FLEXMAT™

MARECON

MARINE ENVIRONMENTAL AND CONSTRUCTION CONSULTANTS

Flexmat Flexible Concrete Block Mattresses

marine (offshore Application)

Flexmats have been applied on many offshore projects since 1984 in the form of:

- **Blanket type mattresses** for erosion prevention, first installed around Woodside Energy's Rankin offshore platform and subsequently at the Goodwin, Wanea and other projects.
- **Gravity anchors** for stabilisation, erosion prevention or impact protection of submarine pipelines, cables and umbilicals, first applied on Western Mining's tanker loading line at Airlie Island Western Australia and on Chevron's pipelines in the Saladin and Chervill Fields.

Applications have covered a wide diameter range, from around .1 m to 1.2 m. which was the largest OD application to date on Woodside's Rankin Trunkline at the N.W shelf.

The applied anchors have an excellent, failsafe, track record whilst permitting lateral pipeline displacement during extreme sea states. (in compliance with DnV Guidelines)

The 'steamlined' profile of the anchor's cross section renders a large reduction in drag and lift coefficient and, as a consequence, greatly reduces the required supplementary weight that would need to be added to the pipeline, cable or umbilical to ensure its stability under the design wave- and current conditions. *This renders a major overall cost saving of at least 50% in comparison to competing systems such as concrete 'cradles', bags or grout mats.* Flexmat cover also increases its allowable free span and, as a consequesnce, greatly reduces the rist of popeline buckling.

By comparison, alternative methods of stabilisation such as trenching, mechanical anchoring and rock dumping are far more costly and less reliable as evidenced by the substantial failure history of these systems during severe sea states.

Flextmat can be installed at a fast rate without requiring sophisticated installation equipment.

If necessary Marecon's popeline specialist PJ de Geeter would be able to provide advice based on more than 60 years (since 1964) practical experience.

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FLEXMAT GRAVITY ANCHOR- AND MATTRESS SYSTEMS FOR PIPELINE STABILIZATION, SCOUR PREVENTION, IMPACT PROTECTION AND PIPELINE SEPARATION (at crossings)

CONTENTS

ATTACHMENTS:

SUMMARY:

FLEXMAT gravity anchors and mattresses have been applied for more than forty years, for pipeline stabilisation, scour control around structures, impact protection and as 'spacers' at pipeline- or cable crossings, in Australian waters (*) as well as overseas. (*) mainly on the North West Shelf

The system has an excellent, failsafe, track record whilst permitting some lateral pipeline displacement during extreme sea states. (in accordance with DnV Guidelines)

The use of gravity anchors instead of weight coating (or to minimize its thickness) renders a significant reduction in required supplementary weight per linear metre and in overall cost. As a consequence of its reduced weight, the allowable free span of the pipeline increases substantially. (before overstressing would occur)

By comparison, alternative methods of stabilisation such as trenching, mechanical anchoring and rock dumping are far more costly and relatively unreliable. (as evidenced by the substantial failure record of these systems, especially during extreme sea states)

Flexmat gravity anchors and scour prevention mattresses can be installed at a fast rate without requiring sophisticated installation equipment. A simple spreader beam frame would normally suffice. Extensive testing has shown that it would be possible to install the anchors during the pipelay process. This would avoid the cost of a separate installation spread (as required for 'post' installation of the anchors)

INTRODUCTION:

The first pipeline Flexmats were manufactured in 1984 for free span control at various locations along Woodside's Rankin trunk line. This was followed by large Flexmat supplies in 1986, 1987 and 1995 for scour prevention near structures and pipelines in the Rankin, Goodwin and Wanaea Developments, offshore Western Australia.

From 1987, Flexmat Anchors were used to stabilise more than twenty offshore and coastal pipelines and pipeline bundles, mainly on the North West Shelf, in waters subject to extreme -cyclone generated- sea states.

Some of these lines are still in operation without any loss of stability at negligible maintenance cost.

RESEARCH AND DEVELOPMENT:

In 1990, the system was thoroughly reviewed by Wholohan Grill and Associates. In accordance with their recommendations the sound –analytical- foundation of the Flexmat system was underpinned by an extensive R & D program which included:

- Extensive flume testing at the University of Western Australia main wave flume for realistic wave and current scenario's.
- Verification of stability analysis software by DnV Singapore;
- Feedback from installation Contractors and the operators of (Flexmat stabilized) pipelines;

The outcome of the above program, in conjunction with successful project applications, confirmed that Flexmat gravity anchors are capable of providing long-term, stability to pipelines, pipeline bundles and 'piggy-back' pipe/umbilical assemblies, even during extreme sea states and at all water depths.(up to the shoreline)

Subsequent large-scale testing, including offshore field trials, conducted by Australian Marine & Offshore Group in regard to Woodside's TSEP (42") trunkline confirmed that even for an untrenched pipeline of such large diameter the Flexmat system could be successfully applied, requiring anchors with a weight of approx. 30 T. (re. AMOG's conclusions in attachment 3)

The same testing program also confirmed that the anchors will not dislodge from the pipeline during extreme sea states and that, in erodable bed material, the anchors subside at the same rate as the pipeline, preventing the anchor's bridles from becoming slack.

As the exposure height of the pipeline/anchors assembly (relative to the surrounding seabed) decreases, the destabilizing (hydrodynamic) force decreases accordingly. This renders an increase in the factor of safety.

COMPARISON TO IN-SITU STABILISATION SYSTEMS:

These traditional systems, which include trenching, mechanical anchoring and rock dumping, are far more costly than gravity stabilisation systems and have a relatively poor performance record, especially in waters subject to extreme -cyclone generated- sea states.

It explains the numerous cases of total or partial failure of such systems, either during the installation stage or later on. (most common problems: inadequate trenching depth and/or 'snail's progress of trencher; deterioration and/or subsequent failure of mechanical anchors, degrading and/or subsidence of rock berms over time)

Also, and most importantly: once failed, these systems can not recover. A typical example was the 'chain' failure of rock bolts on the Varanus pipeline (on the North West Shelf) over many kilometres, necessitating very costly remedial work over many months.

