# EFFECT OF CONFINED REINFORCEMENT ON DEVELOPMENT OF HIGH YIELD STRENGTH DEFORMED (HYSD) BARS

**Sahil S.Mansuri**

PG student, Civil Engineering department, PREC Loni

Savitribai Phule Pune University, Maharashtra, India

**Dr. V. R. Rathi**

Professor, Civil Engineering department, PREC Loni

Savitribai Phule Pune University, Maharashtra, India

## ABSTRACT

The practice of using reinforcement in concrete is one of the most effective methods used in construction from very long time. IS codehave many things to utilize while designing the structure for sound and better stability and selection of the material is one of them. Concrete is one of the most important material for construction of various structures and it exists in various grades like M20, M25, M30 etc where 'M' represents mix design value and the succeeding number indicates strength of concrete in MPa.For proving reinforcement to concrete steel bars are used which comes in different grades like Fe250,Fe415 and Fe500.These bars provide greater tensile strength to structure and ultimately improves stability and life of structure.

In this report an attempt is made to identify the effect of hook shapes on development length, percentage of confined reinforcement in compression on bond strength. The change in shape of hook ultimately provides different values of bond stress with different grade of concrete to be used.

**Keywords:** Bond Strength,Development Length, Lap Splices

## 1. INTRODUCTION:

The term 'bond' in reinforced concrete refers to the interaction between the reinforcing steel and the surrounding concrete. Proper bond between steel and concrete ensures that there is no slip between steel bar and concrete under service load. For many years, bond stress was considered in terms of shear stress at the interface between reinforcing bar and concrete.

The Indian codal provision was revised in year 2000, still the development length provisions remains unchanged and it does not cover the effect of several other parameters whereas US codal provisions considered all this parameters. Hence, the provisions of the Indian code are discussed in this topic. The common assumption in Reinforced concrete is that plane section remains plane after bending will be valid only if there is proper bond between steel and surrounding concrete.

The development length is a certain minimum length of the bar and it has to be provided on either side of point of maximum steel stress to prevent the bar from pulling out under tension. When the sufficient development length is not provided then in practical situations bends, hooks and mechanical anchorages can be used.

## 2. LITRATURE REVIEW

Many studies and experiments are carried out on development length of tension and compression side of the bar. **Mohamed H. Haraji and Bilas S. Hamad (2004)** studied the effect of confinement of bond strength between reinforcing steel and concrete. They concluded that for small development length, the concrete confined with local bond conditions has slightly increases the bond strength. The bond strength due to confinement increases in proportion to modulus of elasticity of confining material which is not depend upon yield strength of the material. **Tharman and T Kaku (2013)** studied the development evaluation of reinforcing concrete beam with CFRP Bars. It is then concluded that the anchorage length in hanging support of reinforced concrete beam, the use of CFRP will be having high tensile strength and no plastic behavior. Additional length of embedded bar has significant influence on increasing capacity of the beams. **David Darwin et.al (2017)** had discovered that there is significant difference between the clear spacing between bars and concrete covers indicates that the bar force increases in linear but non proportional manner, hence the required development length must be increased more rapidly as per steel stress values.

## 3. TESTS ON MATERIAL:

For the further experiment various materials like cement, sand, aggregate and water is used and various tests are performed to check quality of material. Following data shows results.

### 3.1 Tests on Aggregate:

| Sr.No | Material | Specific Gravity | Fineness Modulus |
|---|---|---|---|
| 1 | Coarse Aggregate | 2.9 | 7.01 |
| 2 | Fine Aggregate | 2.6 | 2.94 |

### 3.2 Tests on Cement:

| Sr.No | Tests Performed | Values |
|---|---|---|
| 1 | Fineness Of Cement | 7.25 % |
| 2 | Standard Consistency | 33 mm |
| 3 | Initial Setting Time | 45 Min |
| 4 | Normal Setting Time | 580 Min |

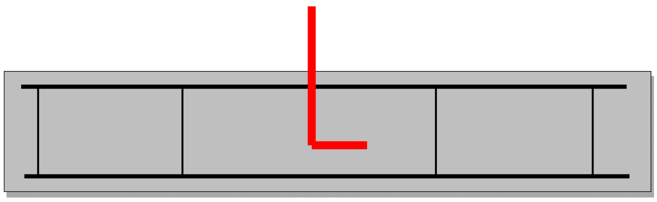
### 3.3 Mix Design Values:

The proportion of M20, M25 and M30 are made for experimental purpose.

