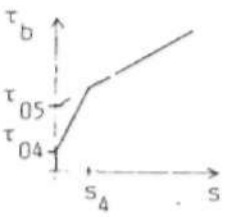
$\tau_b = \tau_{02} + \alpha_2 s$

Tassi/
Balázs /7d/



$$\tau_b = \begin{cases} \tau_{03} + \alpha_3 s & 0 \leq s \leq s_3 \\ C & s_3 < s \end{cases}$$

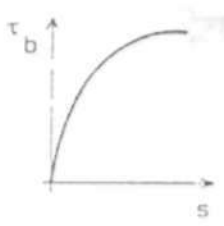
Balázs /7e/



$$\tau_b = \begin{cases} \tau_{04} + \alpha_4 s & 0 \leq s \leq s_4 \\ \tau_{05} + \alpha_5 s & s_4 < s \end{cases}$$

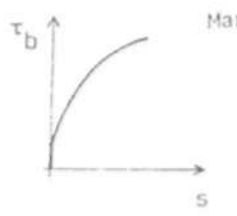
where c, C, $\tau_{01}, \ldots, \tau_{05}$, $\alpha_1, \ldots, \alpha_5$ are parameters from the fitting of experimental results.

FIGURE 7 Linear Bond Slip law approximations.



Mirza & Houde /8a/

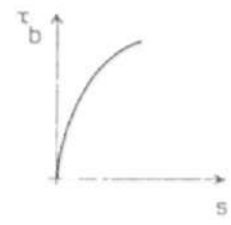
$\tau_b = 539.8s - 256.1\ 10^2 s^2 + 596.2\ 10^3 s^3 - 557.4\ 10^4 s^4$



Martin /8b/

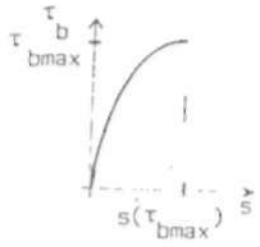
$\tau_b = \beta_w (a_0 + b_0 s^{1/\beta})$

where a_0, b_0 are experimental constants and $\beta > 1$;-



$\tau_b = \beta_w A s^N$

Martin /8c/
Noakowski
Krips /8c/

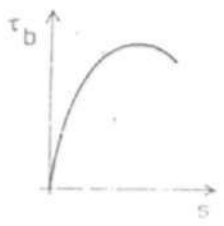


$\tau_b = \tau_{bmax} \left[\frac{s}{s(\tau_{bmax})} \right]^{\alpha}$

Ciampi-
Eligehausen-
Bertero-
Popov /8d/

where τ_{bmax} , $s(\tau_{bmax})$ and α are experimental constants.

Nilson /8e/:



$\tau_b = 998.4s - 584.0\ 10^2 s^2 + 852.2\ 10^3 s^3$

FIGURE 8 Non Linear approximation model .

$$\tau_{b(s)} = \frac{1}{\phi \pi l_b} F(S) \approx \frac{1}{\phi \pi l_b} FS_y \qquad (14)$$

l_b = Embeded Bar Length

$\tau_b(s)$ = Bond Stress

FS_y = Slip Function

ϕ = Bar Diameter

The effect of micro cracks and concrete crushing in front of the ribs are usually taken care of in the experimental curve /35/, /68/. Windish et al /75/ observed that although the theory and mechanism of bond, selection of proper rib patterns of high bond bars and standardisation of test methods had been researched into, there is apparently no information about the real safety bond characteristics such as lap length and anchorage length. The formulae used in existing codes according to Windish et al. /75/ are found not to be compatible with practical deformation. An aspect of bond studies that has attracted the interest of researchers is the bond characteristics of coated materials. The argument for coating reinforced bars is to prevent the bar against corrosion. Protecting the bar this way helps in the reduction of bond loss which is a direct consequence of chemical aggression on reinforcement bars. /23/ ,/36/ ,/58/ . Cases of corrosion induced damages has been reported in several works /15/, /69/, /38/, /36/, and /66/ . An important consideration in the use of coated reinforcing bars is the effect of the coating on the strength of the bond formed between reinforcing bars and concrete . Clifton et al /23/ examined the bond and creep characteristics of coated reinforcing bars in concrete. The effect of nine epoxy coatings

and one polyvinyl chloride coating on bond characteristics of reinforcing bars were examined. Pull out test for the coated specimen were carried out based on the requirement of the A.C.I. Committee 28 code /5/. Concrete used was procured from a transit mix company . The mix proportion of cement ,sand and coarse aggregate was 1 : 1.7 : 2.5 by weight. The five batches of concrete used had a compressive strength of 41 N/m^2. A bar diameter of 20 mm having two deformed patterns was used. Bar B with barrel deformation pattern had a yeild strength of 466 Mpa. Bar D with the diamond shaped deformation pattern had a yield strength of 431 Mpa .The yield strength of the bars were determined by the 0.2 percent offset method /65/. Pull out specimens were tested in a 907kN kg universal electromechanical testing machine. Loads were applied in increments of (9 X 10^{-3}N) to the reinforcing bar in the pull out test until failure occurred either by yielding of the steel or excessive slip between the bar and concrete was attained. At each load increment, the corresponding slip was recorded. Clifton et al /23/ observed that some of the epoxy coated bars had satisfactory bond to the concrete and can be used in structural concrete. The pull out bond stress ratio (B. R.) was calculated as;

$$B.R. = \frac{\text{Pull Out Bond Stress For Coated Bar}}{\text{Pull Out Bond Stress For Uncoated}} \quad (15)$$

Clifton et al /23/ obtained a B .R. range of 0.95 - 1.14 for loaded end and 0.095 - 1.03 for the free end. These values are judged to indicate development of satisfactory bond.

Patil et al /52/ examined the pull out strength of coated steel

reinforcement in concrete. In their study, a wide range of organic coating materials were used. These were paints, cement slurry, cashew shell liquid. Steel rods of length 70 cm and diameter 10 mm both plain and twisted were used for the pull out test. Each rod surface was cleaned using water, sodium hydroxide solution and sulphuric acid. The rods were then dried. Primary coat of polymer was applied on the rods. The second seal coat were given 18 to 20 hours after the application of the primary coat . The coated rods were embedded in concrete cubes of size 150 mm such that the projected length on one side measured 5 mm and on the other 545 mm (fig. 9)

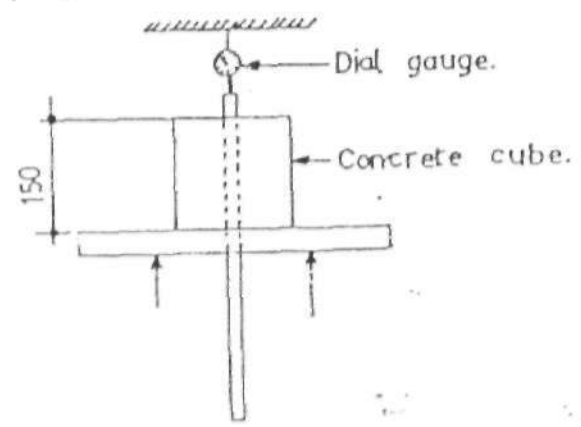


FIGURE 9. Arrangement for the measurement of slip.
[after Patil /52/]

Concrete mix of 1 : 2 : 4 with a water - cement ratio of 0.6 was used. The specimen were cured in water for 28 days. Test was carried out using a 40 tonne Universal Testing Machine. The slip in the reinforcement rod was measured with a dial gauge of least count 0.002 mm per division. It was observed the decrease in load after the peak value is found to be lower in the case of coated rods than in the uncoated cases. Rods coated with bitumen systems did not take much load. (Fig. 10)

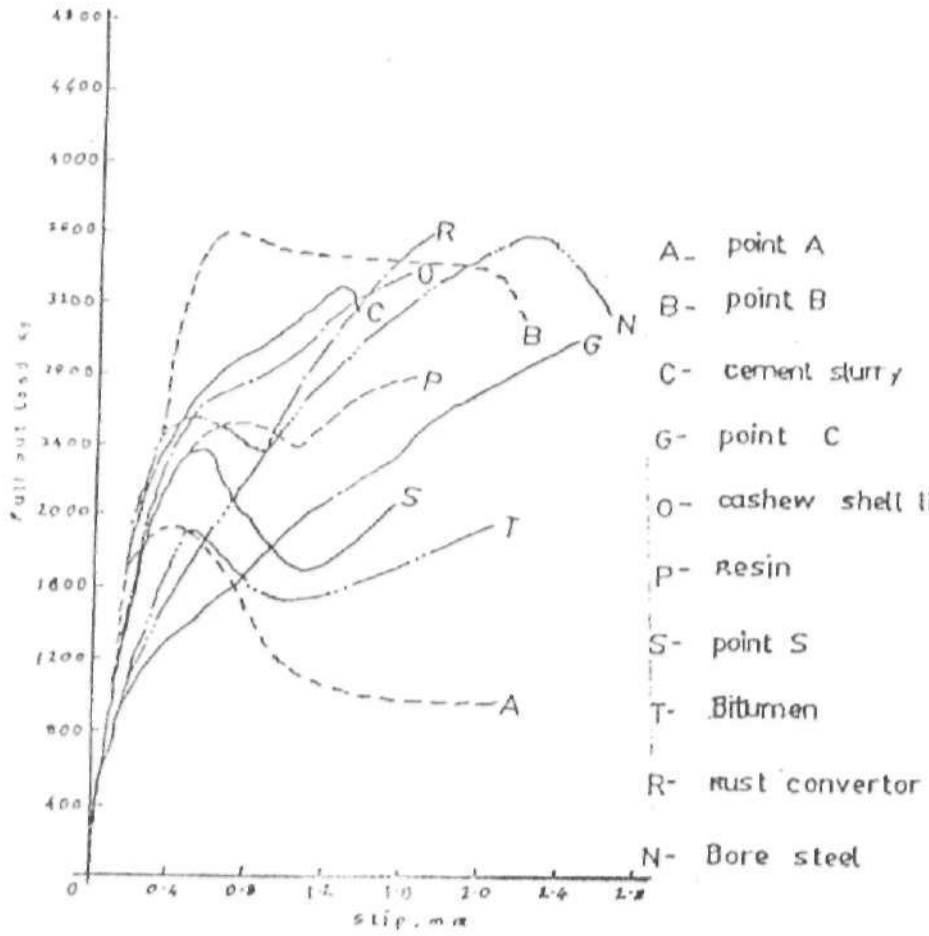


FIGURE 10. Relationship between pull out load and slip at free end for twisted rods. [after Pantil/52/]

Slip of twisted bars coated with polymers were observed to follow that of bare twisted rods except in the case of rust converter and commercial paint and bitumen. The tested cubes underwent complete splitting at the terminal load .Based on these observations, Pantil et al. /52/ inferred that the polymer system used will not destroy the bond between cement concrete and coated steel reinforcement .

Sakamoto et al. /61/ investigated the influence of sodium chloride on the bond properties of a reinforced concrete section. Sakamoto /61/ carried out pull out test on 16 mm diameter reinforcing bars. The test was carried out according to the specifications of ASTM Standard C 234 /10/. The specimen were fabricated using steel mould of 150mm cube mould. The moulds were removed from the specimen into water of selected temperature until testing. Amounts of NaCl of 0 , 0.1 , 0.3 , 2 and 5 percent by weight of sand in oven dried condition was added to the concrete during the mixing process. Curing temperatures of 20 30 and 50^{0}C were distinctly maintained as well as the testing ages of 7 and 28 days. Two specimen were provided for each condition. The nominal bond stress was calculated as the load on the bar divided by the nominal surface area of the entire embedded surface area of the bar. The maximum bond stress was designated as bond strength. Although Sakomoto /61/ did not emphasise on the slip corresponding to the maximum bond strength in his analyses, he recognised it as an important parameter relating to the bond characteristics. He emphasised more on the bond strength. The influence of NaCl on Bond Strength of D16 mm deformed bar is presented in figure 11.

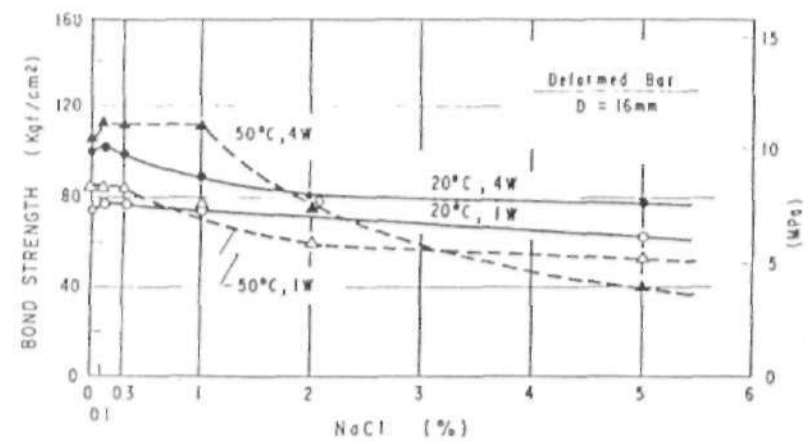


FIGURE 11 . Influence of Sodium Chloride on Bond Strength. [after Sakamoto et al./61/]

Sakomoto observed that the bond strength hardly increased between the ages of 7 and 28 days for NaCl amount of more than 1 percent . However any amount of more than 1 percent leads to its deterioration .The deformed bars taken out of the specimen which showed a lowering of bond strength under the conditions of high NaCl concentration and elevated temperatures were found to be rusty. Sakamoto et al./61/ then concluded that when a decrease in bond strength occurs, it may be considered that the reinforcing bar in the specimen was affected by corrosion even when a case of rust was not evident. Under the same conditions in which non galvanised bars were rusting, galvanised bars were not . However discoloration of the surfaces was noticed . The formation of dense layer of corrosion product between the concrete and the galvanised steel reinforcement is advantageous

according to the opinion of /10/. This layer will decrease the rate of consumption of zinc used in the electroplating of the galvanised reinforcement rod consequently preserving the bond strength over a long period. It was further concluded that zinc coating is an effective means of protecting the reinforcing steel from attack of chlorides contained in concrete. The view of the group is equally shared by ASTM Committe 234 /10/, /13/, /70/, and/11/.

Dhir et al. /27/ highlighted ways of protecting concrete and reinforcing rods. This include odinary-crete, super-crete, coated-crete, coatedrebar-crete and efficient-crete. Bond strength requirement features prominently in the coatedrebar-crete. Coated rebar-crete is designed to satisfy structural requirement and is used when protection of the reinforcement from corrosion is required. The reinforcement is usually coated with zinc or fusion bounded epoxy resin .The close control that is exercised during the manufacture of the coated reinforcement gives rise to more confidence in the in-situ performance of concrete. However the reinforcement is expensive and needs care during the handling and fixing processes as any damage may not be detected and could give rise to intense corrosion attack . There is also an unanswered question regarding bond strength between the differently protected reinforcement rods and concrete /27/.

2.2 BOND BETWEEN CONCRETE AND STEEL

Bond has always been recognised as a vital requirement in reinforced concrete construction /27/. If no bond existed between

the tension reinforcement of a beam and the surrounding concrete, then the beam will function structurally as a member having two structurally non-interacting members . Under this condition, the stiffer concrete member would resist most of the superimposed bending moments and its ultimate strength would be realised, at such a load that the assistance of the reinforcement in resisting bending moment could be described as negligible /47/. Thus for reinforcement to be utilised satisfactorily it has to bond into concrete so that a reinforced concrete beam tends as though it is a homogenous material (the strain in the reinforcement being the same as the strain in the surrounding concrete fibres) /74/.

Bond comprises of two different actions. Firstly, there is the ability of the concrete to stick to the steel, usually refered to as adhesion. Secondly, there is the frictional resistance between the steel and concrete often refered to as grip. When a bar tends to pull out of its surrounding concrete the relative movement of the bar to concrete is known as slip. A bond stress cannot exist without its coexistent strain (i.e. without slip) /74/. Adhesion is an initial resistance to bond and occurs when the slip is minute . In a smooth surface bar for example, the adhesion phenomenon is often attributed to mechanical locking (minute irregularities on the bar mechanically locked to the concrete) /74/. As soon as a small amount of slip occurs the adhesion is ruptured and takes no further part in the bond resistance /74/. For such slips a bond resistance is developed by the friction between the bar and the surrounding concrete . This is aided by the shrinkage of the

concrete upon setting as this cause the concrete to exert a radial pressure on the reinforcing bar, thus increasing the frictional resistance between the materials /74/, /73/.

Bond therefore consist of firstly an adhesive resistance and then the frictional resistance.

2.3 ANCHORAGE OR EMBEDMENT LENGTH : B.S.8110 RECOMMENDATIONS

Figure 12 illustrate a bar anchored into a block of concrete.

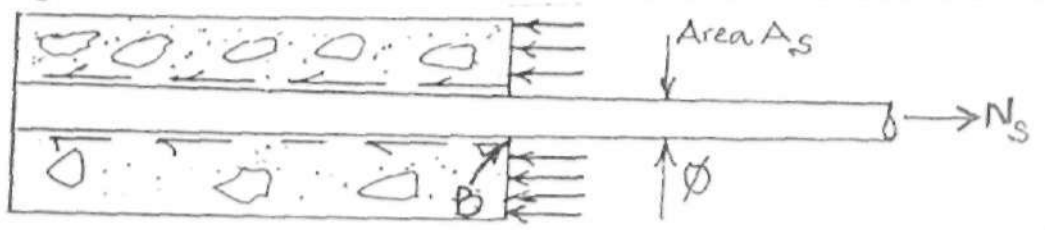


FIGURE 12. Bar anchored in concrete.
[after /76/]

The necessary bond length l_b is to be determined so that the bar can develop a tensile stress of f_s at a section B. If the bar has a cross sectional area A_s and perimeter u, then the force in the bar N_s is given by

$$N_s = A_s F_s \qquad (16)$$

where:

N_s = Force (kN)

A_s = Cross - section area of bar (mm^2)

F_s = Bond Stress (N/mm^2)

If f_{mbs} is the average bond stress between the steel and the concrete , this exist over an area of contact equal to A_s therefore

$$N_s = f_{mbs}\ u\ l_b \qquad (17)$$

$$l=\frac{f_s\phi_e}{4f_{mbs}} \qquad (20)$$

where:

f_s = Steel Stress

u = Bar Perimeter

l = Embedded Length of Bar

f_{mbs} = Average Bond Stress between Steel and Concrete

ϕ_s = Equivalent Diameter of Bar

where $l = l_b$ = f = f_b and ϕ_e = d.ϕ_e is the equivalent diameter in the case of deformed bars .

Therefore $$l=\frac{f_s\phi_e}{4f_b} \qquad (21)$$

B S 8110 gives the design ultimate values of f_b as

$f_{bu} = \beta \sqrt{f_{cu}}$ and values of β as seen in table 1 and 2 depending on whether the bar s are plain or deformed or in fabric form. It also gives the design ultimate values of steel as

$f_s = \gamma_m f_y = 0.87 f_y$ _____ (22)

Therefore from equation 21, expression for bond length can be written as

Eliminating N_s between equations 16 and 17

$$l_b = \frac{A_s f_s}{f_{mbs} u} \qquad (18)$$

where:

A_s = Area of Steel Reinforcement

f_s = Steel Stress

u = Bar Perimeter

l_b = Embeded Length of Bar

f_{mbs} = Average Bond Stress between Steel and Concrete

If the diameter of the bar = d_b , then equation 18 can be rewritten in the form

$$\frac{l_b}{d_b} = \frac{f_s}{4 f_{mbs}} \qquad (19)$$

where:

f_s = Steel Stress

u = Bar Perimeter

l_b = Embedded Length of Bar

f_{mbs} = Average Bond Stress between Steel and Concrete

d_b = Diameter of Bar

The expression in B S 8110 /17/ is of the form

$$l = \frac{0.87 f_y . \phi_e}{4\beta\sqrt{f_{cu}}} \qquad (23)$$

TABLE 1 : TABLE 1 :RATIO OF ANCHORAGES TO DIAMETER OF BARS IN TENSION /52/

f_{cu}	25	30	35	40 or more
250(plain)	39	36	33	31
460(deformed Type1)	51	46	43	40
460(deformed Type 2)	41	37	34	32

Tables of anchorage lengths to be easily determined for bars in tension ; values of the ratio l to ν_e are read off for values of f_{cu} (concrete characteristic strength) and f_y (characteristic strength of steel). Values of β (a coefficient depending on the bar type) and f_y which are shown in table 2.

TABLE 2: VALUES OF β FROM EQUATION 23

Designation	f_y	Tension	Compression
Plain Hot Rolled Mild Steel	250	0.218	0.35
BS 8110 Deformed Type 1	460	0.4	0.50
BS 8110 Deformed Type 2	460	0.5	0.63

BS 8110 has not commented categorically on the bond lengths of coated reinforcing bars.

2.4 LOCAL BOND STRESS

The tension along a reinforcing bar varies with the magnitude of bending moment on the member. For equilibrum the change in

tension must be balanced by the bond between the bar and concrete. To understand the theory of bond stress, a small length δx of a beam which is subjected to a bending moment varying from M to M + δm as shown in figure 13 below is carefully observed.

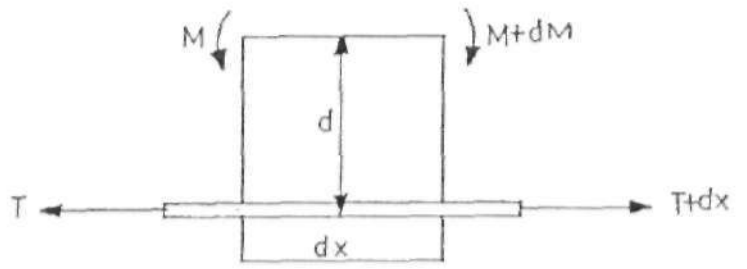


Figure 13 : Forces and stresses acting on elemental length of beam [43].

The change in the moment causes the tension in the steel to vary from T to δT along the length. If Z is the lever arm of the reinforcement then

$$M = TZ \quad (24)$$

$$\text{and } M + \delta M = (T + \delta T)\, z \quad (25)$$

$$\therefore \delta M = \delta T.\ Z \quad (26)$$

From the theory of bending

$$\frac{\partial M}{\partial X} = V \quad (27)$$

the shear force

$$\therefore \delta M = \delta T.z = V\delta x \quad (28)$$

For equilibrum change in tension T = bond force between bar and

concrete = bond stress x bar surface area.

$\therefore \delta T = f_{bs}.\ \delta x.\Sigma U_s$ _____ (29)

$$\rightarrow f_{bs} = \frac{\partial T}{\Sigma U_s \partial x} \qquad (30)$$

where f_{bs} = is the ultimate local bond stress and ΣU_s is the sum of the effective perimeters of group of bars at the section.

From equation 29 and 30

$$\frac{V\partial x}{Z} = f_{bs}.\partial x.\Sigma u_s \qquad (31)$$

$$\rightarrow \therefore f_{bs} = \frac{V}{\Sigma_s Z} \qquad (32)$$

For convenience, Z, in equation 32 has been replaced by the effective depth,d, thus the values for the ultimate bond stress given in Table 2.1 of BS 8110 are reproduced in Table 3 below using effective depth d, instead of the lever arm.

TABLE 3 ULTIMATE LOCAL BOND STRESS IN BEAMS IN N/mm²

BAR TYPE	CONCRETE GRADE			
	20	25	30	40
PLAIN BARS	1.7	2.0	2.2	2.7
DEFORMED BARS TYPE 1	2.1	2.5	2.8	3.4
DEFORMED BARS TYPE 2	2.5	3.0	3.4	4.1

Such bond stress is caused by the change δM in the bending moment, it is known as the flexural bond. If the calculated bond stress, f_{bs} exceeds the ultimate value, then either the beam size must be increased, preferably by increasing the effective depth d, or bars with a larger total perimeter must be used. In order that the reinforcing bar and concrete act together to resist the applied moment, the local bond stress should be calculated using equation 32 and compared with the ultimate in Table 3. Failure in local bond will cause the bar to slip within the concrete so that there is no longer composite action of the steel and the concrete. Local bond stresses are often checked at sections where there are high shears combined with rapid changes in bending moment, such as at

(1) The simply supported ends of a member;

(2) Points of contraflexure;

(3) Supports of cantilevers;

(4) Points where tension bars stop, since the abrupt change in section may cause stress concentrations and possible bond failure.

2.5 CORROSION OF REINFORCEMENT

Bond loss between reinforcing bars and concrete can be a direct consequence of environmental attack on concrete or reinforcement .The mechanism of corrosion of reinforcement has been extensively appraised by research works /16/, /18/, /8/, /51/. Normal cement concrete is strongly alkaline in nature /33/. The alkalinity varies from a pH of about 11.8 to 13.0 depending on whether sea or fresh water is used in the mixing of the concrete /73/, /6/. The value of pH will be between these limit for intermediate situations /6/. The strong alkalinity of concrete prevents the corrosion of the steel reinforcement by the formation of a thin protective film of iron oxide on the metal surface. This protection is known as passivity. However if the concrete is permeable to the extent that carbonation reaches the concrete in contact with the steel or soluble chloride can penetrate right up to the reinforcement, and water, oxygen are present, the corrosion of the reinforcement will take place. The passive iron oxide layer is destroyed when the pH falls below about 11.0 and carbonation lowers the pH to about 9 /47/. The formation of rust results in an increase in volume compared with the original steel so that swelling pressures will cause cracking and spalling of concrete /47/. Figure 14 illustrates the corrosion sequence and cycle of reinforcement.

