Rapid Deployment – Runway Denial Repair (RDRDR)

Expedient and sustainment repair of runway craters.

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RAPID DEPLOYMENT – RUNWAY DENIAL REPAIR (RDRDR)

1 THE MILITARY DOCTRINE OF DENIAL

Throughout the history of warfare, adversaries have regularly attempted to deny one another freedom of movement on the battlefield. Past forms of anti-access served to both protect friendly forces and prevent enemies from gaining positions of advantage.

A key objective in modern conflicts, be they peer to peer, peer to near peer or asymmetric, is to deny the enemy air superiority. First strike military doctrine calls for suppression of enemy air defences (SEAD) operations in conjunction with long range missile and/or air strikes on strategic targets including air assets and related infrastructure in order to secure air dominance.

Given the proliferation of stand-off weapon systems (SOW) – precision long and medium range guided munitions, including cruise missiles capable of air and submarine launch and low-cost precision glide bombs – many nations are now well equipped to execute first strike warfare.

The topic is discussed in further detail in Appendix 5.

Figure 1: Runway denial following an attack with anti-runway penetration munitions.

1.1 CAPABILITY TO RECOVER

Denial of airborne systems is a strategic goal of enemy forces for both tactical and strategic operations, as well as denial of combat service support and re-supply. Other than aircraft (which are evacuated or destroyed), the specific targets are the airfields.

Airfields can be denied by cratering the runways and destroying key supporting facilities. The capability to quickly recover the functionality of the main operating bases (MOBs) in the event of an attack is critical.

In simple terms, one side, by denying the other the ability to fly, gains air superiority.

2 RAPID DEPLOYMENT RUNWAY DENIAL REPAIR (RDRDR)

Just as airport fire services have a clear mandate to save lives in the event of an aircraft accident or incident, an integrated airfield damage repair (ADR) system has as its sole focus the rapid reinstatement of a runway in the event of an attack, to ensure aircraft can take off and land safely.

Runway reinstatement, or airfield damage repair (ADR), is an essential and necessary capability for any frontline airfield to possess. Runway reinstatement capabilities have to be available onsite, rapidly deployable and effective. There is little point in a nation-state investing in a modern, capable and sophisticated air force, if the simple act of denying their runways renders the aircraft redundant and vulnerable to attack on the ground, whilst ceding air superiority to the enemy.

2.1 THE VOLUCON RDRDR SOLUTION

Crater repair is performed under conditions of confusion, high stress, and intense pressure. Simplicity, reliability, robustness and redundancy are key attributes for systems that will work in the field.

The philosophy behind the Volucon RDRDR system is to provide a simplified, turnkey solution, that is ready to use immediately an incident occurs, or as soon as it is deemed safe to proceed, and provides expedient and sustainment repairs of bomb craters.

The system anticipates different types of runway damage and is designed to accommodate these efficiently and effectively.

The key objective is to have the runway surface reinstated as quickly as possible to enable aircraft to get airborne without unnecessary delays – delays which increase their vulnerability exponentially in a conflict situation.

The Volucon turnkey solution provides the capability to return a runway to operational status 60 minutes after repair initiation.

Figure 2: Example of damage inflicted by anti-runway penetration bombs.

2.1.1 TURNKEY SOLUTION

The turnkey solution includes:

- Military specification volumetric concrete mixers
- Pre-mixed materials to produce ultra-rapid hardening concrete repairs in ≤60 minutes
- Comprehensive training on equipment, materials and repair protocols
- Scheduled equipment inspection and maintenance with material inspection and quality control (six / twelve monthly)

Additional available items:

A number of additional items should be available as part of the RDRDR solution. These items, many of which will be found on airfields and bases, can be sourced locally in country if not already onsite, or if unavailable, they can be supplied by Volucon as part of the integrated package.

The list includes runway sweepers to ensure foreign object debris (FOD) free runway surfaces; loaders; blasting machine, reach forklift (> 6m) for lifting/loading the Jumbo Bags, pneumatic jackhammers / paving breakers to remove sections of damaged runway quickly to facilitate rapid patching – typically, surface lifting will occur around a damaged section and the most expedient and timely way to deal with this is to dig out the section and then patch it as described in 2.5 below.

Figure 3: Runway damage following a denial attack.

2.2 THE RDRDR VOLUMETRIC MIXER

The RDRDR volumetric mixer, based on US Department of Defence (DoD) specifications (see 4.3 below), is a self-contained proportional mixer mounted on a tandem-axle straight trailer that can be towed by a wide variety of available vehicles using an adjustable pintle hitch configuration for a secure mount.

The mixer is fully air transportable by fixed wing aircraft and helicopter lift. Helicopter lift allows the unit to be deployed under slung, improving its versatility, as it can be flown into an already damaged and unusable airfield and does not have to have been pre-positioned in order to be effective. Multiple anchor points to accommodate repositioning are described in the specifications, see Appendix 1.

The original RDRDR volumetric mixer is in service with the USAF and deployed on their airbases around the world.

Figure 4: Volucon-ProAll specialised runway repair volumetric mixer

Key features include:

- a single dry material bin with a capacity of 5 cubic meters
- a dry material conveyor belt system
- a variable speed hydraulically driven water pump designed for pre-set flow rates required based on mix design requirements
- an on-board mix water capacity of 1,500 litres
- an on-board pressure washer
- a rapidly replaceable (≤30 minutes) mixing auger mounted in a discharge boom at the rear of the mixer

A full description and specification listing is provided in Appendix 1, with schematics shown in Appendix 2.

2.3 PRE-MIXED BAGGED MATERIALS TO PRODUCE ULTRA-RAPID HARDENING CONCRETE

Moisture proof sacks of quality assured pre-mixed material will be provided for two mix designs: (A) an ultra-rapid hardening (URH) flowable fill, and (B) a URH concrete mix to cap craters.

Volucon's pre-mixed material contains all the ingredients necessary to produce the two-concrete mix designs necessary to repair the damaged runway pavement (see 2.5 below).

The concept adhered to throughout is one of simplicity. Two mixes, marked 'A' and 'B', will be provided and these will be applied in the field using a volumetric mixer capable of making either 'A' or 'B' mix design concrete. This ensure the simplest mode of operation as it is acknowledged that repairs will be carried out in stressful and potentially dangerous circumstances, therefore the process has been designed and simplified to anticipate both the repairs required and the circumstances the repairs will be carried out under.