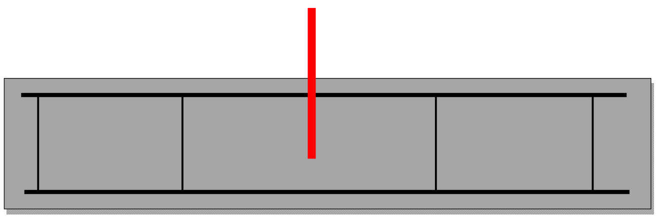
| Grade | Cement | Fine Aggregate | Coarse Aggregate | Water | Ratio |
|---|---|---|---|---|---|
| M20 | 345 Kg | 719.7 Kg | 1166 Kg | 191.58 Lit | 1:2:3.3:0.56 |
| M25 | 399.125 Kg | 456.95 Kg | 793.01 Kg | 191.58 Lit | 1:1.14:1.98:0.48 |
| M30 | 425.73 Kg | 683.3 Kg | 1168 Kg | 191.58 Lit | 1:1.52:2.64:0.45 |

## 4. EXPERIMENT AND RESULTS:

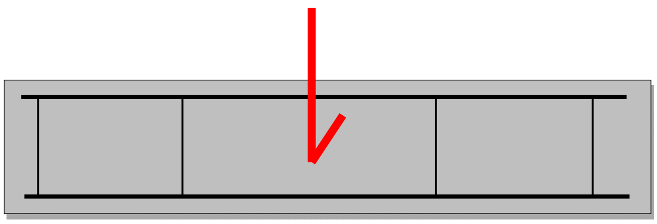
To determine the actual bond between steel and concrete, a mix of grades like M20, M25 and M30 are to be made and along with that bars of various diameter like 12mm, 16mm and 20mm are used.The hooks or bends provided to all the bars diameters are abbreviated as SB1, SB2, SB3, SB4 and SB5.Following are provided abbreviations to the hooks.



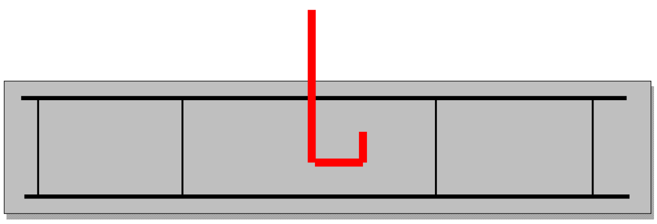
- SB2



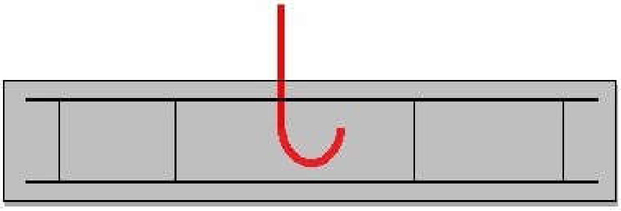
- SB1



- SB3



- SB4



- SB5

For obtaining the results of the specimen casted a pull out test was performed on Universal Testing Machine (UTM). Following are results obtained for the experiments

4.1 Results obtained for M20 Grade**:**

| M20 GRADE (12mm bar) | | | | | | | |
|---|---|---|---|---|---|---|---|
| No | Bend/Hook shape | Yield Stress ($N/mm^2$) | Tensile Strength ($N/mm^2$) | Load at peak (kN) | Load at Break (kN) | Elongation at Peak (mm) | Elongation at break (mm) |
| 1 | SB1 | 289.403 | 339.111 | 89.790 | 22.032 | 44.442 | 52.107 |
| 2 | SB2 | 301.493 | 351.593 | 98.921 | 34.195 | 52.192 | 58.825 |
| 3 | SB3 | 316.925 | 359.433 | 104.105 | 42.210 | 57.302 | 66.110 |
| 4 | SB4 | 319.129 | 363.785 | 100.202 | 44.356 | 62.101 | 65.025 |
| 5 | SB5 | 337.554 | 373.023 | 112.101 | 51.301 | 66.387 | 71.002 |