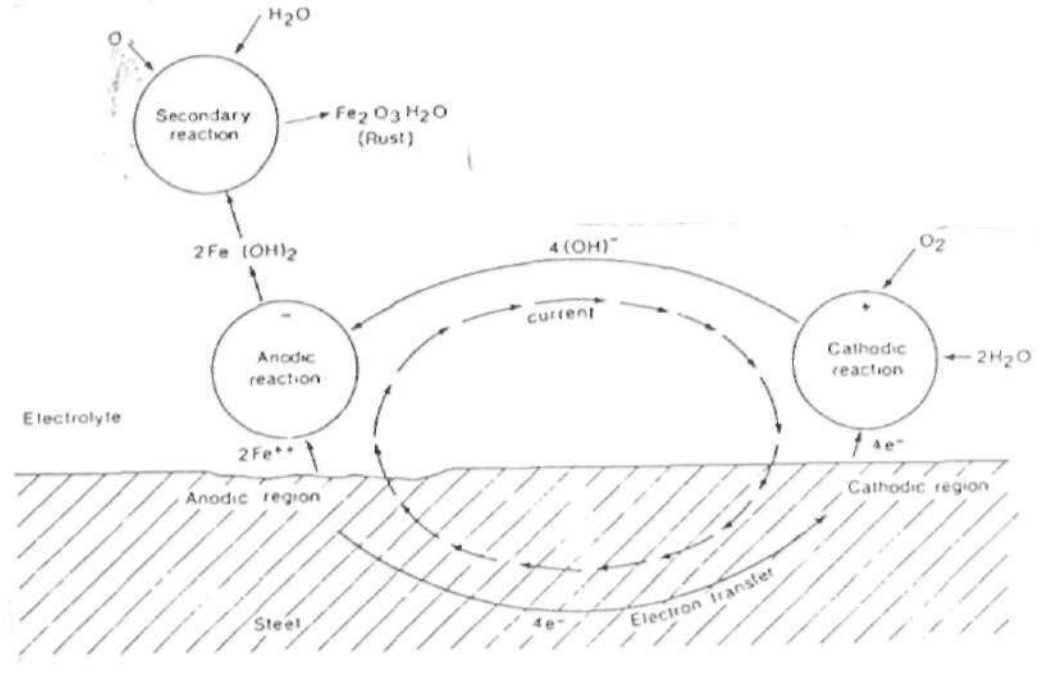


Figure 14. Corrosion Cycle (Idealised). [after Neville /47/]

Development of cracks in the cover will provide easy access to Cl^- ions and moisture and cause consequent acceleration of the corrosion. Chloride ion present in the cement paste surrounding the reinforcement reacts with water to form hydrochloric acid which destroys the passive protection film on the steel /47/. Similarly, the formation of calcium carbonate from $Ca(OH)_2$ by the process of carbonation reduces the alkalinity so that the protective layer is destroyed. Corrosion of reinforcement by chlorides is small in Ordinary Portland Cement Concrete when the total chloride ion content is less than 0.4 percent by mass of cement /76/, /63/.

2.6 CONCRETE IN AGGRESSIVE ENVIRONMENT

The influence of chemically aggressive environment on the strength properties of concrete has been examined by Akpan et al. /9/ and Mohan et al. /9/ among other researchers. Akpan et al /9/ examined the influence of a predominantly acidic media on concrete of three distinct grades , 30, 40 and 50 . After testing cubes of ages 28 , 56 and 84 days in three distinct acidic media, namely, Hydrochloric, Sulphuric and Nitric acids at varied volume fractions (0% -20 %). They /9/ noticed a decrease in the compressive strengths in all the tested cubes. The percentage reduction in compressive strength varied from 23 33% for 5% concentration of HCl at 28 days of immersion to 76.95% for 20% concentration of H_2So4 at 84 days of immersion for grade 30 concrete. A variation from 28.67% for 5 % concentration at 28 days of immersion to 76.70 % for 20% concentration of H_2So_4 at 84 days of immersion for grade 40 concrete was observed. Grade 50 concrete varied from 9.97% for 5% concentration of HCl at 28 days of immersion to 75.79% for 20% concentration of H_2So_4 at 84 days of immersion. This observations clearly suggests the possibility of chemical aggression having an influence on the bond strength of a reinforced concrete section.

The common environments usually associated with aggression include sea water, industrial conditions (such as in chimneys), agricultural conditions (such as floors of dairies), chemical manufacturing companies
(such as fertiliser plants) and domestic sewage. /74/

Concrete attack is usually classified as :

(a) Sulphate Attack

(b) Attack by sea water

(c) Acid Attack

(d) Alkali Silicate Reaction /74/

2.6.1 SULPHATE ATTACK

Sulphate attack on concrete is characterised by whitish appearance, usually starting at the edges and corners and followed by cracking and spalling of the concrete. The reason for this appearance is that the essence of sulphate attack is the formation of calcium sulphate (gypsum) and calcium sulphoaluminate (ettringite); both products occupying a greater volume than the compounds which they replace so that expansion and disruption of hardened concrete can take place /27/, /74/. Salt attack concrete only when present in solution and not in solid form /74/. The strength of the solution is expressed as concentration. A concentration of 1000 ppm is considered to be moderately severe and 2000 ppm very severe /73/.

2.6.2 ATTACK BY SEA WATER

Sea water contains sulphates. Ordinarily sea water could be expected to attack concrete but because of the presence of chloride, sea water does not generally cause expansion of the concrete /27/. The explanation lies in the fact that gypsum and are more soluble in a chloride solution than in ordinary water. This implies that they can be more easily leached by sea water /74/. However expansion can take place as a result of pressure exerted by the crystallisation of salt in the pores of the

concrete /47/, /74/. Crystallisation occurs above the high water level. Since salt solution rises in the concrete by capillary action, the attack takes place only when water can penetrate into the concrete so that permeability of the concrete is again of great importance. Sea water attack can be prevented by the same measures used in prevention of sulphate attack but the type of cement is of little importance compared to the requirements of low permeability /74/.

In reinforced concrete, adequate cover to the reinforcement is essential - at least 50 to 75 mm /76/. A cement content of 350 kg/m^3 and above in concrete structures above the water mark and 300 kg/m^3 for structures below it, with a water-cement ratio of not more than 0.35 to 0.45 are recommended. A well compacted concrete and good workmanship especially in construction joints are of vital importance /47/, /74/, /76/.

2.6.3 ACID ATTACK

All Portland cement is prone to attack by acids /27/,/73/. In damp conditions sulphur dioxide (So_2) and carbon dioxide (Co_2), as well as some other fumes present in the atmosphere, form acids which attack concrete by dissolving and removing a part of the hydrated cement paste leaving a very soft and weak mass. This form of attack is mostly associated with industrial establishment. Practically the degree of attack increases as the acidity increases. Attack occurs at values of pH below 6.5 /74/. A pH less than 4.5 leads to a severe attack. The rate of attack depends on the ability of hydrogen ions to diffuse through the cement gel after Ca $(OH)_2$ has been dissolved and leached out.

Attack of $Ca(OH)_2$ can be prevented or reduced by fixing it. This is achieved by treatment with dilute water glass (sodium silicate). Layers of rubber bituminous paints, epoxy resin among other agents have been successfully used. The degree of protection achieved by the different treatment varies. In all the cases it is essential that the protective coat adheres well to the concrete and remains undamaged by mechanical agencies , so that access for inspection and renewal of the coating is generally unnecessary /7/.

2.6.4 ALKALI - AGGREGATE REACTION

The chemical reaction between the active silica constituent of the aggregate and the alkali in the cement can damage concrete /24/. This process is known as alkali silica reactions. The reactive forms of silica are opal chalcedony and tridymite. These materials occur in several types of rocks. Since lightweight aggregate are often composed of predominantly amorphous silicates, they appear to have the potential of being reactive with alkali in cement /24/. However, there is no documented evidence of damage of lightweight aggregate concrete caused by alkali silicate reaction /24/,/59/,/39/.

CHAPTER 3

3.0 EXPERIMENTATION

Six sets of experimental test were conducted and the results are presented in this chapter. The six sets of experiments include: Steel reinforcement tests, analyses of portland cement used, water sample analysis, concrete cube test under various media, latex coating of steel reinforcements and the Pull out test. As usual experimental proccedures are not described, however mention are made where such proccedures are not stipulated in the prevailing Codes of practice or standards. The results are as discussed and presented below.

3.1 WATER ANALYSIS

Sample of waters were procured from five random sources in Nigeria. These sources were

(a) Atlantic ocean (Bar Beach) in Victoria Island , Lagos.

(b) Cross River at Calabar in Cross River State.

(c) River Niger at Onitsha in Anambra State.

(d) Zaria Dam near Ahmadu Bello University in Zaria.

(e) MOBIL producing Nigeria PLC beach at Ibeno in Akwa Ibom State.

Three samples were collected from each location at different times in the year of observation - 1992. The first samples were collected in January 1992, the next in April 1992 and the last sample was collected in October 1992. These collecting frequency was deliberate. It was meant to monitor any fluctuations in the chemical composition vis a vis the constituent material present in the environment. The analyses was carried out in the

Department of Water Resources Engineering of Ahmadu Bello University in Nigeria. The final results obtained are as presented in table 4 below

TABLE 4: CONCENTRATION OF SALTS FOR THE SITES ANALYSED

MINERAL PRESENT (IONS)	ATLANTIC OCEAN V. I. LAGOS	CROSS RIVER CALABAR	RIVER NIGER ONITSHA	ZARIA DAM ZARIA	MOBIL TERMINAL EKET
Sodium	1.113	1.100	1.108	0.832	1.102
Potassium	0.058	0.034	0.043	0.431	0.061
Calcium	0.048	0.039	0.032	0.044	0.042
Magnesium	0.122	0.113	0.108	0.119	0.127
Chloride	1.912	1.695	1.583	1.593	1.891
Sulphate	0.244	0.215	0.159	0.153	0.213
Total	3.497	3.196	3.033	3.162	3.436
Hardness	1.767	1.518	1.502	1.371	1.621

Based on the results and literature on related works /9/ and /61/, a laboratory condition was simulated with available chemicals . The chemical used consist of two acids ; concentrated Sulphuric acid (1 Molar) and Hydrochloric acid (1molar). Sodium Chloride salt was used as well.

3.2 REINFORCEMENT STEEL RODS.

The steel reinforcing rods used were obtained from a single production batch at Katsina Steel Rolling Mill in Nigeria. Each full length of bar were cut into twelve sample numbers with length of about one metre. One 20mm diameter bar of length one metre was selected at random from each cut bar length [approximately 12 metres] for the Tensile test, Yeild Strength test as well as the Elongation test. The eleven bars remaining were later used for the Pull Out test. From the six

full bar length cut, the total number of sample lengths realised was seventy two. Six of this sample lengths were used for the Reinforcing Steel test while the rest were used for the Pull Out test. The above procedure was repeated for the 12mm diameter bar. The results for the two bars used are as presented in the tables 5 and 6 below:

TABLE:5 TEST RESULTS OF REINFORCING STEEL BARS.
DIAMETER: 20mm

ID NO	Measured Diameter [mm]	Area [mm²]	Yield Strength [N/mm²]	Tensile Strength [N/mm²]	Elong-tion [%]	Remarks
AJ - 01	20.01	314.47	48.18	652.12	15.4	Characteristic Strength (f_k) = 429.04 - 1.64(14.44) = 405.4N/mm²
AJ - 02	20.01	314.16	450.24	637.05	18.2	
AJ - 03	19.98	313.53	429.36	668.36	6.4	
AJ - 04	20.01	314.47	452.27	752.42	9.7	
AJ - 05	19.99	314.16	425.18	694.38	13.8	
AJ - 06	20.00	314.16	456.36	721.38	12.7	

TABLE 6: TEST RESULTS OF REINFORCING STEEL BARS.
DIAMETER: 12mm

ID NO	Measured Diameter [mm]	Area [mm²]	Yield Strength [N/mm²]	Tensile Strength [N/mm²]	Elong-tion [%]	Remarks
AK - 01	12.02	314.47	427.24	785.01	9.3	Characteristic Strength (f_k) = 443.60 - 1.64(11.56) = 424.64N/mm²
AK - 02	12.01	113.47	411.28	703.31	17.1	
AK - 03	12.00	113.29	420.86	721.80	13.2	
AK - 04	12.00	113.29	418.20	605.42	15.1	
AK - 05	12.00	113.29	248.01	702.41	9.9	
AK - 05	12.00	113.29	468.38	735.41	14.4	

3.3 ODINARY PORTLAND CEMENT

The odinary portland cement used for the research work was sourced from the Ashaka Cement Company in Bauchi State, Nigeria. Physical and Chemical tests were carried out on the cement sample in accordance with the specifications by the relevant codes of practice. The results are summarised in table 7, 8 and 9 below.

TABLE 7: PHYSICAL TEST RESULTS OF ODINARY PORTLAND CEMENT USED

S/No	TEST	EXPERIMENTAL RESULTS	NIS: (1974) RECCOMENDATIONS
1.	Initial Setting Time (min)	182 min.	>=45 min.
2.	Final Setting Time (min)	292 min.	<=10 hours.
3.	Sondness (Expansion) (mm)	0.75mm	<10 mm.
4.	Compressive Strength N/mm^2 (28 days)	26.42 N/mm^2	<41N/mm^2

TABLE 8 **CHEMICAL TEST RESULTS OF ODINARY PORTLAND CEMENT USED - OXIDE COMPOSITION**

S/No	OXIDE	PERCENTAGES(%)
1.	CaO	55.24
2.	SiO_2	17.72
3.	AlO_3	12.61
4.	Fe_2O_3	0.59
5.	MgO	0.71
6.	SO_3	3.40
7.	Na_2O	0.076
8.	K_2O	0.09
9.	Loss of Ignition	5.50
10.	Others (MNO_2, TiO_2 etc.)	4.06
	TOTAL	100.00

TABLE 9 **CHEMICAL TEST RESULTS OF ODINARY PORTLAND CEMENT USED - MAIN COMPOUNDS**

S/No	COMPOUND	PERCENTAGE COMPOSITION BY WEIGHT(%)
1.	C_3S	15.12
2.	C_2S	54.72
3.	C_3A	32.42
4.	C_4AF	1.79
5.	LIME SATURATION FACTOR (L.S.F.)	0.81

3.4 **CUBE STRENGTH TEST**.

Table 10 presents the result of the concrete cube strength of grade 30 concrete cured in the three simulated media namely Sulphuric acid, Hydrochloric acid and Sodium Chloride. It also shows the strength of the concrete cubes with respect to the volume fraction and the grade of concrete . Row 7 in the table indicates the strength of concrete cubes in water used as the control strength. The values of the compressive strength shown is an average of the sample cubes. The result is formed from the table presented in APPENDIC ES A2 to A4.

TABLE 10: COMPRESSIVE STRENGTH TEST RESULTS
CONCRETE: GRADE 30

S/No	VOLUME FRACTION [%]	Strength N/mm² Grade 30		
		MEDIUM		
		H_2So_4	HCl	NaCl
1	0.5	25.53	32.76	33.86
2	1.0	22.57	32.36	33.76
3	1.5	21.82	32.49	33.82
4	2.0	21.47	32.36	33.69
5	2.5	21.16	32.27	33.78
6	3.0	21.06	32.13	33.82
7	0.0 % (Control)	33.56	33.56	33.56

Table 11 below presents the cube strength results for grade 40 concrete cured in the three simulated media. The results are mean values got from reduction of results in APPENDICES A5 to A7

TABLE :12 COMPRESSIVE STRENGTH OF CONCRETE GRADE CURED IN H_2So_4

S/No	VOLUME FRACTION [%]	MEDIUM : H_2SO_4	
		CONCRETE GRADE	
		30	40
1	0.5	25.53	32.27
2	1.0	22.57	31.33
3	1.5	21.82	30.89
4	2.0	21.47	30.53
5	2.5	21.16	30.00
6	3.0	21.02	29.68
7	0.0 %(Control)	33.56	33.42

TABLE: 13 COMPRESSIVE STRENGTH OF CONCRETE GRADE CURED IN HCl

S/No	VOLUME FRACTION [%]	MEDIUM: HCl	
		CONCRETE GRADE	
		30	40
1	0.5	32.76	44.98
2	1.0	32.36	44.67
3	1.5	32.49	44.53
4	2.0	32.36	43.55
5	2.5	32.27	43.22
6	3.0	32.13	43.20
7	0.0(Control)	33.56	45.56

TABLE: 14 COMPRESSIVE STRENGTH OF CONCRETE CURED IN NaCl

S/No	VOLUME FRACTION [%]	MEDIUM: NaCl	
		CONCRETE GRADE	
		30	40
1	0.5	33.86	46.67
2	1.0	33.78	46.44
3	1.5	33.82	46.71
4	2.0	33.69	46.62
5	2.5	33.78	46.80
6	3.0	33.82	46.57
7	0.0 %(Control)	33.56	45.56

3.5 CAGE FABRICATION /BASIC TEST PROCEDURE

The 50 tonne Servo - Controlled Electromechanical Test Rig used is generally used for tension and compressive strength tests. The test rig is not specifically designed for any particular test (Bond Strength Test say). This spelt the need for fabricating a unit than can be adapted to the test rig for the pull out test to be carried out. The unit is shown in PLATE 1. The cage was designed and fabricated in the Civil Engineering Department of Ahmadu Bello University by the author. It consist of steel angles butt-welded with a 16 mm high yield bar fixed at one end. At the other end of the cage, a 28 mm diameter hole was bored for ease of placement of the test specimen in the rig. During the welding process the cage



PLATE 1 Fabricated Steel Mould used

was skilfully positioned and was consistently plumed. Consequently the fabricated cage was devoid of eccentricities on clamping to the test rig. Neither yielding in any of the fabrication members nor the welded joints was noticed at the end of the test.

3.6 EXPERIMENTAL SET UP AND TESTING PROCEDURE

The steel reinforcement rod surface used for the pull out test was wiped thrice with cotton wool soaked in the following successions:

(a) soap solution

(b) clean tap water

(c) 10 percent NaOH solution and

(d) 10 percent H_3PO_4 solution.

The above proccedure was part of the cleansing treatment. The rods were dried for 5 minutes and thereafter given a prime coat with the rubber latex using the dipping process [PLATE 2]. The exposure time for drying was as short as 300 seconds so that the will be no possibility for re-contamination of the bar surface before the diping proccess. The first seal coat was administered 12 hours after the application of the primary coat. The second coat was administered 72 hours afterwards. Rods were cured for 4 days in a room temperature of 26° C before being used for casting.

Concrete required for the test specimen of each variant was produced in two batches. The coated reinforcing steel were



PLATE 2 Cured Steel Bars positioned in basin after the cleansing Treatment.

carefully positioned in turn during the introduction of concrete into the 150mm cube moulds. Two precautionary measures were taken here. Firstly, concrete was introduced with utmost care. This step was taken to prevent the surface of the reinforcement from entertaining scratches. Scratches on the surface of the reinforcement could promote chemical aggression on the rod. Secondly, the positioned steel rods in the moulds were carefully adjusted to ensure proper verticality. The essence was to eliminate completely the effect of eccentricities which could lead to error when the specimens were eventually tested.

The pull out specimens were taken out of the mould after 24 hours and cured in tap water at laboratory temperature for 28 days. A set of 114 cubes and 104 pull out specimen were cured for 108 days in identical chemical environment. The chemical media consist of two predominantly acidic media of Sulphuric and Hydrochloric acid of varied volume fractions (0 - 2)%, and a caustic medium of Sodium chloride with the same variation in volume fraction. The fourth medium was ordinary tap water which served as the control. After removal of the test specimen from the respective curing media, they were positioned each in turn, in the steel cage mould clamped in the test rig as shown in PLATE 3. Load was gradually applied at 4kN increment. At any incremental loading, the load slip value displayed on the digital monitor (PLATE 4) was recorded. The Pull Out loads and the corresponding slip values for the two grades of concrete used are presented in APPENDIX C1 and C2.

Tables 15- 18 present the Pull Out failure load results for 20mm reinforcing steel bar while the result of the 12mm bars

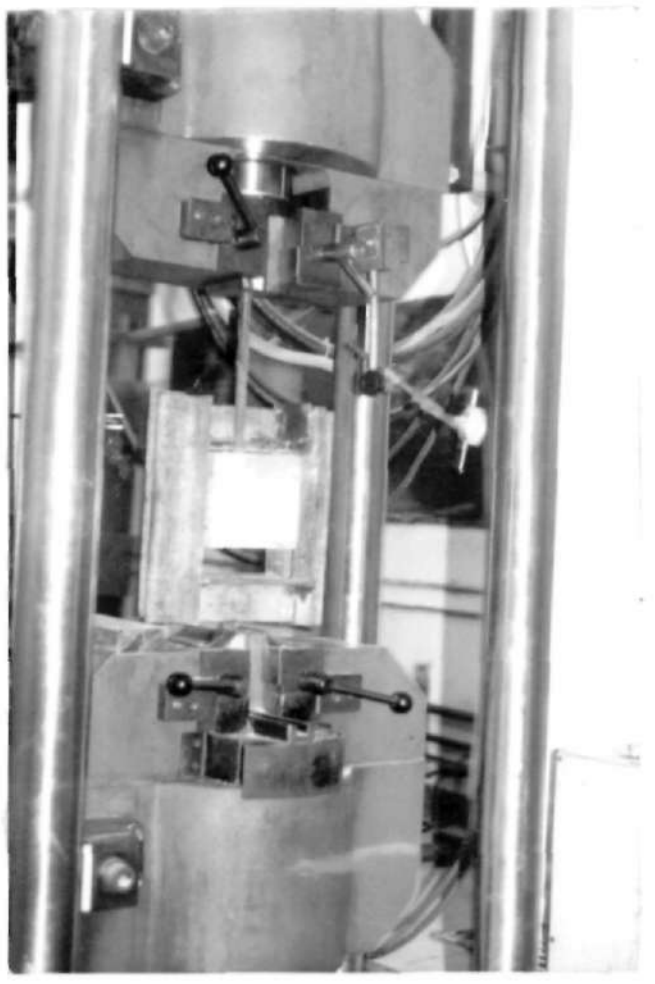


PLATE 3 Sample positioned in Test Rig

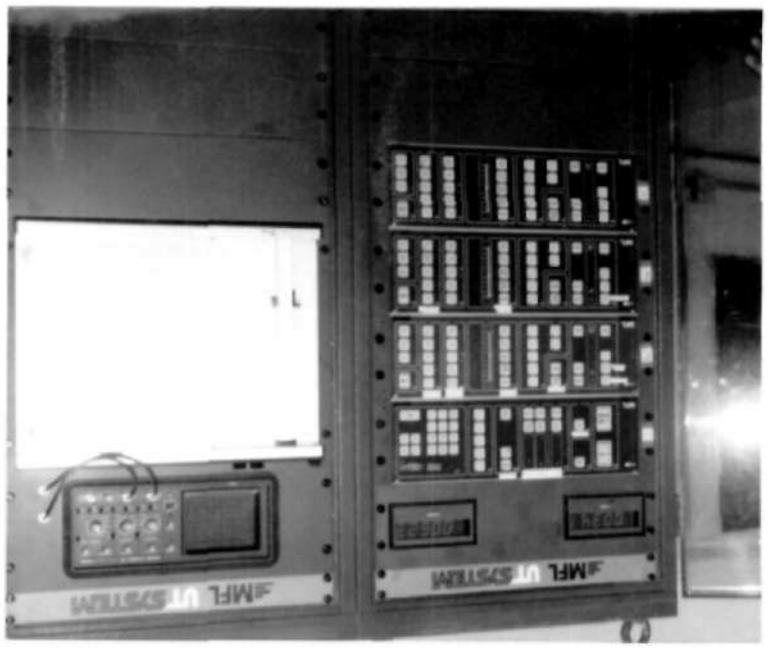


PLATE 4 Digital Monitor Used

TABLE: 16 MAXIMUM PULL OUT FAILURE LOAD RESULTS

MEDIUM: HCl BAR DIAMETER: 20 mm

ID NO	VOLUME [%]	BAR SIZE	FAILURE LOAD (KN)			
			GRADE 30		GRADE 40	
			COATED	UNCOATED	COATED	UNCOATED
1	0.5	20	56.1	58.1	61.3	62.0
2	1.0	20	52.6	53.4	59.8	59.1
3	1.5	20	46.7	48.2	57.2	58.3
4	2.0	20	43.1	44.4	57.1	51.5
5	0.0[Control]	20	66.4	68.9	83.1	61.3

TABLE: 17 MAXIMUM PULL OUT FAILURE LOAD RESULTS

MEDIUM:NaCl BAR SIZE :20mm

ID NO	VOLUME [%]	BAR SIZE	FAILURE LOAD (KN)			
			GRADE 30		GRADE 40	
			COATED	UNCOATED	COATED	UNCOATED
1	0.5	20	66.7	68.2	81.4	80.8
2	1.0	20	66.5	70.2	75.4	75.2
3	1.5	20	70.1	67.3	79.3	81.8
4	2.0	20	65.7	69.1	81.6	82.1
5	0.0 [Control]	20	66.4	68.9	83.1	86.6

TABLE: 21 MAXIMUM SLIP RESULTS

MEDIUM : H_2So_4 BAR SIZE: 20mm

ID NO	VOLUME [%]	BAR SIZE	SLIP [mm]			
			GRADE 30		GRADE 40	
			COATED	UNCOATED	COATED	UNCOATED
1	0.5	20	6.7	8.5	8.1	7.9
2	1.0	20	8.5	10.1	9.8	9.3
3	1.5	20	9.2	10.2	10.1	9.9
4	2.0	20	10.6	14.3	6.5	11.1
5	0.0[Control]	20	5.7	7.2	8.6	7.1

TABLE: 22 MAXIMUM SLIP RESULTS

MEDIUM : HCl BAR SIZE: 20mm

ID NO	VOLUME [%]	BAR SIZE	SLIP [mm]			
			GRADE 30		GRADE 40	
			COATED	UNCOATED	COATED	UNCOATED
1	0.5	20	7.8	10.5	8.3	6.8
2	1.0	20	8.8	11.2	9.1	9.1
3	1.5	20	9.1	10.4	10.3	8.2
4	2.0	20	11.3	11.8	11.3	9.8
5	0.0[Control]	20	5.7	7.2	8.6	9.4

TABLE: 23 MAXIMUM SLIP RESULTS

MEDIUM: NaCl BAR SIZE 20mm

ID NO	VOLUME [%]	BAR SIZE	SLIP (mm)			
			GRADE 30		GRADE 40	
			COATED	UNCOATED	COATED	UNCOATED
1	0.5	20	6.1	6.4	8.4	8.6
2	1.0	20	5.8	6.7	9.1	9.8
3	1.5	20	5.9	5.8	8.9	10.2
4	2.0	20	6.3	7.1	9.1	10.3
5	0.0[Control]	20	5.7	7.2	8.6	7.1

TABLE: 24 MAXIMUM SLIP RESULTS

MEDIUM : H_2So_4 BAR SIZE: 12mm

ID NO	VOLUME [%]	BAR SIZE	SLIP (mm)			
			GRADE 30		GRADE 40	
			COATED	UNCOATED	COATED	UNCOATED
1	0.5	12	3.5	6.1	7.7	7.6
2	1.0	12	6.1	5.9	9.2	10.1
3	1.5	12	6.9	6.8	9.7	11.6
4	2.0	12	7.3	7.2	9.8	12.4
5	0.0[Control]	12	5.3	5.7	6.7	7.5

TABLE: 25 MAXIMUM SLIP RESULTS

MEDIUM : HCl BAR SIZE: 12mm

ID NO	VOLUME [%]	BAR SIZE	SLIP (mm)			
			GRADE 30		GRADE 40	
			COATED	UNCOATED	COATED	UNCOATED
1	0.5	12	6.5	6.3	7.3	8.2
2	1.0	12	5.4	6.2	8.1	9.2
3	1.5	12	8.2	6.6	10.6	8.2
4	2.0	12	7.5	7.3	6.9	9.6
5	0.0 [Control]	12	5.3	5.9	6.7	7.5

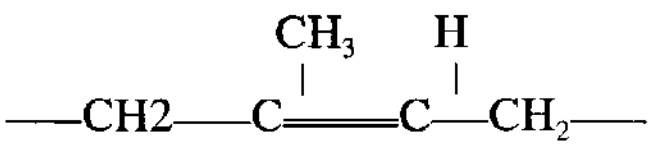
TABLE: 26 MAXIMUM SLIP RESULTS

MEDIUM : NaCl BAR SIZE:12mm

ID NO	VOLUME [%]	BAR SIZE	SLIP (mm)			
			GRADE 30		GRADE 40	
			COATED	UNCOATED	COATED	UNCOATED
1	0.5	12	4.5	4.8	7.9	7.9
2	1.0	12	5.8	6.5	9.6	8.9
3	1.5	12	5.6	5.8	8.4	9.7
4	2.0	12	7.1	6.4	9.2	8.7
5	0.0[Control]	12	5.3	5.7	6.7	7.5

3.7 RUBBER LATEX

The rubber latex used was got from the Rubber Plantation of Calabar Rubber Estate , Calabar, Nigeria. Rubber latex is a whitish fluid that comes out from tapping the rubber tree. The chemical formulae for rubber latex is Poly 1 - 4 Isoprene.



