National Cargo Bureau, Inc.

17 Battery Place, Suite 1232
New York
NY 10004

Tel: (212) 785-8300
Email: ncbnyc@natcargo.org

S.S. EL FARO

Document No. 101CS10720

Calculations using rubber coefficient of friction for bottom of roloc boxes in the "off button" configuration

18 November 2016

Requested by: National Transportation Safety Board
490 L'Enfant Plaza, SW
Washington
DC   20594

This is to certify that the undermentioned personnel of National Cargo Bureau, Inc. did, at the request of the above, perform a series of calculations relating to trailers on roloc boxes stowed off button on Deck 2 of EL FARO. These are attached.

Geoffrey J. Davies	Chief Surveyor
Philip I. Anderson	Chief, Technical Department
Edward F. Walker Jr.	Asst. Deputy Chief, Technical

1.0 INTRODUCTION

We were asked to provide a series of calculations to demonstrate the effect on holding power of adding a rubber mat beneath a roloc box. These are included as an appendix and should be read in conjunction with Appendix 2 of our Supplemental Report No. 101CS01719.

2.0 SUMMARY

The following tables summarize the effects of increasing friction coefficients relating to roloc box only while keeping lashing angles and other parameters the same. The values shown represent maximum weights in lbs. of RO-RO trailers for off button securing in Hold 2A.

Table 1 (lashing angle 45°)

Speed (kts)	GM (m)	Friction Coefficient		
		Steel-Steel (wet)	Steel-Steel (dry)	Steel-Rubber
		0.0	0.1	0.3
19.0	1.31	62656	76657	129177
19.5	1.31	60836	74031	122295
20.0	1.31	59118	71580	116110
20.5	1.31	57494	69285	110520
21.0	1.31	55957	67133	105444
21.5	1.31	54500	65111	100813
22.0	1.31	53117	63207	96572
22.5	1.31	51803	61411	92674
23.0	1.31	50552	59715	89078
23.5	1.31	49360	58110	85750
24.0	1.31	48223	56588	82663
24.5	1.31	21381	55145	79790

Table 2 (lashing angle 60°)

Speed (kts)	GM (m)	Friction Coefficient		
		Steel-Steel (wet)	Steel-Steel (dry)	Steel-Rubber
		0.0	0.1	0.3
19.0	1.31	49415	61470	106745
19.5	1.31	47979	59364	101059
20.0	1.31	46624	57398	95947
20.5	1.31	45343	55559	91328
21.0	1.31	44131	53833	87133
21.5	1.31	42982	52212	83307
22.0	1.31	41892	50685	79802
22.5	1.31	40855	49245	76581
23.0	1.31	39868	47884	73609
23.5	1.31	38928	46597	70860
24.0	1.31	38032	45377	68308
24.5	1.31	37175	44220	65934

Table 3 (EL Heavy Weather Lashing Requirements, lashing angles 58°, 52° and 46° respectively)

Speed (kts)	GM (m)	Friction Coefficient		
		Steel-Steel (wet)	Steel-Steel (dry)	Steel-Rubber
		0.0	0.1	0.3
19.0	1.31	56769	69910	119306
19.5	1.31	55119	67516	112950
20.0	1.31	53563	65280	107237
20.5	1.31	52092	63188	102074
21.0	1.31	50699	61225	97386
21.5	1.31	49379	59381	93109
22.0	1.31	48126	57645	89193
22.5	1.31	46936	56007	85592
23.0	1.31	45802	54460	82271
23.5	1.31	44722	52996	79198
24.0	1.31	43692	51608	76346
24.5	1.31	42708	50292	73692

3.0   <u>REMARKS</u>

This report is issued without prejudice and is for the benefit of whom it may concern.

NATIONAL CARGO BUREAU, INC.

P. I. Anderson
Chief, Technical Department

Maximum weight calculations for a range of speeds and lashing angles with friction coefficient 0.3 (steel-rubber)

Maximum Weight of RORO Trailers for Off Button Securing in Hold 2A

Speed KTS	GM m	B/GM	F1	F2	f	Ay	B/GM corr	Fy/m	COF	Sec kN	COFxg	Max Mass mt	Max Mass lbs
19.0	1.31	21.37	0.438	0.241	0.6796	6.2	1	4.2138	0.3	74.46	2.943	58.594	129,177
19.5	1.31	21.37	0.450	0.241	0.691	6.2	1.00	4.285	0.3	74.46	2.943	55.472	122,295
20.0	1.31	21.37	0.461	0.241	0.703	6.2	1.00	4.357	0.3	74.46	2.943	52.667	116,110
20.5	1.31	21.37	0.473	0.241	0.714	6.2	1.00	4.428	0.3	74.46	2.943	50.131	110,520
21.0	1.31	21.37	0.484	0.241	0.726	6.2	1.00	4.500	0.3	74.46	2.943	47.828	105,444
21.5	1.31	21.37	0.496	0.241	0.737	6.2	1.00	4.571	0.3	74.46	2.943	45.728	100,813
22.0	1.31	21.37	0.507	0.241	0.749	6.2	1.00	4.643	0.3	74.46	2.943	43.804	96,572
22.5	1.31	21.37	0.519	0.241	0.760	6.2	1.00	4.714	0.3	74.46	2.943	42.036	92,674
23.0	1.31	21.37	0.531	0.241	0.772	6.2	1.00	4.786	0.3	74.46	2.943	40.405	89,078
23.5	1.31	21.37	0.542	0.241	0.783	6.2	1.00	4.857	0.3	74.46	2.943	38.896	85,750
24.0	1.31	21.37	0.554	0.241	0.795	6.2	1.00	4.929	0.3	74.46	2.943	37.495	82,663
24.5	1.31	21.37	0.565	0.241	0.807	6.2	1.00	5.000	0.3	74.46	2.943	36.192	79,790

Assumptions: Total of six lashing tensioners and chains (3 each side). Four Chains located forward on ROLOC box and two located on rear (wheels end) of RORO trailer. Lashing angles based on TOTE assumption of 45 degrees. Coefficient of friction based on utilizing 0.3 for tires/wheels and 0.3 for ROLOC box (with rubber mat or timber under ROLOC box) appropriately adjusted based on weight distribution of RORO trailer of 38/62. A rigid body is assumed and the coefficient of friction is considered uniform across the length of the cargo.