Volucon will select from their proprietary cements and based on, (A) the ambient temperature at the airfield location and (B) the anticipated traffic conditions and design mix 'A' and 'B' specifically for each airfield. All the design mixes will adhere to the URH Standards and match or exceed the test data shown in Appendix 3.

2.4 TRAINING

Procedures, equipment, and materials identified will be used to equip and train repair teams. Repair team proficiency will be developed and maintained by local unit training, recurrent training, and centralised training at designated locations as required. Recurring unit inspections and equipment maintenance and material checks combined with *Operational Readiness Training* will be conducted on a regular basis to ensure runway denial repair is optimised and available on demand. There is no substitute for training, experience, and leadership in the repair teams.

2.5 REPAIR METHODOLOGY

Following an airfield attack, and assuming the runway has been damaged, the objective is to repair any surface craters, or surface damage, as quickly as possible.

The longer aircraft sit on the runway after a successful denial attack the more vulnerable they become to subsequent ground and air attack, thus potentially ceding air superiority to the enemy.

The target repair time is ≤60 minutes. This ambitious timescale is achievable if the required equipment and materials are available onsite, together with trained and competent repair teams.

The repair principles to be followed are:

2.5.1 **SCENARIO A**: THE RUNWAY CONCRETE CAP/PAVEMENT LAYER HAS BEEN PENETRATED TO EXPOSE THE BASE LAYER(S) OR SUBGRADE

Assuming the runway concrete pavement has been penetrated to the base layer(s) or sub grade, (See Figure 5 below), the ejecta material is partially returned to the crater to the level of the existing concrete cap with the rest removed from the runway surface by the sweeping equipment to ensure the runway is free from FOD.

2.5.1.1 Subgrade and Base Preparation

A URH flowable fill is added to the partially filled crater. The flowable fill penetrates around the rubble and sets quickly to provide a base that is stable and ready to receive the URH concrete cap. The time to reach structural strength, typically ≥22MPa compressive strength, will have been predetermined based on the anticipated ambient temperature at the location. The time to reach structural strength will be set at no more than 60 minutes. This means aircraft can pass over the repair with impunity after one hour. The concrete cap should be as thick as the original concrete runway pavement.

The URH cement concrete bonds physically and chemically to the infilled material and existing Portland cement concrete (PCC), thus ensuring a robust, durable and long-life repair.

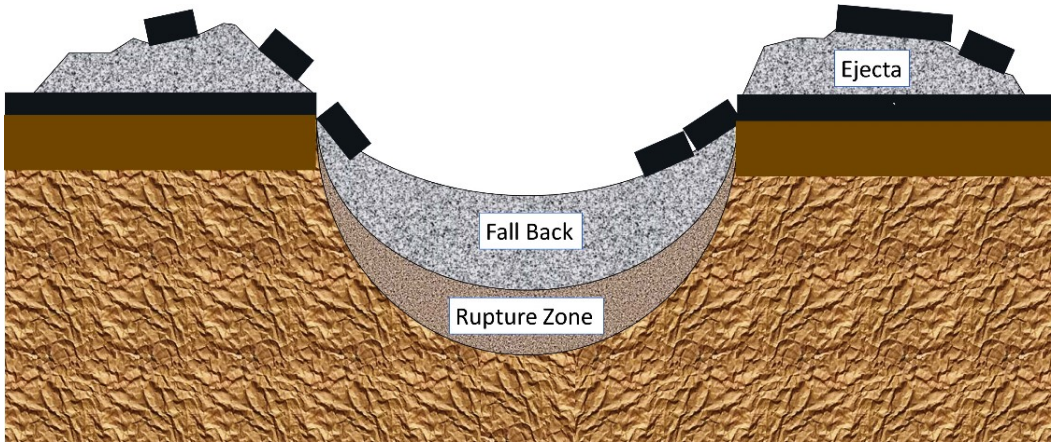

Figure 5: Runway damage caused by penetrating anti-runway bomb.

2.5.2 **SCENARIO B**: THE RUNWAY CONCRETE CAP HAS NOT BEEN PENETRATED TO EXPOSE THE BASE LAYER(S) OR SUB GRADE

If the base layers have not been exposed, then the damage to the runway is more superficial and the repair is a single step procedure, with the flowable fill no longer required to stabilise the base layer(s) and/or subgrade.

In this case the debris is sweep away to clean the crater of fall back debris and the crater is capped with URH concrete. Projected setting times are within the curing time estimate for the runway location and ambient temperature for the time of year if significant variation exists (≤60 minutes).

In both repair scenarios, the workability of the concrete can be controlled from the volumetric mixer's computerised control panel making the runway repair as easy as possible for the reinstatement crews. As in the previous example, the URH concrete will bond physically and chemically to the existing Portland cement concrete (PCC), thus ensuring a robust, long-life and durable repair.

Finally, thought should be given to the placement of the runway reinstatement equipment and materials so they remain accessible and useable in the event of an attack on the airfield.

2.5.3 OPERATIONAL REQUIREMENTS

Each volumetric mixer requires to be towed to the location, needing a driver, a single operator is required per mixer to produce the concrete, plus a loading/reloading crew of two. The repair teams are comprised of four technicians to prepare each damaged section, two to place the concrete and two to finish the placement, a total of 16 trained personnel. Numbers can be adjusted based on the training protocols adopted but an allowance for a crew of 16 is prudent in planning.

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3 CONCLUSION

Volucon is the only global turnkey provider of a *Rapid Deployment Runway Denial Repair* (RDRDR) solution, including all necessary components to ensure airfield readiness, namely:

- Military grade volumetric concrete mixers
- Pre-mixed materials to produce ultra-rapid hardening concrete repairs in ≤60 minutes
- Comprehensive training on equipment, materials and repair protocols
- Scheduled equipment inspection and maintenance with material inspection and quality control (six / twelve monthly)

Each solution is customised and takes account, not only of the current runway's physical condition, the air fleet based at each airfield, but also the location and annual ambient weather conditions and the quality and availability of resources, such as water.

