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Shear Strengthening of Existing Bridge Structure using Carbon Textile-Reinforced Mortar

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***Abstract*—The carbon textile-reinforced mortar is more effective and innovative technique to improve the shear strength of reinforced concrete component has been investigated. The study comprises with the comparative statement of properties of CRT reinforced concrete with conventional concrete based on experiments performed in the laboratory. This research includes of large-scale beam testing on shear response of reinforced concrete beams strengthened with textile-reinforced mortar and to be compared with the same sized conventional beams. This research also proposed study on the strength of the M50 grade reinforced concrete cubes strengthened with carbonized textile fiber sheets. The cubes and beams have been subjected to 7, 14 and 28 days of curing and the results for compression tests are noted. It was found that the cubes subjected to 28 days of curing period showed effective increase in strength gain than the conventional cubes. Results of the beam testing demonstrated that the shear strength gain caused by strengthening was in the range of 51% to 100% depending on the amount of internal stirrups and number of textile-reinforced mortar layers.**

Keywords: Carbon Textile Fibers, M50 Concrete, Shear strength analysis, curing

1. INTRODUCTION:

The carbon textile sheet are used to increase the shear resistance of reinforced concrete members is investigated in this study. TRM may be considered as an alternative to fiber reinforced polymers (FRP), providing solutions to many of the problems associated with application of the latter without compromising much the performance of strengthened members. Based on the experiment, we can say that textile-mortar jacketing makes it better in shear resistance; the shear strength increases with the number of increasing layer. The layers applied are sufficient to transform shear failure to flexural failure. The CTRM layer is a combination of an anticorrosion carbon fiber reinforced polymer fabric and an efficient mortar.

In this paper, the strengthening method and the experimental results obtained by applying a thin layer of textile-reinforced mortar technique to improve the shear response of reinforced concrete beams has been investigated.

Related studies on textile reinforced concrete used for the strengthening and repair of RC beams, notably in relation to shear strengthening, are even less. The use of carbon textile fiber as externally bonded (EB) reinforcement in shear strengthening of RC members has become very popular since last two decades. Yet the TFRC strengthening technique has a few disadvantages mainly due to the use of epoxy resins, high cost, also shows poor performance at high temperatures, can't be applied on wet surfaces.

In an attempt to overcome the problems arising from the use of epoxies, researchers have introduced a novel composite material, namely textile-reinforced mortar (TRM), which combines advanced fibers in form of textiles (with open-mesh configuration) matrices, such as cement-based mortars. Over the last decade it has been reported in the literature that TRM is a very promising alternative to the FRP retrofitting solution. TRM has been used for the strengthening of RC members and, as well as for the seismic retrofitting of masonry-infilled RC frames common. It is clear that the existing literature does not cover adequately the subject of experimental application of the strengthening system CTRC when used in shear strengthening of concrete members. This paper presents the systematic study on the effectiveness of CTRC sheets in shear strengthening of RC beams. The investigations address additional parameters including the number of layers and the strengthening configuration.

Details are provided in the following sections.

2. AIM AND OBJECTIVES OF THE STUDY:

The project aims to investigate shear response of RC beams strengthened in shear with TRM and through the conclusions of provide recommendations for future studies in the field.

The overall objective of the current study is to investigate the shear response of RC beams strengthened in shear with TRM. The detailed objectives are listed herein:

- To study the physical properties of TRMs by conducting durability tests on M50 Grade TRM concrete cubes
- Examine the viability of using TRM strengthening system to improve the shear response of RC beams
- Demonstrate the application of TRM for the strengthening of existing bridge structures.

3. LITERATURE REVIEW:

Various authors presented studies on bond characteristics between TRM and concrete . Previous studies on shear strengthening of RC beams with TRM are then summarized. Based on the literature review, test variables affecting shear strength of RC beams strengthened with TRM are identified and discussed.

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Martin Herbrand, Viviane Adam, Martin Classen, Dominik Kueres and Josef Hegger (19 September 2017) - Strengthening of Existing Bridge Structures for Shear And Bending with Carbon Textile-Reinforced Mortar- In this paper, the strengthening method and the experimental results obtained at RWTH Aachen University are presented.