COMPARISON TO WEIGHT-COAT STABILISATION:

Application of gravity anchors reduces required weight coating thickness and eliminates the need for weight coating altogether in cases where the (steel) pipe has sufficient negative buoyancy and is not at risk of impact damage caused by ship's anchors or trawl boards.

The reduction or elimination of weight coating reduces the pipeline's external diameter and, as a consequence, the peak hydrodynamic forces on the pipeline.

This means that, for a certain required factor of safety, required pipeline weight (and the weight and/or number of gravity anchors) decreases. (approx. in linear proportion to the reduction in pipe OD)

This is especially important in shallow water where, due to a large -wave induced- acceleration force, required weight coat thickness would, otherwise, become excessive. (due to the fact that maximum weight coat density is technically limited to roughly 3.1 T/m3)

By contrast, Flexmat anchors and mattresses for shallow water application can be supplied with a concrete density up to roughly 3.6 T/m3 at only a slight increase in cost per Tonne of submerged weight.

Also: by minimising weight coat thickness (if any), the weight of the pipe joints reduces substantially. This facilitates storage and handling and reduces haulage costs substantially.

Also and most importantly: the reduction of the pipe-line's OD and weight makes it possible to engage a smaller pipelay barge at exponentially reduced day rate.

Also, the weight coating process requires sophisticated rotary machinery. By contrast, the Flexmat's fabrication technology is simple. (only requiring tack-welded steel moulds and pencil vibrators)

Consequently, Flexmat anchors or mattresses can be supplied at short notice. Haulage cost are minimised if the production facility can be located close to the load-out point.

Examples of projects where weight coat thickness was kept to a minimum (with the required supplementary weight provided by Flexmat anchors) are the tanker loading lines operated by WAPET and Chevron in the Saladin- and South Pepper Fields (both with an OD of 550 mm) and Shell Brunei's Tutong pipeline. (OD 600 mm)

FLEXMAT/PIPELINE STABILITY:

Flexmat Gravity anchors differ fundamentally from other types of gravity anchors or mattresses in that:

- The concrete blocks fit tightly around the pipeline, eliminating the risk of dislodging and
- The anchor profile is streamlined, increasing overall weight efficiency due to a proportionate reduction in hydrodynamic drag- and lift forces.

Stability computations of the Flexmat/pipeline system are based on conventional 2-D analysis for the significant wave condition using Morison's well proven hydrodynamic force equations with conservative values for the drag- lift- and inertia coefficients.(based on experimental work performed by Jacobson and Lambrakos et al) Including the incremental effect of wake flow reversal. (in accord. with DnV's Rules and Recommended Practice E305)

Hydrodynamic coefficient values for the Flexmat anchor profile were calculated mathematically and confirmed experimentally.

A (verified) three-dimensional stability analysis program is available to compute the pipeline's lateral displacement during an extreme sea state of a certain duration. (to check that it would not exceed the safe limit specified in DnV's Guidelines RP E305)

FLEXMAT / SEABED INTERACTION:

In areas where the pipeline is free spanning, the tensile strength of the matting bridle(s) across the top of the pipe prevents any sagging distortion of the Flexmat profile. Consequently the hydrodynamic forces on the Flexmat/ pipeline profile are not affected by the degree of scour or subsidence.

In such situation, the rotational stability of the anchors is assured, both in transverse and longitudinal direction, due to a low centre of gravity. (note: in free spanning areas, rigid gravity anchors such as concrete cradles would rotate off the pipeline due to the fact that the cradle's centre of gravity is located well above the centre of the pipeline)

In the case of a trenched pipeline, natural infilling by sediments will occur over time. Liquefaction of this material under wave action could cause flotation or heave buckling of the pipeline.

This upward motion can be prevented by the downward force provided by Flexmat anchors. This would also provide a solution in areas where the required trench depth has not been accomplished.

FLEXMAT COMPONENTS:

The high-strength polypropylene bridle- and base matting contains special additives against oxidization and leaching, ensuring a durability in seawater of at least eighty years.

The matting has a thirty year history of successful application on major projects, worldwide, and is environmentally safe. It is chemically inert and fully resistant to all forms of marine life.

The matting's properties are fully specified in the document COMPREHENSIVE DOCUMENTATION ON ROBUSTA POLY PROPYLENE MATTING. (available from MARECON on request)

Cement type and aggregate gradation are such that the durability of the concrete in seawater matches that of the matting. In deep water, concrete of normal density can be applied as wave-induced acceleration force per unit volume is small in comparison to the submerged unit weight of the concrete.

However, at decreasing water depth the wave-induced acceleration force increases until, in the nearshore zone, the horizontal acceleration force becomes almost as large as the gravitational force. This implies that high density concrete would be required. Its higher cost per Tonne is largely offset by increased weight efficiency under water.

FLEXMAT INSTALLATION:

Weight of the individual Flexmat blocks is kept below a safe limit in order to prevent impact damage to the pipeline in the unlikely event that the anchor descends onto the pipeline with a velocity higher than intended. (due to lack of adequate heave compensation, for example)

Installation rates on past projects ranged from two to four anchors per hour, depending on anchor size and water depth. The anchors are launched from a self-propelled vessel or towed barge by means of a revolving crane and a relatively simple installation frame. (as shown in attachments 6 and 11)

Such frame can be manufactured in a short time. (days rather than weeks)

During its descent to the seafloor the Flexmat anchor is directionally controlled (aligned with the pipeline) by means of guy rope(s) held by diver(s) or, in deep water, by means of an ROV. (which subsequently disconnects the lift slings from the blocks)

On almost all past projects, the anchors were guided into position by one diver, positioned on the seabed at the end of the anchor. (note: in the case of heavy Anchors, with a weight larger than -roughly- 5 T. it was found preferable to engage two divers, located at opposite ends of the anchor)

Extensive testing in the large wave channel of the University of Western Australia has demonstrated that it is possible to install the anchors during the pipelay process, from the stern of the laybarge, as schematically indicated in Attachment 8.

It greatly reduces installation time and cost, without slowing down the lay barge. At the same time any risk of impact damage to the pipeline is eliminated.

