WELL SITE CORE STABILIZATION AND PACKAGING - THE FIRST STEP IN ACQUIRING UNDISTURBED CORE –

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ABSTRACT

The fundamental objective of a coring operation is to obtain core samples that are representative of the reservoir rock properties. Therefore, core handling procedures and transportation methods should provide protection against core damage from environmental changes, mechanical vibration and mishandling.

This paper presents recommendations for core processing and core handling techniques which should prevent core damage and thus maximise the success of formation evaluation studies. Results obtained from testing the stabilization, the packaging and methods of core transportation are presented in this document, demonstrating the importance of properly planning every step from rig to the laboratory.

Using rock types varying from soft sediments to fractured formations, structural analyses have been performed using standard methods. These include petrographic thin sections and CT-scanning. These analyses have been performed before and after "crash" tests in order to measure and quantify damage to the core, if any at all.

Recommendations for core stabilization and packaging are provided for various types of formation lithologies.

INTRODUCTION

In the past, coring operations were planned and designed from a drilling perspective. Success of a coring job was completely dependent on the core recovery. Nowadays next to the recovery the quality of the core is important too since that is a key driver for successful formation evaluation programs. This is recognized by the industry paying now particular attention to coring technique, core processing, handling and transportation. Improvements that have been implemented at the rig site to maintain the integrity of the core are:

Stabilization of core inside full length inner barrel:
This prevents the core from rotation inside the barrel during cutting in manageable 3 ft or 1 meter sections. Full length stabilization is done using expanded polyurethane foam or if applicable with epoxy resin.

Core transportation:

i) The traditional wooden core boxes are replaced by specialized containers which allow packaging of up to 20m of 4″ diameter core. These containers are often equipped with pre-shaped spacers of foam to prevent the core from moving.

ii) Full length stabilized core (20ft) rather than 3ft sections are transported inside a Cargo-core basket from the rig site to the laboratory. This is often done in the UK sector of the North Sea. In this way rig site handling is limited and core cutting is done under controlled laboratory conditions.

These improvements are complementary to the core handling recommendations presented by McCollough 1972, Mattax 1975, Worthington 1987 and Skopec 1994. However, the effect of transportation on core integrity has so far been not been fully investigated.

To understand the shock distribution inside core containers during handling and transportation and the resulting damage to the core if improper packaging is used, a series of tests were carried out using artificial sand packs representative of fragile core samples susceptible to deteriorate if mishandled and various ways of stabilization and packaging.

A total of 256 different combinations of tests were carried out (see Appendix)

METHODS AND MATERIALS

Core packaging and transportation containers

Pre-shaped layers of foam			**Self contained core container**	
Description	*Abbr.*	*Density*	Material	Rigid plastic
Hard foam	HF	35kg/m^3	Dimension (OD)	1200x1000x765mm
Soft foam	SF	22kg/m^3	Dimension (ID)	1135x935x600 mm
Flat layers (soft foam)	FSF	23kg/m^3	Net Weight: 45kg	20m of 4″ core

Stabilization method

Two components Polyurethane foam injection		**Two components Epoxy Resin injection**	
Density	0.035g/cm^3	Density	1.1g/cm^3 @ 68 °F / 20 °C

Shock recording

Shocks and vibrations are recorded by mounting an accelerometer equipped with a triaxial sensor inside the core container. The tool records shocks (in 3 directions) and the free fall height and indicates the duration and the energy of a shock. The accelerometer was presenting the following specifications: dynamic range +/- 6G, mounted base resonance 75Hz, temperature range from -20°C to +40°C and can be sourced through company like Honeywell, Electrochem, SensR or MicroStrain.

Core sample preparation

Water was added to loose sand to provide unconsolidated samples with 25% water saturation. In this way unconsolidated sandstone of fine/medium moderately sorted grains was mimicked.

Shock recorders (Tracker) positioning

The shock recorders were positioned inside each core container such that all zones are covered (see Fig. 1).