Zoi C. Tetta, Lampros N. Koutas, Dionysios A. Bournas (2015) -Textile-reinforced mortar (TRM) versus fiber-reinforced polymers (FRP) in shear strengthening of concrete beams- This paper presents an experimental study on shear strengthening of rectangular reinforced concrete (RC) beams with advanced composite materials.

Thanasis C. Triantafillou, Catherine G. Papanicolaou (2006) - the authors straightforward presents the Shear strengthening of reinforced concrete members with textile reinforced mortar (TRM) jackets. And the Modelling of reinforced concrete members strengthened in shear with TRM jackets is presented by the proper experiment as well they had derived jackets and its effectiveness.

Frederik Teworte, Martin Herbrand, Josef Hegger (2015)- Structural Assessment of Concrete Bridges in Germany— Shear Resistance under Static and Fatigue Loading- In this paper, modified approaches for the static and fatigue shear assessment of existing bridges considering the provided shear reinforcement are presented, which were implemented in an updated guidelineFirst, confirm that you have the correct template for your paper size. This template has been tailored for output on the A4 paper size. If you are using US letter-sized paper, please close this file and download the file "MSW_USltr_format".

4. EXPERIMENTAL PROGRAMME:

4.1 Test specimens and investigated parameters:

The main objective of this study was to study the effectiveness of CTRC in shear strengthening of RC beams. A total of eighteen rectangular RC beams (cross-section dimensions of 150 x 150 x 700 mm.) were constructed and tested as simply supported in (non-symmetric) three-point bending as shown in Fig. 1. The total length of the beams was equal to 700 mm, whereas the effective flexural span was equal to 600 mm (Fig. 1b), providing adequate anchorage length to the longitudinal reinforcement.

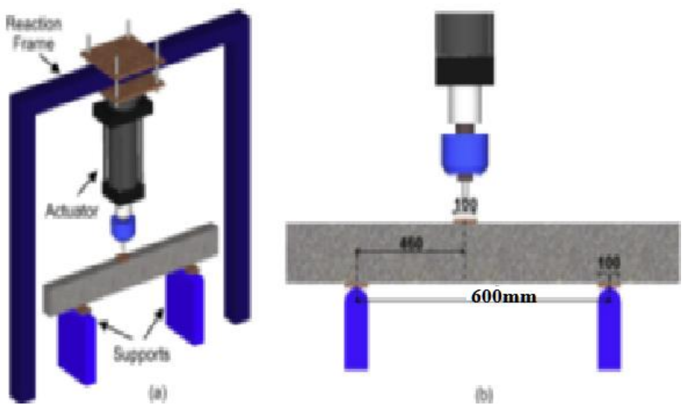

Figure 1: Test set-up: (a) Overall 3D view; (b) front view

Strengthening was applied only at the critical shear span aiming to increase its shear resistance. By design, the shear force demand in order to develop the full flexural capacity of the (unretrofitted) beams was targeted to be 3 times their shear capacity.

The key investigated parameters of this study comprise: (a) the strengthening system (CTRC), (b) the strengthening configuration, and (c) the number of layers. One beam was tested as-built without receiving strengthening and served as control specimen

Out of eighteen beams the specimens are varied as: (a) the first group received one layer of CTRC sheet, (b) the second consisted of two layers of CTRC sheets. Both these arrangements are repeated with beams having different stirrups and longitudinal reinforcements.

Prior to the beam tests, cube tests were conducted to determine the mechanical aspects of the M50 grade concrete cubes covered with textile fiber sheets on two sides. These cubes are then compared with conventional M50 grade cubes and the difference in the results is presented further.

Nine cubes for strengthening were casted and nine conventional cubes were casted for study with 7, 14 and 28 days curing periods.

4.2 Effect of Method of Application:

Contained (2013) used two methods to apply CTRM layers to tested specimens: hand lay-up directly on the beam, and bonding of precast plates using epoxy resin. Experimental results from the literature showed that the method of application of CTRM to the beams did not significantly affect the strength gains of the strengthened specimens and hence, hand application of the sheets is done to the beams and cube specimens in this study.