POLY 1 - 4 ISOPRENE

FIGURE 15: Molecular structure of Natural Rubber [72]

The glass transition temperature (T_g) of latex is - 60°C /72/. It has a particle diameter of 0.02 - 6.0 micron /72/. The rubber tree grows in the rain forest belt of Nigeria between latitude 13 and 17 degrees North of the equator. During the dry season (usually between the months of October and April), the rubber tree sheds its leaves in order to check transpiration. Tapping of the tree during this period is discouraged. This exercise takes place in the months of May to September which have less intensity of sunlight. A key frustration in the tapping process is the ingress of water into the tapping cups from the stem of the tree. Depending on the anticipated use of the tapped product, the moisture content is usually expelled or controlled as desired. The author was part of the tappping crew in an effort to ensure that the quality of latex got is pure. Because of its rapid setting properties the procured latex was introduced into an

air tight container. The coating process took place 40 hours after this. Coating was done by dipping. A common phenomenon that is usually encountered with the dipping process is the "holidaying effect" of the coating substance on the surface of the reinforcement bar. The presence of air in the coating medium (liquid State) leads to the formation of air bubbles on the surface of the bar. This results in non uniformity of coat on the rebar. To minimise the effect, on each dip, the rod was gently stired in a clockwise direction and at an angle of 90° while in the latex solution. By so doing the formation of air bubles is reduce because of the relative friction generated at the medium interface. Three dips were carried out at 30 minutes intervals. The curring processs of the dipped bars was consistently monitored in an order to ensure that segregation (un- eveness of coating) of the latex on the rebar is avoided.

CHAPTER 4

4.0 ANALYSIS AND DISCUSSIONS OF RESULTS

4.1 REINFORCING STEEL BAR.

The result of the reinforcing steel bar used for the experiments are presented in table 5 and 6. The mean yield strength for the two types of bar used were 421.17N/mm^2 and 447.1N/mm^2 for the 12mm and 20mm diameter bars respectively. The mean elongation was 12 percent. The results are satisfactory from the point of view of elongation. However the calculated characteristic strengths 409.2N/mm^2 and 424.6N/mm^2 for the 12mm and 20mm diameter bars respectively, are lower than the the rated characteristic strength - f_y [460N/mm^2]. This has a structural consequence on the quality of steel produced in the country and the acceptability of f_y = 460N/mm^2 as a design parameter for high yeild bars in structural design calculations. It was observed from the experimental results that failure loads, consequently pull out bond stresses of the pull out specimens [tables 15 - 20] are lower than the mean yield stresses of the reinforcing steel bars used. Failure in the pull out experiments were caused as a result of loss of bond at the steel - concrete interface and not the yielding of the steel reinforcement bars.

4.2 COMPRESSIVE STRENGTH OF CUBES IN AGGRESSIVE MEDIA

The results of the 108 - day compressive strength for the cubes cured in the three distinct simulated media, namely, Sulphuric acid, Hydrochloric acid and Sodium chloride are presented in tables 12 - 14 as well as APPENDIX A2 - A7 for grade 30 and 40 concrete. A noticeable decrease in compressive strength was

observed in the acid simulated medium as the volume fraction of the aggressive medium increases. The compressive strength trend in the sodium chloride solution is however different.

In Sulphuric acid medium the strength variation for Grade 30 concrete falls between [0 - 37.4] percent corresponding to a strength range of [33.65(control) - 21.02] N/mm^2. For grade 40 concrete, the cube strength varied from 45.55 N/mm^2 [control] to 29.68 N/mm^2 [3 percent volume fraction]. This represents a strength variation of [0 - 13] percent.

The fall in strength in grade 30 concrete cured in Hydrochloric acid medium [Table 10] is from 33.56 N/mm^2 [control] to 32.13/mm^2 at 3 percent volume fraction and this represents a strength variation of [0 - 4.26] percent. Grade 40 concrete recorded a strength loss which varied from 45.56/mm^2 [control] to 43.20. This represents a strength variation of [0 - 5.18] percent.

Table 14 presents the compressive strength test results of the cubes cured in Sodium Chloride solution. For Grade 30 concrete the compressive strength varied from 33.56N/mm^2 to 33.82 N/mm^2. Grade 40 concrete shows a variation of 45.56N/mm^2 [control] to 46.77N/mm^2 corresponding to 2 percent

From the results of the compressive strength tests of the three curing media used, it is evident that the Sulphuric Acid medium is the most aggressive with strength variations in cube strength of [0 - 37] N/mm^2 and [0 - 34] percent for Grade 30 and 40 concrete respectively [TABLES 10 and 11]. The presence of a higher proportion of cement [422.2kg/m^3] in the mix resulting in more dense and impermeable concrete compared with 358.5kg/m^3 in grade 30 concrete explains the comparatively lower strength

variation results in grade 40 concrete compared with grade 30 for the sulphuric acid media.

4.2.1 **SULPHURIC ACID [H_2SO_4]**

The action of Sulphuric acid can be explained as follows. Together with $Ca[OH]_2$ of cement it forms the poorly soluble gypsum. Gypsum thus produced tends initially to seal the pores and to offer a certain degree of protection. In the case of continuous exposure to Sulphuric acid, concrete is destroyed by the expansion of gypsum. The wastes of factories producing sulphuric acid destroys concrete sewers during a very short period, unless neutralised before being discharged into the sewer. Conventional concretes and cement mortars are equally attacked by sulphuric acid in both weakly and highly concentrated solutions, and are destroyed sooner or later /39/. The formation of Sulphuric acid from the chemical elements, radicals, and compounds in the soil is an important step that has not been given a proper attention in almost all the literatures reviewed. In damp conditions sulphuric acid could be formed in the soil by simple or complex chemical reactions. For example, many acid hydroxides can be obtained by addition of water to the respective non-metallic oxide

$$SO_3 + H_2O \rightarrow H_2SO_4$$

4.2.2 AGGRESSIVE EFFECT OF SULPHATE IONS

From experimental results, Ludwing /42/ formulated the following reaction mechanism for sulphate attack. A reaction front of topochemically formed ettringite (calcium sulphoaluminate

hydrate) just below the surface causes the formation of the first cracks. This front penetrates the mortar or concrete. Changes in the equilibrium of the liquid phase caused by the reaction itself brings the ettringite formation on the rear of the reaction front to an end and decompose the firstly crystallized ettringite. The cracks due to the ettringite formation are filled gradually with gypsum. The gypsum formation within the cracks is a secondary reaction which could be an explanation of the often observed rehealing process. On the other hand, the crystallization of gypsum may possibly contribute to the total expansion. However, the ettringite formation is the initial reaction of every sulphate attack. The intensity of the attack depends more or less on the type of cation in the sulphate solution. There seems to be a general consensus on the theoretical processes of sulphate corrosion. The general theoretical opinion on sulphates corrosion mechanisms is that sulphates react with the calcium hydroxide, $Ca[OH]_2$ in the cement to produce first, a secondary gypsum, $CaSO_4.2H_2O$. The gypsum reacts with tricalcium aluminate, C_3A, of the cement to form calcium sulphoaluminate hydrate [ettringite], $C_3A.\ 3CaSO_4.31H_2O$, which leads to swelling, expansion and disintegration of the concrete. The action of Sulphuric acid on cement can be adequately represented by the following stages of equations to conform with the general theoretical idea - formation of gypsum; the gypsum reacting with C_3A and combines 31 molecules of water to form the ettringite.

[i] $H_2SO_4 + Ca[OH]_2 \rightarrow CaSO_4.2H_2O$

[ii] $3CaSO_4.2H_2O + 3CaO.Al_2O_3 + 25H_2O \rightarrow 3CaO.Al_2O_3.3CaSO_4.31H_2O$

Calcium sulphoaluminate hydrate [ettringite].

4.2.3 HYDROCHLORIC ACID [HCl]

Hydrochloric acid [HCl] decomposes the calcium hydroxide, $Ca[OH]_2$, of cement into $CaCl_2$ which being readily soluble in water, is either washed from concrete or crystallizes. Therefore, weak solutions are already detrimental. Hydrochloric acid is extremely corrosive to clinker minerals as well, so that effective protection must be provided for concrete /39/. Hydrochloric acid has been reported by some researchers as the acid causing the greatest damage to building structures. Ten percent hydrochloric acid is also adopted, for most materials, as the standard by which "acid resistance" is measured. Materials that is capable of resisting exposure to 10 percent hydrochloric acid is classified as "acid resistant". Even 0.5 percent solution of hydrochloric acid has been reported to attack conventional concrete and destroy it completely within few weeks /39/. The formation of hydrochloric acid from the chlorides in the soil has not been reflected in almost all the literatures reviewed. However, from relevant texts of chemistry, there exists a wide range of possibilities of chlorides and water reacting at room temperature to form HCl /41/,/32/.

4.2.4 AGGRESSIVE EFFECT OF CHLORIDE IONS

The nature of the ions and their concentrations can govern the types of deleterious chemical reactions occurring in structural concretes exposed to the salt solutions. Strong solutions of sodium, potassium, calcium and magnesium chlorides, to mention but few chlorides, react with the $Ca[OH]_2$ present in the Portland Cement paste and even gradually destroy calcium silicate hydrate. These reactions initially produce surface softening followed by strength loss due to reaction proceeding inwards into the concrete. The detection of the onset of deterioration would be delayed considerably in large concretes as would the dimensional changes that are caused by the deleterious chemical reaction.[30] There is in general a relatively little chlorine in soil, nor can much [30 to 100mg/l] be detected in ground water. It should be noted here that water leaching manure and faeces may have a chlorine content as high as 700 to 1000 mg/litre. Industrial wastes may also contain much chlorine, especially where domestic salt is used /39/.

It has been reported that chloride ions, Cl^-, present in sea water form with the alumina, a monochoroaluminate, $C_3A.CaCl_2.10H_2O$ which crystallizes into the hexagonal platelets unstable in the presence of sulphates /55/. There is also a general agreement in literatures /47/, /55/ that the chloride react with the lime in cement to form calcium chloride hydrate. The calcium chloride hydrate react with the tricalcium aluminate with the combination of 10 molecules of water to produce calcium chloroaluminate hydrate which is responsible for the softening of the concrete

and weakening its bonds.

The following reactions represent this process.

[i] $2HCl + Ca[OH]_2 \rightarrow CaCl_2.2H_2O$ [Calcium chloride hydrate]

[ii] $3CaO.Al_2O_3 + CaCl_2.2H_2O + 8H_2O \rightarrow 3CaO.Al_2O_3\ CaCl_2.10H_2O$ [Calcium chloroaluminate hydrate]

The results of the compressive strength test in Hydrochloric Acid simulated medium as well as Sodium Chloride show less aggression. With Sodium Chloride medium a clearly observed case of chemical aggression is not obvious with the percentage rage of Sodium chloride present in the solution. This could be due to the caustic nature of the sodium chloride solution. Rather than attacking the concrete cube which is basically alkaline in nature, the chloride [Cl^-] ion level is boosted by the dissolved chlorides which is present in the material property of the cement used. From literature / 74, 51 / the corrosion action of chloride on concrete is more pronounced in circumstances where the basic salt is impregnated into the concrete itself.

The problem of chloride related corrosion has been identified long ago. Numerous researches have been carried out in order to access the process of chloride related corrosion and the possibility of eliminating or, at least, reducing its adverse effects on reinforced concrete structures /2,62/.

It should however, be noted that most of these researchers have been more concerned with the adverse effects on steel reinforcements rather than concrete. Chlorides - caused corrosion in reinforced concrete structures has been recognised for at least 75 years. But this was mainly seen as affecting the steel reinforcement and its effect on concrete was either not known or

ignored. This research work however emphasized on both cconcrete and steel. This is because bond as a phenomenon involves the interaction of concrete and steel. The influence of chloride and indeed other simulated media are evident fron the compressive strength test results presented in chapter three.

4.3 FAILURE LOAD AND MAXIMUM SLIP

The results of the failure loads at maximum slips are presented in tables [21 - 26] of chapter 3 for the two grades of concrete used for the three distinct media. In all the curing media the failure loads for the uncoated bars are generally higher than that of the coated bars. This trend holds for the two grades of concrete used namely Grade 30 and 40 concrete. The bar diameter, invariably the concrete cover does have an influence on the maximum failure loads. Although the failure load are lower with 12 mm diameter bars compared with 20 mm diameter bars the calculated bond stress for the 12 mm diameter bars for each grade of concrete is of a higher value than the 20 mm diameter bars. This is due to the relatively smaller surface of the 12mm diameter reinforcing bars. Whereas it is evident from the cases of the acid base media [namely Hydrochloric and Sulphuric acids] that the failure loads decreases with increase in the volume fraction of acid solution [Tables 12,13,15,and 16], the sodium chloride media does not hold this true [Tables 14 and 17]. From literature [55] an attack by Sodium Chloride solution can only be pronounced if the Sodium Chloride present is an integral part of the mix. This means that the Sodium Chloride must either be sourced from the aggregate or the water used in the mixing

process if the later is not free from corrosion inducing radicals.

The maximum slip appears to be a function of the volume percent in the acid media. From tables 18 - 20, the maximum slip varies from 5.7mm to 10.6mm and from 8.6mm to 10.1mm for grade 30 and 40 concrete respectively for the coated 20mm bar size.

A corresponding higher value of 7.2mm to 14.3mm and 7.1mm to 11.1mm for grade 30 and 40 concrete is observed for the uncoated 20 mm diameter bar. The coated 12mm diameter bar has a slip variation of 5.3mm to 7.3mm mm and 6.7mm to 9.8mm for Grade 30 and 40 concrete respectively. These values are in a comparative sense lower than those previously observed for the coated bar of the same diameter.

From the results presented in table 23, the maximum slip values for Sodium chloride solution cured samples do not show any feasible suggestions of a possible correlation with respect to the volume fraction variation of the media. This is because the the concentration of chloride ions present Sodium Chloride simulated media is low enough to initiate any appreciable corossion attack on concrete. The chloride of sodium is less aggressive on concrete than other metals in the Electrochemical series of Metals /41/. Two slip ranges of 5.7mm - 6.3mm and 8.6mm - 9.1mm were observed for the uncoated 20 mm diameter bar. With the uncoated 20 mm bar The maximum slip range recorded recorded for the 20mm and 12mm diameter bars were 5.8mm - 7.1mm and 6.7mm - 9.6mm respectively. This range compares with the slip results of the uncoated bars presented in table 26.

TABLE: 28 MAXIMUM BOND STRESS RESULTS
MEDIUM: HCl

S/No	VOL. [%]	BAR SIZE Y [mm]	BOND STRESS [N/mm²]				BOND RATIO B.R.	
			COATED		UNCOATED		G30	G40
			30	40	30	40		
1	0.0	20	7.30	9.14	7.58	9.53	0.96	0.96
2	0.5	20	6.17	6.74	6.39	6.83	0.97	0.99
3	1.0	20	5.80	6.59	5.87	6.50	0.99	0.99
4	1.5	20	5.14	6.29	5.30	6.41	0.97	0.97
5	2.0	20	4.74	6.28	4.85	5.67	0.98	0.98
1	0.0	12	9.67	12.56	9.76	12.92	0.99	0.97
2	0.5	12	8.21	10.00	8.24	10.13	0.99	0.99
3	1.0	12	7.85	8.37	8.01	8.34	0.98	0.96
4	1.5	12	7.40	7.33	7.47	7.56	0.99	0.99
5	2.0	12	6.50	7.25	7.11	7.86	0.91	0.92

TABLE: 29 MAXIMUM BOND STRESS RESULTS
MEDIUM: NaCl

S/No	VOL. [%]	BAR SIZE Y [mm]	BOND STRESS [N/mm₂]				BOND RATIO B.R.	
			COATED		UNCOATED		G30	G40
			30	40	30	40		
1	0.0	20	7.30	9.14	7.58	9.53	0.96	0.96
2	0.5	20	7.34	8.95	7.50	8.89	0.98	1.00
3	1.0	20	7.23	8.29	7.72	8.27	0.95	1.00
4	1.5	20	7.71	8.72	7.40	9.00	1.04	0.97
5	2.0	20	7.23	8.98	7.60	9.03	0.95	0.99
1	0.0	12	9.67	12.56	9.76	12.92	0.99	0.97
2	0.5	12	9.74	11.02	9.83	12.31	0.99	0.90
3	1.0	12	9.70	11.50	10.18	11.16	0.95	0.99
4	1.5	12	10.06	12.00	10.04	11.38	1.00	1.05
5	2.0	12	9.77	12.04	9.56	11.74	1.02	1.03

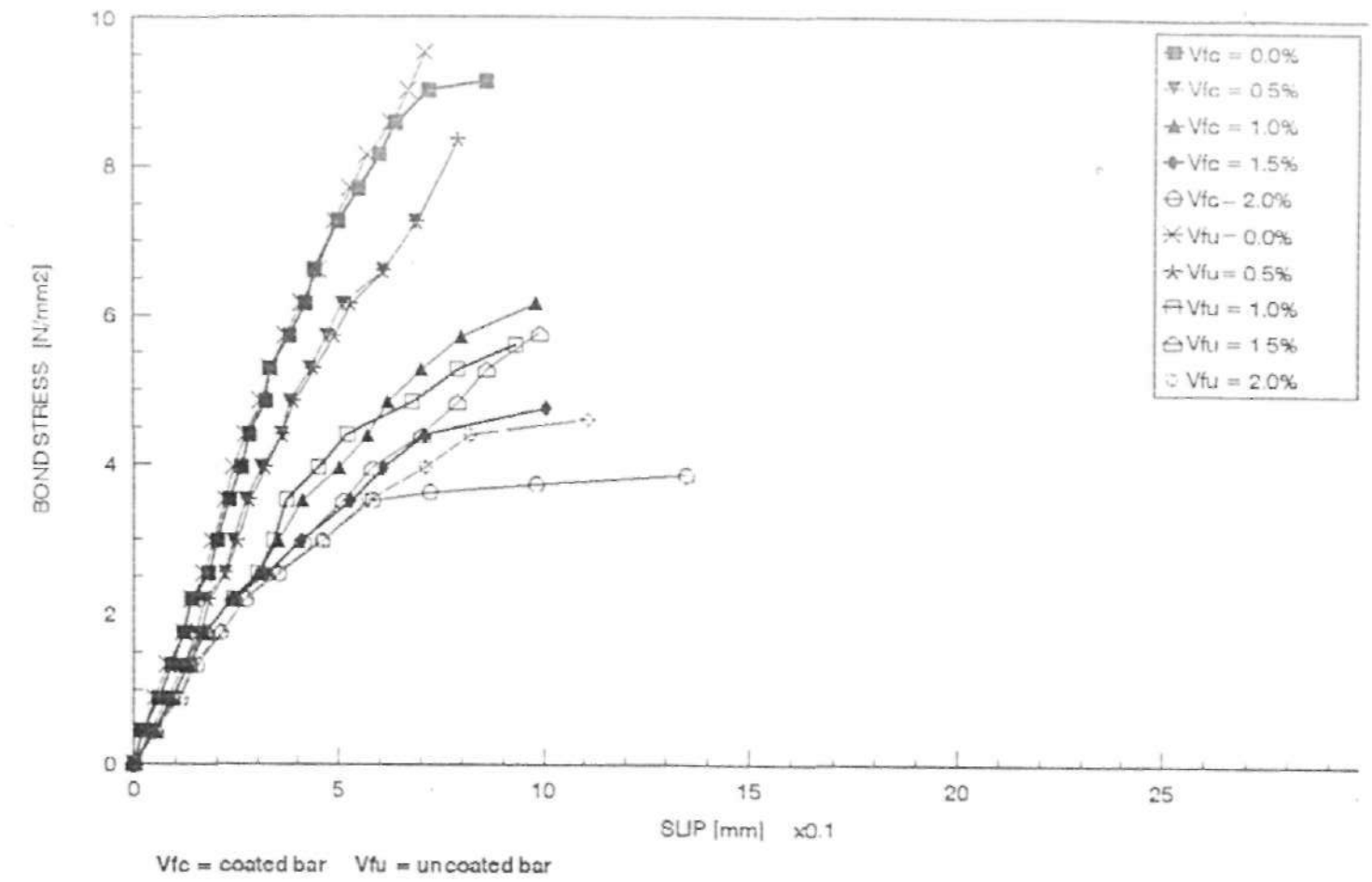
The values are judged to indicate development of satisfactory bond relationships between the coated and the uncoated bars /52/. The bars cured in Sodium chloride solution have the highest B.R. values. This is due the less aggressive nature of Sodium chloride solution consequently the increase in the pull out bond stress of the coated bar. The latex used provided a lean protective coat . The coating from literature has an effect on the bond properties of coated bars / 75/. A Bond Ratio value range of 0.87 to 0.99 was observed for the pull out specimen cured in sulphuric acid medium for grade 30 and 40 concrete. A range of 0.91 to 0.99 and 0.95 to 1.03 was recorded for the cases of hydrochloric acid and sodium chloride respectively. The thickness advantage of the rubber latex used explains the low range of variation of the bond ratios.

4.5 LOCAL BOND - SLIP CURVES TREND

Figures 16 - 31 presents the graphical pictures of the bond - slip curves. While the relationship between bond stress and slip for distinct bar types at specified grades and media are presented in Figures 16 - 27 for both the coated and the uncoated case, Figures 28 - 31 on the other hand show a behavioral trend of the bars with grade 40 concrete for all the simulated media conditions. At 0 percent volume fraction "[control], the behaviour of the bond slip curve for coated bar is similar to that of the uncoated bar. This corresponds to the near unity Bond Ratio [B.R.] [Table 24 - 26] computed for the cases. The near coincidental plot points behaviour may be attributed to the thin film obtained using the coating medium -

the rubber latex. A bond stress range of [8.41 - 9.18] N/mm^2 and a slip range of [6.5 - 11.1]mm is obtained with the control specimen for coated and uncoated Y20 bars with grade 40 concrete [Appendix C2] and figures [16 - 22]. Grade 40 concrete produced a higher bond stress than Grade 30 concrete for the same bar diameter. This is expected because of the higher compressive strength value. The results from literature / 27,47 and 74 / on the strength superiority of grade 40 concrete over grade 30 is in perfect agreement with this.

