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Mild Steel Twisted Bars for Concrete Reinforcement

Dr. S. M. K. CHETTY & SURINDER SINGH

CENTRAL BUILDING RESEARCH INSTITUTE
ROORKEE, (U. P.)
India

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Dr S. M. K. Chetty and Surinder Singh

The use of twisted bars for concrete reinforcement was recommended by the Central Building Research Institute, Roorkee, as early as 1954. The Institute had, at the same time, developed a machine for twisting bars. Although twisted bars have been codified by the Indian Standards Institution their use in construction has not been extensive for one reason or another. It is desirable to use high grade concrete for the optimum utilization of twisted reinforcement, but in this paper its design aspects and economics are treated in conjunction with concrete of grade M 150.

Single- and twin-twisted bars had been in use for a number of years in most industrialized countries, until alternative special types of deformed bars were placed on the market. In India, single-twisted bars have been used for the Integral Coach Factory at Perambur where 1100 tons of steel were consumed; the saving in steel due to the use of twisted steel bars was reported to be 28 per cent [1,2]. Twisted bars are also being used for the construction of the office building of the railway headquarters of the newly-formed South-Central Zone at Secundrabad; a rough estimate shows that the saving in using twisted bars instead of plain bars is about 30 per cent[3].

Mild steel bars normally used as reinforcement have an yield stress between 2400 to 2600 kg/cm² and an ultimate strength of 4200 kg/cm²[,4]. Since the excessive strain in the steel beyond its yield point causes failure of the structural member by crushing of the concrete, it is the yield point and not the ultimate strength that is considered for design purposes. Thus, only about 60 to 65 per cent of the ultimate strength of the steel is made use of if plain mild steel bars are used. In order to utilize the strength of mild steel to a greater extent it is subjected to certain physical processes that raise its yield point. A simple process consists in cold twisting of mild steel bars till they are torsionally strained to a certain degree beyond the yield point. The steel then acquires an yield point between 4200 to 4950 kg/cm²[,4] and an ultimate strength of 4950 to 5650 kg/cm² (*Fig* 1). In this manner, about 85 per cent of the ultimate strength of steel becomes available for design purposes. A permissible stress in steel between 1300 and 1900 kg/cm² can then be adopted in design compared with only between 1,000 and 1,400 kg/cm² for plain bars. This type of steel is covered by IS : 1786-1961, *Specifications for cold twisted steel bars for concrete reinforcement*, and its use is codified in IS : 456-1964, *Code of practice for plain and reinforced concrete*. The cost of twisting bars is about Rs 100 per ton and twisting machines can be easily installed even at the project sites. It should be noted that no welding must be done after the bars are twisted.

Advantages of twisted bars

The use of single-twisted bars in reinforced concrete construction in place of plain bars results in the following advantages :

- Permissible stresses being greater, there is a saving in steel
- Each bar gets automatically tested during twisting ; this is a special advantage when using untested bars
- Concrete can be placed more easily because of the reduction in the number of bars used in a member
- The charges for the fabrication of reinforcement are less because of the reduction in the quantity of steel
- Twisted bars are comparatively more fire resistant[5]
- Web widths of members can be reduced as the number of bars is very likely less
- Twisted bars permit the efficient use of high-strength concrete which otherwise is not economical using

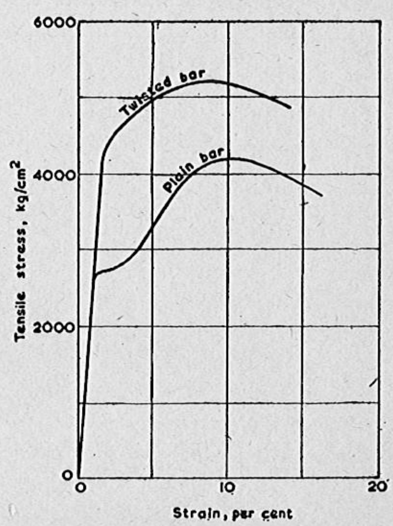

Fig 1 Showing the stress-strain curves for plain and twisted mild steel bars

Dr S. M. K. Chetty, Scientist Coordinator, Central Building Research Institute, Roorkee

Surinder Singh, Scientist, Central Building Research Institute, Roorkee

mild steel bars and the working stress method of design[6]

As compared to hot-rolled bars, cold-worked bars deflect gradually and give better warning before failure[7].