Table: 4.1.1 Result obtained for M20- 12mmØ for different hooks and shapes patterns

| M20 GRADE (16mm bar) | | | | | | | |
|---|---|---|---|---|---|---|---|
| No | Bend/Hook shape | Yield Stress ($N/mm^2$) | Tensile Strength ($N/mm^2$) | Load at peak (kN) | Load at Break (kN) | Elongation at Peak (mm) | Elongation at break (mm) |
| 1 | SB1 | 298.025 | 389.514 | 102.020 | 58.031 | 54.123 | 67.017 |
| 2 | SB2 | 309.452 | 401.228 | 109.425 | 63.119 | 61.663 | 73.120 |
| 3 | SB3 | 326.340 | 415.021 | 115.142 | 66.631 | 68.000 | 78.249 |
| 4 | SB4 | 335.019 | 419.874 | 124.502 | 74.825 | 74.511 | 82.889 |
| 5 | SB5 | 343.009 | 425.019 | 134.512 | 81.021 | 79.089 | 83.014 |

Table: 4.1.2 Result obtained for M20- 16mmØ for different hooks and shapes patterns

| M20 GRADE (20mm bar) | | | | | | | |
|---|---|---|---|---|---|---|---|
| No | Bend/Hook shape | Yield Stress ($N/mm^2$) | Tensile Strength ($N/mm^2$) | Load at peak (kN) | Load at Break (kN) | Elongation at Peak (mm) | Elongation at break (mm) |
| 1 | SB1 | 308.198 | 412.020 | 121.684 | 74.258 | 63.286 | 61.647 |
| 2 | SB2 | 320.425 | 421.610 | 133.701 | 80.086 | 69.431 | 67.012 |
| 3 | SB3 | 332.808 | 431.000 | 141.942 | 88.079 | 73.458 | 73.755 |
| 4 | SB4 | 342.999 | 441.363 | 153.062 | 94.704 | 79.068 | 81.086 |
| 5 | SB5 | 358.012 | 452.713 | 164.000 | 103.052 | 82.623 | 89.125 |

Table: 4.1.3 Result obtained for M20- 20mmØ for different hooks and shapes patterns

4.2 Results obtained for M25 Grade:

| M25 GRADE (12mm bar) | | | | | | | |
|---|---|---|---|---|---|---|---|
| No | Bend/Hook shape | Yield Stress ($N/mm^2$) | Tensile Strength ($N/mm^2$) | Load at peak (kN) | Load at Break (kN) | Elongation at Peak (mm) | Elongation at break (mm) |
| 1 | SB1 | 304.512 | 342.040 | 98.013 | 37.120 | 51.586 | 61.627 |
| 2 | SB2 | 317.729 | 357.018 | 116.123 | 42.314 | 57.028 | 67.105 |
| 3 | SB3 | 330.121 | 369.785 | 124.001 | 59.041 | 68.052 | 77.789 |
| 4 | SB4 | 342.082 | 382.125 | 135.034 | 67.621 | 75.710 | 85.025 |
| 5 | SB5 | 355.501 | 399.021 | 144.025 | 81.124 | 89.642 | 98.197 |

Table: 4.2.1 Result obtained for M25- 12mmØ for different hooks and shapes patterns

| M25 GRADE (16mm bar) | | | | | | | |
|---|---|---|---|---|---|---|---|
| No | Bend/Hook shape | Yield Stress ($N/mm^2$) | Tensile Strength ($N/mm^2$) | Load at peak (kN) | Load at Break (kN) | Elongation at Peak (mm) | Elongation at break (mm) |
| 1 | SB1 | 317.729 | 410.721 | 105.480 | 49.420 | 63.131 | 72.521 |
| 2 | SB2 | 329.100 | 423.142 | 119.421 | 58.175 | 69.412 | 81.121 |
| 3 | SB3 | 341.842 | 431.089 | 127.576 | 68.954 | 75.105 | 91.920 |
| 4 | SB4 | 352.014 | 440.012 | 134.728 | 79.951 | 81.234 | 99.925 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5 | SB5 | 367.852 | 458.124 | 143.008 | 86.546 | 92.045 | 113.020 |