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4 APPENDIX 1 – VOLUMETRIC MIXER AND TRAILER SPECIFICATIONS

4.1 VOLUMETRIC MIXER GENERAL DESCRIPTION

The volumetric mixer is a self- contained proportional mixer mounted on a tandem-axle straight trailer that is towable by a variety of vehicles using its adjustable pintle hitch configuration.

1. a single dry material bin with a capacity of 5 cubic meters
2. a dry material conveyor belt system
3. a variable speed hydraulically driven water pump designed for pre-set flow rates required based on mix design requirements
4. an on-board mix water capacity of 1,500 litres
5. an on-board pressure washer
6. a rapidly replaceable mixing auger mounted in a discharge boom at the rear of the mixer (change out time ≤30 minutes)

4.2 VOLUMETRIC MIXER GENERAL SPECIFICATION

1.	Total empty weight	16,940 lbs	7,684 kg
2.	Shipping weight	16,940 lbs	7,684 kg
3.	Loading cubage	169.8 cubic feet	4.81 cubic metre
4.	Overall height	10.5 feet	320.04 cm
5.	Overall width	8.5 feet	259.08 cm
6.	Overall length	30.0 feet	914.4 cm
7.	Landing gear load rating	50,000 lbs	22,679.62 kg
8.	Tie down rating	17,600 lbs each	7,983.23 kg each
9.	Number of tie downs	8	
10.	Axle load empty	6,430 lbs	2,916.56 kg
11.	Landing gear load empty	4,080 lbs	1,850.66 kg

12. The mixer is powered by an electric start diesel engine with a minimum gross horsepower of 59HP
13. The electrical system is a 12V DC system
14. The hydraulic system includes a hydraulic oil cooler that maintains temperature for continuous operation

15. The mixer meets existing current Volumetric Mixer Manufacturers Bureau standards
16. Single bin for pre-blended dry materials with a capacity of 5 cubic meters
17. Two removable fixed bag splitters are included that extend 30 centimetres above the side of the bin and can split the bottom and withstanding the weight of super sacks of dry pre-blended concrete materials
18. Friction resistant coating applied to the inner walls of the bin
19. Four (4) electronically activated high-impact 12V DC automatic bin vibrators with manual and automatic settings to adjust cycle times are mounted on the bin walls
20. Fold-away 250-lb capacity lightweight catwalks that provide bin access with safety rails, non-skid surfaces and grated floors are located on each side of the bin
21. An optional weatherproof aluminium bin cover can be provided for inclement weather with a maximum weight of 55kg
22. A full-length heavy-duty tarpaulin equipped with an assisted deployment mechanism with tie down cords for temporary weather protection. The tarpaulin covers the full length of the mixer including the dry storage
23. The conveyor consists of a 50- centimetres wide conveyor belt bolted to a roller chain and crossbar assembly to provide positive flow with no slippage
24. The conveyor chain has automatic lubrication
25. The dry material conveyor system includes an adjustable strike-off gate
26. The mixing auger is 2.4 meters in length and 25 centimetres in diameter
27. The speed of the mixing auger is adjustable
28. The top of the mixing auger provides for rapid access for cleaning during operation
29. The mixing auger assembly and hydraulic lines include pins for quick disconnection to replace the auger assembly within 30 minutes
30. A spare mixing auger assembly and associated hydraulic lines are provided and mounted on the trailer in an accessible location to facilitate rapid retrieval and replacement
31. A hydraulically powered 200 bar pressure washer with hand wand, including spare tips for pressure washing the mixer
32. The operator controls are located at the rear of the machine and include:
    a. Hoist Control for raising and lowering the mixer and chutes,
    b. Swivel Control for swivelling the mix auger left and right +/- 70 degrees,
    c. Mixer Control for activating the auger (bidirectional),
    d. Conveyor control that activates the linked conveyor and mixing water distribution system, and
    e. Pressure Washer Control

33. The operator controls have identification plates that are engraved, etched, or stamped metal and constructed from non-corroding, UV-resistant, metal material, that can withstand frequent pressure washing and harsh environmental exposure
34. The mixer can produce a variable production rate which will be determined by the mix designs. In our experience without modification to our existing product the unit can produce approximately up to 1,200kg or 0.5m^3 of concrete per minute. The rate limiting factor is, in our experience, is the placement and finishing of the concrete.
35. Six (6) LED flood lights with integrated wiring harnesses are mounted on the mixer. The lights include one on each side and 2 each at the front and the rear of the machine mounted on adjustable height stands to facilitate night-time operation
36. The mixer includes a spare parts kit including: one (1) set of Ni-HARD steel wear auger blades; one (1) lower auger bearing; two (2) spare auger bottom skirts; seals; and a grease gun and two (2) cartridges
37. A solar-powered trickle charger is installed to ensure the 12V deep cycle battery is consistently charged
38. The mixer can transport a 22,046 lbs (10,000 kg) payload over improved roads at sustained speeds of 75 KPH and unimproved roads at sustained speeds of 40 KPH
39. The machine includes data plates that are engraved and constructed from non- corroding metal

4.3 FULLY HYDRAULIC DESIGN CHANGE

The mixers specified by, and manufactured for the USAF to the above referenced DoD specification, were based on a legacy design which is now outdated and obsolete, use a two-speed mechanical transmission coupled with a positive displacement water pump which limits the flexibility of the mixer to vary the water flow rate limiting the range of concrete mix designs the units can produce without having to physically change the gearing.

To address this operational limitation, the new generation ProAll Volucon RDRDR volumetric mixer design utilises over 90% of the existing DoD specified RDRDR equipment and subsystems, but replaces the mechanical pump and its associated mechanical/gear subsystems with a modern variable displacement centrifugal water pump, thereby increasing the versatility of the system which is now able to produce a significantly wider range of concretes, making the unit more versatile.

The latest version of the ProAll Volucon RDRDR volumetric mixer is in use worldwide, including in the Gulf States, where they have been fully tested and approved by Saudi Aramco.