The bond - stress curves for Y12 coated bars for grade 40 concrete shown in [Figs 17,18,20] are observed to be higher than that of Y20 bars presented in [Figs 17,19,21] for both coated and uncoated cases in the control experiment. Whereas a bond stress range of [12.35 - 12.70] N/mm^2 is observed for the Y12 bars with a corresponding maximum slip range of [6.7-7.5]mm, a stress range of [12.35 - 12.71] N/mm^2 [Figs 17,18 and 20] with a corresponding maximum slip range of [5 - 9]mm is recorded for the Y20 bars. This is agreeably due to the small bar diameter which agrees with literature /27, 74 /. However in the design of reinforced concrete structural elements, where a large bar diameter [up to 20mm] is used it will therefore become structurally advantageous to use a concrete mix of a sensibly higher grade. The coating medium [i:e the rubber latex] seems to be more clustered on the Y12 bars than the Y20 bars. The relative smaller surface area of the 12mm diameter bar over the 20mm bar partly explains this. The cohesive force between the latex is much stronger than the adhesive force that exist between the bar and the coating material. The consequence of this is that of observed slips on



Vfc = coated bar Vfu = uncoated bar

FIG 16 BOND STRESS VRS SLIP CURVE

MEDIUM : H2So4 BAR :Y20 COATED AND UNCOATED GD : 40

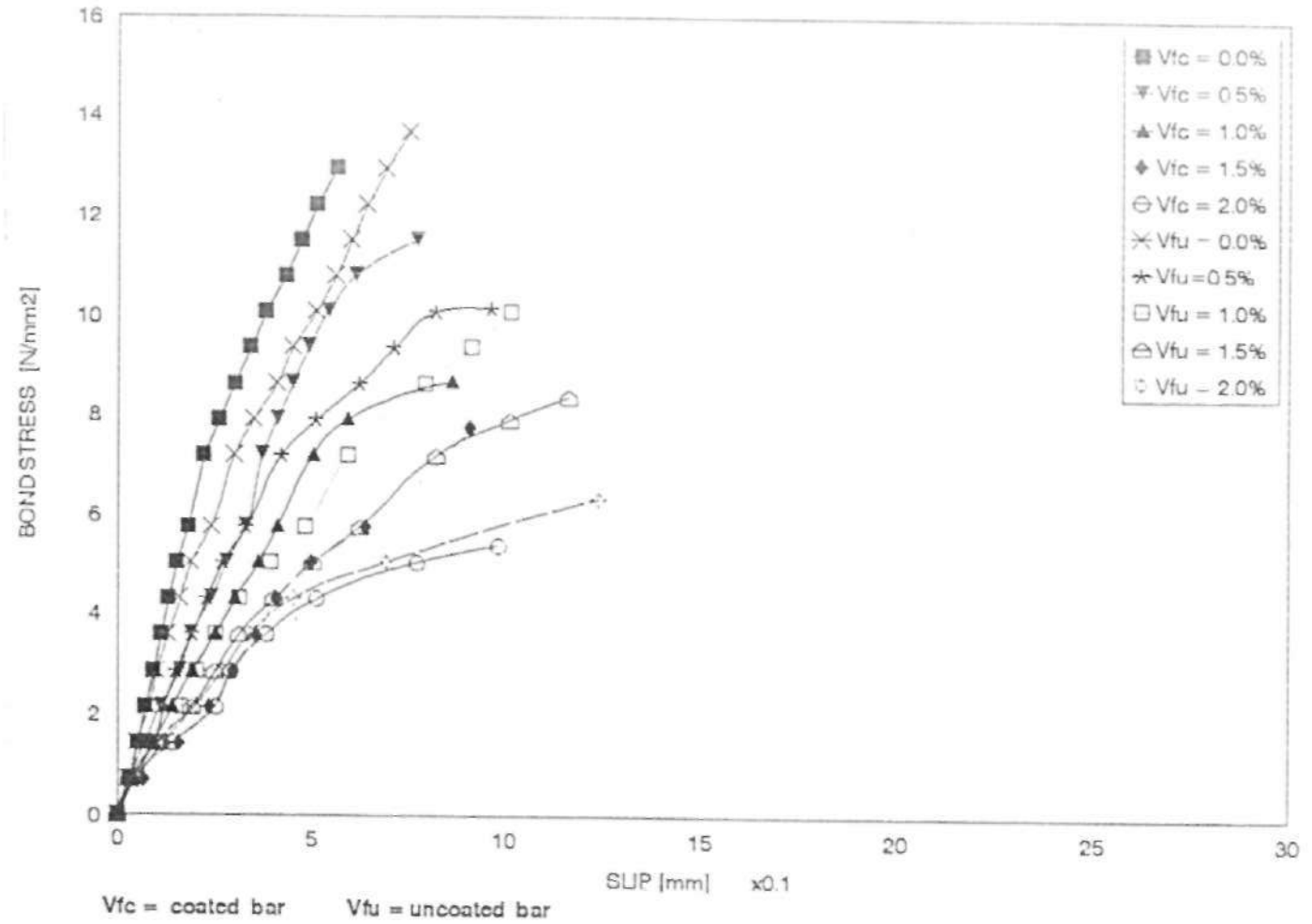
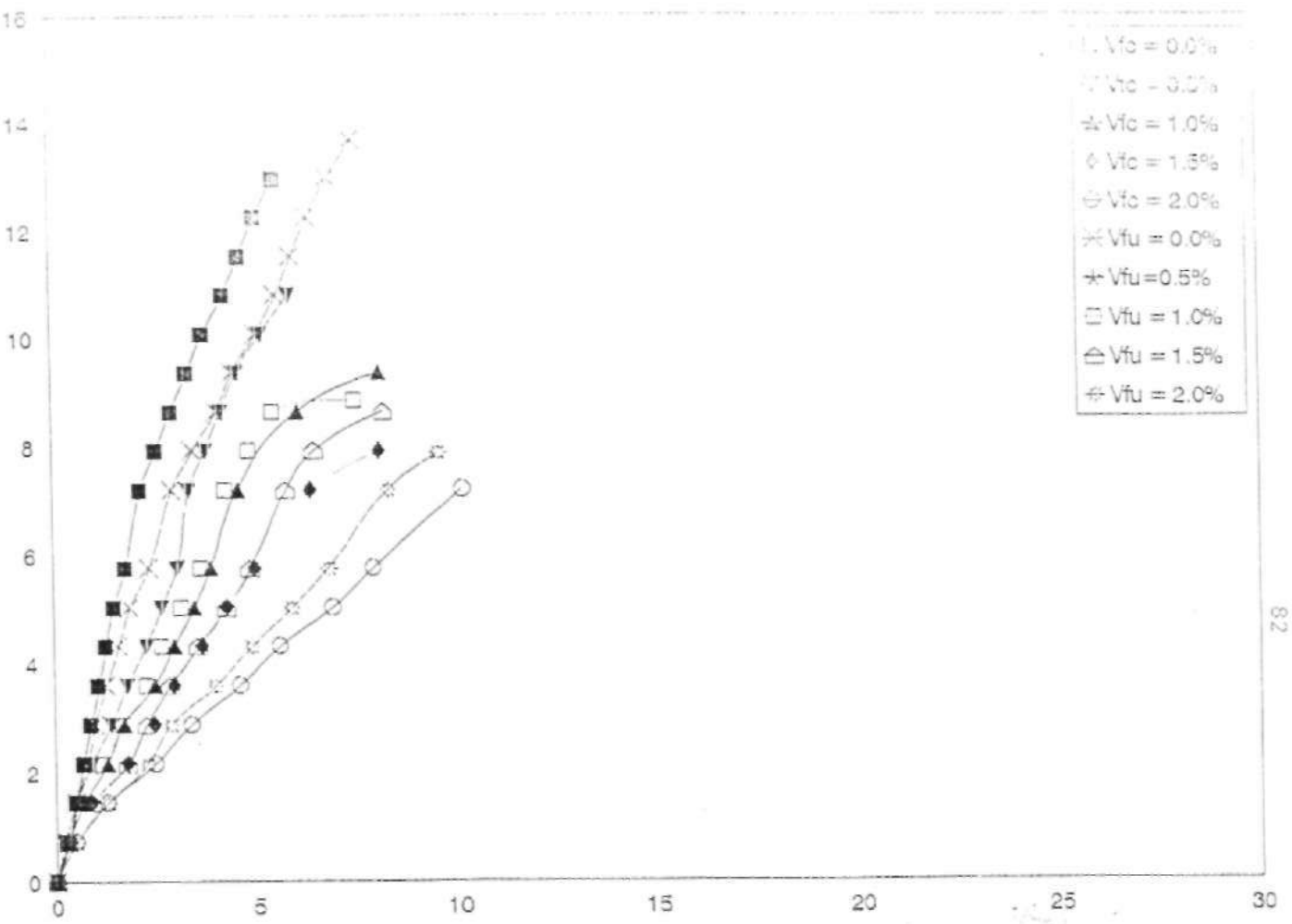