Table: 4.2.2 Result obtained for M25- 16mmØ for different hooks and shapes patterns

| **M25 GRADE (20mm bar)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| No | Bend/Hook shape | Yield Stress ($N/mm^2$) | Tensile Strength ($N/mm^2$) | Load at peak (kN) | Load at Break (kN) | Elongation at Peak (mm) | Elongation at break (mm) |
| 1 | SB1 | 330.121 | 431.380 | 118.120 | 56.943 | 72.740 | 83.120 |
| 2 | SB2 | 342.056 | 440.120 | 129.489 | 67.621 | 83.820 | 97.975 |
| 3 | SB3 | 356.085 | 458.001 | 139.873 | 79.254 | 91.512 | 106.125 |
| 4 | SB4 | 368.645 | 471.251 | 151.120 | 88.824 | 103.120 | 119.941 |
| 5 | SB5 | 383.357 | 783.124 | 162.024 | 101.125 | 114.120 | 134.746 |

Table: 4.2.3 Result obtained for M25- 20mmØ for different hooks and shapes patterns

4.3 Results obtained for M30 Grade:

| **M30 GRADE (12mm bar)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| No | Bend/Hook shape | Yield Stress ($N/mm^2$) | Tensile Strength ($N/mm^2$) | Load at peak (kN) | Load at Break (kN) | Elongation at Peak (mm) | Elongation at break (mm) |
| 1 | SB1 | 348.124 | 453.845 | 129.245 | 62.123 | 71.720 | 86.825 |
| 2 | SB2 | 361.587 | 464.212 | 134.201 | 70.125 | 81.254 | 92.123 |
| 3 | SB3 | 372.130 | 473.487 | 143.246 | 82.476 | 92.925 | 106.125 |
| 4 | SB4 | 385.846 | 482.346 | 151.246 | 89.891 | 105.146 | 118.142 |
| 5 | SB5 | 402.412 | 493.124 | 158.124 | 99.941 | 119.834 | 127.521 |

Table: 4.3.1 Result obtained for M30- 12mmØ for different hooks and shapes patterns

| M30 GRADE (16mm bar) | | | | | | | |
|---|---|---|---|---|---|---|---|
| No | Bend/Hook shape | Yield Stress ($N/mm^2$) | Tensile Strength ($N/mm^2$) | Load at peak (kN) | Load at Break (kN) | Elongation at Peak (mm) | Elongation at break (mm) |
| 1 | SB1 | 327.245 | 452.125 | 105.127 | 53.268 | 69.653 | 75.162 |
| 2 | SB2 | 339.472 | 468.239 | 117.124 | 63.412 | 79.778 | 86.542 |
| 3 | SB3 | 352.479 | 476.645 | 129.249 | 75.124 | 89.124 | 93.134 |
| 4 | SB4 | 369.754 | 489.234 | 142.412 | 88.213 | 96.124 | 104.120 |
| 5 | SB5 | 386.042 | 501.014 | 162.124 | 101.124 | 109.124 | 114.102 |

Table: 4.3.2 Result obtained for M30- 16mmØ for different hooks and shapes patterns

| M30 GRADE (20mm bar) | | | | | | | |
|---|---|---|---|---|---|---|---|
| No | Bend/Hook shape | Yield Stress ($N/mm^2$) | Tensile Strength ($N/mm^2$) | Load at peak (kN) | Load at Break (kN) | Elongation at Peak (mm) | Elongation at break (mm) |
| 1 | SB1 | 330.124 | 476.214 | 118.124 | 56.348 | 79.124 | 83.825 |
| 2 | SB2 | 348.124 | 482.124 | 129.465 | 69.215 | 88.825 | 92.912 |
| 3 | SB3 | 361.745 | 499.021 | 142.124 | 81.124 | 98.124 | 101.248 |
| 4 | SB4 | 375.641 | 511.034 | 161.246 | 92.124 | 113.014 | 119.142 |
| 5 | SB5 | 391.548 | 528.415 | 175.124 | 101.124 | 119.025 | 129.246 |

Table: 4.3.3 Result obtained for M30- 20mmØ for different hooks and shapes patterns