CASE HISTORIES:

Flexmats were supplied on a large scale to Woodside for application on the Rankin trunkline and scour prevention around the footings of the Rankin, Wanaea and Goodwin platforms. Other applications include:

- Stabilisation of WAPET's tanker loading line and many inter field lines and pipe/cable bundles in the Saladin field near Thevenard Island;
- (former) Bond Oil's trunkline at the Harriet field; (near Barrow Island)
- Wesminco's tanker loading line near Airlie Island; (currently operated by Chevron)
- A large number of flowlines and trunklines in the South Pepper- and Chervill Fields;
- Shell's 600 OD Tutong pipeline in Brunei;
- Coastal and nearshore pipelines near Bunbury, Albany and in Bass Strait. (BHP- and Exxon pipelines)

Despite having been regularly exposed to extreme sea states, all pipelines stabilised with Flexmat Anchors have remained fully operational without any loss of stability, to the entire satisfaction of the Clients.
(more detailed information can be provided on request)

DESIGN AND TECHNICAL SUPPORT:

MARECON provides Flexmat Anchor design(s) for specific project conditions, using conservative 2D or 3D stability analysis software (as verified by DnV). This includes free span- and vertical stability analyses.

If water depth along the pipeline varies substantially, its alignment needs to be subdivided in such way that, per sub- section, water depth varies no more than 10%.

The required input data are underlined in Attachment 1. Section length, average depth (h) and design water level (y) relative to LAT would need to provided as well

Note: a similar service is provided for scour prevention mattresses of a design as shown in Attachment 12.

Upon award of contract the required Flexmats could be fabricated by the installation Contractor or a reputable precast Company at a location near the load-out point.

For this purpose a one-off manufacturing Licence would be issued by Marecon.

(*Unlicensed fabrication of Flexmats or similar type of anchors by a third party would infringe patents 642965 and 203539*)

Detailed manufacturing- and installation directives would be provided under the terms of the Licence Agreement.

For more information please contact Marecon's Principal:

P J (Jan) de Geeter.

Email: marecon1@bigpond.net.au
Mob: +61 409 366 612

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ATTACHMENT 1

(STABILITY ANALYSIS PERFORMED FOR EXXON'S 'BASSGAS' PIPELINE)

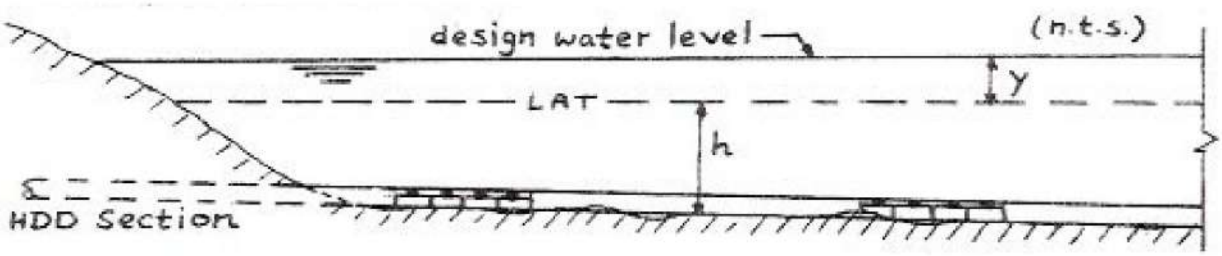
PIPEMAT.MAR:
2-D STABILITY ANALYSIS PROGRAMME for gravity stabilization of untensioned marine pipeline by means of FLEXMAT Gravity Anchors on the basis of Morison's force equations, in accordance with DnV's Recommended Practice E305 and Offshore Standard OS-F101, section 5, clause E409
(programme developed/owned by Marecon P/L, certified by DnV)

GENERAL INPUT:
pipe OD, wall thickness and coated OD are 356 mm 14.3 mm and 360 mm.
assumed marine growth is 0 mm.
density of (sea)water is 1025 kg/m3
failure (yield) stress of pipe material is 357 MPa
pipeline drag- and lift coefficients are 1.2 and .7
inertia coefficient of pipeline is 3.29
required safety factor (FOS) for stability is 1.1
concrete density of Flexmats is 3040 kg/m3.
Flexmat length and subm. weight are 4 m. and 3.29 T.
drag- and lift coeff. of pipeline/Flexmat profile are 1.4 and .3
inertia coefficient of pipeline/Flexmat profile is 8.3
submerged weight of pipeline is 260 N/m.

ADDITIONAL INPUT FOR PIPELINE SECTION 1 :
section length is 350 m. at (averaged) water depth of 20.5 m.
pipeline subsidence into bed material is assumed to be zero
lateral friction factor pipe/bed material is .6
steady current at 1 m. above seafloor is .64 m/s.
design wave height is 12.4 m.
relevant wave period is 14 sec.
corresponding (first order) wave length is 184 m.
for peakedness param. of 3.3 , wave vel. acc. to E305, is 3.35 m/s
current- and wave vel. approach angles are 90 deg. and 20 deg.
wave dir./spread. reduct. fact. acc. DnV's RP E305 fig 2.3 is .45
Keulegan/Carpenter number (KC) is 59
steady current/wave velocity ratio (M) is .33
semi-orbit/pipe diameter ratio (S/D) is 22.8
Reynolds number for combined wave vel. and current (Nre) is 2852000
phase shift in lift force, acc. to RP E305 ref 10 fig 2, is 50 deg.
(this effect is conservatively disregarded)

OUTPUT:
At pipe level, perpendicular to pipeline:
steady current and wave-induced velocity are .51 m/s and 1.51 m/s.
wave-induced acceleration is .68 m/s2.

at worst wave phase angle (11 deg.):
required submerged pipe weight (incl. FOS) is 2253 N/m.
required spacing of Flexmat Anchors (centre to centre) is 15.5 m.
required number of Flexmats for section 1 is 23
maximum pipe stress due to lateral deflection is 4 % of failure stress



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WOODSIDE
AUSTRALIAN ENERGY

ATTACHMENT 2

Our reference: OU6:FGP-230

Your reference:

9 March 1992

RECEIVED

KAC

Wembley Cement Industries
P O Box 555
VICTORIA PARK WA 6100

Attention: Mr Kevin Crosato

Dear Sir

WOODSIDE'S EXPERIENCE OF FLEXMATS

Further to your request for feedback on your product's field performance, we are able to confirm the following:-

- Flexmats were selected by Woodside for anti-scour protection of the NRA jacket and flare support structures of the North West Shelf Gas Project.