Maximum Weight of RORO Trailers for Off Button Securing in Hold 2A

Speed KTS	Length	Beam	GM m	B/GM	F1	F2	f	Ay	B/GM corr	Fy/m	COF	Sec kN	COFxg	Max Mass mt	Max Mass lbs
19.0	223.70	28.00	1.31	21.37	0.438	0.241	0.680	6.2	1.00	4.214	0.3	61.53	2.943	48.419	106,745
19.5	223.70	28.00	1.31	21.37	0.450	0.241	0.691	6.2	1.00	4.285	0.3	61.53	2.943	45.839	101,059
20.0	223.70	28.00	1.31	21.37	0.461	0.241	0.703	6.2	1.00	4.357	0.3	61.53	2.943	43.521	95,947
20.5	223.70	28.00	1.31	21.37	0.473	0.241	0.714	6.2	1.00	4.428	0.3	61.53	2.943	41.426	91,328
21.0	223.70	28.00	1.31	21.37	0.484	0.241	0.726	6.2	1.00	4.500	0.3	61.53	2.943	39.523	87,133
21.5	223.70	28.00	1.31	21.37	0.496	0.241	0.737	6.2	1.00	4.571	0.3	61.53	2.943	37.787	83,307
22.0	223.70	28.00	1.31	21.37	0.507	0.241	0.749	6.2	1.00	4.643	0.3	61.53	2.943	36.198	79,802
22.5	223.70	28.00	1.31	21.37	0.519	0.241	0.760	6.2	1.00	4.714	0.3	61.53	2.943	34.737	76,581
23.0	223.70	28.00	1.31	21.37	0.531	0.241	0.772	6.2	1.00	4.786	0.3	61.53	2.943	33.389	73,609
23.5	223.70	28.00	1.31	21.37	0.542	0.241	0.783	6.2	1.00	4.857	0.3	61.53	2.943	32.141	70,860
24.0	223.70	28.00	1.31	21.37	0.554	0.241	0.795	6.2	1.00	4.929	0.3	61.53	2.943	30.984	68,308
24.5	223.70	28.00	1.31	21.37	0.565	0.241	0.807	6.2	1.00	5.000	0.3	61.53	2.943	29.907	65,934

Assumptions: Total of six lashing tensioners and chains (3 each side). Four Chains located forward on ROLOC box and two located on rear (wheels end) of RORO trailer. Lashing angles based on NCB assumption of 60 degrees. Coefficient of friction based on utilizing 0.3 for tires/wheels and 0.3 for ROLOC box (with rubber mat or timber under ROLOC box) appropriately adjusted based on weight distribution of RORO trailer of 38/62. A rigid body is assumed and the coefficient of friction is considered uniform across the length of the cargo.

Maximum Weight of RORO Trailers for Off Button Securing in Hold 2A

Speed KTS	GM m	B/GM	F1	F2	f	Ay	B/GM corr	Fy/m	COF	Sec kN	COFxg	Max Mass mt	Max Mass lbs
19.0	1.31	21.37	0.438	0.241	0.680	6.2	1.00	4.214	0.3	68.77	2.943	54.116	119,306
19.5	1.31	21.37	0.450	0.241	0.691	6.2	1.00	4.285	0.3	68.77	2.943	51.233	112,950
20.0	1.31	21.37	0.461	0.241	0.703	6.2	1.00	4.357	0.3	68.77	2.943	48.642	107,237
20.5	1.31	21.37	0.473	0.241	0.714	6.2	1.00	4.428	0.3	68.77	2.943	46.300	102,074
21.0	1.31	21.37	0.484	0.241	0.726	6.2	1.00	4.500	0.3	68.77	2.943	44.174	97,386
21.5	1.31	21.37	0.496	0.241	0.737	6.2	1.00	4.571	0.3	68.77	2.943	42.234	93,109
22.0	1.31	21.37	0.507	0.241	0.749	6.2	1.00	4.643	0.3	68.77	2.943	40.457	89,193
22.5	1.31	21.37	0.519	0.241	0.760	6.2	1.00	4.714	0.3	68.77	2.943	38.824	85,592
23.0	1.31	21.37	0.531	0.241	0.772	6.2	1.00	4.786	0.3	68.77	2.943	37.317	82,271
23.5	1.31	21.37	0.542	0.241	0.783	6.2	1.00	4.857	0.3	68.77	2.943	35.923	79,198
24.0	1.31	21.37	0.554	0.241	0.795	6.2	1.00	4.929	0.3	68.77	2.943	34.630	76,346
24.5	1.31	21.37	0.565	0.241	0.807	6.2	1.00	5.000	0.3	68.77	2.943	33.426	73,692

Assumptions: Total of six lashing tensioners and chains (3 each side). Four Chains located forward on ROLOC box and two located on rear (wheels end) of RORO trailer. Lashing angles based on angles shown in EL Heavy Weather Lashing Requirements. Coefficient of friction based on utilizing 0.3 for tires/wheels and 0.3 for ROLOC box (with rubber mat or timber under ROLOC box) appropriately adjusted based on weight distribution of RORO trailer of 38/62. A rigid body is assumed and the coefficient of friction is considered uniform across the length of the cargo.