4.4 Graphs ofthe Results Obtained

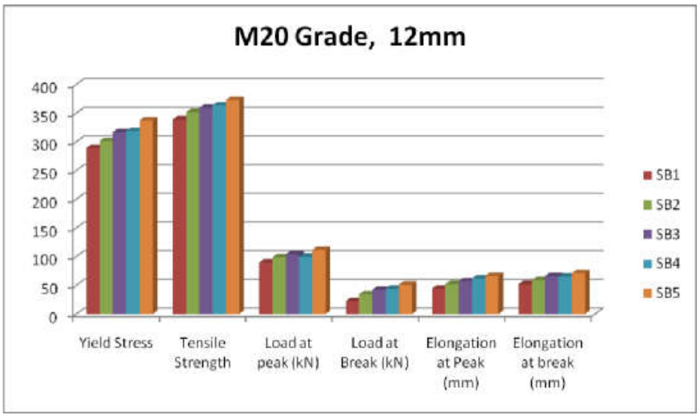



Fig 4.4.1:- Graphical representation of table 4.1.1

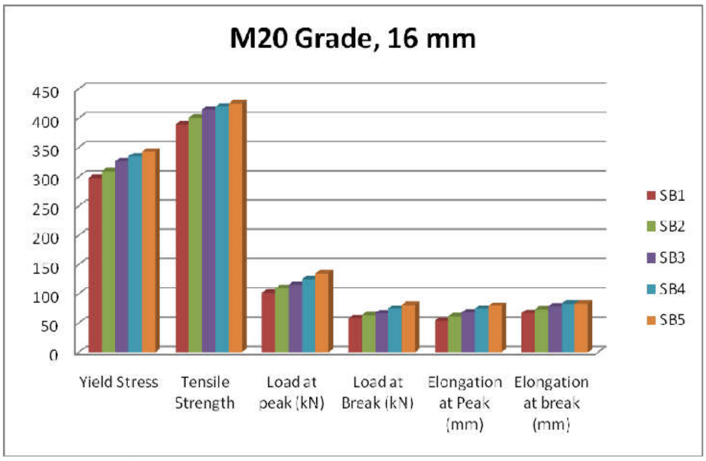



Fig 4.4.1:- Graphical representation of table 4.1.2

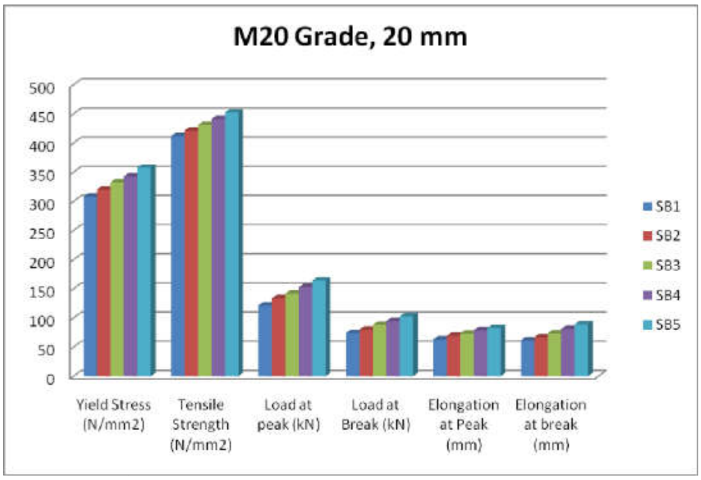



Fig 4.4.1:- Graphical representation of table 4.1.3

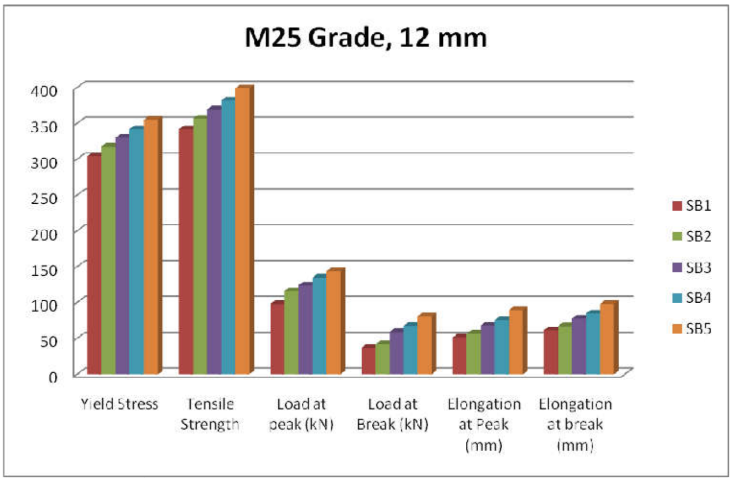



Fig 4.4.1:-Graphical representation of table 4.2.1

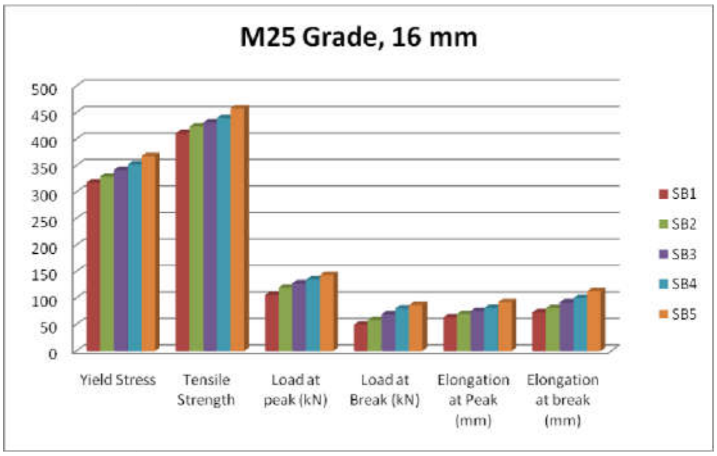



Fig 4.4.1:- Graphical representation of table 4.2.2

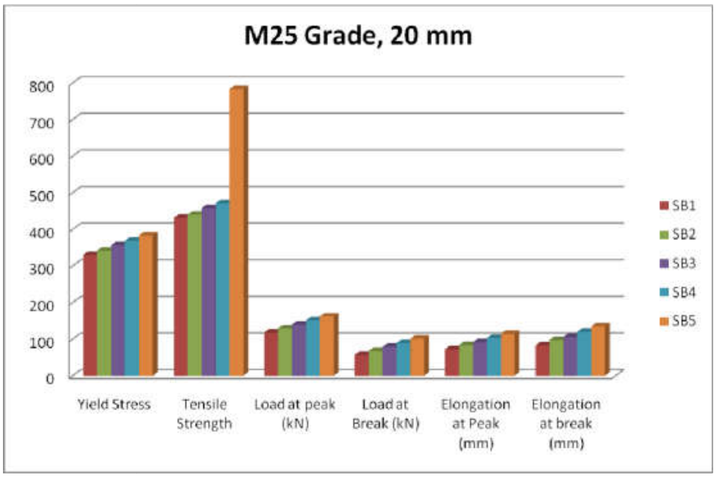



Fig 4.4.1:- Graphical representation of table 4.2.3

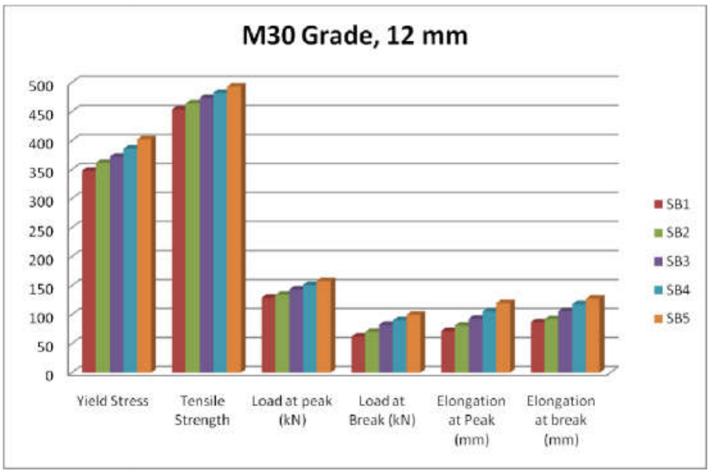



Fig 4.4.1:- Graphical representation of table 4.3.1

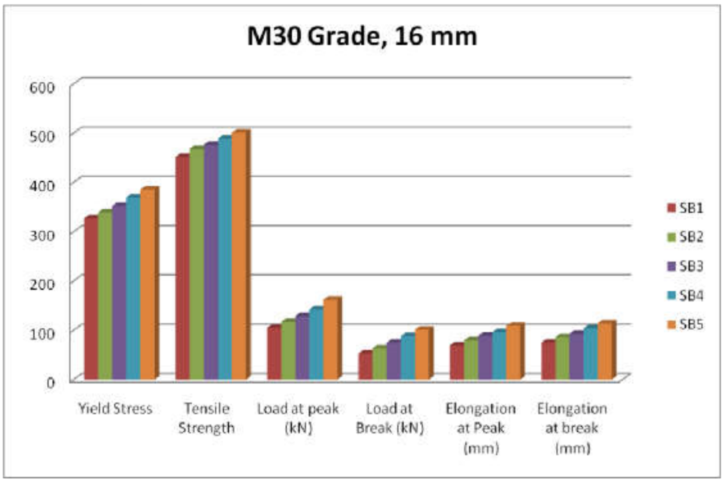



Fig 4.4.1:- Graphical representation of table 4.3.2

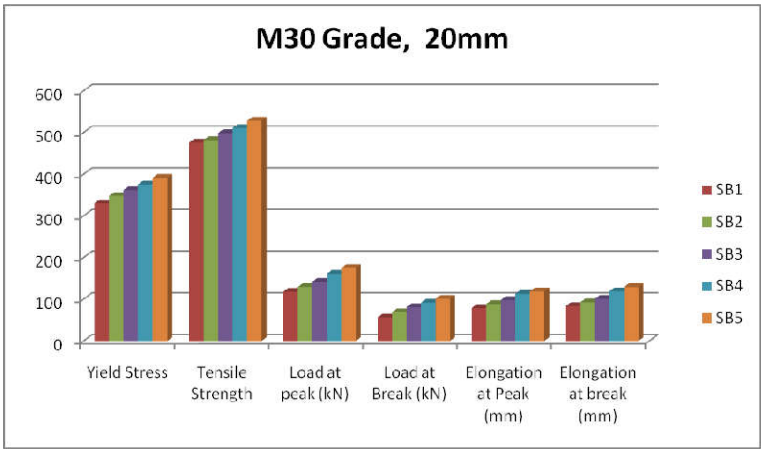



Fig 4.4.1:- Graphical representation of table 4.3.3