- The Flexmats were installed in 1986 and 1987. Approximately 450 mats, each weighing 5 tonnes in air were installed by remote means i.e. no divers required, from a Woodside vessel.

- Since installation, 3 severe tropical cyclones have affected the NRA area:-

  1988 - T.C. Ilona, 10 year severity
  1989 - T.C. Orson, 100 year severity
  1992 - T.C. Ian, 10 year severity

  T.C. Orson generated waves in excess of 20 metres height. The water depth is 125 metres at NRA.

- Following each of the above cyclones and on an annual frequency a detailed inspection of the Flexmats has been performed to check for scour, movement or deterioration of the Flexmats. No anomalies have been found during these inspections.

- Woodside considers that Flexmats are an effective means of scour control and may be used for similar applications in the future.

Yours faithfully

F G PEARCE
Senior Underwater Operations Engineer

P.S: mats designed by Marecon P/L in accord. with design life specification by Woodside of 50 years.
(footnote by Marecon P/L)

WOODSIDE OFFSHORE PETROLEUM PTY. LTD.
A.C.N. 004 945 097
Registered Office: No. 1 Adelaide Terrace, Perth, Western Australia, 6000.
GPO Box 555 G.P.O. Perth, Western Australia, 6001. Telephone: (09) 224 4111. Cables: Woodev. Telex: AA92326. Facsimile: (09) 325 8178

(as commissioned by Woodside Energy P/L)

9. CONCLUSIONS AND RECOMMENDATIONS (after extensive, three year, testing programme)

9.1 CONCLUSIONS

1. The peak force coefficients derived in this study for a pipeline on a flat non-erodible bed were found to compare closely with those generated in the DHI investigation for the AGA to develop their On-Bottom Stability Design Guidelines. Hence the model test results are considered to reliably represent the hydrodynamic loading of the pipeline on the seabed and of the other orientations tested in this program.

2. In general, the presence of the FLEXMAT does not attract a significantly greater hydrodynamic load on the pipeline. In most instances the vertical and horizontal loading appears to be slightly suppressed by the FLEXMAT, though the difference is not sufficiently great to quantify and rely upon such an apparent mechanism.

3. The comparison with mattress spacings derived via the DnV RP E305 Simplified Procedure (Spectral) illustrates the significant difference in mattress spacings obtained depending upon the on-bottom stability design procedure adopted. More refined on-bottom stability analysis techniques (as developed by Marecon and verified by DNV) are likely to further increase the required spacing in shallower waters as well as reduce the depth along the pipeline route to which the FLEXMATs are required.

4. The FLEXMATs appear to provide a feasible and reliable means of stabilisation to the Woodside 2nd Trunkline for all but the very shallowest water depths (ie. < 25 m) (*) along the pipeline route and storm conditions pertaining to those depths.

5. Depending upon the methodology adopted to assess the on-bottom stability of the pipeline, the following minimum FLEXMAT spacings can be derived for the range of water depths and storm conditions along the pipeline route for the pipe on a flat non-erodible bed.

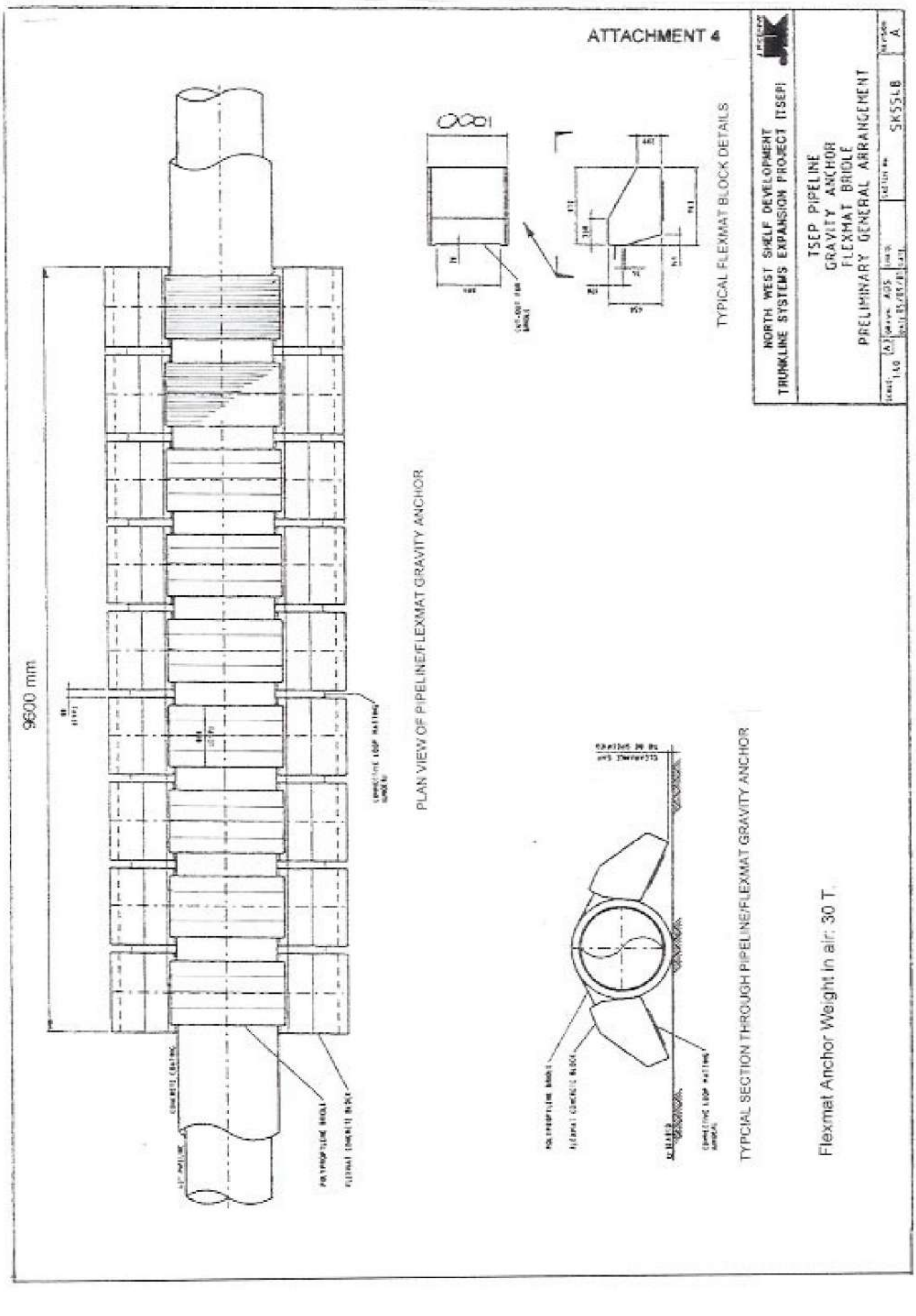
Sea State	Minimum Spacing at Given Water Depth			
	25	50	70	120
100 year Hm + 10 year Uc	3	7	12	177
100 year Hm + 100 year Uc	3	6	11	50
100 year Hs + 10 year Uc	10	25	150	Not Req
100 year Hs + 100 year Uc	8	17	43	Not Req