- 5 units in the bottom layer
- 3 units in the second layer
- 3 units in the third layer
- 3 units in the top fourth layer

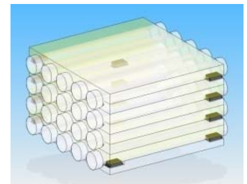


Fig. 1: Positioning of the shock recorders inside the container

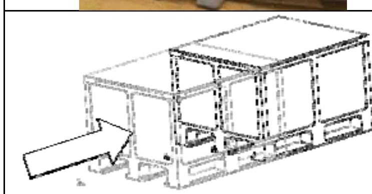
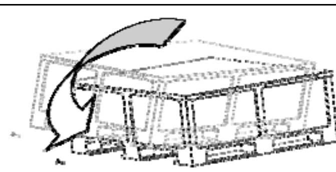
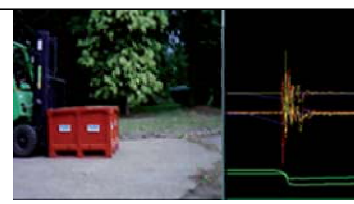
CT-scanning of the core samples

All the core samples have been scanned using a CT[1] Scanner before the actual tests in order to record the initial condition. On completion of each test, samples were scanned for comparison with the original samples.

Shock monitoring of the transportation of the samples for CT Scan have been carried out to ensure correct interpretation of the recordings. No relevant records show that sample could have been damaged during that phase.

Experiments

Numerous situations that are much in evidence at the rig site have been simulated.

Test 1: Lateral shock from forklift bumping the container	**Test 2:** Angular shock drop from a height of 13 cm	**Test 3:** Forklift transport on broken ground (bouncing effect)
		
		

RESULTS

Definition: Acceleration is a mechanical or physical shock caused by impact or drop.
In our test the shock is measured by an accelerometer (Tracker) which describes a shock pulse as a plot of acceleration versus time. To evaluate the impact on the core, we are looking to the peak acceleration and its duration. The magnitude of these shock recorded is stated as a multiple of the standard acceleration due to free fall in the Earth's gravity, the unit of measurement is in G equivalent to the value 9.80665 m /s^2.

[1] CT standing for Computed Tomography Scanner. The scanner provides 64 slices/sec and 60 images in one single rotation (360°)

Table 1 gives the results of transportation tests using samples stabilised with foam reinforced with foam pillow for all types of pre-shaped foam layers within a container full of core (20m). The figures in the table represent the acceleration recorded in G. In red are highest level of acceleration recorded by one of the shock trackers positioned in the bottom of the container. Decrease in acceleration can be observed in the upper layers. The hard foam shows the lowest decrease as the mixed layers and soft foam show the best results.

Position	Tracker number	HF # 163	SF # 179	FSF # 195	Mixed layers* #211
Top layer	14	3.41	2.94	3.05	2.96
	13	3.94	3.11	2.89	3.25
	12	4.16	3.07	3.37	3.28
Third layer	11	3.98	3.12	3.47	3.33
	10	3.89	3.17	3.74	3.24
	9	4.31	3.26	3.63	3.39
Second layer	8	4.22	3.75	3.98	3.64
	7	3.92	3.47	3.64	3.72
	6	4.3	3.54	3.69	3.63
Bottom layer	5	5.16	5.11	5.13	5.07
	4	5.65	4.86	4.79	5.71
	3	6.17	5.35	5.46	6.26
	2	7.08	6.59	6.25	7.33
	1	7.91	6.43	6.96	7.45

*Bottom layer with HF, second,third and top layer with SF

Table 1

Position	Tracker number	Semi full Container with HF # 251	Semi full Container with SF # 255
Top layer		N/a	
Third layer			
Second layer	8	6.97	7.88
	7	10.03	7.97
	6	10.3	9.3
Bottom layer	5	8.1	7.25
	4	7.08	7.86
	3	10.1	9.35
	2	9.24	6.28
	1	7.83	7.4

Table 2

Table 2 gives the results of transportations tests for hard and soft pre-shaped foam layers within a container partly filled with stabilised core placed at the bottom. No foam pillows were used. The figures in the table represent the acceleration recorded in G. In red are highest levels of acceleration recorded by the accelerometer. Due to bouncing effect, level of acceleration are higher on the first 2 layers with the hard foam, the soft foam amortizing better the shock diffusion.