4.3.1 THE VOLUCON UNITS OFFER A MORE CURRENT, FULLY HYDRAULIC DESIGN RDRDR VOLUMETRIC MIXER

Volucon working with their equipment partner, ProAll International, considers the fully hydraulic design to have the following advantages over the hydraulic/gear version:

- Simpler maintenance requirements and greater reliability
    - Fewer moving parts
    - Less complex and more commonly used centrifugal water pump
- Operational advantages
    - Simplicity – the mixer is now fully hydraulic rather than a combination of hydraulic and mechanical driven components
    - Slump variation can be achieved by varying the water rather than changing the volume of dry premixed material by changing the gate settings
    - The Volucon mixer provides the opportunity for pre-adjustment of the two pre-set water volume selections as stipulated on the USAF design which has no adjustment to the two pre-set water volumes thereby limiting the application and use of alternative premixed materials, meaning the mixer can now be used to make concrete for other base related purposes e.g. security and blast barriers

4.4 TRAILER GENERAL SPECIFICATIONS

A. The trailer is a tandem-axle straight trailer equipped with air brakes integrated into the frame.
B. The minimum tandem-axle rating is 36,000 lbs.
C. The minimum trailer rating is 45,500 lbs.
D. The trailer meets applicable lighting standards for general road travel
E. The minimum ground clearance is 10 inches.
F. The hitch consists of an adjustable pintle hitch configuration for a secure mount - ideal for rougher terrain
G. The trailer includes a back-up warning system
H. An integrated tool box is included for stowage of the tarpaulin and spare parts
I. Axle Load Rating
    a. GAWR 20,500 lbs (9,299 kg)
    b. Tires 235 / 75R17.5 16PR

c. RIM 17.5 X 6.75 X 8”
d. Cold inflation pressure 110 PSI (7.6 Bar)