Design and economics

Comparative designs, carried out both by the working stress and the ultimate load method in accordance with IS : 456-1964, have shown that economy results from the use of twisted bars. Continuous spans varying from 2·5 to 4·5 m for slabs and 4 to 8 m for beams, with increments of 0·5 m, were considered in the designs. The concrete grade adopted was M 150 which corresponds to the 1 : 2 : 4 nominal mix. This mix was adopted because it is commonly used in reinforced concrete work and because users are often reluctant to use high-grade concrete, though with a higher permissible stress in steel it is preferable to use a higher grade of concrete.

The anchorage length required for a reinforcing bar either in compression or tension zone depends upon the actual stresses developed in it when other factors affecting it are kept constant. In the case of twisted bars, a greater anchorage length is required along with additional lengths for end hooks[8]. All these factors have been taken into account in calculating the comparative quantities of steel for the various spans.

Continuous slabs : Normally the support moment is considered for determining the depth of the slab and this is maintained throughout with suitable modifications in the main reinforcement required at midspan. In designing slabs by the working stress method using twisted bars an extra depth of section would be required since the value of the bending moment constant is less; in order to maintain the same depth of slab as required for

TABLE 1 Consumption of concrete and steel per square metre for one-way slab using plain and twisted bars

Span m	*Working stress method*				*Ultimate load method*			
	Plain bars		*Twisted bars*		*Plain bars*		*Twisted bars*	
	Concrete, m³	*Steel, kg*	*Concrete, m³*	*Steel, kg*	*Concrete, m³*	*Steel, kg*	*Concrete, m³*	*Steel, kg*
2·5	0·08	4·77	0·08	0·96* + 2·84	0·08	4·53	0·08	0·96* + 2·76
3·0	0·10	5·58	0·10	1·22* + 3·48	0·09	5·49	0·09	1·10* + 2·40
3·5	0·12	6·57	0·12	1·47* + 3·73	0·10	6·90	0·10	1·22* + 3·00
4·0	0·13	7·88	0·13	1·57* + 4·83	0·12	7·64	0·12	1·47* + 3·27
4·5	0·15	9·13	0·15	1·83* + 5·72	0·13	8·91	0·13	1·57* + 3·73

* Indicates the quantity of plain bars used as distribution steel.

TABLE 2 Savings in weight and cost for various spans of slab by using twisted bars instead of plain reinforcement

Span of slab, m	*Working stress method*			*Ultimate load method*		
	Saving in steel, per cent		*Saving in overall cost, per cent*	*Saving in steel, cost, per cent*		*Saving in overall cost, per cent*
	Weight	*Cost*		*Weight*	*Cost*	
2·5	20·3	15·9	4·7	17·9	13·2	3·8
3·0	15·8	11·3	3·4	36·2	33·0	10·9
3·5	20·9	14·8	4·6	38·9	35·6	12·4
4·0	18·8	14·3	4·8	38·0	32·4	12·0
4·5	17·3	12·5	4·4	40·5	37·3	13·7

Notes: This analysis is based on market prices prevailing in Delhi in July 1966.
The extra cost of twisting bars is Rs 100 per tonne.

TABLE 3 Consumption of concrete and steel for T-beams using plain and twisted bars