FIG.17 BOND STRESS VRS SLIP CURVE

MEDIUM : H2So4 BAR : Y12 GD : 40



Vfc = coated bar Vfu = uncoated bar

FIG.18 BOND STRESS VRS SLIP CURVE

MEDIUM : HCL BAR : Y12 GD : 40

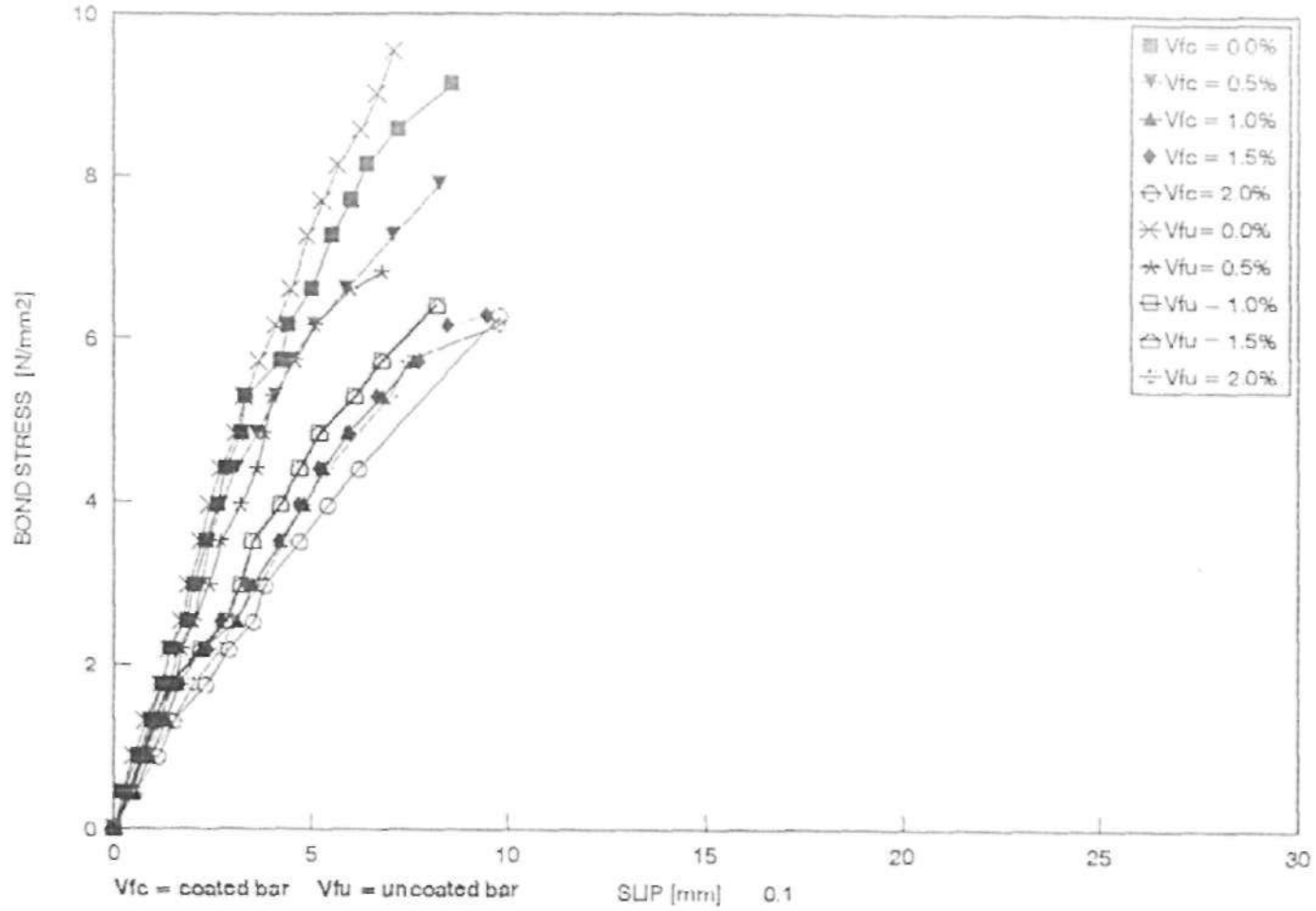


FIG. 19 BOND STRESS VRS SLIP CURVE

MEDIUM : HCL BAR : Y20 COATED AND UNCOATED GD : 40

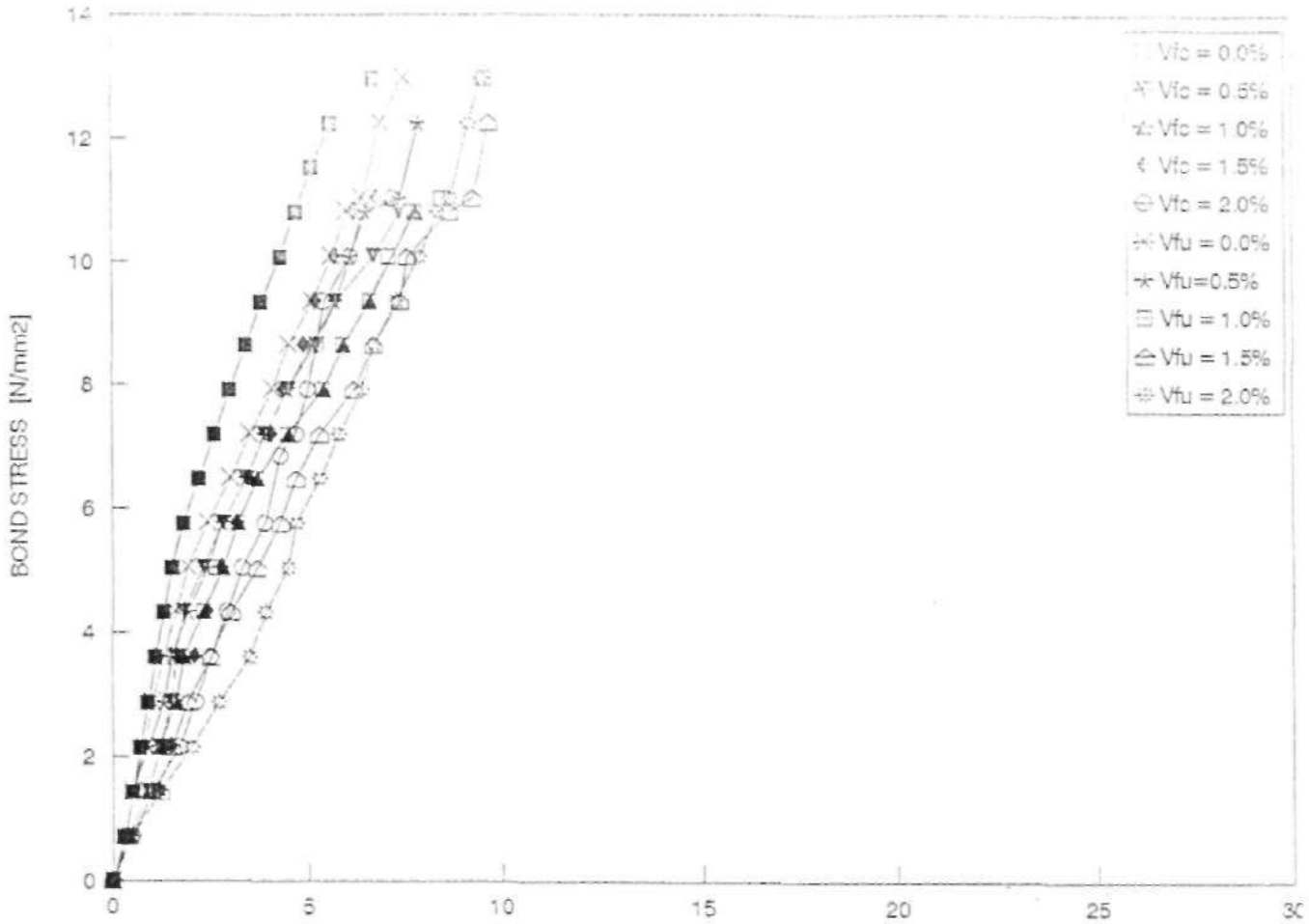


FIG. 4.6 BOND STRESS VRS SLIP CURVE

MEDIUM :NaCL BAR : Y12 GD : 40

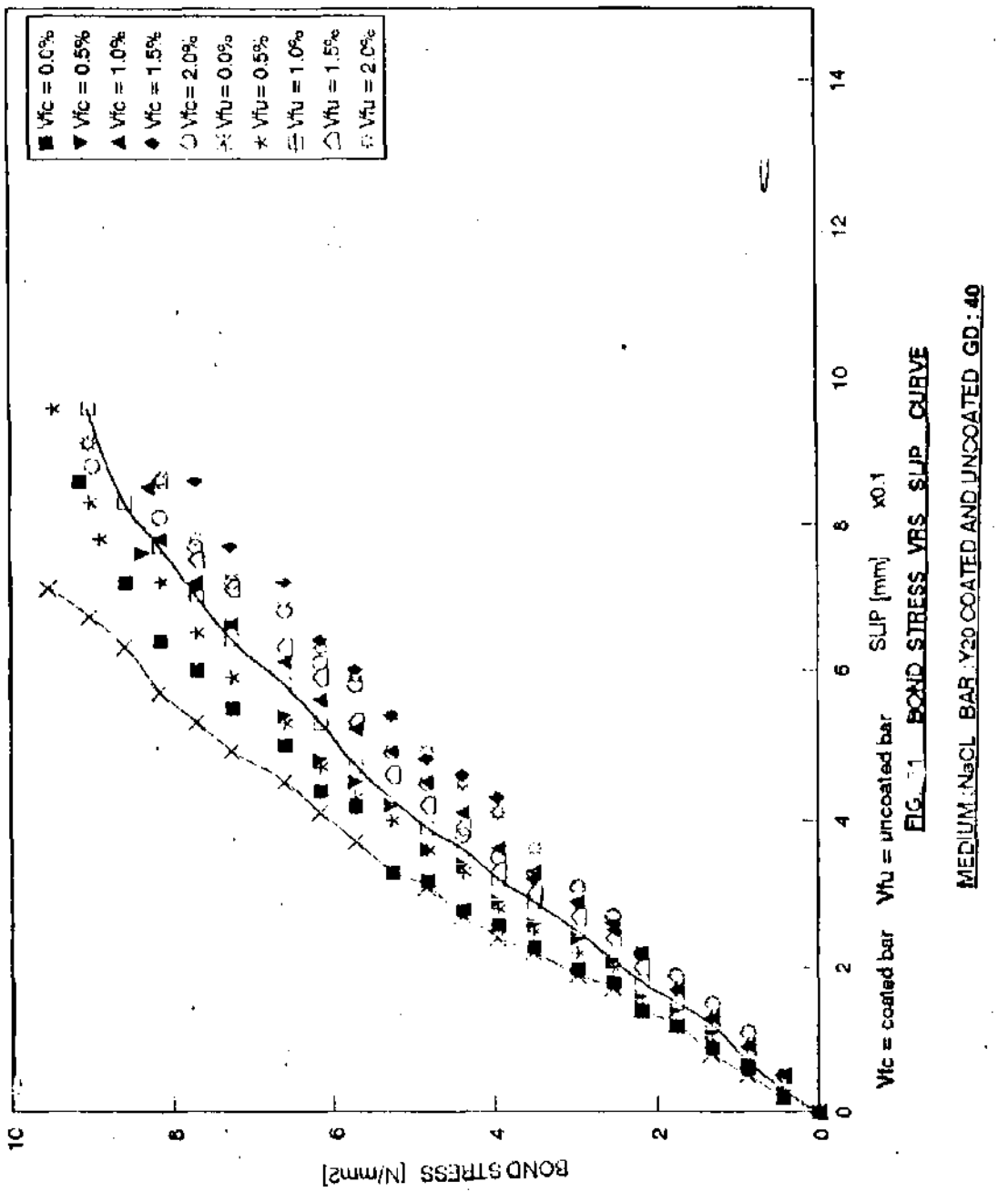


FIG. 11 BOND STRESS VRS SLIP CURVE

MEDIUM:NaCL BAR:Y20 COATED AND UNCOATED GD: 40

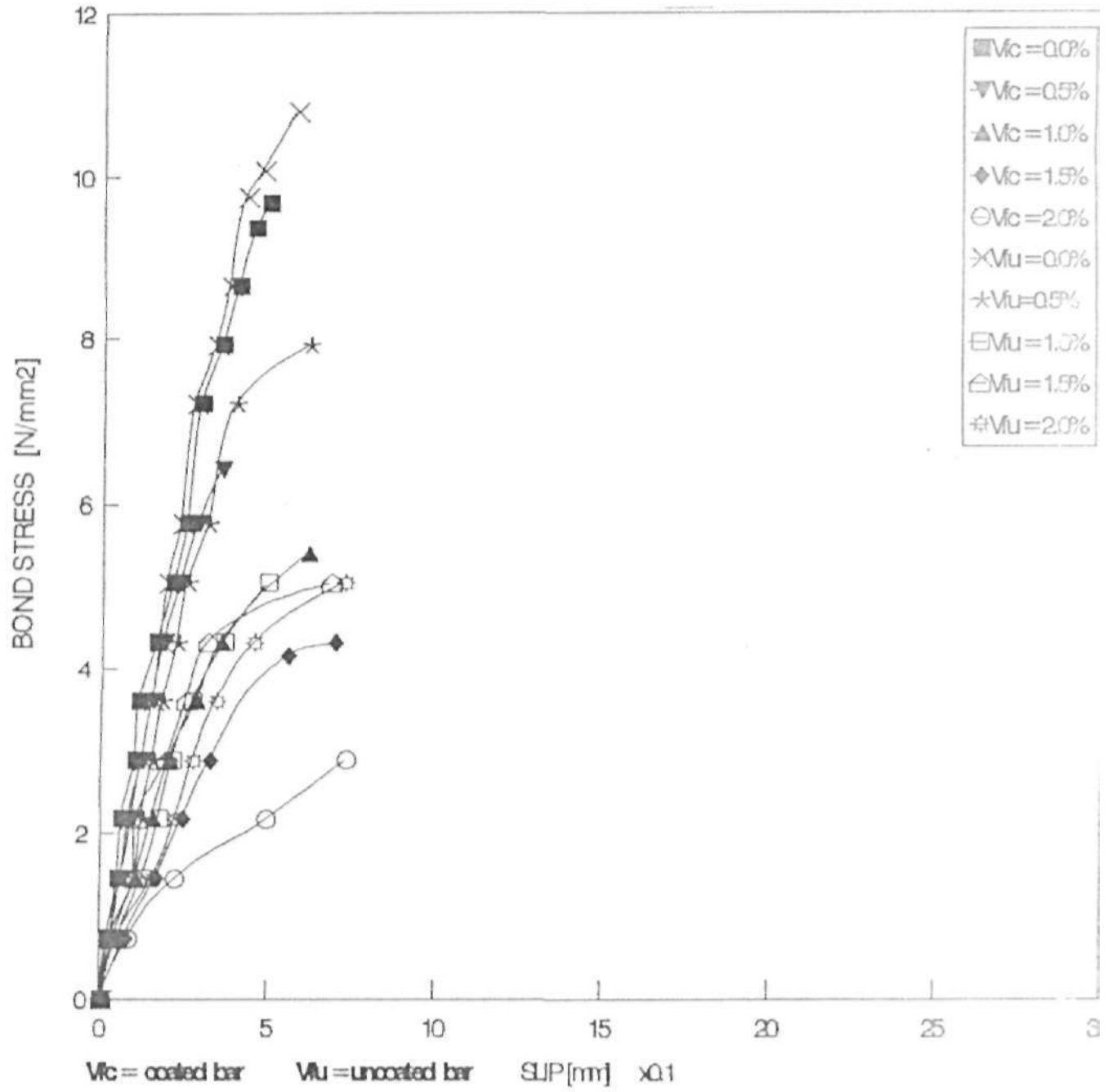


FIG. 23 BOND STRESS VRS SLIP CURVE
MEDIUM: H2So4 BAR: Y12 GD: 30

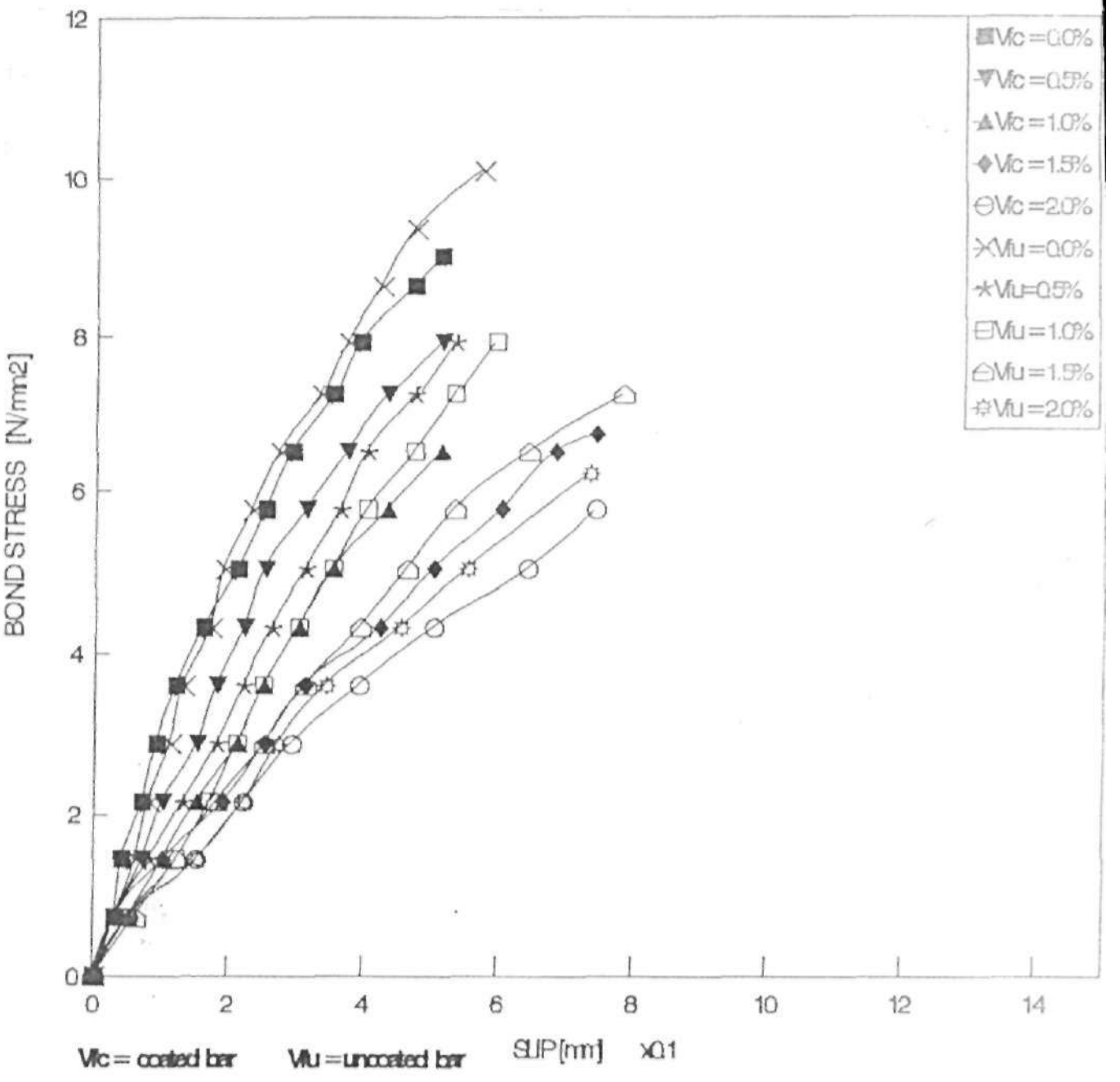


FIG 24 BOND STRESS VRS SLIP CURVE
MEDIUM: HCL BAR: Y12 GD: 30

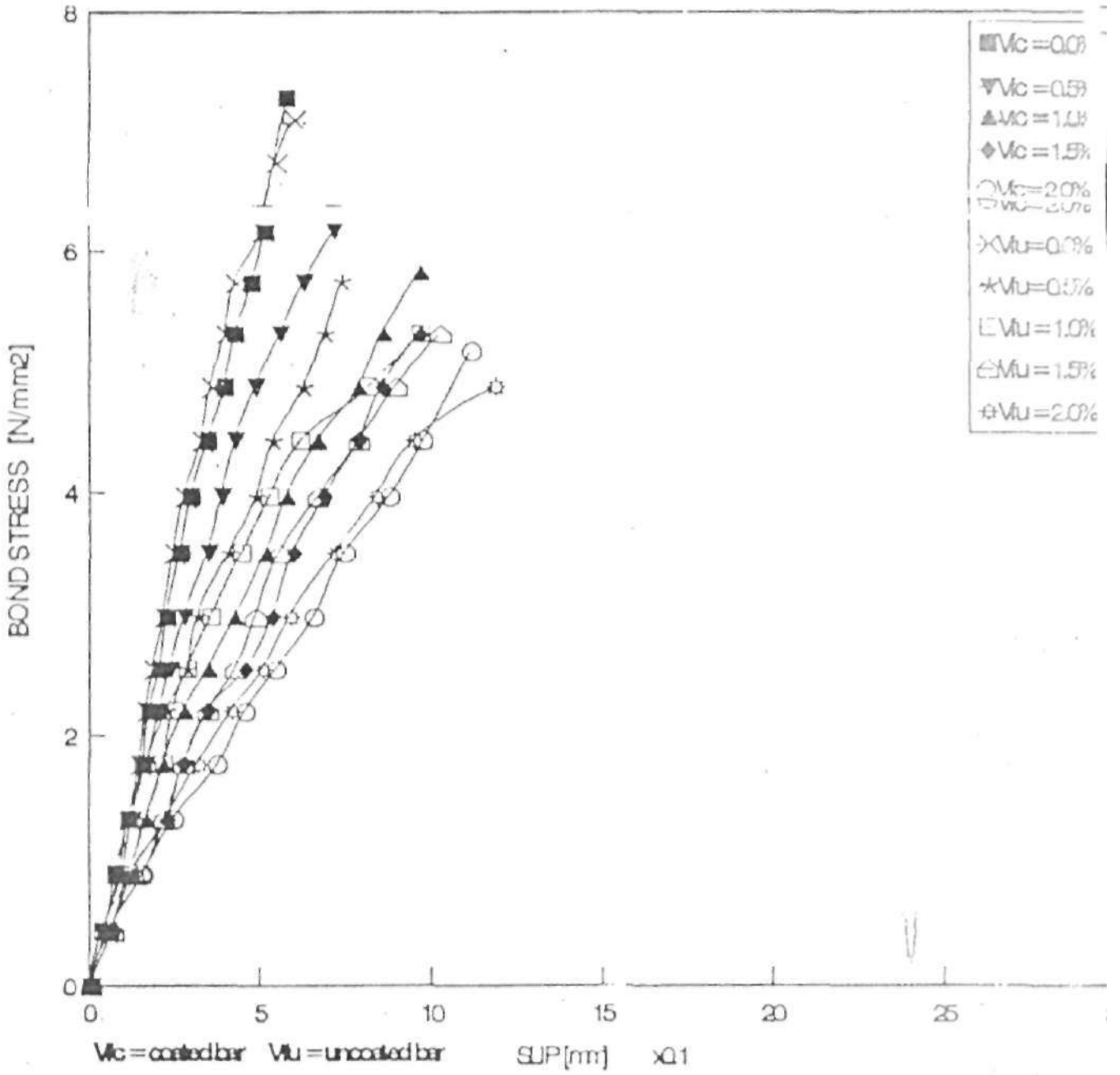


FIG. 25 BOND STRESS VRS SLIP CURVE
MEDIUM: HOL BAR: Y20 CD: 30

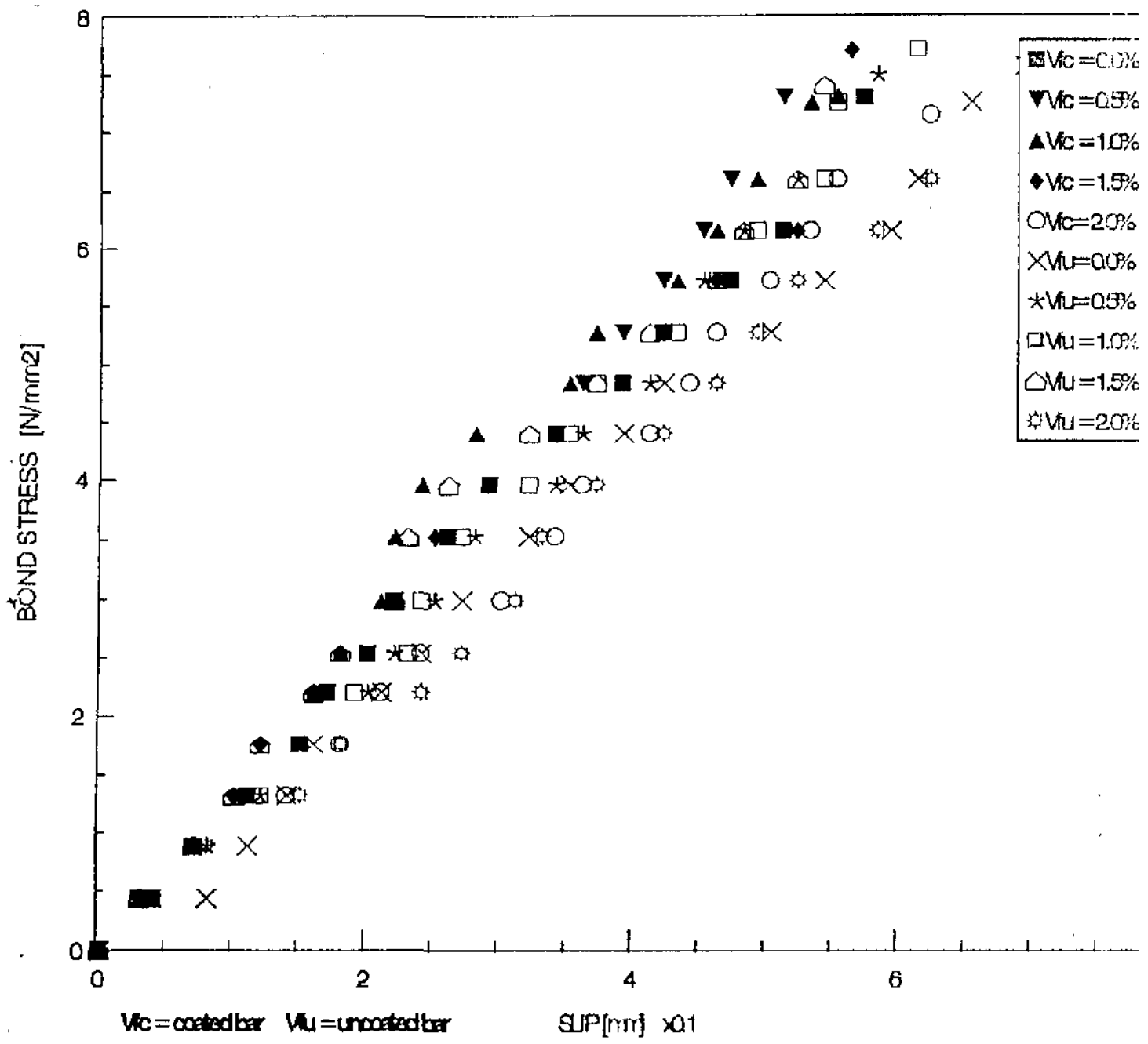


FIG.26 BOND STRESS VRS SLIP CURVE
MEDIUM: NaCL BAR:Y20 GD:30

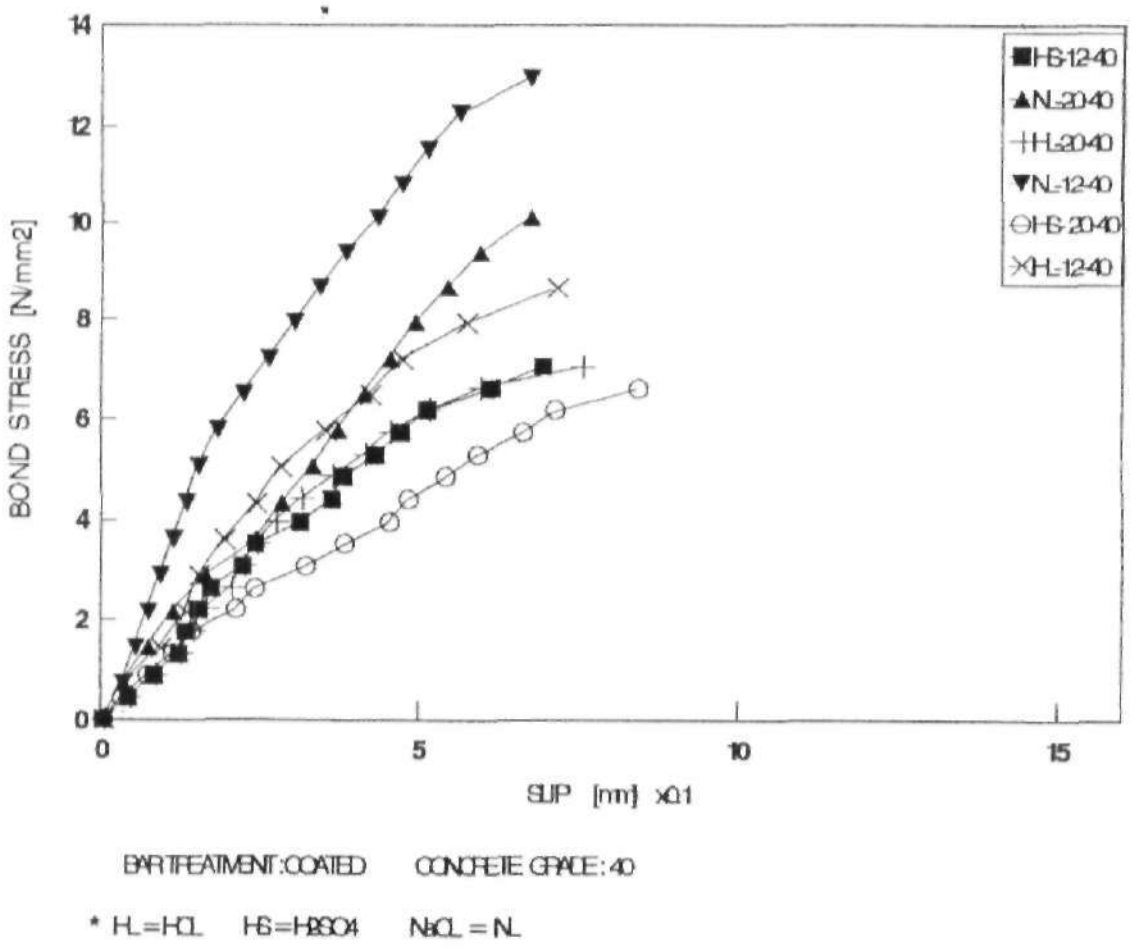
increase in sustained loading. The ultimate failure bond stress of the uncoated bar noticeably 12.35 N/mm^2 [Fig.17] is slightly higher than that of the coated bar which is 12.70 N/mm^2. However the maximum slip value for the coated bar [0.67mm] is less than that of the uncoated bar [0.75mm].

For both grades of concrete used, there is an observed decrease in the slope of the bond - slip curves as the volume fraction of the aggressive medium increases except in the case of Sodium Chloride solution. This observation is devoid of bar diameter and surface condition [i.e. coated or uncoated]. Up to a volume fraction of 1.0 percent, the behaviour of the curve is linear in nature. As the volume fraction increase, the behaviour of the curve for Sulphuric acid and Hydrochloric acid media tends to assume a non linearity [Figs. 5 - 10]. The failure loads consequently failure stresses, are lower in the case of Sulphuric acid simulated environment [Fig.16,17,22 and 23]. However these values correspond to comparatively higher maximum slip values. Considering the case of a grade 30 concrete in a zero percent Sulphuric acid concentration for example, the maximum failure stress for a Y20 coated bar [control] is 7.50N/mm^2 corresponding to a maximum slip value of 0.60mm while for the same bar in a 2.0 percent Sulphuric acid medium the maximum stress is 3.62N/mm^2 corresponding to a slip value of 1.06 mm [Fig. 22].

The bond stress curve in the case of sodium chloride solution which has a caustic base for both grades of concrete is different from the other media. From figures 20,21, 26 and 27 the relation ship appears to be linear in all cases. There is a noticeable overlapping of the curves. It is not clear from the

5. Sulphuric acid - Y12 Bar [coated] and

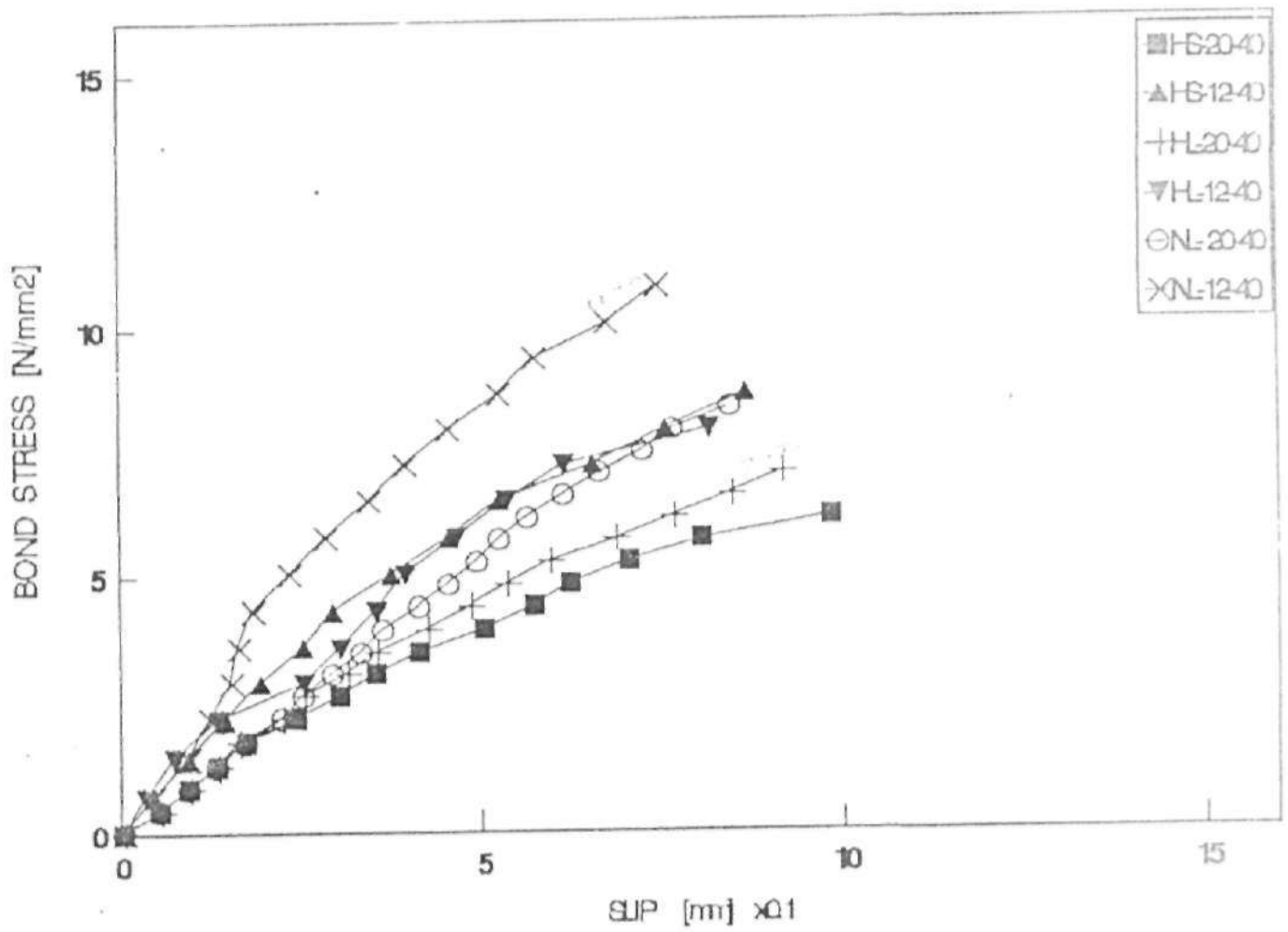
6. Sulphuric acid - Y20 Bar [coated]



BAR TREATMENT: COATED CONCRETE GRADE: 40

* HL = HCL HS = H2SO4 NaCL = NL

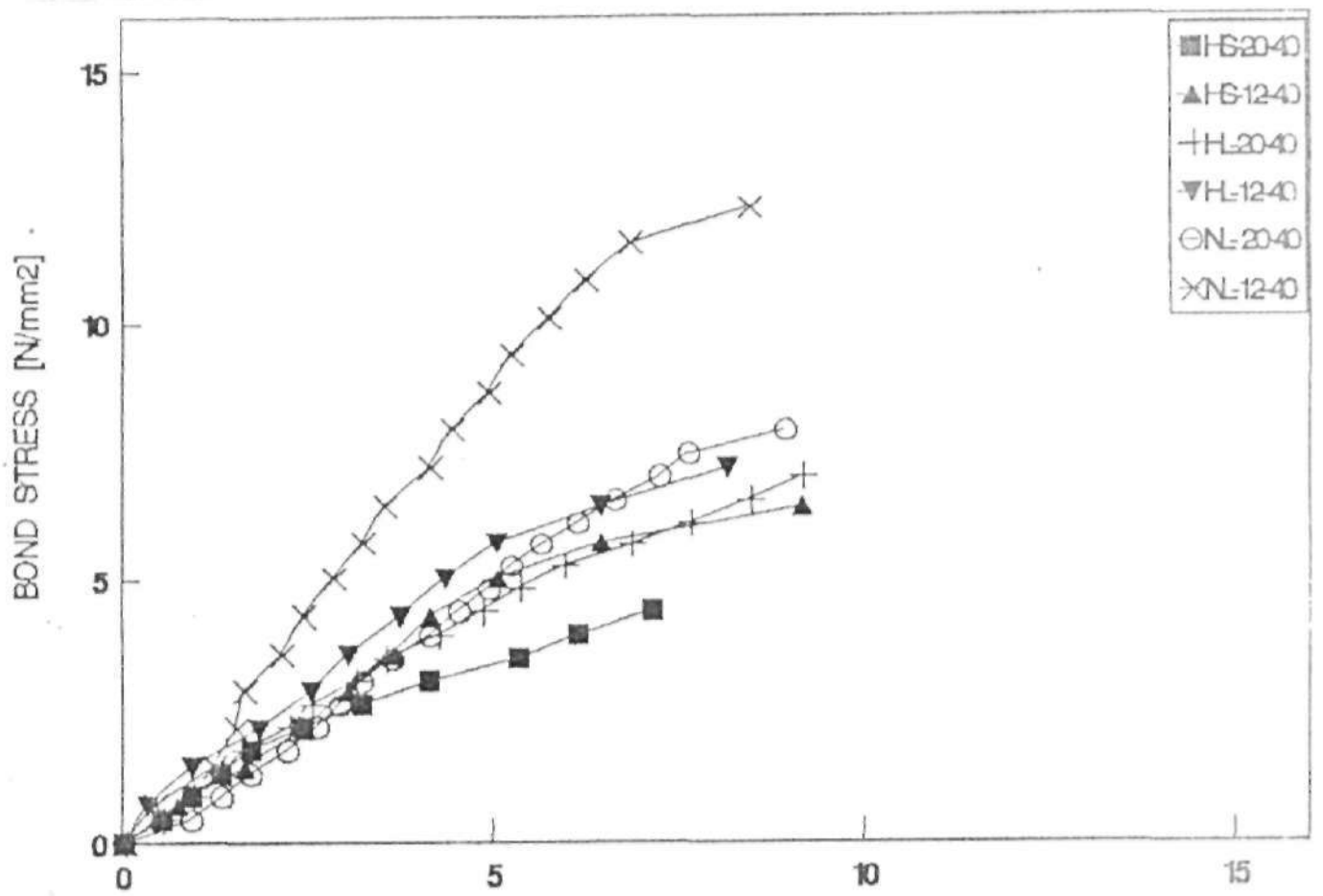
FIG 28 BOND STRESS - SLIP CURVES FOR 0.5% (ALL MEDIA)



BAR TREATMENT: COATED CONCRETE GRADE: 40

* HL = HCL HS = H2SO4 NaCL = NL

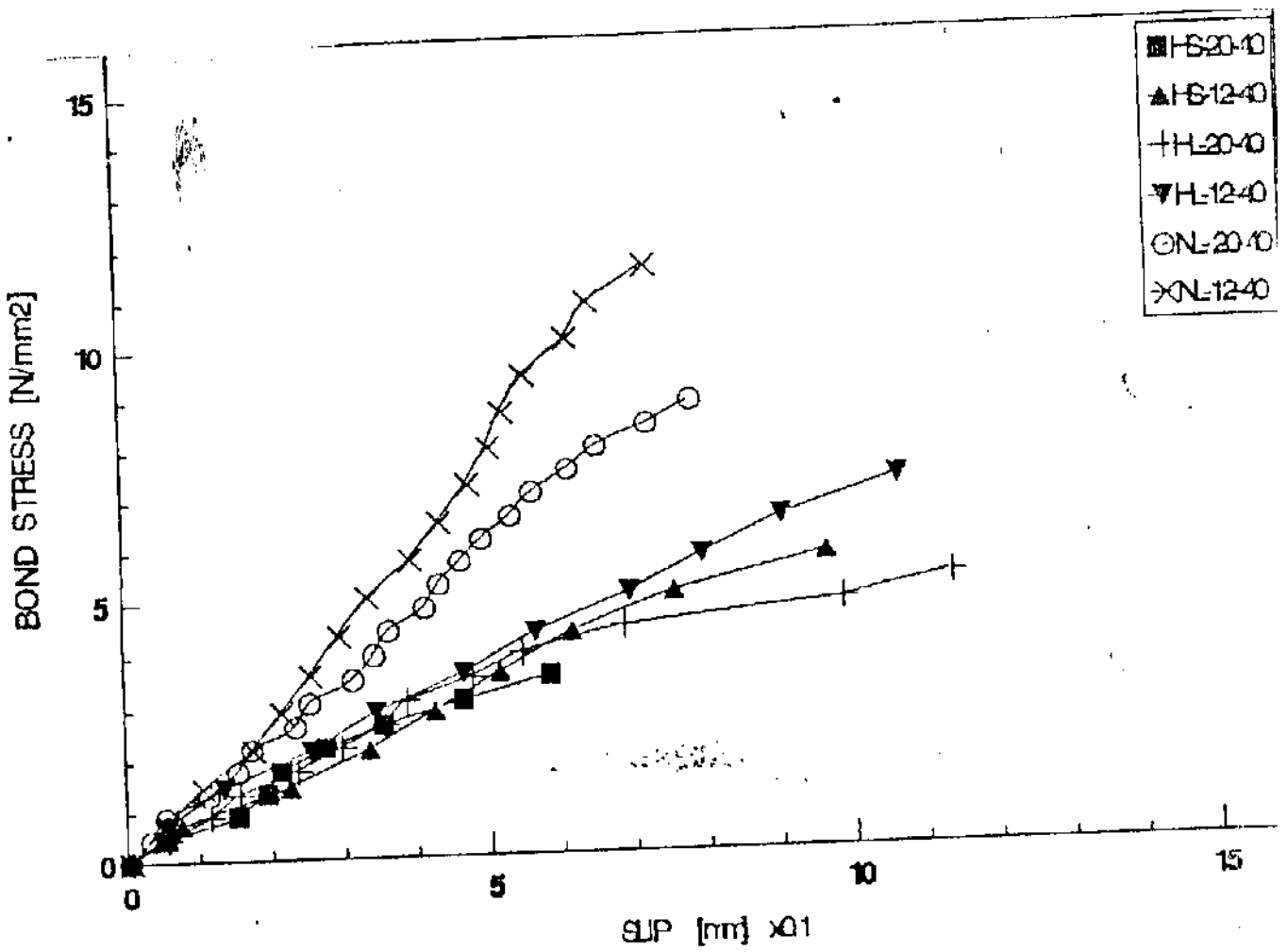
FIG.29 BOND STRESS - SLIP CURVES FOR 1.0% [ALL MEDIA]



BAR TREATMENT: COATED CONCRETE GRADE: 40

* H-L = HCL H-S = H2SO4 NaCL = NL

FIG 30 BOND STRESS - SLIP CURVES FOR 1.5% [ALL MEDIA]



BAR TREATMENT: COATED CONCRETE GRADE: 40

* HL = HCL HS = H2SO4 NaCL = NL

FIG 31 BOND STRESS - SLIP CURVES FOR 2.0% [ALL MEDIA]

CHAPTER 5

5.0 MATHEMATICAL MODELLING OF RESULTS

5.1 BOND STRESS - SLIP CURVES MODEL

Figure 32 - 35 shows the polynomial regression of the bond slip curve for H_2So_4 simulated media for Y12 and Y20 bars for grade 30 and 40 concrete respectively. The examination of the bond slip curve for the media was justified because of it is the worst case] [Table 13 and 14].

The relationship between the bond stress f_{bs} [N/mm^2] and the slip [s] mm for the control experiment was fitted after regression of the experimental data in [Appendix C1,C2]. A second degree polynominal of the form;

$$f_{bs} = a_0 + a_1 s + a_2 s^2$$

was used as best to describe the relationship between the bond stress and slip. The terms a_0 , a_1, and a_2 are coefficient got from regression analysis.

The first derivative of the slip equation is the stiffness of the concrete layer transferring the forces to the steel bar. In otherwords if

$$f_{bs} = a_0 + a_1 s + a_2 s^2 \quad (33)$$

it follows that

$$\frac{df_{bs}}{ds} = a_1 + 2a_2 s \quad (34)$$

Equation [34] is the equation describing the concrete stiffness. for an uncoated Y20 bar (Fig.16] The relationship betwen the bond stress and the slip is of the form;

$f_{bs} = 0.06 + 3.2s - 0.2s^2$ _____ (35)

This implies that;

$\frac{df_{bs}}{ds} = 3.2 - 0.4s$ _____ (36)

At failure bond stress the maximum slip s = 0.71,

f'_{bs} from equation 36 has the value 3.2 - 0.4 [0.71] = 2.92

The value is the Tangent Modulus of the curve. Values of the Tangent Modulus for other bar treatments and diameters are presented in tables 30 - 33. It can be inferred from the tables that there is a decrease in the concrete bond stiffness as the volume fraction of the aggressive media [H_2So_4] increases. This can be attributed to the gradual loss of bond as the rate of chemical aggression increase. The trend in result is identical to that obtained using the Y12 bars. It can equally be inferred from the tables [30 - 33] that the Y12 bars enhances higher concrete stiffness than the Y20 bars cured in the same medium.