(*) for the considered concrete density. Trials at UWA have shown that, at higher density, Flexmats can be applied up to shoreline

6. The derived minimum FLEXMAT spacings show a rapid increase with water depth (**) for spacings above 70 metres, indicating that small variations in the underlying assumptions will lead to large variations in the derived spacing. Also, it is considered that derived spacings above the wavelength of the maximum sea state, about 300 metres, effectively mean that no additional weight is required. Therefore it is

(**) as done at Shell's Tutong pipeline in Borneo

ATTACHMENT 4



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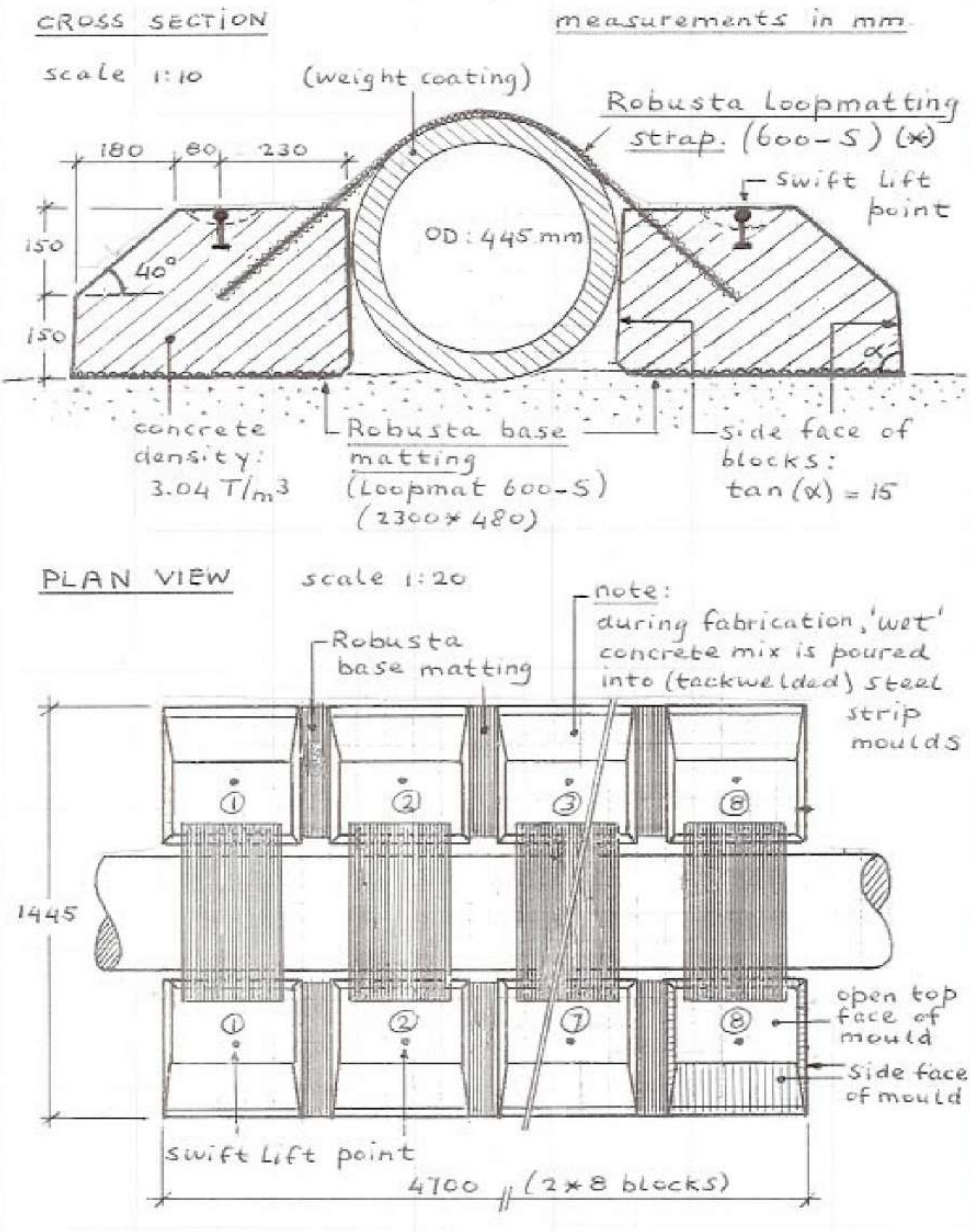
Assignment: for Shell-Brunei/Clough Calculation Sheet 1 of 1

Flexmat Anchor for Tutong pipeline

Job No./Ref: 99-23 Prepared by: P.J de Geeter Date: 15/06/99



ANCHOR WEIGHT: in air: 3.07 T. submerged: 2.05 T.