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5 APPENDIX 2 – RDRDR VOLUMETRIC MIXER – GENERAL SCHEMATICS

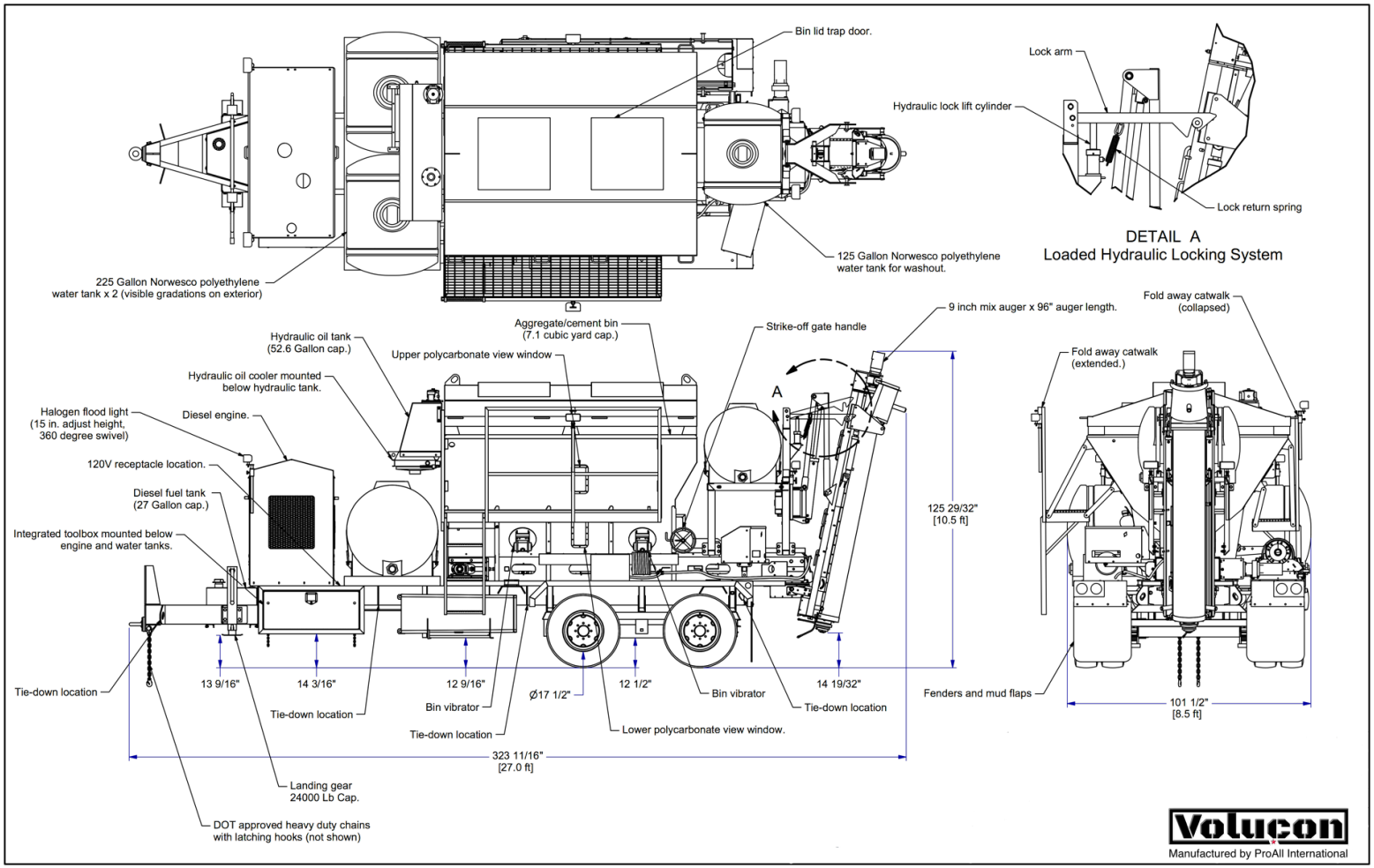

Figure 6: RDRDR Mixer Schematic 1

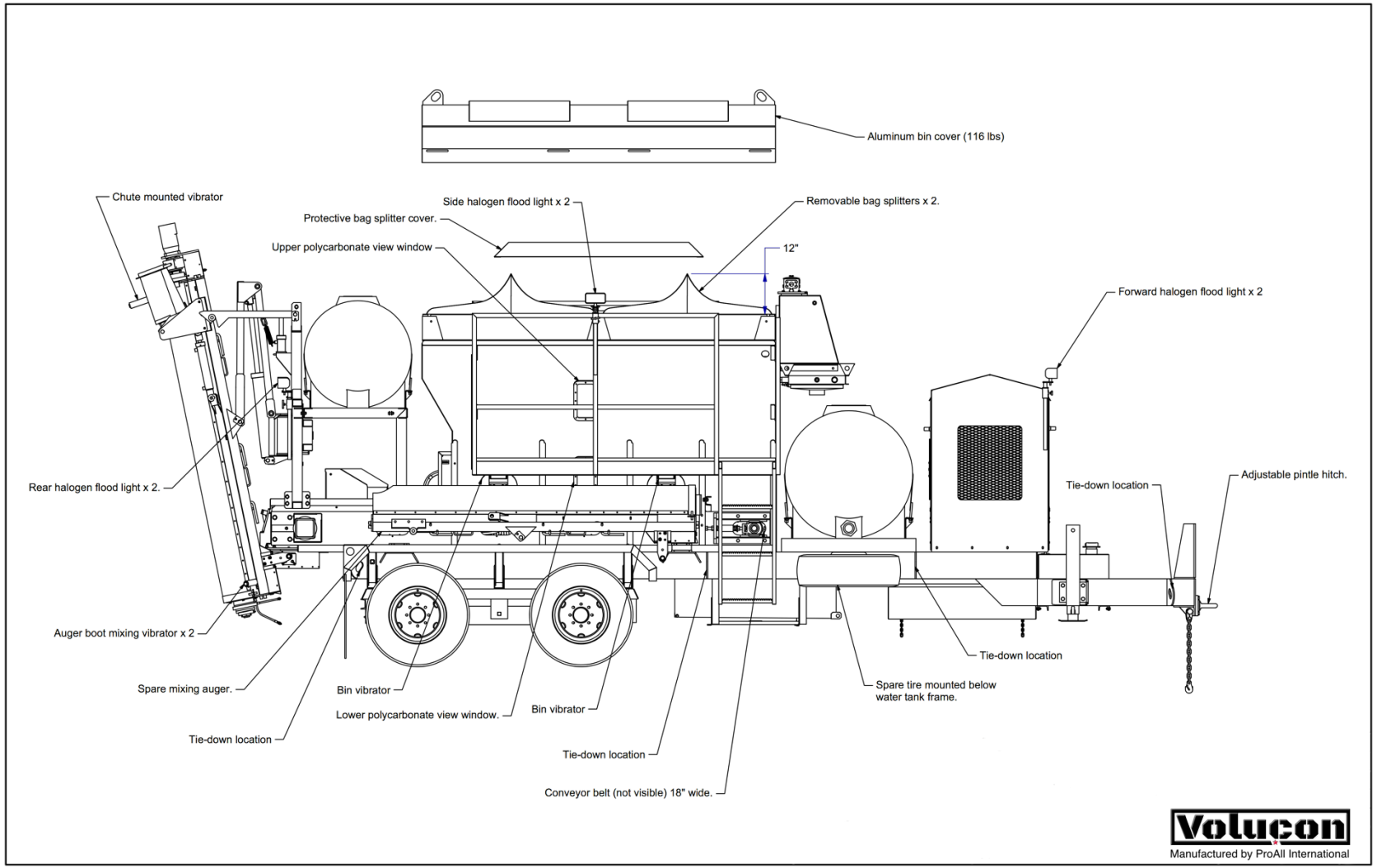

Figure 7: RDRDR Mixer Schematic 2

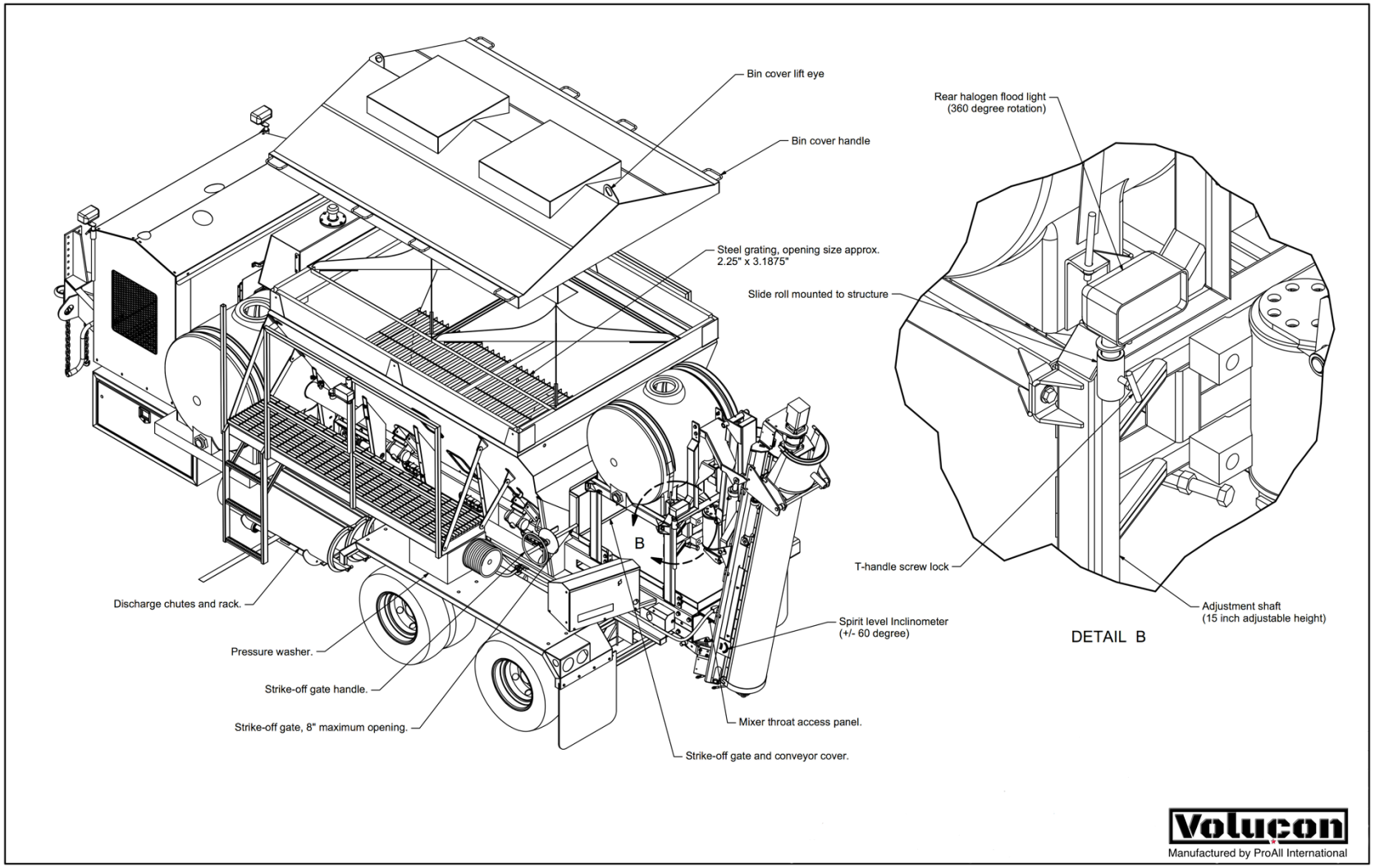

Figure 8: RDRDR Mixer Schematic 3

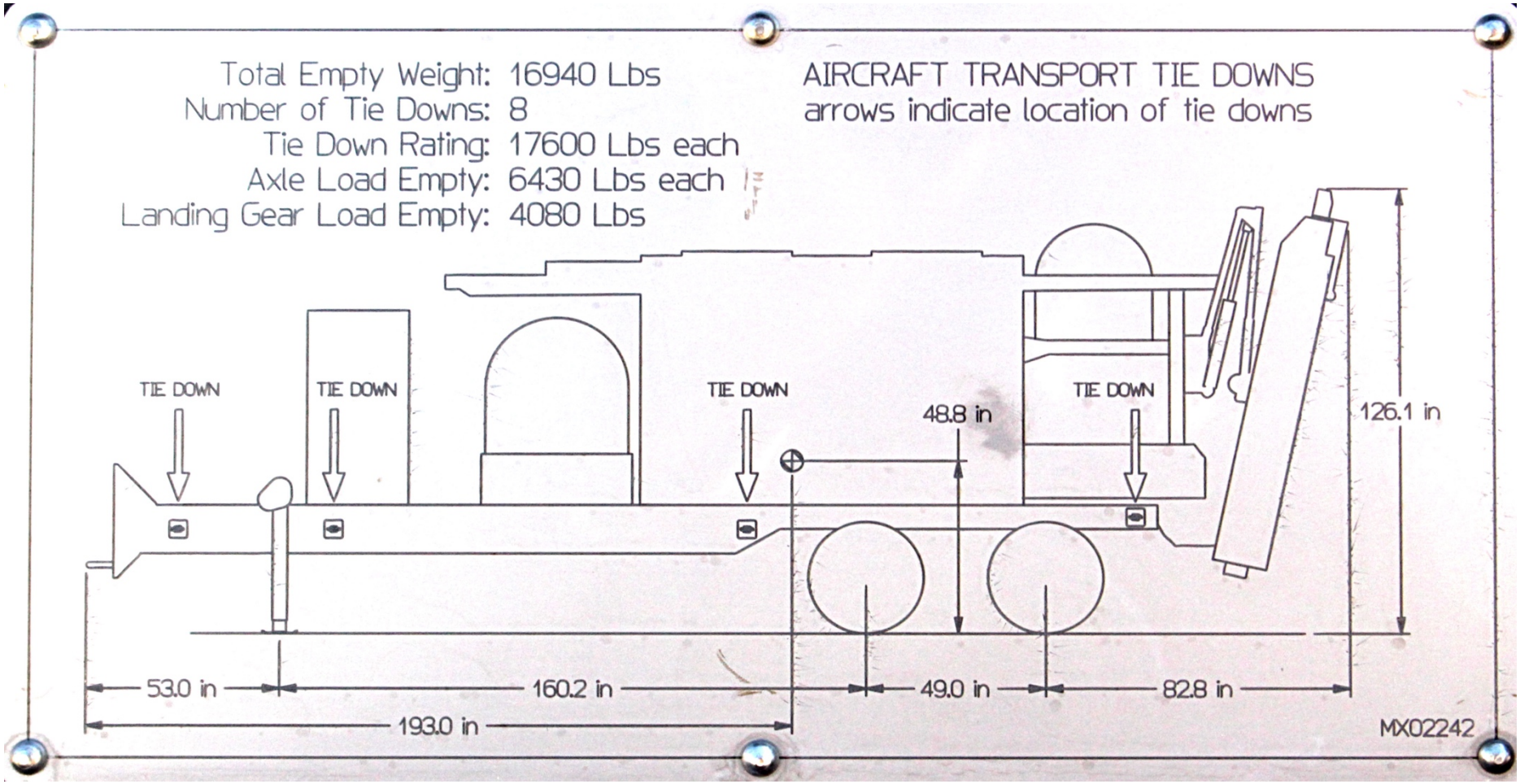

Figure 9: RDRDR Trailer Schematic

6 APPENDIX 3 – PERFORMANCE OF ULTRA RAPID HARDENING CONCRETE FOR AIRPORT PAVING

6.1 QUALITY ASSURANCE – URH ASTM STANDARD

Volucon's URH concrete complies with the following ASTM international standard issued under the fixed designation C1600/C1600M ASTM C1600, "*Standard Specification for Rapid Hardening Hydraulic Cement".*

Actual test data follows the ASTM specifications listed below.