## 5. CONCLUSION

From the experiment conducted in the report it can be concluded that bond strength of the concrete and steel bars depends upon various factors. The bond between steel and concrete seems to be increasing by increase in diameter of bar, change in hook shape and Grade of concrete. The pull in upward direction determines the tension produced in specimen and the point at which it breaks.

Some of the factors which are discussed in the report are

1. GRADE OF THE CONCRETE:-

With increase in the grade of the concrete bond strength between steel and concrete also increases. The grade of concrete plays important role in increasing the bond value between steel and concrete. As the grade value increases the interaction of bond is improved and better results are obtained.

2. DIAMETER OF BAR:

Change in diameter of bar ultimately increases the tensile strength of the bar. The greater the diameter of the bar greater will be bond value between steel and concrete.

3. SHAPE OF HOOKS :

Shape and bends provided as per calculated bending schedule is very important aspect while bending the bar. The various hooks as discussed provides better grip and proven to have higher bond value and can bear higher pull in tension condition.

## 6. REFERENCES

1. J. Sperry, D. Darwin, A. Lepage, S. Yasso, A. Ajaam,-"Conventional Effect and High Strength Steel Hooked Bars".
2. David Darwin, Steven L. McCabe, Idun and Steven P. Schoenekase,- " Development length criteria : Bars not confined by transverse reinforcement''
3. Mohamed H Harajli, Bilas S Hamad, Ahmad A Rteil,-"Effect of confinement of bond strength between steel bars and concrete''
4. N Subramanian (4), have studied "Development length of reinforcing bars- Need to revise Indian Codal provision"
5. Jeffery H. Greenwald, Jason J. Thompson, David L. McLean -"Effects of confinement reinforcement on bar splice performance"
6. Jose L.G. Marques and James O. Jirsa - "A Study of Hooked Bar Anchorages in beam-Column Joints"
7. R. Tharman and T. Kaku - "Development Length Evaluation of Reinforced Concrete Beam with CFRP Bars"
8. V.Kalyanaraman- 'Special Design Requirements: A Comparison of IS 456-2000 With ACI 318-77''