(*) double layer (folded over with loops facing outward) dimensions: 800*1100 (folded to 400*1100)

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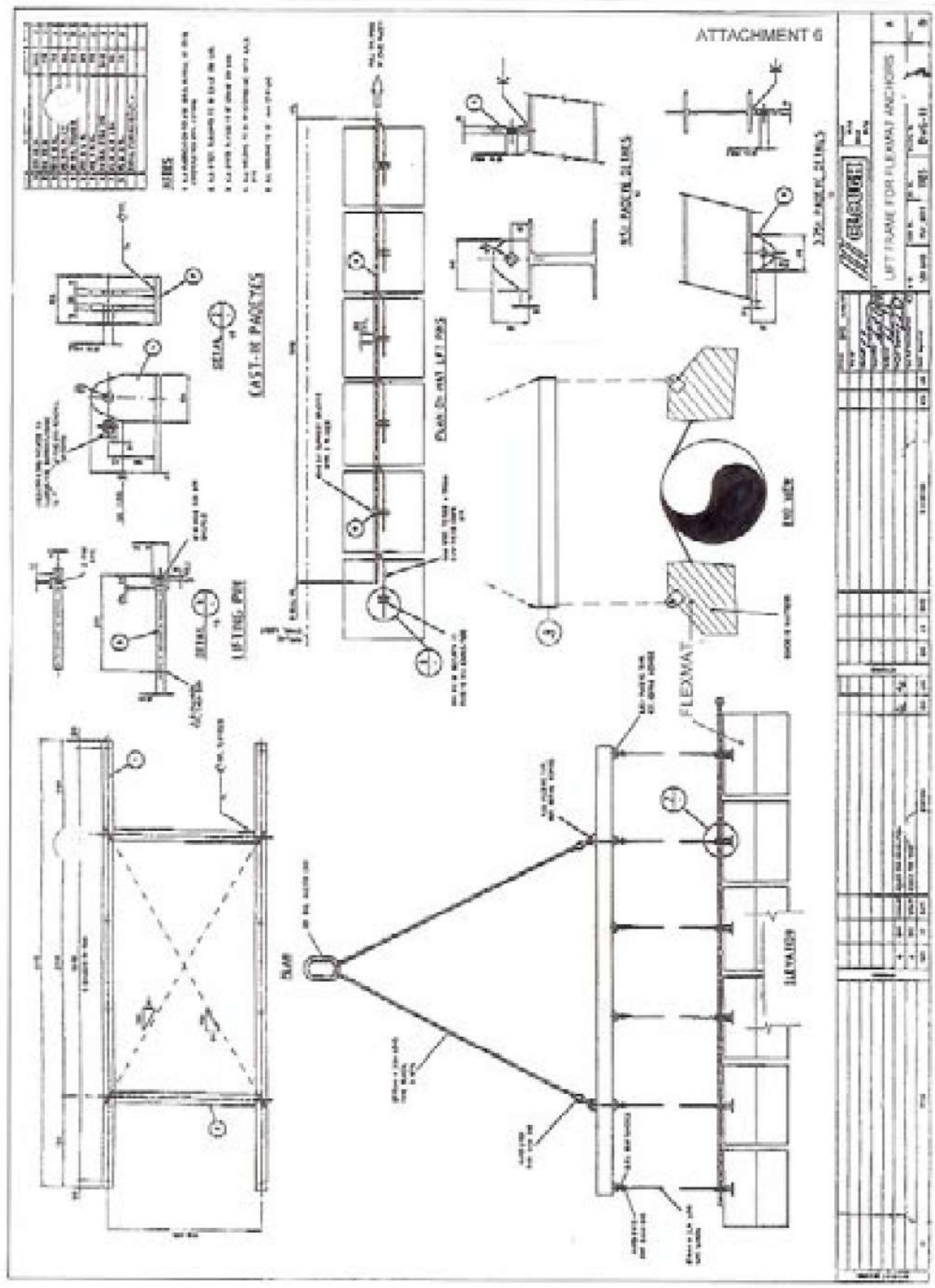

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Assignment: for SAIPEM/INTEC Calculation Sheet 1 of 1

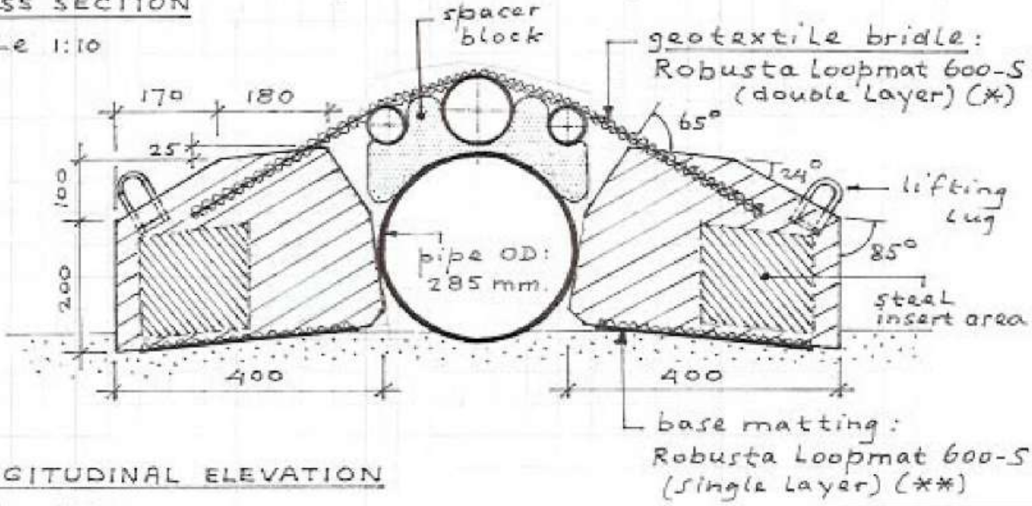
Flxmt Anchor design for Minerva Line (from KP 9863) (*)