The concrete will comply with the following standards unless modified by the following specifications:

1. ASTM C33-03 Standard Specification for Concrete Aggregates
2. ASTM C78-02 Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
3. ASTM C150-04 Standard Specification for Portland Cement
4. ASTM C109/C109M-02 Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. Cube Specimens)
5. ASTM C469-02 Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression
6. ASTM C597-02 Standard Test Method for Pulse Velocity Through Concrete
7. ASTM C666/C666M-03 Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing
8. ASTM C672/C672M-03 Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to De-icing Chemicals
9. ASTM C1157-03 Standard Performance Specification for Hydraulic Cement
10. ASTM C882-99 Standard Test Method for Bond Strength of Epoxy-Resin Systems Used with Concrete by Slant Shear

Volucon cement concrete will exceed the following minimum ASTM performance requirements:

Compressive strength of extended material per ASTM C109 (Mod.):

- 1 hour 2,000 psi (13.8 MPa)
- 3 hours 4,400 psi (30.3 MPa)
- 1 day 5,500 psi (37.9 MPa)
- 28 days 6,000 psi (41.4 MPa)

Flexural strength of extended material per ASTM C78 (Mod.):

- 5 hours 500 psi (3.4 MPa)
- 1 day 650 psi (4.5 MPa)
- 28 days 750 psi (5.2 MPa)

Bond strength of extended material per ASTM C882 (Mod.):

- 1 day 1,200 psi (8.3 MPa)
- 20 days 2,500 psi (17.2 MPa)

Scaling resistance per ASTM C672:

Number of cycles	Relative Modulus	Remarks
72	97.9	Slight scaling
180	89.1	Loss of surface fines
252	84.1	Increased loss
300	82.4	Moderate scaling

Modulus of Elasticity of extended material per ASTM C469:

- 28 days 4,000,000

The concrete shall meet ASTM C150, ASTM C597, and ASTM C1157, and shall be non-metallic with no added chlorides.

Sand: Meeting ASTM C33.

Course Aggregate: Meeting ASTM C33.

6.2 QUALITY ASSURANCE – INDEPENDENT LABORATORY TEST DATA

Compressive Strength [Volucon URH Data vs ASTM Standard C1600/C1600M]			
Compressive Strength (MIXED with Potable Water) – W/C 0.36.		**Compressive Strength (Mixed with Sea Water) – W/C 0.36.**	
27.6 MPA after 1.5 Hours	**ASTM C1600 – 21 MPA**	**30 MPA after 1.5 Hours**	**ASTM C1600 – 21 MPA**
35 MPA after 3 Hours	**ASTM C1600 – 28 MPA**	**34 MPA after 3 Hours**	**ASTM C1600 – 28 MPA**
47.8 MPA after 24 Hours	**ASTM C1600 – 35 MPA**	**45 MPA after 24 Hours**	**ASTM C1600 – 35 MPA**
60.4 MPA after 7 Days	**ASTM C1600 – 41 MPA**	**54 MPA after 7 Days**	**ASTM C1600 – 41 MPA**
64.3 MPA after 28 Days	**ASTM C1600 – 57 MPA**	**63 MPA after 28 Days**	**ASTM C1600 – 57 MPA**
Heat of HYDRATION of ignited Cement (28 Days)			
268 KJ/KG	**ASTM C1600 – 290 KJ/KG MAX**	**276 KJ/KG**	**ASTM C1600 – 290 KJ/KG MAX**

Table 1: Compressive Strength [Volucon URH Data vs ASTM Standard C1600/C1600M]

Final Setting Time
ASTM C 191 AT 23°C – > 10 Minutes
Permeability
DIN 1048: PART 5 : 1991 – 1MM (Portland Cement 15 MM).
Slump
Controllable from zero slump up to Flowable (SCC Self-Compacting Concrete)
Curing
Volucon URH Concrete doesn't require water curing except for extreme weathering conditions (heat & windy) water curing might be needed for 4 Hours.
Finishing (Concrete Surface)
Depends on the form work used, using the proper form work can provide a very smooth, levelled concrete finishes which usually doesn't need any kind repairs or plastering works, Also coloured concrete can be provided.
Flexural Strength
Minimum 3.8 MPA after 28 Days

Table 2: Final Setting Time, Permeability, Slump, Curing, Finishing & Flexural Strength

Drying Shrinkage
ASTM C-596 – 0.03% after 28 Days (Portland Cement 0.15%).
Expansion in Water
ASTM C-1038 – 0.016% (14 Days) – [ASTM C 1157 Max Limit 0.02%]
Sulphate Expansion
6 Months - ASTM C 1012 - 0.01% [ASTM C 1157 Max Limit 0.05%, ASTM C 150 Max Limit Type (V) 0.04% - 2 Weeks]

Table 3: Drying Shrinkage, Expansion in Water & Sulphate Expansion

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7 APPENDIX 4 – RDRDR PACKAGE AND BUDGETARY PRICING

The following is the suggested package configured for each individual runway / airfield.

7.1 MATERIAL

7.1.1 PRE-MIX MATERIAL

- The assumption is both deep crater and lighter damage may be incurred and the rapid deployment solution must accommodate both eventualities
- The more severe damage requires two concrete design mixes to ensure the ≤60-minute reinstatement target can be achieved
- All jumbo bags will be pre-dried, packed in water proof bags, Q.A/Q.C checked to insure a minimum shelf life of 18 months from production date
- Mix (A) URH Flowable Fill & Mix (B) URH Concrete will be pre-bagged dry in Jumbo Bags of 1 tonne

7.1.2 STOCK LEVELS

Minimum stock levels to be decided and finalized according to the client threat assessment. An assumption has been made that 20 craters will be repaired and a 30% allowance has been made to accommodate more severe damage and/or more extensive damage.

- 320 Jumbo Bags of Mix (A) - Sufficient to produce 140 m^3 of URH Flowable Fill
- 320 Jumbo Bags of MIX (B) - Sufficient to produce 140 m^3 of URH Concrete
- Both Packages (A) & (B) are designed/engineered to produce a volume of 0.437M^3/bag

7.2 EQUIPMENT

7.2.1 MILITARY SPECIFICATION RDRDR VOLUMETRIC MIXER

Each runway or base is equipped with two specialised volumetric mixers. Each unit is configured to produce either of the concrete design mixes, Mix ‘A’ - URH Flowable Fill, and Mix ‘B’ - URH Concrete. Note: units can produce both design mixes by simply selecting an ‘A’ or ‘B’ switch.

7.2.2 OTHER EQUIPMENT

Other equipment such as runway sweepers, loaders, blasting machine, reach forklift (> 6m) for lifting/loading Jumbo Bags, pneumatic jackhammers etc., can be sourced locally. If these additional items cannot be sourced locally Volucon can arrange for these items to be supplied as part of the turnkey package.

Reinstatement teams will be trained by Volucon engineers on all equipment and materials and shown how to perform repairs to international best practice standards.

7.3 TRAINING & INSPECTION PROGRAM

Technical training, equipment and general inspection shall be conducted at the client's bases biannually by Volucon Training/Inspection team.