Span, m	*Working stress method*				*Ultimate load method*			
	Plain bars		*Twisted bars*		*Plain bars*		*Twisted bars*	
	Concrete, m³	*Steel kg*	*Concrete, m³*	*Steel, kg*	*Concrete, m³*	*Steel, kg*	*Concrete, m³*	*Steel, kg*
4·5	0·26	60·51	0·26	25·54* 27·40	0·26	56·59	0·26	18·76* 22·58
5·0	0·39	77·74	0·39	30·77* 36·45	0·39	74·04	0·39	21·38* 31·28
5·5	0·50	89·13	0·50	36·88* 43·10	0·50	85·31	0·50	23·96* 37·97
6·0	0·59	104·08	0·59	35·92* 55·23	0·59	95·96	0·59	24·90* 43·78
6·5	0·72	121·55	0·72	39·85* 55·23	0·72	113·71	0·72	27·43* 52·04
7·0	0·84	136·29	0·84	45·49* 72·60	0·84	130·27	0·84	27·88* 63·02
7·5	0·99	153·90	0·99	48·91* 85·29	0·99	147·22	0·99	31·50* 71·61
8·0	1·18	167·40	1·18	42·26* 105·62	1·18	151·95	1·18	30·28* 80·12

* Indicates the quantity of plain bars used as distribution and compression steel.

TABLE 4 Savings in weight and cost for different spans of T-beam by using twisted bars instead of plain reinforcement

Span of beam, m	*Working stress method*			*Ultimate load method*		
	Saving in steel, per cent		*Saving in overall cost, per cent*	*Saving in steel, per cent*		*Saving in overall cost, per cent*
	Weight	*Cost*		*Weight*	*Cost*	
4·5	12·5	9·1	6·3	26·9	23·9	16·4
5·0	13·5	9·0	6·0	28·9	25·7	16·8
5·5	10·3	6·6	4·2	27·4	24·0	15·1
6·0	12·4	8·4	5·4	29·5	24·9	15·4
6·5	13·9	9·9	6·2	30·1	26·6	16·3
7·0	13·4	9·3	5·8	30·2	26·6	16·1
7·5	12·8	8·6	5·2	30·0	26·3	15·7
8·0	11·7	6·9	4·0	27·4	23·3	13·1

Notes: This analysis is based on market prices prevailing in Delhi in July 1966.
The extra cost of twisting bars is Rs 100 per tonne.

plain bars, either a high-grade concrete should be used or the compression zone should be reinforced. However, in the case of continuous slabs the need for using high-grade concrete will not arise as in practice the arrangement of the bars is such that there always exists reinforcement in the compression zone at the supports which can be taken advantage of in providing the necessary resistance. In the design for various spans the depth was determined for the moment at the support section considering plain bars, and this was maintained for the twisted bars as well. The necessary checks were made to ensure that adequate reinforcement was available in the compression zone for the latter case. In the ultimate load method of design, comparatively low depths are obtained for a balanced design, for both plain and twisted bars. The depths were, therefore, increased to satisfy the limits of the span-depth ratios specified in the code. In view of this, the compression zone would be adequate even when twisted bars were used.

The comparative consumption of concrete and steel per square metre is given in *Table* 1. It can be seen that in the design of slabs using twisted bars, plain bars have been used as distribution reinforcement. The savings in the weight and cost of steel using twisted reinforcement for the various spans of slabs are indicated in *Table* 2.

Continuous T-beams : Normally the depth of a T-beam is obtained for the moments occurring at midspan and this is always more than that indicated by balanced design. In view of this the compression zone will not be weak even when twisted bars are used. At supports the section is designed as a doubly reinforced section or on the steel-beam theory. The former method was adopted here.

The comparative quantities of concrete and steel required for various spans are shown in *Table* 3. The steel quantities with the asterisk indicate plain mild steel bars used in conjunction with twisted bars. These plain bars have been used for stirrups and compression reinforcement required at the supports. Savings in the weight and cost of the steel and in overall cost are shown in *Table* 4.

Tables 2 *and* 4 indicate that the use of twisted bars offer on an average a saving in weight of steel of 19 per cent and 13 per cent for slabs and beams, respectively, when the working stress method is employed. When the ultimate load method is used, the savings are 38 per cent and 29 per cent. As regards the savings in overall cost, they are about 4·5 per cent and 5·5 per cent in slabs and beams, respectively, with the working stress method. The corresponding savings with the ultimate load method of design are 12 per cent and 15·5 per cent. In view of the correspondingly greater economy using the ultimate load method it is desirable that this method be employed when using twisted steel.

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