TABLE 30: MAXIMUM LOCAL BOND - SLIP APPROXIMATIONS
BAR TYPE/SIZE: Y/20mm CONCRETE GRADE: 40

VOL. [%]	BAR TREATMENT	EQUATION OF FIT	MAX. SLIP [mm]	CONCRETE STIFFNESS [TANGENT MODULUS]
0 [control]	uncoated	$f_{bs} = 0.06+3.2s-0.20s^2$	0.71	2.92
	coated	$f_{bs} = 0.061+1.44s$	0.86	1.44
2	uncoated	$f_{bs} = 0.26+1.27s-0.07s^2$	1.11	1.11
	coated	$f_{bs} = 0.13+.1.35s-0.06s^2$	0.65	1.07

463005

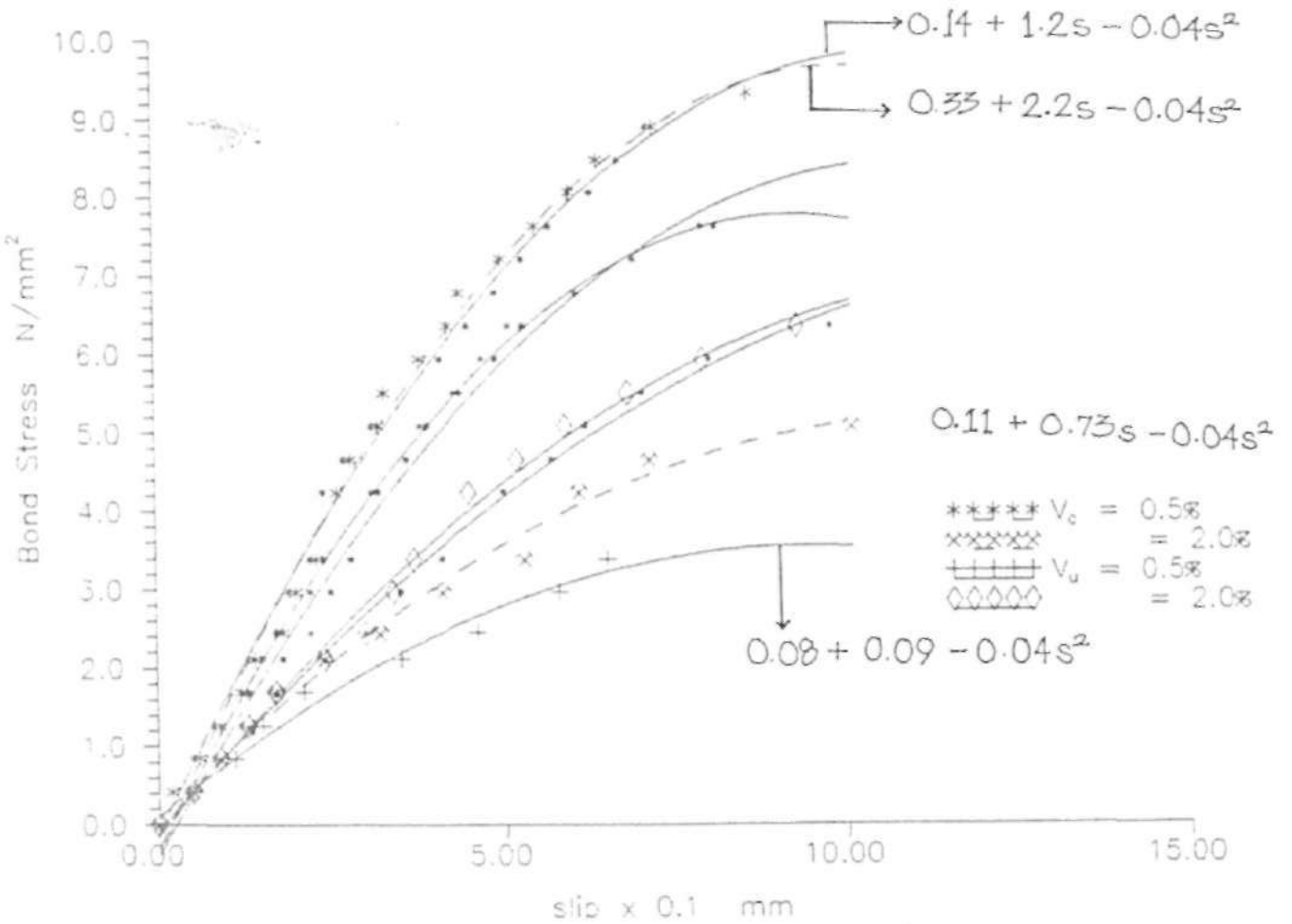


FIG 32 : REGRESSED ULTIMATE LOCAL BOND VRS SLIP CURVE
MEDIUM : H_2So_4 CONCRETE GRADE : 40 BAR SIZE : 20

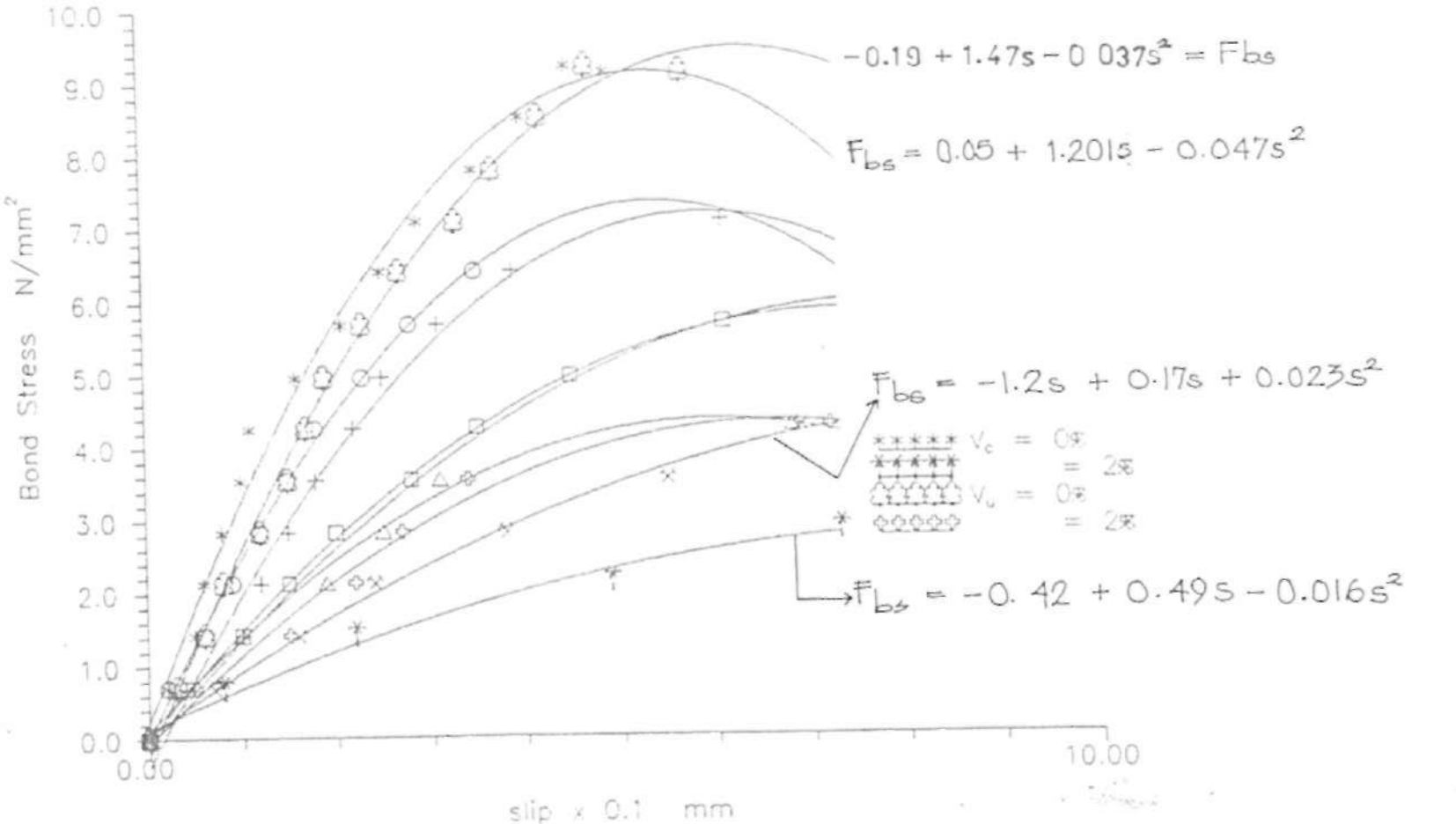


FIG 35: REGRESSED ULTIMATE LOCAL BOND VRS SLIP CURVE
MEDIUM : H_2So_4 CONCRETE GRADE : 30 BAR SIZE :

TABLE 31: MAXIMUM LOCAL BOND - SLIP APPROXIMATIONS
BAR TYPE/SIZE: Y/12mm CONCRETE GRADE: 40

VOL. [%]	BAR TREATMENT	EQUATION OF FIT	MAX. SLIP [mm]	CONCRETE STIFFNESS [TANGENT MODULUS]
0 [control]	uncoated	$f_{bs} = 0.33+2.2s-0.04s^2$	0.67	1.42
	coated	$f_{bs} = 0.14+1.12s-0.04s^2$	0.75	0.78
2	uncoated	$f_{bs} = 0.11+0.73s-0.04s^2$	1.24	0.63
	coated	$f_{bs} = 0.08+0.09s-0.04s^2$	0.98	0.01

TABLE 32: MAXIMUM LOCAL BOND - SLIP APPROXIMATIONS
BAR TYPE/SIZE: Y/20mm CONCRETE GRADE: 30

VOL. [%]	BAR TREATMENT	EQUATION OF FIT	MAX. SLIP [mm]	CONCRETE STIFFNESS [TANGENT MODULUS]
0 [control]	uncoated	$f_{bs} = -1.9+1.5s-0.04s^2$	0.72	0.94
	coated	$f_{bs} = -.05+1.21s-0.05s^2$	0.57	0.63
2	uncoated	$f_{bs} =-1.21+0.17s-0.02s^2$	1.43	0.19
	coated	$f_{bs} = -.04+0.50s-0.02s^2$	1.06	0.49

TABLE 33: MAXIMUM LOCAL BOND - SLIP APPROXIMATIONS
BAR TYPE/SIZE: Y/12mm CONCRETE GRADE: 30

VOL. [%]	BAR TREATMENT	EQUATION OF FIT	MAX. SLIP [mm]	CONCRETE STIFFNESS [TANGENT MODULUS]
0 [control]	uncoated	$f_{bs} = -2.1+3.35s-0.03s^2$	0.57	1.82
	coated	$f_{bs} = -.01+2.73s-0.03s^2$	0.53	1.42
2	uncoated	$f_{bs} =-1.1+1.41s-0.02s^2$	0.72	1.00
	coated	$f_{bs} = -.06+1.31s-0.01s^2$	0.73	0.95

These results is in agreement with the bond stress results presented in table [27]. Although no claims is made for the generality of the equations in tables [30 - 33], they are used here only to illustrate one type of function that may be used as the basis of local bond behaviour.

5.2 BOND STRESS - VOLUME FRACTION MODEL

The results of mathematical modelling of the bond stress relationship with the volume fraction and the 108 - day cube strength for the simulated media [H_2So_4, HCl and NaCl] is presented in table 31 and 32 respectively. A prediction of the bond stress which is a function of the bar diameter used can be carried out for the concrete grades used namely, grades 30 and 40.

TABLE 34 BOND STRESS f_{bs} (N/mm^2) - VOLUME FRACTION V_f (%)

MEDIUM/ BAR SIZE	CONCRETE GRADE			
	30		40	
	COATED	UNCOATED	COATED	UNCOATED
H_2So4/ Y20	$^{**}f_{bs}=6.79-1.82V_f$ **$7.1-2.85V_f+.51V_f^2$**	$f_{bs}=7.11-1.81V_f$ **$7.2-2.30V_f+.27V_f^2$**	$f_{bs}=7.85-1.50V_f$ **$8.8-3.92V_f+.56V_f^2$**	$f_{bs}=9.15-2.44V_f$ **$9.3-2.84V_f+0.2V_f^2$**
HCl/ Y20	$f_{bs}=6.79-1.82V_f$ **$6.9-1.85V_f+.33V_f^2$**	$f_{bs}=7.04-1.26V_f$ **$7.2-2.03V_f+0.39V_f^2$**	$f_{bs}=7.94-1.19V_f$ **$8.6-3.75V_f+1.28V_f^2$**	$f_{bs}=8.30-1.57V_f$ **$7.1-8.8V_f+3.86V_f^2$**
NACl/ Y20	$f_{bs}=7.07+0.04V_f$	$f_{bs}=7.30+0.01V_f$	$f_{bs}=8.6+0.11V_f$	$f_{bs}=8.79-0.17V_f$
H_2So4/Y12	$f_{bs}=6.79-1.82V_f$ **$9.3-5.87V_f+1.52V_f^2$**	$f_{bs}=8.68-2.73V_f$ **$9.4-5.58V_f+1.42V_f^2$**	$f_{bs}=11.6-2.53V_f$ **$12.3-.88V_f+1.17V_f^2$**	$f_{bs}=12.2-2.94V_f$ **$12.3-25.28V_f+1.48V_f^2$**
HCl/ Y12	$f_{bs}=8.56-2.63V_f$ **$9.3-1.98V_f+.29V_f^2$**	$f_{bs}=9.24-1.23V_f$ **$9.5-2.24V_f+.51V_f^2$**	$f_{bs}=11.8-2.76V_f$ **$12.7-6.3V_f+1.77V_f^2$**	$f_{bs}=11.6-2.32V_f$ **$12.3-5.28V_f+1.48V_f^2$**
NACl/ Y12	$f_{bs}=9.51+0.11V_f$	$f_{bs}=9.74+0.03V_f$	$f_{bs}=11.6+0.01V_f$	$f_{bs}=12.2+0.51V_f$

$^{**}f_{bs} = a + bV_f$: Based on linear regression

$f_{bs} = a + bV_f + cV_f^2$: Based on power regression

TABLE 35: CUBE STRENGTH $f_{c,108}$ - VOLUME FRACTION RELATIONSHIP BASED ON TABLES 9 - 11

MEDIUM	CONCRETE GRADE	
	30	40
H_2So_4	$f_{cu} = 28.96 - 3.39V_f$	$f_{cu} = 38.57 - 3.78V_f$
HCl	$f_{cu} = 33.13 - 0.38V_f$	$f_{cu} = 45.96 - 1.05V_f$
NaCl	$f_{cu} = 33.70 + 0.04V_f$	$f_{cu} = 46.01 - 0.25V_f$

The bond stress results presented in table 31 on substitution of the volume fractions are ultimate values. Several codes of practice state minimum geometric requirements for bar ribs, in addition to performance requirements in standard tests, for acceptance as a high bond bar. the CEB - FIP Model Code [59] requirements for a 20mm diameter bar for instance limits the ultimate bond stress to 5.6 N/mm^2. From the results presented in table 31, the limiting volume fraction for a Grade 30 concrete structure in a sulphuric acid dominated medium can be deduced from the equations;

$$f_{bs} = 7.1 - 2.85V_f + 0.51V_f^2 \quad (37)$$

$$f_{bs} = 7.2 - 2.30Vf + 0.56V_f^2 \quad (38)$$

Equation 37 represents the coated medium while equation 38 is for the uncoated medium.

From equations 37 and 38 the limiting volume fraction would have satisfied the equations:-

$$7.1 - 2.85V_f + 0.51V_f^2 \geq 5.6 \quad (39)$$

$7.2 - 2.30V_f + 0.27\ V_f^2 \geq 5.6$ _____ (40)

This implies that the limiting values of Volume fractions $V_f[\%]$ for the bars in this medium are 0.57 and 0.74 percent respectively.

Simmilary for coated and uncoated bars in a grade 40 concrete structure in the same medium;

$f_{bs} = 8.8 - 3.92V_f + 0.56V_f^2$ _____ (41)

$f_{bs} = 9.3 - 2.84V_f + 0.20V_f^2$ _____ (42)

consequently;

$8.8 - 3.92V_f + 0.56V_f^2 \geq 5.6$ _____ (43)

$9.3 - 2.84V_f + 0.20V_f^2 \geq 5.6$ _____ (44)

The limiting volume fraction becomnes 0.95 and 1.45 respectively for the coated and uncoated bars. The overall results of the test is an presented in table 24. It is not worthy mentioning here that the limiting values for the Sodium Chloride simulated media were not conceptually realistic. The bond stress slip curve was linearly positive which mathematically suggests an unlimited ultimate bond stress range.

TABLE 36: LIMITING VALUE OF VOLUME FRACTION [%] BASED ON TABLE 24 AND CEB - FIP REQUIREMENTS [59], [42]

MEDIUM/BAR DIAMETER	CONCRETE GRADE			
	30		40	
	COATED	UNCOATED	COATED	UNCOATED
H_2So_4/Y20	*0.57	*0.74	*0.95	*1.45
HCl/Y20	*0.95	*1.00	*1.50	*1.50
NaCl/Y20	relationship is positively linear	relationship is positively linear	relationship is positively linear	relationship is positively linear
H_2So_4/Y12	0.74	1.12	1.10	1.15
HCl/Y12	0.28	0.36	1.08	1.20
NaCl/Y12	relationship is positively linear	relationship is positively linear	relationship is positively linear	relationship is positively linear

* Based on power regression

From table 33, it can be inferred that the limiting values of the fraction in an aggressive environment is concrete strength dependent. From the results presented, which is a function of the bar diameter, it can be said to be technically unsafe for example to stay a substructure designed for grade 30 concrete and with Y20 diameter bars in a damp environment that has as high as 1.0 percent of predominantly sulphate radical. The limiting results of the coated bars are less than that of the uncoated bars. This trend is attributed to the relatively higher failure load values of the uncoated bars to the coated bars [table 15 - 20]. This however, is not necessarily advantageious. The benefit derived from the protection offered by the coating substance, which is principaly to protect the steel reinforcement bar surfaces is a long benefit. From visual observations of the reinforcement rods

at the end of the experiments there were negligible visible distortion of the coating material on the bar profile. The fact too that the bond ratio is within an acceptable range scores the latex acceptable as a coating substance. The emphasis on the work was directed towards protection of the steel reinforcement bars of small diameter with the bond comparability of concrete and steel reinforcement still mentioned.

5.3 CONCRETE STRESS VRS VOLUME FRACTION MODEL

From the results presented in table 35, it is evident that there exist a functional relationship between the 108 - day cube strength and the volume fraction of the aggressive medium. At a volume fraction percent of 5 say, in a sulphuric acid medium, the cube strength of Grade 30 concrete would have been as low as 1.84 N/mm^2. Similarly with a grade 40 concrete cured in a simulated medium of 6 percent Hydrochloric acid, the cube strength will be 39.66 N/mm^2. The predicted results are in agreement with the experimental results of [46].

CHAPTER 6

6.0 SUMMARY AND CONCLUSIONS

The behaviour of two types of coated and uncoated bar with rubber latex [Poly 1 - 4 Isoprene] has been examined. Water from five different sources have equally been analysed. The one hundred and twenty six pullout test specimen and cubes have been tested for ultimate local bond strength after curing for one hundred and eight days in three distinct simulated aggressive media namely, sulphuric acid, hydrochloric acid and sodium chloride. Based on the discussions of the previous chapters, the following conclusions are drawn.

1. Based on the water analyses carried out, Atlantic ocean at the continental shelf of Lagos [Victoria Island], is hardest and has the greatest percentage of corrosion element. The salt concentration is 3.49g/100cm^3. The Mobil oil terminal at Eket follows closely with 3.436g/100cm$_3$ of salt. The least hard of the water samples analysed is the Zaria Dam with 1.371g/100cm^3 of salt.

2. A noticeable decrease in compressive strength is observed in cubes cured in the acid based media. A strength variation of 33.56N/mm^2 [3 percent volume fraction] is obtained for hydrochloric acid based media for Grade 30 concrete. Grade 40 varied from 45.56N/mm^2 [control] to 43.20N/mm^2 at 3 percent volume fraction. Sulphuric acid simulated medium recorded a variation of 33.56/mm^2 [control] to 21.02N/mm^2 in 3 percent volume fraction

for Grade 30 concrete. A strength of 45.50N/mm² [control] to 29.68N/mm² was at 3 percent recorded for Grade 40 concrete. In sodium chloride simulated environment, the strength varied from [33.56 to 33.82]N/mm² and [45.56 to 46.57]N/mm$_2$ for Grade 30 and 40 concrete respectively. Sulphuric acid simulated medium is most aggressive and the aggression is noticeable even at as low as [0 to 0.5] percent volume fraction range.

3. Pure rubber latex can be used as a coating substance on reinforcement rods for light structures with bar diameter between 8mm and 20 mm. The bond ratio falls between 0.97 and 1.05 for all the tested cases. The leanness of the coating film [0.025mm thick] on the surface of the reinforcement is advantageous. However optimal results depend on dipping expertise, consequently a reduction of the "holidaying" effect on the bar surface.

4. There exist a functional relationship between the volume fraction of an aggressive medium and the local bond stress. A quadratic equation of the form $\mathbf{f_{bs}} = \mathbf{a} + \mathbf{b}V_f + \mathbf{c}V_f^2$ is developed where V_f is the volume fraction of the medium, $\mathbf{f_{bs}}$ is the local bond stress and **a**, **b** and **c** are experimental constants that are medium dependent [TABLE 31].

5. The relationship between the cube strength and the volume fraction is at best linear and of the form $f_{cu} = \mathbf{n} + \mathbf{m}V_f$ where $\mathbf{f_{cu}}$ is the 108 -day cube strength, V_f is the volume fraction of the media, m and n are experimental constants that are medium dependent [TABLE 32].

6. From the bond slip curves, [figs. 16 - 27] the relationship between the bond stress and slip can be fitted as a second degree polynomial of the form $f_{bs} = a + bs + cs^2$, where f_{bs} is the ultimate local bond stress, s is the corresponding slip and **a, b, c** are constants that are medium, bar and concrete grade dependent. This can form the basis of reasoning for simulation of visco-elastic models that could lead to an in dept study of the concept of bond.

7. The limiting volume fraction for maximum ultimate bond stress is a function of the bar size and the concrete grade. For grade 30 concrete, the limiting value is between the range of [0.57 to 0.74] percent for sulphuric acid simulated medium and [0.95 to 1.0] for hydrochloric acid simulated medium. The limiting value for grade 40 concrete in a sulphuric acid and hydrochloric acid simulated media are within the range of [0.95 to 1.45] percent and [1.10 to 1.20] percent respectively.

8. The quality of steel produced in some of the Nigerian Steel Rolling Mills have their tested Yield Strength lower than their rated values from the factories [Table 5 and 6]. In view of this there is need to take two remedial approaches in designing and construction of a safe reinforced concrete structure. Firstly an appropriate factor of safety should be used in conjunction with codes recommendations by the design engineer to take care of these strength uncertainties in the design process. Secondly,the steel reinforcements for construction should be tested in standard laboratories for confirmation of their rated strengths

before usage. This becomes more necessary when the design engineer would not have used any strength uncertainties factor of safety.

6.1 RECOMMENDATION FOR FURTHER RESEARCH.

1. Accelerated curing method should be sought. This could be by way of chemical stabilisation of the material with organic [synthetic] or inorganic compounds.

2 A complementary Reliability appraisal on the permissible bond and cube strengths should be carried out.

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APPENDIX 1 BATCHING QUANTITIES

	CONCRETE GRADE (N/mm²)	
	40	30
w/c ratio	0.45	0.52
Cement [kg/m³]	422.2	358.5
Fine Aggregate [kg/m³]	637.9	660.0
Coares Aggregate [kg/m³]	1184.8	1226.5
Water [kg/m³]	190.0	16.3
Slump	Medium	Medium

APPENDIX A1

TEST RESULTS OF REINFORCING BARS

TEST/ ID No.	MEAN DIAMETER MEASURED[ASSUMED] [mm]	AREA [mm]	MEAN YEILD STRENGTH [N/mm²]	TENSILE STRENGTH [N/mm²]	ELONGATION [%]
NG 1	20.01 [20.00]	314.47	448.18	652.12	15.4
NG 2	20.00 [20.00]	314.16	450.24	637.05	18.2
NG 3	12.02 [12.00]	113.47	427.49	785.01	9.3
NG 4	12.01 [12.00]	113.29	411.28	703.31	17.1
NG 5	11.99 [12.00]	112.91	420.86	721.80	13.2
NG 6	12.00 [12.00]	113.10	418.29	605.42	15.1
NG 7	19.98 [20.00]	313.53	429.36	668.36	6.4
NG 8	20.01 [20.00]	314.47	452.27	752.42	9.7
NG 9	12.00 [12.00]	113.29	428.01	702.42	9.9
NG 10	19.99 [20.00]	114.16	425.18	694.38.	13.8
NG 11	20.00 [20.00]	314.16	456.38	712.38	12.7
NG 12	12.01 [12.00]	113.29	468.38	735.41	14.4

APPENDIX A 2

COMPRESSIVE STRENGTH TEST RESULTS
MEDIUM : H_2SO_4 GRADE:30 AGE:108 DAYS

S/No	VOLUME FRACTION[%]	FAILURE LOAD [kN]			MEAN FAILURE LOAD [kN]	COMP. STRENGTH [N/mm^2]
1	0% [CONTROL]	755	760	750	755	33.56
2	0.5	550	575	565	570	25.53
3	1.0	495	500	515	508	22.57
4	1.5	490	495	490	491	21.82
5	2.0	485	480	485	483	21.47
6	2.5	480	475	475	476	21.16
7	3.0	475	475	470	473	21.02

APPENDIX A 3

COMPRESSIVE STRENGTH TEST RESULTS
MEDIUM :HCl GRADE:30 AGE: 108 DAYS

S/No	VOLUME FRACTION[%]	FAILURE LOAD [kN]			MEAN FAILURE LOAD [kN]	COMP. STRENGTH [N/mm^2]
1	0% [CONTROL]	755	760	750	755	33.56
2	0.5	730	750	730	737	32.76
3	1.0	725	720	740	728	32.36
4	1.5	725	745	725	731	32.49
5	2.0	725	730	730	728	32.36
6	2.5	720	735	725	726	32.27
7	3.0	725	720	725	723	32.13

APPENDIX A 4

COMPRESSIVE STRENGTH TEST RESULTS
MEDIUM : NACl GRADE: 30 AGE: 108 DAYS

S/No	VOLUME FRACTION[%]	FAILURE LOAD [kN]			MEAN FAILURE LOAD [kN]	COMP. STRENGTH [N/mm^2]
1	0% [CONTROL]	755	760	750	755	33.56
2	0.5	760	770	755	762	33.86
3	1.0	760	770	755	760	33.78
4	1.5	770	760	750	761	33.82
5	2.0	740	755	740	758	33.69
6	2.5	765	760	755	760	33.78
7	3.0	760	765	760	761	33.82

APPENDIX A 5

COMPRESSIVE STRENGTH TEST RESULTS
MED :H_2SO_4 GRADE:40 AGE 108 DAYS

S/No	VOLUME FRACTION[%]	FAILURE LOAD [kN]			MEAN FAILURE LOAD [kN]	COMP. STRENGTH [N/mm^2]
1	0% [CONTROL]	1020	1025	1030	1025	33.42
2	0.5	725	725	730	725	32.27
3	1.0	705	690	720	705	31.33
4	1.5	700	695	690	695	30.89
5	2.0	690	680	690	687	30.53
6	2.5	670	675	680	675	30.00
7	3.0	670	660	675	668	29.68

APPENDIX A 6

COMPRESSIVE STRENGTH TEST RESULTS
MEDIUM : HCl GRADE: 40 AGE: 108 DAYS.