Job No./Ref: 02/19 Prepared by: P.J. de Geeter Date: 5/9/02

(*) nearshore section (350 m.) from HDD exit point

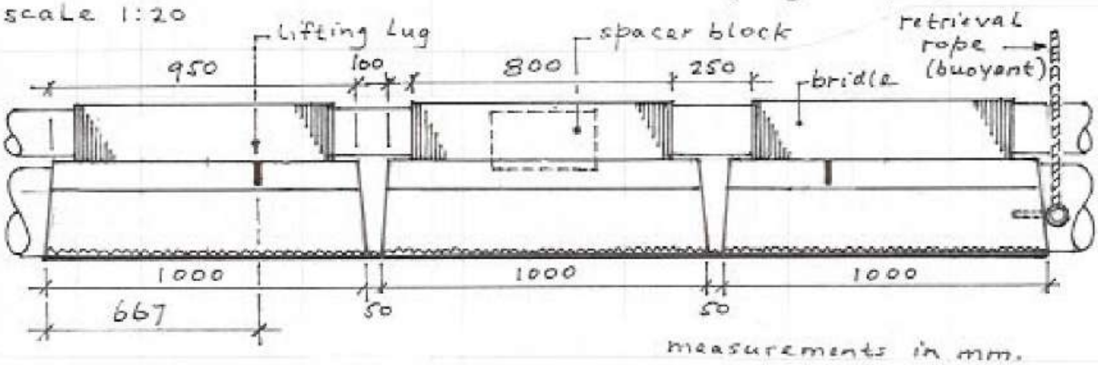
CROSS SECTION

scale 1:10



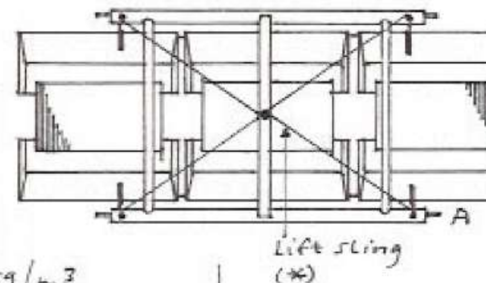
LONGITUDINAL ELEVATION

scale 1:20



measurements in mm.

PLAN VIEW
(with install. frame)
scale 1:40

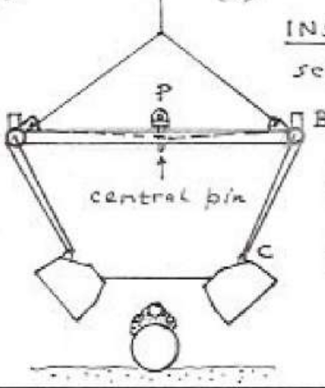


Anchor data:

- concrete density: 3400 kg/m^3
- Anchor weight:
  - in air: 2.0 T.
  - subm: 1.4 T.
- Anchor spacing (centre to centre): 12.4 m.

INSTALLAT. MODE

scale 1:40



(*) attached to Lug A, passing thru lift lug C, 'rounding' bollard B towards central pin P (retractable)

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ATTACHMENT 8

Wray & Associates
PATENT & TRADE MARKS ATTORNEYS • Est 1920

ATTACHMENT TO PATENT APPLICATION PR 7579

SCHEMATIC DRAWING OF CONCURRENT
PIPELINE/FLEXMATS INSTALLATION

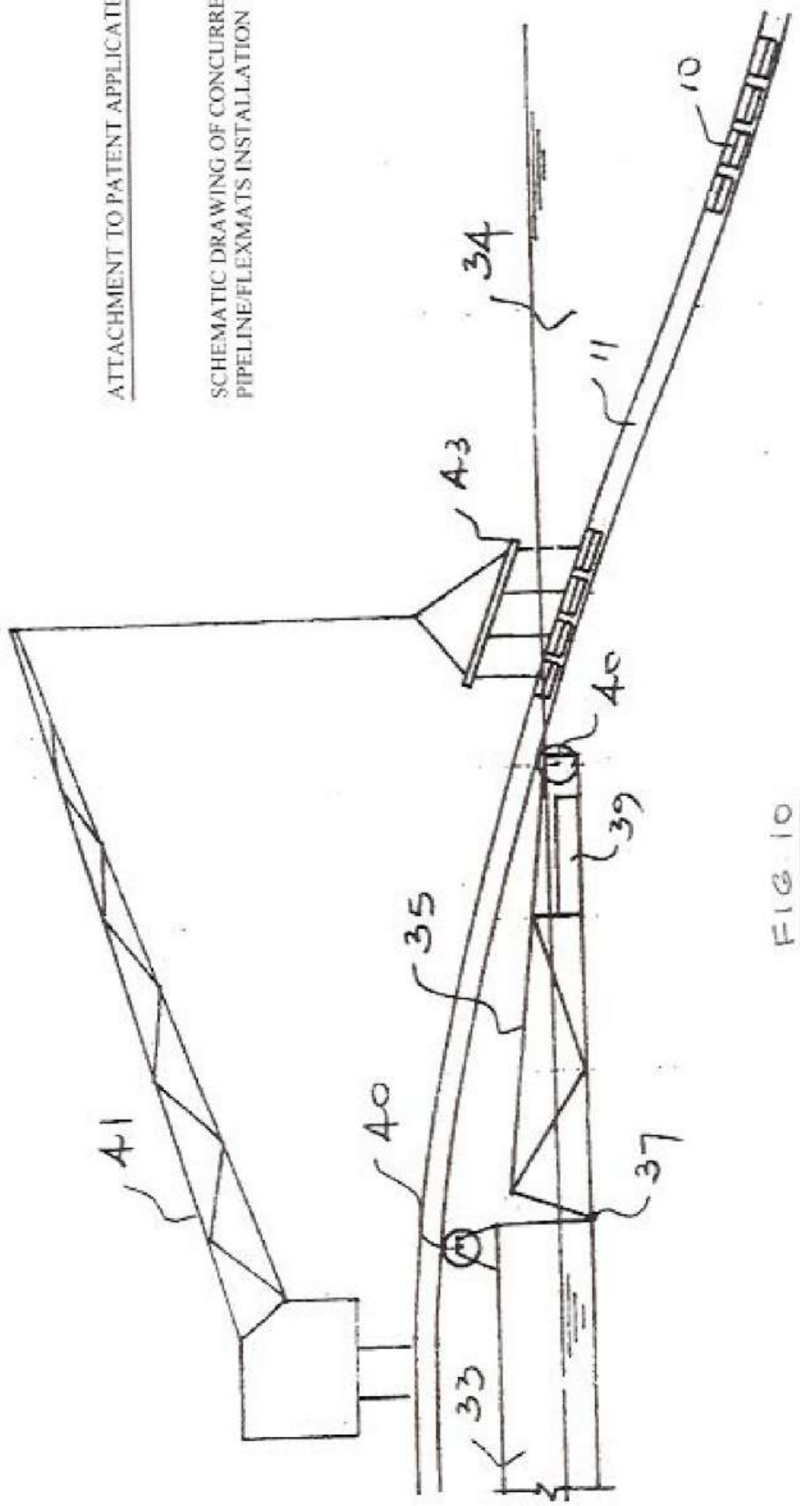

FIG 10

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DNV

ATTACHMENT 9

Western Mining Corporation Ltd (*)
P.O. Box 1099
West Perth
Western Australia 6872

Attention : **Mr Hans Haardt**
Offshore Construction Manager

Our ref : **TD/EN/L93393** **September 10, 1993**

Dear Sir

BASIS-OF-DESIGN DOCUMENT [incorporating stability analysis software] **BY MARECON PTY LTD**
VERIFICATION STATEMENT (*)

We refer to your letter L.516-HH-JS of 26 Aug 93 and are pleased to enclose our verification statement for your records.