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4.3 Materials Properties:

Materials used in Concrete:

The materials used in the experimental work listed below were used preparation of the specimens:

- Portland cement (PPC) : Shankar cements
- M sand : Clean River sand purchased from Siddeheshwar transport
- Textile fiber : Treated carbon fibre - procured from Carbon Rotofluid Pvt. ltd (ISO 9001-2008 Certified Company) L-464, G.I.D.C. Odhav Ahmedabad-382 415 India
- Water : Collected from local fresh water sources
- Coarse aggregate : Aggregates passing through 20mm IS sieve

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Carbon Woven Reinforcement Fabric- Technical Data:
240 GSM – 2X2 Twill Woven Carbon Fabric

Table -1: Specifications of Carbon Woven Reinforcement Fabric

Characteristic	Specification	Tolerance	Test Method
Areal Weight (g/m2)	240	± 3%	ASTM D3801
Width* (mm)	1000	-0/+10mm	ASTM D3774
Dry Fabric Thickness(mm)	0.23	± 0.03mm	ASTM D1777

Figure 2: Carbonized textile fiber sheet (Purchased for experiment)

Table -2: Specifications of Carbon Woven Reinforcement Fabric

WEFT		WARP	
Carbon Fiber	50% by weight	Carbon Fiber	50% by weight
Standard Modulus 3K		Standard Modulus 3K	
15.24 ends/inch		15.24 picks/inch	

Table -3: Properties of Fiber

Density (g/cm3)	1.8
Filament Diameter (μm)	7
Tensile Strength (MPa)	3450
Tensile Modulus (GPa)	230
Elongation (%)	1.5
Sizing	Epoxy Compatible

4.4 Mix proportions:

Materials used include ordinary Portland cement (53 grade, conforming to is 8112-1989), coarse aggregate of crushed rock (maximum size, 20mm), fine aggregate of clean river sand (zone II of is: 383-1970) and portable water. A sieve analysis conforming to IS 383-1970 was carried out for both fine and coarse aggregates. The concrete mix was designed so as to achieve cube strength of 50MPa (28 days). Textile fiber sheets of the above mentioned properties were applied to the concrete cubes on either side by means of mortar.

The cubes were left for hardening for 7 days and then extracted from the molds and attach the sheets to the cubes by mortars. The surfaces are roughened first for applying the mortar and then by applying hand force the sheets were fixed on the cubes. The samples were then let to harden. After 28 days the tests for durability was carried out on the cubes.

5.0 EXPERIMENTAL RESULTS:

5.1: Impact value test results (10mm Aggregate):

Table 4: Aggregate impact test results

Sr. No.	Determination	Trial 1	Trial 2	Trial 3	Average
1	Total weight of oven dried sample(passing 12.5mm-retained on 10mm sieve)- W1 gms	390	394	400	
2	Wt. of material retained on 2.36mm after testing- W2 gms	366	370	372	
3	Wt. of material passing on 2.36mm after testing- W3 gms	24	24	28	6.42%
4	Aggregate Impact value (%) = (W3/W1)* 100	6.15%	6.09%	7.00%	

5.2 Dry Bulk Density of 10mm aggregates:

Table 5: Aggregate density test results

Sr. No.	Determination	Trial 1
1	Volume of cylinder	3 lit
2	Empty Weight of cylinder	2590
3	Wt of cylinder+ aggregates	7224.00
4	Wt of Aggregate	4634.00
5	Density	1544.67

5.3 Dry Bulk Density of River Sand:

Table 6: Aggregate density test results

Sr. No.	Determination	Trial 1
1	Volume of cylinder	3 lit
2	Empty Weight of cylinder	2590
3	Wt of cylinder+ aggregates	7820.00
4	Wt of Aggregate	5230.00
5	Density	1743.33

5.4 Specific Gravity and Water Absorption:

A) Fine Aggregates- River sand

After conducting three trials on the aggregate sample the average values calculated are as follows:
Water absorption (%) – 1.35

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Specific Gravity (gm/cc) – 2.77

5.5 Sieve Analysis:

A) Coarse Aggregates: 10mm

Table 7: Sieve Analysis test results of Coarse Aggregates: 10mm

IS Sieve size in mm	Material retained (gms)	% retained	% Retained Cum	% Passing	IS % Passing
12.5	0	0	0	100.00	100
10	229	7.63	7.63	92.37	85-100
4.75	2690	89.67	97.30	2.70	0-20
2.36	81	2.70	100.00	0.00	0-5
Pan	0	0.00	100.00	0.00	0