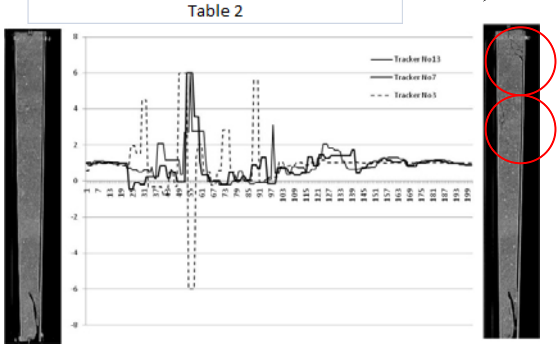


Figure 2: The above figure gives the results of angular shock (test 2) with non stabilized core and CT-scans before (left) and after test (right). Structural damaged are circled in red. Hard layer foam inserts were used (Test#81).

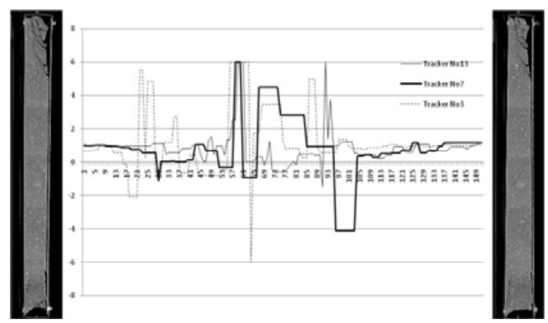


Figure 3: The above figure gives the results of angular shock (test 2) with foam stabilized core and CT-scans before (left) and after test (right). No structural damaged were recorded after test. Hard layer foam inserts were used (Test#82).

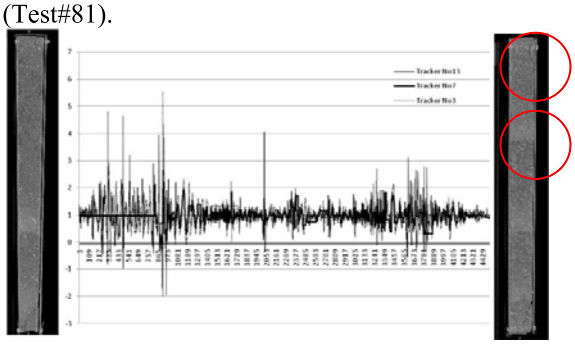


Figure 4: The above figure gives the results of forklift transport (test 3) with non stabilized core and CT-scans before (left) and after test (right). Structural damaged are circled in red. Hard layer foam inserts were used (Test#161).

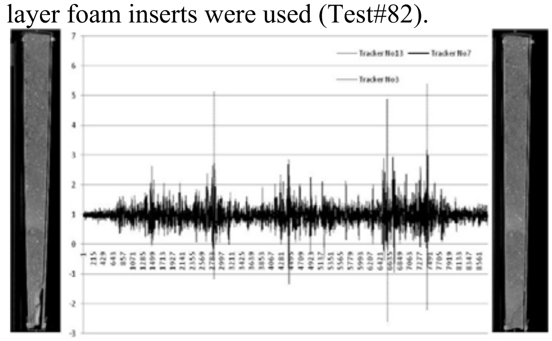


Figure 5: The above figure gives the results of forklift transport (test 3) with foam stabilized core and CT-scans before (left) and after test (right). No structural damaged were recorded after test. Hard layer foam inserts were used (Test#162).

FINDINGS

- Soft foam layers absorb vibrations (bouncing effect) caused by road transport, however it is less prone to absorb heavy shocks.
- Hard foam layers seem to absorb all shocks but cause a bounce effect during road transportation.
- Regardless the type of foam material used, it has been observed that the bottom layers are the zones that are prone to damage.
- Cores that partly fill core containers from the bottom upward are prone to damage.
- Foam pillows placed inside the container prevent movement of the package of foam layers and thus improve proper core transportation.

CONCLUSIONS AND RECOMMENDATIONS

From the numerous shock tests performed it reveals that core damage during handling and transportation can be prevented when attention is paid to the following:

- Choose the right specifications and shape of the foam inserts for storing cores in a container thus allowing better shock absorption.
- Position fragile samples inside the core container starting from top to bottom and stow them equally spaced inside the container. This can be done by providing a geological assessment of the core end face. In the eventuality of small amount of core samples not entirely filling the core container, it is recognised to leave the bottom layers empty and position the core starting from the top layers. Ideally if we are talking about a large amount of core, it is advisable to spread the quantity over two containers still leaving the bottom layers empty and equilibrating the weight.
- Fill up empty space inside the core container with foam pillows thus preventing any movement of the core.
- Install trackers gauges inside the core shipment containers to monitor and record shocks, vibrations and changes to temperature of the cores to trace down damage that might have occurred to the core during transportation

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APPENDIX

The below table is providing a detailed inventory of the 256 tests done with their specific configurations.