S/No	VOLUME FRACTION[%]	FAILURE LOAD [kN]			MEAN FAILURE LOAD [kN]	COMP. STRENGTH [N/mm^2]
1	0% [CONTROL]	1020	1025	1030	1025	45.56
2	0.5	1010	1015	1010	1012	44.98
3	1.0	1015	1005	995	1005	44.67
4	1.5	1005	990	1010	1002	44.53
5	2.0	1000	990	1005	998	43.55
6	2.5	1005	985	995	995	43.22
7	3.0	975	960	980	972	43.20

APPENDIX A 7

COMPRESSIVE STRENGTH TEST RESULTS
MEDIUM :NACl AGE: 108 DAYS GRADE:40

S/No	VOLUME FRACTION[%]	MEAN FAILURE LOAD [kN]			MEAN FAILURE LOAD [kN]	COMP. STRENGTH [N/mm^2]
1	0% [CONTROL]	1020	1025	1030	1025	45.56
2	0.5	1050	1060	1040	1050	46.67
3	1.0	1050	1045	1040	1045	1045
4	1.5	1045	1055		1051	46.71
5	2.0	1045	1065	1040	1049	46.62
6	2.5	1050	1055		1053	46.80
7	3.0	1035	1065	1045	1048	46.57

APPENDIX A8

MAXIMUM PULL OUT SLIP RESULTS
MEDIUM: H_2So_4

S/No	Vol	BAR [Y]		MAXIMUM FAILURE LOAD [kN]		MAXIMUM SLIP [mm]	
	[%]	SIZE	TREATMENT	GD.30	GD.40	GD.30	GD.40
1	0.0	20	COATED	66.4	83.1	5.7	8.6
2	0.5	20	COATED	54.2	67.8	6.7	8.1
3	1.0	20	COATED	45	54.3	8.5	9.8
4	1.5	20	COATED	36.2	43.3	9.2	101
5	2.0	20	COATED	32.5	36.1	10.6	6.5
6	0.0	20	UNCOATED	68.9	86.6	7.2	7.1
7	0.5	20	UNCOATED	55.7	76.0	8.5	7.9
8	1.0	20	UNCOATED	51.6	61.9	10.1	9.3
9	1.5	20	UNCOATED	40.1	50.5	10.2	9.9
10	2.0	20	UNCOATED	34.1	1.9	14.3	11.1
11	0.0	12	COATED	53.7	69.8	5.3	6.7
12	0.5	12	COATED	35.5	55.6	3.5	7.7
13	1.0	12	COATED	30.3	49.1	6.1	9.2
14	1.5	12	COATED	22.1	43.1	6.9	9.7
15	2.0	12	COATED	20.5	40.3	7.3	9.8
16	0.0	12	UNCOATED	54.2	71.8	5.7	7.5
17	0.5	12	UNCOATED	36.1	56.3	6.1	7.6
18	1.0	12	UNCOATED	32.5	51.6	5.9	10.1
19	1.5	12	UNCOATED	23.2	46.5	6.8	11.6
20	2.0	12	UNCOATED	22.1	35.2	7.2	12.4

APPENDIX A9

MAXIMUM PULL OUT SLIP RESULTS
MEDIUM:HCl

S/No	Vol[%]	BAR [Y]		MAXIMUM FAILURE LOAD [kN]		MAXIMUM SLIP [mm]	
		SIZE	TREATMENT	GD.30	GD.40	GD.30	GD.40
1	0.0	20	COATED	66.4	83.1	5.7	8.6
2	0.5	20	COATED	56.1	61.3	7.8	8.3
3	1.0	20	COATED	52.6	59.8	8.8	9.1
4	1.5	20	COATED	46.7	57.2	9.1	10.3
5	2.0	20	COATED	43.1	57.1	11.3	11.3
6	0.0	20	UNCOATED	68.9	86.6	7.2	9.4
7	0.5	20	UNCOATED	58.1	62.0	10.5	6.8
8	1.0	20	UNCOATED	53.4	59.1	11.2	9.2
9	1.5	20	UNCOATED	48.2	58.3	10.4	8.2
10	2.0	20	UNCOATED	44.1	51.5	11.8	9.8
11	0.0	12	COATED	53.7	71.8	5.3	6.7
12	0.5	12	COATED	45.6	55.6	6.5	7.3
13	1.0	12	COATED	43.6	46.5	5.4	8.1
14	1.5	12	COATED	41.1	40.7	8.2	10.6
15	2.0	12	COATED	36.1	40.3	7.5	6.9
16	0.0	12	UNCOATED	54.2	69.8	5.9	82.9
17	0.5	12	UNCOATED	46.8	56.3	6.3	8.2
18	1.0	12	UNCOATED	44.5	49.1	6.2	9.2
19	1.5	12	UNCOATED	41.5	43.1	6.6	8.2
20	2.0	12	UNCOATED	39.5	43.7	7.3	9.6

APPENDIX A10

MAXIMUM PULL OUT SLIP RESULTS
MEDIUM: NaCl

S/No	Vol[%]	BAR [Y]		MAXIMUM FAILURE LOAD [kN]		MAXIMUM SLIP [mm]	
		SIZE	TREATMENT	GD.30	GD.40	GD.30	GD.40
1	0.0	20	COATED	66.4	83.1	5.7	6.6
2	0.5	20	COATED	66.7	81.4	6.1	8.4
3	1.0	20	COATED	665.5	75.4	5.8	9.1
4	1.5	20	COATED	70.1	79.3	5.9	8.9
5	2.0	20	COATED	65.7	81.6	6.3	9.1
6	0.0	20	UNCOATED	68.9	86.6	7.2	7.1
7	0.5	20	UNCOATED	68.2	80.8	6.4	8.6
8	1.0	20	UNCOATED	70.2	75.2	7.7	9.8
9	1.5	20	UNCOATED	67.3	818	5.8	10.2
10	2.0	20	UNCOATED	69.1	82.1	7.1	10.3
11	0.0	12	COATED	53.7	71.8	5.3	6.7
12	0.5	12	COATED	54.1	61.3	4.5	7.9
13	1.0	12	COATED	53.9	63.9	5.8	9.6
14	1.5	12	COATED	55.9	66.7	5.6	8.4
15	2.0	12	COATED	54.3	66.9	7.1	7.2
16	0.0	12	UNCOATED	54.2	69.8	5.7	7.5
17	0.5	12	UNCOATED	54.6	68.4	4.8	7.9
18	1.0	12	UNCOATED	56.6	64.5	6.5	8.8
19	1.5	12	UNCOATED	55.8	63.2	5.8	9.7
20	2.0	12	UNCOATED	53.1	65.2	6.4	8.7

APPENDIX C1

LOADED END RESULTS

CONCRETE GRADE:30

PULL OUT TEST RESULTS ON COATED BAR (LOADED END)

Test No :BC37
Identification Mark : CY/20/30/37
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.7
4	12.0	1.1
5	16.0	1.5
6	20.0	1.7
7	24.0	2.0
8	28.0	2.2
9	32.0	2.6
10	36.0	2.9
11	40.0	3.4
12	44.0	3.6
13	48.0	3.9
14	52.0	4.2
15	56.0	4.5
16	60.0	5.1
17	66.4	5.9

PULL OUT TEST RESULTS ON COATED BAR (LOADED END)

Test No :BC40
Identification Mark : CY/20/30/40
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.5 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.7
4	12.0	1.3
5	16.0	1.7
6	20.0	2.1
7	24.0	2.3
8	28.0	2.7
9	32.0	3.1
10	36.0	3.6
11	40.0	4.5
12	44.0	4.9
13	48.0	5.6
14	52.0	6.1
15	54.7	6.7

PULL OUT TEST RESULTS ON COATED BAR (LOADED END)

Test No :BC27
Identification Mark : CY/20/30/27
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.0 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.3
4	12.0	2.0
5	16.0	2.4
6	20.0	2.8
7	24.0	3.3
8	28.0	3.7
9	32.0	4.9
10	36.0	5.6
11	40.0	6.7
12	44.0	7.6
13	45.2	8.5

PULL OUT TEST RESULTS ON COATED BAR (LOADED END)

Test No :BC24
Identification Mark : CY/20/30/24
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.5 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.9
3	8.0	1.6
4	12.0	2.2
5	16.0	2.8
6	20.0	3.7
7	24.0	4.6
8	28.0	5.9
9	32.0	6.7
10	36.1	9.2

PULL OUT TEST RESULTS ON COATED BAR (LOADED END)

Test No :BC38
Identification Mark : CY/20/30/38
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :2.0% Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	1.0
3	8.0	2.3
4	12.0	2.8
5	16.0	3.7
6	20.0	4.7
7	24.0	6.6
8	28.0	8.3
9	32.0	9.8
10	32.5	10.6

PULL OUT TEST RESULTS ON UNCOATED BAR (LOADED END)

Test No :BU18
Identification Mark :UCY/20/30/18
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.8
4	12.0	1.1
5	16.0	1.4
6	20.0	1.6
7	24.0	1.8
8	28.0	2.1
9	32.0	2.4
10	36.0	2.7
11	40.0	3.2
12	44.0	3.5
13	48.0	3.9
14	52.0	4.2
15	56.0	5.0
16	60.0	5.4
17	64.0	5.9
18	68.9	7.2

PULL OUT TEST RESULTS ON UNCOATED BAR (LOADED END)

Test No :BU5
Identification Mark :UCY/20/30/05
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.5 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	1.1
4	12.0	1.6
5	16.0	2.0
6	20.0	2.4
7	24.0	2.8
8	28.0	3.3
9	32.0	3.7
10	36.0	4.3
11	40.0	5.3
12	44.0	6.2
13	48.0	6.8
14	52.0	7.9
15	55.7	8.5

PULL OUT TEST RESULTS ON UNCOATED BAR (LOADED END)

Test No :BU39

Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.0 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.7
3	8.0	1.4
4	12.0	2.1
5	16.0	2.4
6	20.0	3.1
7	24.0	3.6
8	28.0	4.6
9	32.0	5.2
10	36.0	5.9
11	40.0	7.5
12	44.0	8.4
13	48.0	9.2
14	51.6	10.1

PULL OUT TEST RESULTS ON UNCOATED BAR (LOADED END)

Test No :BU43
Identification Mark :UCY/20/30/43
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :1.5 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.9
3	8.0	1.7
4	12.0	2.4
5	16.0	3.2
6	20.0	3.8
7	24.0	4.6
8	28.0	5.8
9	32.0	6.8
10	36.0	8.4
11	40.1	10.2

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No : BU45
Identification Mark :UCY/12/30/45
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 2.0 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.8
3	8.0	1.6
4	12.0	2.8
5	16.0	3.7
6	20.0	4.7
7	24.0	6.6
8	28.0	8.3
9	32.0	9.8
10	34.1	14.3

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC01
Identification Mark : CY/12/30/01
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.2
3	8.0	0.5
4	12.0	0.6
5	16.0	0.8
6	20.0	1.0
7	24.0	1.1
8	28.0	1.6
9	32.0	2.1
10	36.0	2.5
11	40.0	2.9
12	44.0	3.5
13	48.0	4.0
14	52.0	4.5
15	53.7	4.9

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No :BC13
Identification Mark : CY/12/30/13
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :0.5 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.2
3	8.0	0.6
4	12.0	0.9
5	16.0	1.2
6	20.0	1.5
7	24.0	1.8
8	28.0	2.3
9	32.0	2.8
10	35.5	3.5

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC25
Identification Mark : CY/12/30/25
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.0% Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	1.0
4	12.0	1.5
5	16.0	2.0
6	20.0	2.8
7	24.0	3.5
8	28.0	4.5
9	30.3	6.1

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC41
Identification Mark : CY/12/30/41
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :1.5 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.7
3	8.0	1.6
4	12.0	2.4
5	16.0	3.8
6	20.0	5.5
7	22.1	6.9

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No :BC20
Identification Mark : CY/12/30/20
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :2.0 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.8
3	8.0	2.2
4	12.0	4.9
5	20.5	7.3
6	24.0	
7	28.0	
8	32.0	
9	36.0	
10	40.0	
11	44.0	
12	48.0	
13	52.0	
14	56.0	
15	60.0	
16	64.0	
17	68.0	

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No :BU52
Identification Mark :UCY/12/30/52
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :0.0 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.6
4	12.0	0.8
5	16.0	1.2
6	20.0	1.5
7	24.0	1.7
8	28.0	1.9
9	32.0	2.3
10	36.0	2.7
11	40.0	3.3
12	44.0	3.7
13	48.0	4.2
14	52.0	4.7
15	54.2	5.7

PULL OUT TEST RESULT ON UCOATED BAR (LOADED END)

Test No :BU46
Identification Mark : UCY/12/30/46
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :0.5 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	1.0
4	12.0	1.2
5	16.0	1.5
6	20.0	1.8
7	24.0	2.2
8	28.0	2.5
9	32.0	3.1
10	36.0	3.9
11	36.1	6.1

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No :BU32
Identification Mark : UCY/12/30/32
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.0 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.2
4	12.0	1.7
5	16.0	2.1
6	20.0	2.7
7	24.0	3.6
8	28.0	4.9
9	32.5	5.9

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No :BU47
Identification Mark : UCY/12/30/47
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :1.5% Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	1.0
4	12.0	1.9
5	16.0	2.5
6	20.0	3.1
7	23.2	6.8

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No : BU15
Identification Mark : UCY/12/30/15
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :2.0 % Sulphuric Acid (H_2So_4)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.5
4	12.0	2.2
5	16.0	2.7
6	20.0	3.4
7	20.5	7.2

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC01
Identification Mark : CY/12/30/01
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.2
3	8.0	0.5
4	12.0	0.6
5	16.0	0.8
6	20.0	1.0
7	24.0	1.3
8	28.0	2.1
9	32.0	2.5
10	36.0	2.9
11	40.0	3.4
12	44.0	3.6
13	48.0	4.0
14	52.0	4.5
15	53.7	5.3

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No :BC42
Identification Mark : CY/12/30/42
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :0.5 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.0
4	12.0	1.2
5	16.0	1.5
6	20.0	1.8
7	24.0	2.4
8	28.0	2.6
9	32.0	3.9
10	36.0	4.5
11	40.0	5.1
12	44.0	5.4
13	45.6	5.7

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC21
Identification Mark : CY/12/30/21
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.0 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.2
4	12.0	1.5
5	16.0	2.1
6	20.0	2.5
7	24.0	3.0
8	28.0	3.5
9	32.0	4.3
10	36.0	4.5
11	40.0	5.1
12	41.5	5.4

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC12
Identification Mark : CY/12/30/12
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :1.5% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	1.9
4	12.0	2.5
5	16.0	3.1
6	20.0	4.2
7	24.0	5.3
8	28.0	6.0
9	32.0	6.8
10	36.0	7.4
11	40.0	7.8
12	41.1	8.2

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No :BC48
Identification Mark : CY/12/30/48
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :2.0 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.5
4	12.0	2.2
5	16.0	3.4
6	20.0	4.5
7	24.0	5.7
8	28.0	6.4
9	32.0	6.9
10	36.0	7.3
11	36.1	7.5

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No :BU52
Identification Mark :UCY/12/30/52
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.6
4	12.0	0.8
5	16.0	1.2
6	20.0	1.5
7	24.0	1.7
8	28.0	1.9
9	32.0	2.3
10	36.0	2.7
11	40.0	3.3
12	44.0	3.7
13	48.0	4.2
14	52.0	4.7
15	54.2	5.7

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No :BU11
Identification Mark : UCY/12/30/11
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :0.5 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.2
4	12.0	1.5
5	16.0	1.8
6	20.0	2.4
7	24.0	3.1
8	28.0	3.9
9	32.0	4.3
10	36.0	4.7
11	40.0	5.3
12	44.0	5.7
13	46.8	6.3

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No : BU50
Identification Mark : UCY/12/30/50
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :1.0 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.2
4	12.0	1.7
5	16.0	2.1
6	20.0	2.5
7	24.0	3.0
8	28.0	4.1
9	32.0	4.5
10	36.0	4.7
11	40.0	5.3
12	44.0	5.9
13	44.5	6.3

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No : BU19
Identification Mark : UCY/12/30/19
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.5% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	1.9
4	12.0	2.5
5	16.0	3.1
6	20.0	3.7
7	24.0	4.5
8	28.0	5.2
9	32.0	5.7
10	36.0	6.2
11	40.0	6.4
12	44.1	6.6

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No :BU44
Identification Mark : UCY/12/30/44
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :2.0 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.5
4	12.0	2.2
5	16.0	2.7
6	20.0	3.4
7	24.0	4.5
8	28.0	5.0
9	32.0	6.2
10	36.0	6.9
11	36.1	7.3

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC37
Identification Mark : CY/20/30/37
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :0.0 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	End Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.7
4	12.0	1.1
5	16.0	1.5
6	20.0	1.7
7	24.0	2.0
8	28.0	2.2
9	32.0	2.6
10	36.0	2.9
11	40.0	3.4
12	44.0	3.6
13	48.0	3.9
14	52.0	4.2
15	56.0	4.5
16	60.0	4.7
17	64.0	5.1
18	66.4	5.7

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No :BC04
Identification Mark : CY/20/30/04
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :0.5 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.9
4	12.0	1.2
5	16.0	1.6
6	20.0	2.0
7	24.0	2.3
8	28.0	2.9
9	32.0	3.5
10	36.0	3.8
11	40.0	4.2
12	44.0	4.8
13	48.0	5.5
14	52.0	6.2
15	56.0	7.1
16	58.1	7.8

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC17
Identification Mark : CY/20/30/17
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.0 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	End Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	1.1
4	12.0	1.6
5	16.0	2.1
6	20.0	2.7
7	24.0	3.5
8	28.0	4.3
9	32.0	4.6
10	36.0	5.2
11	40.0	5.9
12	44.0	6.4
13	48.0	7.5
14	52.0	8.6
15	52.8	8.8

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC14
Identification Mark : CY/20/30/14
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.5 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.6
3	8.0	1.1
4	12.0	2.2
5	16.0	2.7
6	20.0	3.4
7	24.0	4.5
8	28.0	5.3
9	32.0	5.9
10	36.0	6.4
11	40.0	7.5
12	44.0	8.6
13	46.7	9.1

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC29
Identification Mark : CY/20/30/29
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :2.0 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.5
4	12.0	2.4
5	16.0	3.7
6	20.0	4.7
7	24.0	5.6
8	28.0	6.7
9	32.0	7.4
10	36.0	8.7
11	40.0	9.7
12	44.0	11.1
13	44.1	11.3

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No : BU18
Identification Mark :UCY/20/30/18
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :0.0 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.8
4	12.0	1.1
5	16.0	1.4
6	20.0	1.6
7	24.0	1.8
8	28.0	2.1
9	32.0	2.4
10	36.0	2.7
11	40.0	3.2
12	44.0	3.5
13	48.0	3.9
14	52.0	4.2
15	56.0	5.0
16	60.0	5.4
17	64.0	5.9
18	68.0	7.2
19	69.8	8.1

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No : BU34
Identification Mark : UCY/20/30/34
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :0.5 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.9
4	12.0	1.2
5	16.0	1.6
6	20.0	2.2
7	24.0	2.7
8	28.0	3.1
9	32.0	3.8
10	36.0	4.3
11	40.0	5.3
12	44.0	6.5
13	48.0	7.5
14	52.0	8.4
15	56.0	9.4
16	58.1	10.5

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No : BU36
Identification Mark : UCY/20/30/36
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.0 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	1.1
4	12.0	1.6
5	16.0	2.1
6	20.0	2.4
7	24.0	3.1
8	28.0	3.8
9	32.0	4.5
10	36.0	5.5
11	40.0	6.5
12	44.0	8.1
13	48.0	9.6
14	52.0	10.9
15	53.4	11.2

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No :BU08
Identification Mark : UCY/20/30/08
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :1.5% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.6
3	8.0	1.2
4	12.0	2.1
5	16.0	2.7
6	20.0	3.4
7	24.0	4.2
8	28.0	4.8
9	32.0	5.3
10	36.0	6.6
11	40.0	7.8
12	44.0	8.9
13	48.0	10.2
14	48.2	10.4

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No : BU07
Identification Mark : UCY/20/30/07
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :2.0 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.5
4	12.0	2.4
5	16.0	3.7
6	20.0	4.7
7	24.0	5.6
8	28.0	6.2
9	32.0	7.1
10	36.0	8.3
11	40.0	9.4
12	44.1	11.8

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No :BU52
Identification Mark : UCY/12/30/52
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :0.0 % Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.6
4	12.0	0.87
5	16.0	1.2
6	20.0	1.5
7	24.0	1.7
8	28.0	1.9
9	32.0	2.3
10	36.0	2.7
11	40.0	3.3
12	44.0	3.7
13	48.0	4.2
14	52.0	4.7
15	54.2	5.7

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No : BU03
Identification Mark : UCY/12/30/03
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :0.5 % Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.7
4	12.0	0.8
5	16.0	1.2
6	20.0	1.5
7	24.0	1.7
8	28.0	2.1
9	32.0	2.4
10	36.0	2.9
11	40.0	3.5
12	44.0	3.7
13	48.0	4.2
14	52.0	4.5
15	54.6	4.8

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No :BU51
Identification Mark : UCY/12/30/51
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :1.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.8
4	12.0	1.4
5	16.0	1.9
6	20.0	2.2
7	24.0	2.5
8	28.0	3.0
9	32.0	3.5
10	36.0	4.0
11	40.0	4.4
12	44.0	5.2
13	48.0	5.6
14	52.0	5.9
15	56.6	6.5

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No :BU09
Identification Mark : UCY/12/30/09
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :1.5 % Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.8
4	12.0	1.4
5	16.0	1.9
6	20.0	2.2
7	24.0	2.5
8	28.0	3.0
9	32.0	3.5
10	36.0	4.0
11	40.0	4.4
12	44.0	4.8
13	48.0	5.2
14	52.0	5.6
15	55.8	5.8

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No : BU30
Identification Mark : UCY/12/30/30
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :2.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.7
4	12.0	1.2
5	16.0	1.7
6	20.0	2.0
7	24.0	2.4
8	28.0	2.7
9	32.0	3.2
10	36.0	4.0
11	40.0	4.6
12	44.0	5.2
13	48.0	5.7
14	52.0	6.0
15	53.1	6.4

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No :BC 01
Identification Mark : CY/12/30/01
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0 % Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.2
3	8.0	0.2
4	12.0	0.6
5	16.0	0.8
6	20.0	1.0
7	24.0	1.3
8	28.0	2.1
9	32.0	2.5
10	36.0	2.9
11	40.0	3.4
12	44.0	3.6
13	48.0	4.0
14	52.0	4.5
15	53.7	5.3

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No :BC26
Identification Mark : CY/12/30/26
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.5% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.4
4	12.0	0.5
5	16.0	1.1
6	20.0	1.3
7	24.0	1.5
8	28.0	2.0
9	32.0	2.4
10	36.0	2.8
11	40.0	3.4
12	44.0	3.9
13	48.0	4.2
14	53.7	4.5

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No :BC02
Identification Mark : CY/12/30/02
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :1.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.5
4	12.0	1.1
5	16.0	1.3
6	20.0	1.5
7	24.0	2.0
8	28.0	2.4
9	32.0	2.8
10	36.0	3.4
11	40.0	3.9
12	44.0	4.2
13	48.0	4.8
14	52.0	5.4
15	54.1	5.8

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC 06
Identification Mark : CY/12/30/06
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :1.5% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.8
4	12.0	1.4
5	16.0	1.9
6	20.0	2.2
7	24.0	2.5
8	28.0	2.7
9	32.0	3.2
10	36.0	4.0
11	40.0	4.4
12	44.0	4.8
13	48.0	5.2
14	55.9	5.6

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC28
Identification Mark : CY/12/30/28
Bar Type/Diameter :Y12
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :2.0 % Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.7
4	12.0	1.2
5	16.0	1.7
6	20.0	2.0
7	24.0	2.4
8	28.0	3.0
9	32.0	4.0
10	36.0	4.8
11	40.0	5.4
12	44.0	6.1
13	48.0	6.5
14	52.0	6.9
15	54.3	7.1

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC 37
Identification Mark : CY/20/30/37
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :0.0 % Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.7
4	12.0	1.1
5	16.0	1.5
6	20.0	1.7
7	24.0	2.0
8	28.0	2.2
9	32.0	2.6
10	36.0	2.9
11	40.0	3.4
12	44.0	3.6
13	48.0	3.9
14	52.0	4.2
15	56.0	4.5
16	60.0	5.1
17	66.4	5.9

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC16
Identification Mark : CY/20/30/16
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :0.5% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.7
4	12.0	1.1
5	16.0	1.5
6	20.0	1.7
7	24.0	2.0
8	28.0	2.2
9	32.0	2.6
10	36.0	2.9
11	40.0	3.4
12	44.0	3.6
13	48.0	3.9
14	52.0	4.2
15	56.0	4.5
16	60.0	4.7
17	64.0	5.1
18	66.4	6.1

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC10
Identification Mark : CY/20/30/10
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :1.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.8
4	12.0	1.0
5	16.0	1.6
6	20.0	1.8
7	24.0	2.1
8	28.0	2.2
9	32.0	2.4
10	36.0	2.8
11	40.0	3.5
12	44.0	3.7
13	48.0	4.3
14	52.0	4.6
15	56.0	4.9
16	60.0	5.3
17	64.0	5.5
18	66.5	5.7

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC35
Identification Mark : CY/20/30/35
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :1.5 % Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.7
4	12.0	1.0
5	16.0	1.2
6	20.0	1.6
7	24.0	1.8
8	28.0	2.2
9	32.0	2.5
10	36.0	2.9
11	40.0	3.4
12	44.0	3.9
13	48.0	4.2
14	52.0	4.6
15	56.0	4.8
16	60.0	5.2
17	64.0	5.6
18	70.1	5.9

PULL OUT TEST RESULT ON COATED BAR (LOADED END)

Test No : BC31
Identification Mark : CY/20/30/31
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :2.0 % Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.7
4	12.0	1.4
5	16.0	1.8
6	20.0	2.1
7	24.0	2.4
8	28.0	3.0
9	32.0	3.4
10	36.0	3.6
11	40.0	4.1
12	44.0	4.4
13	48.0	4.6
14	52.0	5.0
15	56.0	5.3
16	60.0	5.5
17	65.7	6.3
18		

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No : BU 18
Identification Mark : UCY/20/30/18
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :0.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.8
4	12.0	1.1
5	16.0	1.4
6	20.0	1.6
7	24.0	1.8
8	28.0	2.1
9	32.0	2.4
10	36.0	2.7
11	40.0	3.2
12	44.0	3.7
13	48.0	3.9
14	52.0	4.8
15	56.0	5.4
16	60.0	5.9
17	64.0	6.4
18	68.9	7.2

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No : BU 23
Identification Mark : UCY/20/30/23
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :0.5 % Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.8
4	12.0	1.2
5	16.0	1.5
6	20.0	1.7
7	24.0	2.0
8	28.0	2.2
9	32.0	2.5
10	36.0	2.8
11	40.0	3.4
12	44.0	3.6
13	48.0	4.1
14	52.0	4.2
15	56.0	4.5
16	60.0	4.8
17	64.0	5.2
18	68.0	5.8
19	68.2	6.4

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No : BU 22
Identification Mark : UCY/20/30/22
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :1.0 % Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.7
4	12.0	1.2
5	16.0	1.5
6	20.0	1.9
7	24.0	2.3
8	28.0	2.4
9	32.0	2.7
10	36.0	3.2
11	40.0	3.5
12	44.0	3.7
13	48.0	4.3
14	52.0	4.6
15	56.0	4.9
16	60.0	5.4
17	64.0	5.5
18	68.0	6.1
19	70.2	6.7