B) Coarse Aggregates: 20mm

Table 8: Sieve Analysis test results of Coarse Aggregates: 20mm

IS Sieve size in mm	Material retained (gms)	% retained	% Retained Cum	% Passing	IS % Passing
25	0	0	0	100.00	100
20.0	411	13.70	13.70	86.30	85-100
10	2513	83.77	97.47	2.53	0-20
4.75	76	2.53	100.00	0.00	0-5
Pan	0	0.00	100.00	0.00	0

C) Fine Aggregates – River sand:

Table 9: Sieve Analysis test results of Fine Aggregates: River sand

IS Sieve size in mm	Material retained (gms)	% retained	% Retained Cum	% Passing	IS % Passing
10	0	0	0	100.00	100
4.75	35	3.50	3.50	96.50	90-100
2.36	198	19.80	23.30	76.70	75-100
1.18	185	18.50	41.80	58.20	55-90
0.60	239	23.90	65.70	34.30	35-59
0.30	139	13.90	79.60	20.40	8-30
0.15	104	10.40	90.00	10.00	0-10
Pan	100	10.00	100.00	0.00	0

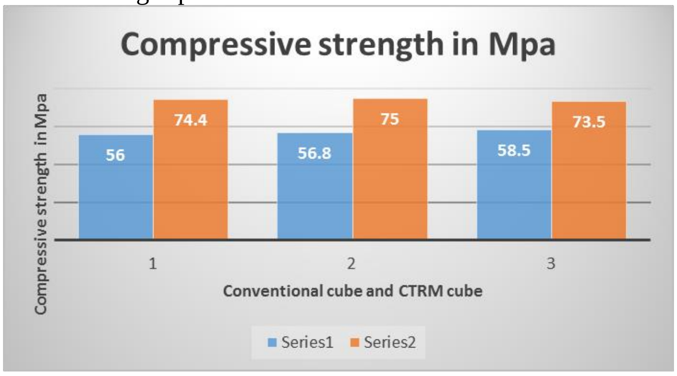
5.6 Compressive strength test results of CTRM Applied Cubes and Conventional cubes:

Table 10: Compressive strength test results of Cubes:

Sample type	Sample No.	Compressive Strength (MPa)	Average compressive Strength (MPa)	Standard deviation (MPa)
CTRM Cube (150 × 150)	1	74.40	74.3	0.8
	2	75.0		
	3	73.5		
Conventional Cube (150 × 150)	1	56.0	57.1	7.0
	2	56.8		
	3	58.5		

5.7 RESULTS:

Specimens which received one TRM layer, reached an ultimate load of 56.6 and 78.22 kN. The corresponding increase in their shear capacity was equal to 9% and 51%. The failure of these specimens was associated with damage of the CTRM sheets. The first Specimen exhibited a diagonal-tension mode of failure where one major inclined shear crack initiated within the shear span at the peak load. Due to the absence of stirrups, the shear crack extended rapidly through the beam depth. The failure occurred suddenly without warning.
The second specimen with stirrups experienced minor inclined flexural-shear cracks close to the load point at a load value that corresponded to approximately 30% of the peak load. The first visible principal diagonal shear crack developed in the mid of the shear span was observed at a load that corresponded to approximately 65% of the peak load. As the load progressed, more shear cracks developed adjacent to the principal diagonal crack then extended towards the load and support points. The beam failed by formation of longitudinal cracks at the top and bottom surfaces of the beam causing separation of the side concrete covers.



Graph 1: Compressive strength of CTRM and conventional cubes.

Specimens with double CTRM sheets failed in shear at a load of 88.7 and 120.2 kN, respectively. Compared to the control specimen the increase in the shear resistance was equal to 71% and 132%, respectively.
In The third specimen with double layer of CTRM sheet first visible principal diagonal shear crack in was developed at the middle of the shear span at a load value that corresponded to approximately 66% of the peak load. This crack slightly extended in length as the load progressed. Some cracks also initiated within the end region of the shear span closer to the load point. At about 92% of the peak load, many shear cracks developed in the lateral triangular portion below the principal diagonal crack. Failure of this specimen involved separation of the two side concrete covers of the beam's lateral face.
Fourth Specimen exhibited the first visible principal diagonal shear crack in the mid of the shear span at a load value that corresponded to approximately 76% of the peak load. As the load increased, the principal crack extended towards the load point and additional diagonal shear cracks developed above it. Prior to reaching the peak load, some flexural-shear cracks developed below the load point forming a triangular portion. Eventually, the beam failed by detachment of the side concrete covers of the beam's lateral faces.