The target of this team is to train the client's personnel regularly on calibration, repair techniques, operations, maintenance and concrete production. The objective is to enhance the overall performance and readiness of the repair teams.

In addition, a comprehensive technical report on the equipment, operational status and checklist together with advice on optimisation will be provided to each base. If there are any malfunctions, equipment damage or spare parts needed, these will be reported and repair procedures initiated together with follow up until everything is fully and efficiently operational. This program includes both educational and field training for the maintenance crews.

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8 PPENDIX 5 – RUNWAY DENIAL

8.1 ANTI-RUNWAY PENETRATION BOMBS

Anti-runway weapons are typically penetration bombs – systems involving bombs or bomblets – designed to disrupt the surface of an airfield runway and make it unusable for flight operations.

Perhaps the most strategically decisive, and first wartime use of specialized cratering anti-runway weapons, was by Israel during the 1967 Six-Day War. The anti-runway penetration bombs used played a major part in the near complete destruction of the large Egyptian Air Force. The surprising elimination of the Egyptian air force and resulting Israeli air supremacy contributed significantly to the outcome of the war on all fronts.

A more recent example, is the invasion of Kuwait on 2 August 1990, a 2-day operation conducted by Iraq against its neighbour, which resulted in the seven-month-long Iraqi occupation of Kuwait. In the initial stages of the operation the Iraqi Air Force bombed Kuwait's airfields with Durandal anti-runway penetration bombs delivered by Mirage F1 jets.

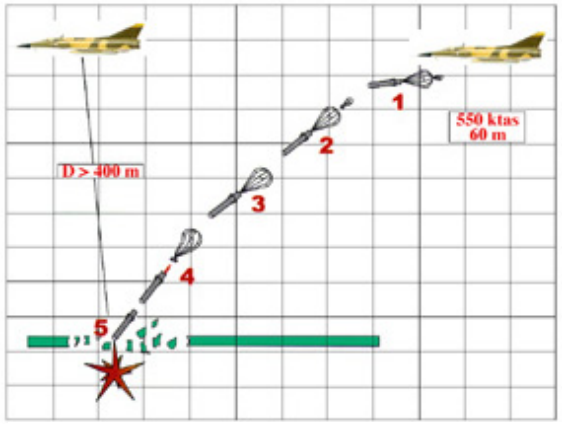

Figure 10: Durandal anti-runway bomb delivery.

Subsequently, during the Gulf War, Durandal bombs were used again, this time by the USAF in the initial stages of the 1991 operation Desert Storm against Iraqi airfields, and the occupied airfields in Kuwait, delivered by F-111s. Kuwait's runways having been repaired in the interim period between the initial Iraqi invasion and the start of the *Desert Storm* offensive.

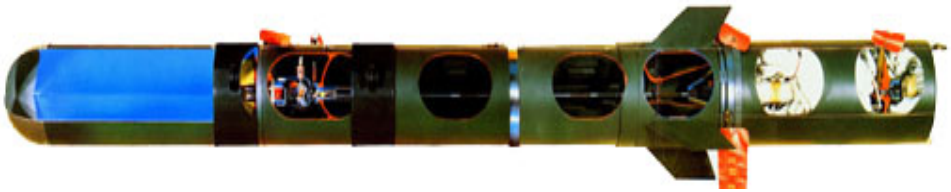

Figure 11: Ordtech OMI-ARW1 anti-runway weapon based on French Durandal used to neutralize enemy airfields.

After being dropped by an aircraft flying at low level the Durandal missile is braked by parachute, then when at the correct angle a rocket fires to impact the runway, first igniting a large warhead to create a crater and then subsequently using a smaller secondary charge that had penetrated the crater to displace adjacent concrete slabs. The slabs, once displaced, are harder to deal with than a simple hole that could be patched with asphalt. The Durandal has been widely exported.

8.2 STAND OFF WEAPON SYSTEMS (SOW)

Airbases are heavily defended territory and consequently, the risk of sending in attack aircraft can be high. To counter this risk, anti-runway operations are increasingly conducted using stand-off attack missiles, ushering in a new era of air combat effectiveness dubbed, *The Revolution in Strike Warfare.*

Using standardized medium range precision guided weapons, especially for engagement of defended targets from outside the range of standard anti-aircraft defences, thereby increasing aircraft survivability and minimizing friendly losses, is now the preferred doctrine. These SOW systems, whether air, sea or land launched are often referred to as *fire-and-forget*.

The British and French, for example, have specific air-launched cruise missiles that were designed to take out runways. The Storm Shadow / SCALP is a long-range, air-launched, stand-off attack missile designed and developed by France-based MBDA Systems. The missile is intended to strike high-valued stationary assets such as airbases, radar installations and communications hubs.

Figure 12: Eurofighter Typhoon IPA2 aircraft fitted with the Storm Shadow cruise missile.

The Storm Shadow is also in service with the air forces of Italy, Greece, Saudi Arabia and the United Arab Emirates (UAE), where it referred to as the *Black Shaheen.* The missile can be integrated into Tornado GR4, Tornado IDS, Saab Gripen, Mirage 2000, Rafale, Eurofighter Typhoon and F-35 Joint Strike Fighter aircraft.

Joint stand-off weapons (JSOW) are glide weapons carried by both naval and air forces. The USAF and US Navy utilises glide bombs for anti-runway destruction, for example, the AGM-154 JSOW releases cluster bombs designed to create long uneven stretches of runway. Bomber launched cruise missiles like the B-52 launched AGM-86 cruise missile, and the advanced land-attack version of the Harpoon AGM-84H/K SLAM-ER are also a significant threat.

By contrast, coastal airbases are usually attacked by ship or submarine launched cruise missiles like the American Tomahawk Land Attack Missile (TLAM) or the Russian P-700 Granit and its replacement, the Kalibr.

There are also land vehicle launched cruise missiles, examples include the long-ranged Indian made Nirbhay and Babur from Pakistan.

Whilst the voluntary Missile Technology Control Regime (MTCR) establishes a strong presumption against the sale of cruise missiles capable of carrying a 500kg payload to more than 300km, this has not prevented export sales and proliferation. Whilst reduced fuel load range is used to comply with MTCR guidelines, concerns exist that this can be modified and extended.