Layer used		Core used	No of core	Stabilization	Lateral (bumping)	Angular (Drop off)	Transport (bouncing)
HF	WITH PILLOWS	1% cement	20	NONE	1	81	161
				Foam	2	82	162
				Resin	3	83	163
			10	NONE	4	84	164
				Foam	5	85	165
				Resin	6	86	166
		3% cement	20	Foam	7	87	167
			10		8	88	168
	WITHOUT PILLOWS	1% cement	20	NONE	9	89	169
				Foam	10	90	170
				Resin	11	91	171
			10	NONE	12	92	172
				Foam	13	93	173
				Resin	14	94	174
		3% cement	20	Foam	15	95	175
			10		16	96	176
SF	WITH PILLOWS	1% cement	20	NONE	17	97	177
				Foam	18	98	178
				Resin	19	99	179
			10	NONE	20	100	180
				Foam	21	101	181
				Resin	22	102	182
		3% cement	20	Foam	23	103	183
			10		24	104	184
	WITHOUT PILLOWS	1% cement	20	NONE	25	105	185
				Foam	26	106	186
				Resin	27	107	187
			10	NONE	28	108	188
				Foam	29	109	189
				Resin	30	110	190
		3% cement	20	Foam	31	111	191
			10		32	112	192
C(1SF,1HF)	WITH PILLOWS	1% cement	10	None	73	153	233
				Foam	74	154	234
				Resin	75	155	235
		3% cement		Foam	76	156	236
	WITHOUT PILLOWS	1% cement		None	77	157	237
				Foam	78	158	238
				Resin	79	159	239
		3% cement		Foam	80	160	240
C(2 HF)	WITH PILLOWS	1% cement	10	None	81	161	241
				Foam	82	162	242
				Resin	83	163	243
		3% cement		Foam	84	164	244
	WITHOUT PILLOWS	1% cement		None	85	165	245
				Foam	86	166	246
				Resin	87	167	247
		3% cement		Foam	88	168	248

Layer used		Core used	No of core	Stabilization	Lateral (bumping)	Angular (Drop off)	Transport (bouncing)
FSF	WITH PILLOWS	1% cement	20	NONE	33	113	193
				Foam	34	114	194
				Resin	35	115	195
			10	NONE	36	116	196
				Foam	37	117	197
				Resin	38	118	198
		3% cement	20	Foam	39	119	199
			10		40	120	200
	WITHOUT PILLOWS	1% cement	20	NONE	41	121	201
				Foam	42	122	202
				Resin	43	123	203
			10	NONE	44	124	204
				Foam	45	125	205
				Resin	46	126	206
		3% cement	20	Foam	47	127	207
			10		48	128	208
C(1HF,3SF)	WITH PILLOWS	1% cement	20	None	49	129	209
				Foam	50	130	210
				Resin	51	131	211
				Foam	52	132	212
				None	53	133	213
				Foam	54	134	214
				Resin	55	135	215
					56	136	216
	WITH PILLOWS	1% cement		None	57	137	217
				Foam	58	138	218
				Resin	59	139	219
				Foam	60	140	220
				None	61	141	221
				Foam	62	142	222
				Resin	63	143	223
					64	144	224
C(2HF,2SF)	WITH PILLOWS	1% cement		None	65	145	225
				Foam	66	146	226
				Resin	67	147	227
		3% cement		Foam	68	148	228
	WITHOUT PILLOWS	1% cement		None	69	149	229
				Foam	70	150	230
				Resin	71	151	231
		3% cement		Foam	72	152	232
C(2 SF)	WITH PILLOWS	1% cement	10	None	89	169	249
				Foam	90	170	250
				Resin	91	171	251
		3% cement		Foam	92	172	252
	WITHOUT PILLOWS	1% cement		None	93	173	253
				Foam	94	174	254
				Resin	95	175	255
		3% cement		Foam	96	176	256

Table A1: Summary of all test performed