6.0 DISCUSSION:

The shear response of RC beams strengthened in shear with CTRM has been investigated in this research. The work comprised experimental testing. It is important to note that the results derived in this study are only applicable to the fabric and matrices/adhesives used and should not be extrapolated to other strengthening systems. A variation in the size of the specimens, amount and/or distribution of steel/TRM reinforcement, properties of materials, and loading conditions would change the structural response before and after strengthening.

A total of 4 tests conducted on RC beam specimens were included in the beam tests. Variables of the large-scale beam tests included the number of TRM layers (one or two layers), and amount of internal stirrups (no stirrups, stirrups with a spacing of 0.6d, stirrups with a spacing of 0.3d), where d = depth of the tensile steel measured from extreme compression fiber. Based on the results of beam tests, the following conclusions are drawn:

The effect of the strengthening configuration on the shear capacity enhancement and the effectiveness of the CTRM sheets (expressed as the shear capacity enhancement) was 5.5 and 1.85 times the conventional control specimen for 1 and 2 layers, respectively. Therefore, the benefit of applying the sheets was more pronounced in TRM system, especially as the number of layers increased. Increasing in the stirrups and longitudinal reinforcements there was a dramatic increase in the CTRM specimens shear capacities.

The unstrengthened specimens, except that with the smaller stirrup spacing of 0.3d, failed in a diagonal-tension mode of failure. The specimen with a stirrup spacing of 0.3d failed in a shear-compression mode of failure. All of the strengthened specimens failed by concrete side cover separation of the specimen's lateral faces. Such a premature mode of failure can be avoided by increasing the amount of TRM layers or varying the matrix type on the shear strength gain for the specimens with internal steel stirrups.

Shear strengthening with CTRM/TRP limited growth of cracks, reduced the rate of increase of stirrup strain, delayed yielding of stirrup, and hence increased the beam's shear capacity.

The CTRM/TRP shear strengthening system was very effective in improving the shear response and increasing the shear capacity of RC beams.

As the amount of internal stirrups increased the shear strength gain decreased. The shear strength gains of the specimens with the greater stirrup spacing and strengthened with one layer of CTRM, two layers of CTRM, were 42%, 54%, lower than those that did not include internal stirrups, respectively.

The shear capacity increased by increasing the number of CTRM layers but the additional shear strength gain was not proportional to the added amount of CTRM sheets. The effect of increasing the amount of CTRM layers on the shear strength gain was proportional to the addition of internal steel stirrups.

7.0 RECOMMENDATIONS FOR FUTURE STUDIES:

The present study provided insight into shear response of RC beams strengthened in shear with CTRM through an experimental testing. The following are recommendations for future studies in the field of shear strengthening of RC structures with CTRM:

- Develop FE models for the specimens of the double-shear tests. Results of these FE models along with those of the corresponding experimental data can be used to study the bond characteristics between the CTRM and concrete presented in this study.

Perform a parametric study using the developed FE models to investigate the effect of a wider range of variables on the shear response of RC beams strengthened with CTRM.

Study the viability of using TRM in improving the structural response of predamaged or corrosion-damaged RC beams.

Investigate the durability performance of RC beams strengthened with CTRM under harsh environment conditions.

REFERENCES

[1] Alfred Strauss; Konrad Bergmeister; Simon Hoffmann; Radomir Pukl; and Drahomir Novák (2008) - Advanced Life-Cycle Analysis of Existing Concrete Bridges-Journal of materials in Civil engineering /volume 20-issue 1- January 2008

[2] Christian Escrig, 'Experimental and analytical study of reinforced concrete beams strengthened with different types of textiles', Journal Of Construction and building materials,2015.

[3] C G Papakonstantinou , C Kakae , N Gryllakis (2018) - Can Existing Design Codes Be Used to Design Flexural Reinforced Concrete Elements Strengthened with Externally Bonded Novel Materials- IOP Conf. Series: Materials Science and Engineering **371** (2018) 012031 doi:10.1088/1757-899X/371/1/012031

[4] Eva O.L. Lantsoght, Ane de Boer, Cor van der Veen (2016) -**Levels of Approximation for the shear assessment of reinforced concrete slab bridges**- Erratum, *Structural Concrete*, **19**, 1, (325-325), (2017).