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No : BU 33
Identification Mark : UCY/20/30/33
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :1.5% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.7
4	12.0	1.0
5	16.0	1.2
6	20.0	1.6
7	24.0	1.8
8	28.0	2.2
9	32.0	2.3
10	36.0	2.6
11	40.0	3.2
12	44.0	3.7
13	48.0	4.1
14	52.0	4.6
15	56.0	4.8
16	60.0	5.2
17	64.0	5.4
18	67.3	5.8

PULL OUT TEST RESULT ON UNCOATED BAR (LOADED END)

Test No : BU49
Identification Mark : UCY/20/30/49
Bar Type/Diameter :Y20
Time of Immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :2.0 % Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Slip(mm) x0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.8
4	12.0	1.5
5	16.0	1.8
6	20.0	2.4
7	24.0	2.7
8	28.0	3.1
9	32.0	3.3
10	36.0	3.7
11	40.0	4.2
12	44.0	4.6
13	48.0	4.9
14	52.0	5.2
15	56.0	5.8
16	60.0	6.2
17	65.7	7.1

APPENDIX C1

LOADED END RESULTS

CONCRETE GRADE:40

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC37
Identification Mark :CY20/40/37
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0% Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.2
3	8.0	0.6
4	12.0	0.9
5	16.0	1.2
6	20.0	1.4
7	24.0	1.8
8	28.0	2.0
9	32.0	2.3
10	36.0	2.6
11	40.0	2.8
12	44.0	3.2
13	48.0	3.3
14	52.0	3.8
15	56.0	4.2
16	60.0	4.4
17	64.0	5.0
18	68.0	5.5
19	72.0	6.0
20	76.0	6.4
21	80.0	7.2
22	83.1	8.6

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC40
Identification Mark :CY20/40/40
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium 0.5% Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.8
4	12.0	1.2
5	16.0	1.3
6	20.0	1.5
7	24.0	1.7
8	28.0	2.2
9	32.0	2.4
10	36.0	3.1
11	40.0	3.6
12	44.0	3.8
13	48.0	4.3
14	52.0	4.7
15	56.0	5.1
16	60.0	6.1
17	64.0	6.9
18	67.8	8.1

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC27
Identification Mark :CY20/40/27
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium 1.0% Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	0.9
4	12.0	1.3
5	16.0	1.7
6	20.0	2.4
7	24.0	3.0
8	28.0	3.5
9	32.0	4.1
10	36.0	5.0
11	40.0	5.7
12	44.0	6.2
13	48.0	7.0
14	52.0	8.0
15	54.3	9.8

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC24
Identification Mark :CY20/40/24
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.5% Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	0.9
4	12.0	1.3
5	16.0	1.7
6	20.0	2.4
7	24.0	3.2
8	28.0	4.1
9	32.0	5.3
10	36.0	6.1
11	40.0	7.1
12	43.3	10.1

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC38
Identification Mark :CY20/40/38
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium: 2.0 % Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.1
4	12.0	1.5
5	16.0	2.1
6	20.0	2.7
7	24.0	3.5
8	28.0	4.6
9	32.0	5.8
10	35.2	3.5

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU18
Identification Mark :UCY20/40/18
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium: 0.0% Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.2
3	8.0	0.5
4	12.0	0.8
5	16.0	1.2
6	20.0	1.4
7	24.0	1.7
8	28.0	1.9
9	32.0	2.2
10	36.0	2.4
11	40.0	2.7
12	44.0	3.1
13	48.0	3.3
14	52.0	3.7
15	56.0	4.1
16	60.0	4.5
17	64.0	4.9
18	68.0	5.3
19	72.0	5.7
20	76.0	6.3
21	80.0	6.7
22	86.6	7.1

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AU05
Identification Mark :CY20/40/05
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.5 % Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.8
4	12.0	1.2
5	16.0	1.6
6	20.0	1.8
7	24.0	2.2
8	28.0	2.5
9	32.0	2.8
10	36.0	3.2
11	40.0	3.6
12	44.0	3.9
13	48.0	4.4
14	52.0	4.9
15	56.0	5.3
16	60.0	6.1
17	64.0	6.9
18	76.1	7.9

PULL OUT TEST RESULTS ON COATED BAR [LOADE END]

Test No :AU39
Identification Mark :UCY20/40/39
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium: 1.0% Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	0.9
4	12.0	1.3
5	16.0	1.7
6	20.0	2.4
7	24.0	3.0
8	28.0	3.4
9	32.0	3.7
10	36.0	4.5
11	40.0	5.2
12	44.0	5.9
13	48.0	6.8
14	52.0	7.9
15	61.9	9.3

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AU43
Identification Mark :UCY20/40/43
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium:1.5 % Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	0.9
4	12.0	1.3
5	16.0	1.7
6	20.0	2.4
7	24.0	3.2
8	28.0	4.1
9	32.0	5.1
10	36.0	5.8
11	40.0	7.0
12	44.0	7.9
13	48.0	8.6
14	50.5	9.9

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU45
Identification Mark :UCY20/40/45
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium: 2.0 % Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	1.1
4	12.0	1.4
5	16.0	2.1
6	20.0	2.7
7	24.0	3.4
8	28.0	4.6
9	32.0	5.7
10	36.0	7.1
11	40.0	8.2
12	41.9	11.1

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC01
Identification Mark :CY12/40/01
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium:0.0 % Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.5
4	12.0	0.7
5	16.0	0.9
6	20.0	1.1
7	24.0	1.3
8	28.0	1.6
9	32.0	1.9
10	36.0	2.2
11	40.0	2.6
12	44.0	3.0
13	48.0	3.4
14	52.0	3.8
15	56.0	4.3
16	60.0	4.7
17	64.0	5.1
18	68.0	5.6
19	69.8	6.7

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC13
Identification Mark :CY12/40/13
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium: 0.5 % Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.7
4	12.0	1.1
5	16.0	1.6
6	20.0	1.9
7	24.0	2.4
8	28.0	2.8
9	32.0	3.3
10	36.0	3.7
11	40.0	4.1
12	44.0	4.5
13	48.0	4.9
14	52.0	5.4
15	55.6	7.7

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC25
Identification Mark :CY12/40/25
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium: 1.0% Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.9
4	12.0	1.4
5	16.0	1.9
6	20.0	2.4
7	24.0	2.8
8	28.0	3.3
9	32.0	3.7
10	36.0	4.1
11	40.0	4.7
12	44.0	5.9
13	48.0	8.6
14	49.1	9.2
15		
16		
17		
18		
19		
20		
21		
22		
24		

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC41
Identification Mark :CY12/40/41
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium: 1.5% Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.7
3	8.0	1.6
4	12.0	2.4
5	16.0	3.0
6	20.0	3.6
7	24.0	4.1
8	28.0	5.0
9	32.0	6.4
10	36.0	9.1
11	43.1	9.7

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC20
Identification Mark :CY12/40/20
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium: 2.0% Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.8
3	8.0	2.2
4	12.0	3.3
5	16.0	4.2
6	20.0	5.1
7	24.0	6.1
8	28.0	7.5
9	32.0	9.6
10	35.2	9.7

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AU52
Identification Mark :UCY12/40/52
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0% Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.5
4	12.0	1.0
5	16.0	1.3
6	20.0	1.6
7	24.0	2.4
8	28.0	3.0
9	32.0	3.5
10	36.0	4.1
11	40.0	4.5
12	44.0	5.1
13	48.0	5.6
14	52.0	6.0
15	56.0	6.4
16	60.0	6.9
17	71.8	7.5

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AU46
Identification Mark :UCY12/40/46
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.5% Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.9
4	12.0	1.2
5	16.0	1.5
6	20.0	1.9
7	24.0	2.3
8	28.0	2.7
9	32.0	3.3
10	36.0	4.2
11	40.0	5.1
12	44.0	6.2
13	48.0	7.1
14	52.0	8.2
15	56.3	9.6

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AU32
Identification Mark :UCY12/40/32
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.0% Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.1
4	12.0	1.6
5	16.0	2.0
6	20.0	2.5
7	24.0	3.1
8	28.0	3.9
9	32.0	5.1
10	36.0	6.1
11	40.0	7.0
12	44.0	7.9
13	51.6	10.1

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AU47
Identification Mark :UCY12/40/47
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.5 % Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	1.0
4	12.0	1.9
5	16.0	2.5
6	20.0	3.1
7	24.0	4.0
8	28.0	5.0
9	32.0	6.6
10	36.0	8.2
11	40.0	10.1
12	46.5	11.6

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AU15
Identification Mark :UCY12/40/15
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 2.0% Sulphuric Acid (H_2So_4).

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.2
4	12.0	2.0
5	16.0	2.7
6	20.0	3.4
7	24.0	4.5
8	28.0	6.9
9	35.2	12.4

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC42
Identification Mark :CY12/40/42
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.5
4	12.0	0.7
5	16.0	0.9
6	20.0	1.1
7	24.0	1.3
8	28.0	1.5
9	32.0	1.8
10	36.0	2.2
11	40.0	2.6
12	44.0	3.0
13	48.0	3.4
14	52.0	3.8
15	56.0	4.3
16	60.0	4.7
17	64.0	5.1
18	68.0	5.6
19	71.8	6.7

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC22
Identification Mark :CY12/40/22
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.5% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.2
3	8.0	0.5
4	12.0	0.9
5	16.0	1.4
6	20.0	1.8
7	24.0	2.3
8	28.0	2.7
9	32.0	3.1
10	36.0	3.4
11	40.0	3.6
12	44.0	4.2
13	48.0	4.6
14	52.0	5.2
15	55.6	7.3

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC21
Identification Mark :CY12/40/21
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.0 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.7
4	12.0	1.3
5	16.0	1.7
6	20.0	2.5
7	24.0	3.0
8	28.0	3.5
9	32.0	3.9
10	36.0	4.6
11	40.0	5.3
12	44.0	6.1
13	46.5	8.1

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC12
Identification Mark :CY12/40/12
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.5% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.9
4	12.0	1.8
5	16.0	2.5
6	20.0	3.0
7	24.0	3.7
8	28.0	4.3
9	32.0	5.0
10	36.0	6.4
11	40.7	8.1

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC43
Identification Mark :CY12/40/43
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 2.0% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.3
4	12.0	2.5
5	16.0	3.4
6	20.0	4.6
7	24.0	5.6
8	28.0	6.9
9	32.0	7.9
10	36.0	9.0
11	40.3	10.6

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU52
Identification Mark :UCY12/40/52
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.5
4	12.0	0.8
5	16.0	1.0
6	20.0	1.3
7	24.0	1.6
8	28.0	1.9
9	32.0	2.4
10	36.0	3.0
11	40.0	3.5
12	44.0	4.1
13	48.0	4.5
14	52.0	5.1
15	56.0	5.6
16	60.0	6.0
17	64.0	6.4
18	68.0	6.9
19	71.8	7.5

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU11
Identification Mark :UCY12/40/11
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.5% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.4
4	12.0	0.7
5	16.0	1.2
6	20.0	1.7
7	24.0	2.3
8	28.0	2.7
9	32.0	3.1
10	36.0	3.5
11	40.0	4.0
12	44.0	4.5
13	48.0	5.1
14	56.0	6.3
15	56.3	8.1

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU50
Identification Mark :UCY12/40/50
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.0% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.6
4	12.0	1.2
5	16.0	1.7
6	20.0	2.3
7	24.0	2.7
8	28.0	3.2
9	32.0	3.7
10	36.0	4.3
11	40.0	4.9
12	44.0	5.5
13	48.0	7.5
14	49.1	9.2

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU19
Identification Mark :UCY12/40/19
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :1.5% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.9
4	12.0	1.8
5	16.0	2.3
6	20.0	2.9
7	24.0	3.6
8	28.0	4.3
9	32.0	4.9
10	36.0	5.8
11	40.0	6.5
12	43.1	8.2

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU44
Identification Mark :UCY12/40/44
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :2.0% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.3
4	12.0	2.3
5	16.0	2.9
6	20.0	4.0
7	24.0	4.9
8	28.0	5.9
9	32.0	7.2
10	36.0	8.3
11	43.7	9.6

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC37
Identification Mark :CY20/40/37
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.2
3	8.0	0.9
4	12.0	0.6
5	16.0	1.2
6	20.0	1.4
7	24.0	1.8
8	28.0	2.0
9	32.0	2.3
10	36.0	2.6
11	40.0	2.8
12	44.0	3.2
13	48.0	3.4
14	52.0	3.7
15	56.0	3.9
16	60.0	4.5
17	64.0	5.0
18	68.0	5.5
19	72.0	6.0
20	76.0	6.4
21	80.0	7.2
22	83.1	8.6

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC04
Identification Mark :CY20/40/04
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.5 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.8
4	12.0	1.2
5	16.0	1.4
6	20.0	1.6
7	24.0	2.0
8	28.0	2.2
9	32.0	2.4
10	36.0	2.7
11	40.0	3.1
12	44.0	3.6
13	48.0	4.1
14	52.0	4.5
15	56.0	5.1
16	60.0	5.9
17	64.0	7.1
18	71.3	8.3

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC17
Identification Mark :CY20/40/17
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.0% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	0.9
4	12.0	1.3
5	16.0	1.6
6	20.0	2.2
7	24.0	2.5
8	28.0	3.1
9	32.0	3.5
10	36.0	4.2
11	40.0	4.8
12	44.0	5.3
13	48.0	5.9
14	52.0	6.8
15	56.0	7.6
16	60.0	8.4
17	69.8	9.1

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU18
Identification Mark :UCY20/40/18
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.2
3	8.0	0.5
4	12.0	0.8
5	16.0	1.2
6	20.0	1.4
7	24.0	1.7
8	28.0	1.9
9	32.0	2.2
10	36.0	2.4
11	40.0	2.7
12	44.0	3.1
13	48.0	3.3
14	52.0	3.7
15	56.0	4.1
16	60.0	4.5
17	64.0	4.9
18	68.0	5.3
19	72.0	5.7
20	76.0	6.3
21	80.0	6.7
22	84.0	7.1
24	86.6	9.4

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU34
Identification Mark :UCY20/40/34
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.5% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.7
4	12.0	1.1
5	16.0	1.5
6	20.0	1.7
7	24.0	2.0
8	28.0	2.4
9	32.0	2.7
10	36.0	3.2
11	40.0	3.6
12	44.0	3.8
13	48.0	4.0
14	52.0	4.6
15	56.0	5.1
16	60.0	6.0
17	64.0	6.4
18	71.9	6.8

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU36
Identification Mark :UCY20/40/36
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium :1.0% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.7
4	12.0	1.2
5	16.0	1.5
6	20.0	2.3
7	24.0	2.5
8	28.0	3.1
9	32.0	3.4
10	36.0	3.8
11	40.0	4.1
12	44.0	4.4
13	48.0	4.9
14	52.0	5.9
15	56.0	6.8
16	69.1	9.1

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU08
Identification Mark :UCY20/40/08
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.5% Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.7
4	12.0	1.0
5	16.0	1.4
6	20.0	2.2
7	24.0	2.8
8	28.0	3.2
9	32.0	3.5
10	36.0	4.2
11	40.0	4.7
12	44.0	5.2
13	48.0	6.1
14	52.0	6.8
15	58.3	8.2

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU07
Identification Mark :UCY20/40/07
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 2.0 % Hydrochloric Acid (HCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	0.9
4	12.0	1.5
5	16.0	2.0
6	20.0	2.7
7	24.0	3.0
8	28.0	4.3
9	32.0	4.8
10	36.0	5.4
11	40.0	6.3
12	44.0	7.0
13	48.0	8.1
14	51.5	9.8

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU52
Identification Mark :UCY20/40/52
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.6
4	12.0	0.9
5	16.0	1.3
6	20.0	1.5
7	24.0	1.9
8	28.0	2.4
9	32.0	2.8
10	36.0	3.4
11	40.0	3.9
12	44.0	4.5
13	48.0	5.1
14	52.0	5.7
15	56.0	6.1
16	60.0	6.5
17	64.0	7.4
18	68.0	7.9
19	72.0	8.3
20	76.0	8.7
21	80.0	9.1
22	84.0	10.2
24	86.6	10.4

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU03
Identification Mark :UCY20/40/03
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.5% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.5
4	12.0	0.9
5	16.0	1.3
6	20.0	1.5
7	24.0	1.9
8	28.0	2.4
9	32.0	2.8
10	36.0	3.4
11	40.0	3.9
12	44.0	4.5
13	48.0	5.1
14	52.0	5.7
15	56.0	6.1
16	60.0	6.5
17	64.0	7.4
18	68.0	7.9
19	72.0	8.1
20	76.0	8.4
21	80.1	8.6

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU51
Identification Mark :UCY20/40/51
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.9
4	12.0	1.2
5	16.0	1.6
6	20.0	1.8
7	24.0	2.3
8	28.0	2.8
9	32.0	3.2
10	36.0	3.7
11	40.0	4.5
12	44.0	5.4
13	48.0	5.9
14	52.0	6.6
15	56.0	7.1
16	60.0	7.8
17	64.0	8.5
18	68.0	8.9
19	72.0	9.6
20	75.2	9.8

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU09
Identification Mark :UCY20/40/09
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.5% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	1.2
4	12.0	1.5
5	16.0	1.9
6	20.0	2.5
7	24.0	3.0
8	28.0	4.1
9	32.0	4.3
10	36.0	4.7
11	40.0	5.3
12	44.0	6.2
13	48.0	6.7
14	52.0	7.4
15	56.0	7.6
16	60.0	8.7
17	64.0	9.3
18	68.0	9.7
19	72.0	9.9
20	76.0	10.2
21	81.8	10.5

PULL OUT TEST RESULTS ON UNCOATED BAR [LOADED END]

Test No :AU30
Identification Mark :UCY20/40/30
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 2.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.2
4	12.0	2.0
5	16.0	2.7
6	20.0	3.5
7	24.0	3.9
8	28.0	4.5
9	32.0	4.7
10	36.0	5.3
11	40.0	6.4
12	44.0	6.7
13	48.0	7.3
14	52.0	7.9
15	56.0	8.4
16	60.0	8.7
17	64.0	9.2
18	68.0	9.5
19	72.0	9.7
20	76.0	9.9
21	80.0	10.2
22	82.1	10.3

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC37
Identification Mark :CY20/40/37
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.2
3	8.0	0.6
4	12.0	0.9
5	16.0	1.2
6	20.0	1.4
7	24.0	1.8
8	28.0	2.0
9	32.0	2.3
10	36.0	2.6
11	40.0	2.8
12	44.0	3.2
13	48.0	3.4
14	52.0	3.7
15	56.0	3.9
16	60.0	4.5
17	64.0	5.0
18	68.0	5.5
19	72.0	6.0
20	76.0	6.4
21	80.0	7.2
22	83.1	8.6

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC26
Identification Mark :CY20/40/26
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.5% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.7
4	12.0	1.1
5	16.0	1.4
6	20.0	2.1
7	24.0	2.4
8	28.0	2.6
9	32.0	3.4
10	36.0	4.2
11	40.0	4.5
12	44.0	4.8
13	48.0	5.4
14	52.0	5.9
15	56.0	6.6
16	60.0	7.1
17	64.0	7.6
18	68.0	7.9
19	72.0	8.1
20	76.0	8.2
21	81.4	8.4

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC02
Identification Mark :CY20/40/02
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	0.9
4	12.0	1.3
5	16.0	1.7
6	20.0	2.2
7	24.0	2.5
8	28.0	2.9
9	32.0	3.3
10	36.0	3.6
11	40.0	4.1
12	44.0	4.5
13	48.0	4.9
14	52.0	5.2
15	56.0	5.6
16	60.0	6.1
17	64.0	6.6
18	68.0	7.2
19	72.0	7.6
20	75.4	8.9

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC06
Identification Mark :CY20/40/06
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.5% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	0.9
4	12.0	1.3
5	16.0	1.7
6	20.0	2.2
7	24.0	2.6
8	28.0	2.9
9	32.0	3.2
10	36.0	3.6
11	40.0	4.1
12	44.0	4.5
13	48.0	4.9
14	52.0	5.2
15	56.0	5.6
16	60.0	6.1
17	64.0	6.6
18	68.0	7.2
19	72.0	7.6
20	79.3	8.9

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC28
Identification Mark :CY20/40/28
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 2.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.1
4	12.0	1.5
5	16.0	1.9
6	20.0	2.2
7	24.0	2.7
8	28.0	2.7
9	32.0	3.1
10	36.0	3.3
11	40.0	3.5
12	44.0	3.8
13	48.0	4.5
14	52.0	4.9
15	56.0	6.1
16	60.0	6.8
17	64.0	7.2
18	68.0	7.7
19	72.0	8.1
20	76.0	8.8
21	81.6	9.1

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC42
Identification Mark :CY12/40/42
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.5
4	12.0	0.7
5	16.0	0.9
6	20.0	1.1
7	24.0	1.3
8	28.0	1.5
9	32.0	1.8
10	36.0	2.2
11	40.0	2.6
12	44.0	3.0
13	48.0	3.4
14	52.0	3.8
15	56.0	4.3
16	60.0	4.7
17	64.0	5.1
18	68.0	5.6
19	71.8	6.7

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC23
Identification Mark :CY12/40/23
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.5% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.5
4	12.0	0.9
5	16.0	1.3
6	20.0	1.5
7	24.0	1.9
8	28.0	2.4
9	32.0	2.8
10	36.0	3.4
11	40.0	3.9
12	44.0	4.5
13	48.0	5.1
14	52.0	5.7
15	56.0	6.1
16	60.0	6.5
17	61.3	7.9

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC10
Identification Mark :CY12/40/10
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.9
4	12.0	1.2
5	16.0	1.5
6	20.0	1.6
7	24.0	1.8
8	28.0	2.3
9	32.0	3.2
10	36.0	3.7
11	40.0	4.5
12	44.0	5.4
13	48.0	5.9
14	52.0	6.6
15	56.0	7.1
16	60.0	7.8
17	63.9	9.6

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC35
Identification Mark :CY12/40/35
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.5% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	1.2
4	12.0	1.5
5	16.0	1.6
6	20.0	2.1
7	24.0	2.4
8	28.0	2.8
9	32.0	3.2
10	36.0	3.5
11	40.0	4.1
12	44.0	4.4
13	48.0	4.9
14	52.0	5.2
15	56.0	5.7
16	60.0	6.2
17	64.0	6.8
18	66.7	8.4

PULL OUT TEST RESULTS ON COATED BAR [LOADED END]

Test No :AC31
Identification Mark :CY12/40/31
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 2.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.0
4	12.0	1.7
5	16.0	2.1
6	20.0	2.5
7	24.0	2.9
8	28.0	3.3
9	32.0	3.9
10	36.0	4.3
11	40.0	4.7
12	44.0	5.0
13	48.0	5.2
14	52.0	5.5
15	56.0	6.1
16	60.0	6.4
17	66.9	7.2

PULL OUT TEST RESULT ON UNCOATED BAR [LOADED END]

Test No :AU52
Identification Mark :UCY12/40/52
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.5
4	12.0	0.8
5	16.0	1.0
6	20.0	1.3
7	24.0	1.6
8	28.0	1.9
9	32.0	2.4
10	36.0	3.0
11	40.0	3.5
12	44.0	4.1
13	48.0	4.5
14	52.0	5.1
15	56.0	5.6
16	60.0	6.0
17	64.0	6.4
18	68.0	6.9
19	69.8	7.5

PULL OUT TEST RESULT ON UNCOATED BAR [LOADED END]

Test No :AU52
Identification Mark :UCY12/40/52
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 0.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.3
3	8.0	0.5
4	12.0	0.8
5	16.0	1.0
6	20.0	1.3
7	24.0	1.6
8	28.0	1.9
9	32.0	2.4
10	36.0	3.0
11	40.0	3.5
12	44.0	4.1
13	48.0	4.5
14	52.0	5.1
15	56.0	5.6
16	60.0	6.0
17	64.0	6.4
18	68.0	6.9
19	69.8	7.5

PULL OUT TEST RESULT ON UNCOATED BAR [LOADED END]

Test No :AU22*
Identification Mark :UCY12/40/22*
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.9
4	12.0	1.2
5	16.0	1.6
6	20.0	1.8
7	24.0	2.3
8	28.0	2.6
9	32.0	3.2
10	36.0	3.7
11	40.0	4.5
12	44.0	5.4
13	48.0	5.9
14	52.0	6.6
15	56.0	7.1
16	60.0	7.8
17	64.5	8.9

PULL OUT TEST RESULT ON UNCOATED BAR [LOADED END]

Test No :AU33
Identification Mark :UCY12/40/33
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.5% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	1.2
4	12.0	1.5
5	16.0	1.9
6	20.0	2.5
7	24.0	3.0
8	28.0	4.1
9	32.0	4.3
10	36.0	4.7
11	40.0	5.3
12	44.0	6.2
13	48.0	6.7
14	52.0	7.4
15	56.0	7.6
16	60.0	8.7
17	63.2	9.7

PULL OUT TEST RESULT ON UNCOATED BAR [LOADED END]

Test No :AU49
Identification Mark :UCY12/40/49
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 2.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.2
4	12.0	2.0
5	16.0	2.7
6	20.0	3.5
7	24.0	3.9
8	28.0	4.5
9	32.0	4.7
10	36.0	5.3
11	40.0	5.8
12	44.0	6.4
13	48.0	6.7
14	52.0	7.3
15	56.0	7.9
16	60.0	8.4
17	65.2	8.7

PULL OUT TEST RESULT ON UNCOATED BAR [LOADED END]

Test No :AU22*
Identification Mark :UCY12/40/22*
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	0.9
4	12.0	1.2
5	16.0	1.6
6	20.0	1.8
7	24.0	2.3
8	28.0	2.6
9	32.0	3.2
10	36.0	3.7
11	40.0	4.5
12	44.0	5.4
13	48.0	5.9
14	52.0	6.6
15	56.0	7.1
16	60.0	7.8
17	64.5	8.9

PULL OUT TEST RESULT ON UNCOATED BAR [LOADED END]

Test No :AU33
Identification Mark :UCY12/40/33
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 1.5% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.4
3	8.0	1.2
4	12.0	1.5
5	16.0	1.9
6	20.0	2.5
7	24.0	3.0
8	28.0	4.1
9	32.0	4.3
10	36.0	4.7
11	40.0	5.3
12	44.0	6.2
13	48.0	6.7
14	52.0	7.4
15	56.0	7.6
16	60.0	8.7
17	63.2	9.7

PULL OUT TEST RESULT ON UNCOATED BAR [LOADED END]

Test No :AU49
Identification Mark :UCY12/40/49
Time of immersion in Aggresive Medium (14/4/93 - 6/8/93)
Aggresive Medium : 2.0% Sodium Chloride (NaCl)

S/No	Applied Load (KN)	Loaded End Slip (mm) x 0.1
1	0.0	0.0
2	4.0	0.5
3	8.0	1.2
4	12.0	2.0
5	16.0	2.7
6	20.0	3.5
7	24.0	3.9
8	28.0	4.5
9	32.0	4.7
10	36.0	5.3
11	40.0	5.8
12	44.0	6.4
13	48.0	6.7
14	52.0	7.3
15	56.0	7.9
16	60.0	8.4
17	65.2	8.7