We thank you for engaging us to undertake the verification work and look forward to future opportunities in which DNV can again be of assistance to WESMINCO.

Yours faithfully

(*) Verification work undertaken at the request of the Client (Western Mining)

EDWARDUS NG
TECHNICAL DIRECTOR

CC : Marecon Pty Ltd
Attention : PJ de Geeter

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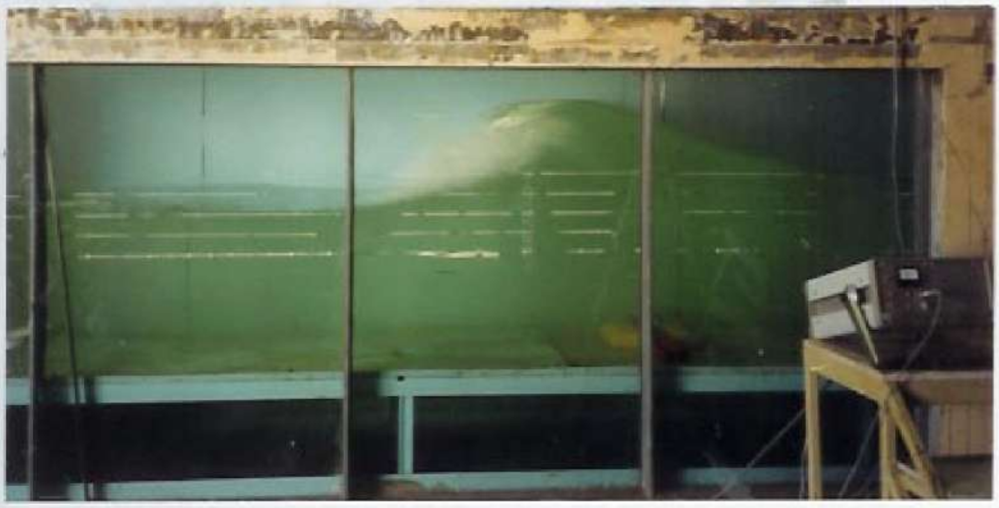
ATTACHMENT 10



Extreme (breaking wave) Loading of Flexmat/pipes bundle assembly.
(Agincourt Project) Shallow water tests at UWA's major wave flume

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ATTACHMENT 11

FLEXMATS FOR STABILISATION OF TANKER LOADING LINE (*)

(*) SALADIN FIELD (W.A.)

FLEXMAT(S) FOR STABILISATION OF OIL LINE (8") IN CHERVILL FIELD (W.A.)

ATTACHMENT 12

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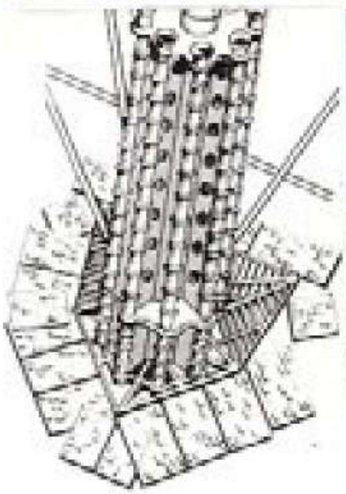
ATTACHMENT 12

Flexmat™*
for marine pipeline stabilisation

FLEXMAT™
for
scour control



suspended (5 T.) scour control mat before installation at the footing of Woodside Energy's Rankin platform

Flexmat stabilises 6.5km offshore pipeline

Some 40km north west of Onslow in Western Australia is Airlie Island the centre of the Chervil oil field, a development of the Western Mining Corporation.

The Chervil field is expected to produce approximately 6000 barrels of oil per day and are the third marginal oilfield to be developed after the successful North Herald and South Pepper fields. Produced fluids will be piped to processing facility on Airlie Island.

An oil pipeline with an outside diameter of 219mm runs from the offshore well near Taunton reef to the tank farm on the island. The 6.5km pipeline is untrenched, resting on a sandy seabed. The depth ranges between 15 and 20m and the area is subject to cyclones that approach from the north-west.

One of the major design difficulties of the project is that the submerged weight of the oil filled pipeline would not have been sufficient to ensure its stability on the seabed. Another factor was the relatively short lead time of 10 months to complete the line.

The design also needed to ensure that it would not be dislodged under cyclonic conditions. The solution was provided in the form of concrete block mats (Flexmats), placed from a barge by means of a crane.

The stability design used a 3D computer programme which was specially developed for Flexmat applications. This programme found that to stabilise the pipeline some 160 mats would be required, each weighing approximately 2.3 tonnes at an average spacing of 40m. An absence of steel in Flexmats is a major advantage as there can be no electrolytic interference as the result of seawater reaction with the steel pipeline.

The Flexmats were manufactured in Perth between March and June this year by The Readymix Group subsidiary Wembley Cement Industries.

Once the pipeline was in place Flexmats were installed at a rate of 2 per hour by the barge. The whole job of placing mats was completed in 3 days.

This method of using Flexmats to stabilise the pipeline proved to be highly effective and economical and enabled Western Mining to have the line fully operational almost immediately after installation was completed.

Inset below: A diver positions the Flexmat ready for lowering onto the pipeline seen in the top left of the picture.

Below: The 2.3 tonne Flexmat is ready for the stockpile. In between the concrete blocks can be seen the fabric that will stretch over the pipeline with the concrete blocks either side. This fabric has been selected for its resistance to the harsh marine conditions.