[5] Frederik Teworte, Martin Herbrand, Josef Hegger (2015) - Structural Assessment of Concrete Bridges in Germany— Shear Resistance under Static and Fatigue Loading- Structural Engineering International 3/2015 266 Scientific Paper

[6] Isabella Colombo, Matteo Colombo,Anna Magri,Giulio Zani and Marco di Prisco (2011)- Textile Reinforced Mortar at High Temperatures-
Applied Mechanics and Materials (Volume 82) I. Colombo et al., "Textile Reinforced Mortar at High Temperatures", Applied Mechanics and Materials, Vol. 82, pp. 202-207, 2011.

[7] Josef Hegger, Alaa Sherif, and Stephan Gortz (2004)- Investigation of Pre- and Postcracking Shear Behavior of Prestressed Concrete Beams Using Innovative Measuring Techniques- ACI Structural Journal Volume: 101 Issue Number: 2 Publisher: American Concrete Institute (ACI) ISSN: 0889-3241Serial URL: http://www.concrete.org/PUBS/JOURNALS/SJHOME.ASP

[8] Luciano Ombres 'Structural performance of reinforced concrete beams strengthened in shear with cement based fiber composite material', Journal Of Composite Structures,2015.

[9] Manfred Curbach, Frank Jesse (1999) - High-Performance Textile-Reinforced Concrete- Structural Engineering International 4/99 Reports 2S9

[10] Martin Herbrand, Viviane Adam, Martin Classen, Dominik Kueres and Josef Hegger (19 September 2017) - **Strengthening of Existing Bridge Structures for Shear and Bending with Carbon Textile-Reinforced Mortar**-Materials **2017**, 10, 1099; doi:10.3390/ma10091099 www.mdpi.com/journal/materials

[11] Papanicolaou,C.G.,Triantafillou,T.C.,Papathanasiou,M.,andKarlos,K. (2008). "Textile reinforced mortar (TRM) versus FRP as strengthening

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 06, June-2019

material of URM walls: Out-of-plane cyclic loading.” Material Structure, 41(1), 143–157,2008.

[12] Thanasis C. Triantafillou, Catherine G. Papanicolaou (2006) -Shear strengthening of reinforced concrete members with textile reinforced mortar (TRM) jackets- Materials and Structures (2006) 39:93–103 DOI 10.1617/s11527-005-9034-3

[13] Triantafillou, T. C., and Papanicolaou, C. G. “Shear strengthening of reinforced concrete members with textile reinforced mortar (TRM) jackets.” Mater. Struct., 39(1), 93–103,2006.

[14] Yousef A. Al-Salloum, Nadeem A. Siddiqui, Hussein M. Elsanadedy et al. ‘Textile-Reinforced Mortar versus FRP as Strengthening Material for Seismically Deficient RC Beam-Column Joints’, Journal Of Composites For Construction, ASCE,2010.

[15] Yousef A. Al-Salloum, Hussein M. Elsanadedy, Saleh H. Alsayed and Rizwan A. Iqbal, ‘Experimental and Numerical Study for the Shear Strengthening of Reinforced Concrete Beams Using Textile-Reinforced Mortar’, Journal Of Composites For Construction, ASCE,16, 74-90,2012.

[16] Zoi C. Tetta, Lampros N. Koutas, Dionysios A. Bournas (2015) -Textile-reinforced mortar (TRM) versus fiber-reinforced polymers (FRP) in shear strengthening of concrete beams- *Composites Part B* 10.1016/j.compositesb.2016.03.076 Reference: JCOMB 4177

[17] G. Eason, B. Noble, and I.N. Sneddon, “On certain integrals of Lipschitz-Hankel type involving products of Bessel functions,” Phil. Trans. Roy. Soc. London, vol. A247, pp. 529-551, April 1955. (*references*)

[18] J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68-73.

[19] I.S. Jacobs and C.P. Bean, “Fine particles, thin films and exchange anisotropy,” in Magnetism, vol. III, G.T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271-350.

[20] K. Elissa, “Title of paper if known,” unpublished.

[21] R. Nicole, “Title of paper with only first word capitalized,” J. Name Stand. Abbrev., in press.

[22] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface,” IEEE Transl. J. Magn. Japan, vol. 2, pp. 740-741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].

[23] M. Young, The Technical Writer’s Handbook. Mill Valley, CA: University Science, 1989.