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simplified concrete tank construction and associated equipment

INTRODUCTION

The tank construction methods and equipment outlined in this paper relate to the INKA concrete tank technology system and the associated equipment developed for use with such concrete tank constructions.

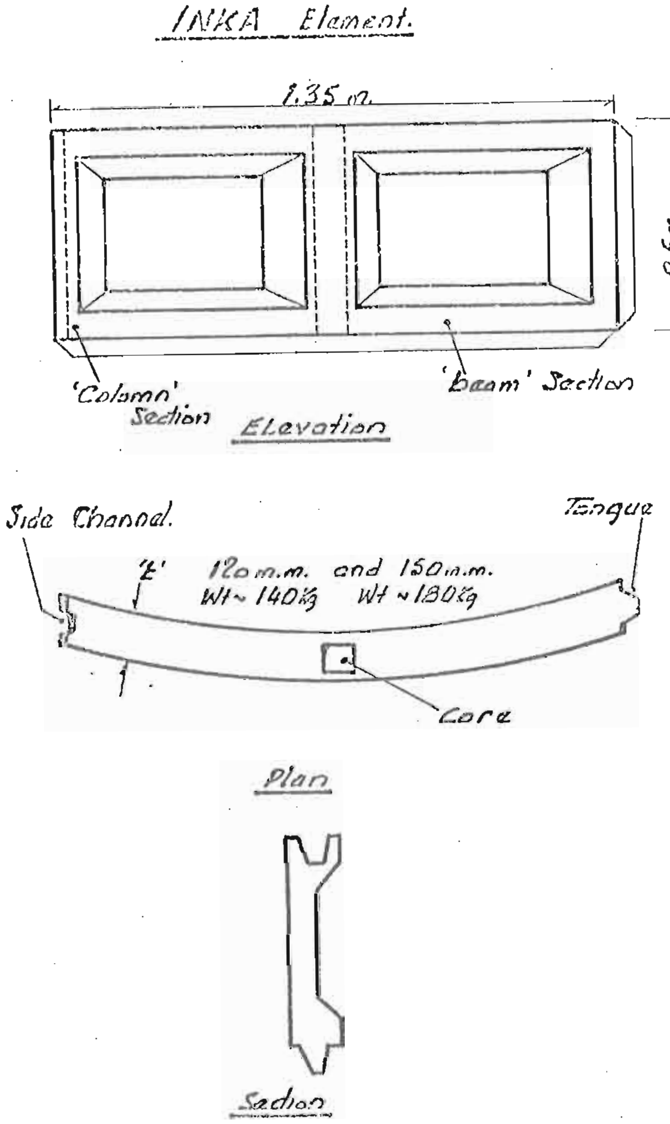
Such systems are normally applicable for construction in developing countries in a flow range between 900 and 800 m^3 per day although the concrete tank system has been utilised in flow ranges as low as 100 m^3 per day in the UK. The flow range of 900/1000 m^3 per day generally equates to a population range of 4000/35 000 population equivalents (p.e's). Also later in this Paper I have described a method of steel tank construction for use in developing countries for population ranges of 200 to 4000 persons, the tanks being designed for construction into the ground under full earth backfill conditions, or earth embankment as required.

CONCRETE TANK CONSTRUCTION

Design

INKA tanks are circular reinforced concrete tanks constructed from a series of prefabricated precast concrete panels which we describe as 'elements' produced essentially under factory controlled conditions. Such an element is described in figure 1, and the individual element measures approximately 1.35 metres in length, being 0.5 metres high with a gross thickness, dependent upon the diameter of the tank to be constructed, between 120 mm and 150 mm, corresponding to an element weight of some 140/180 kg.

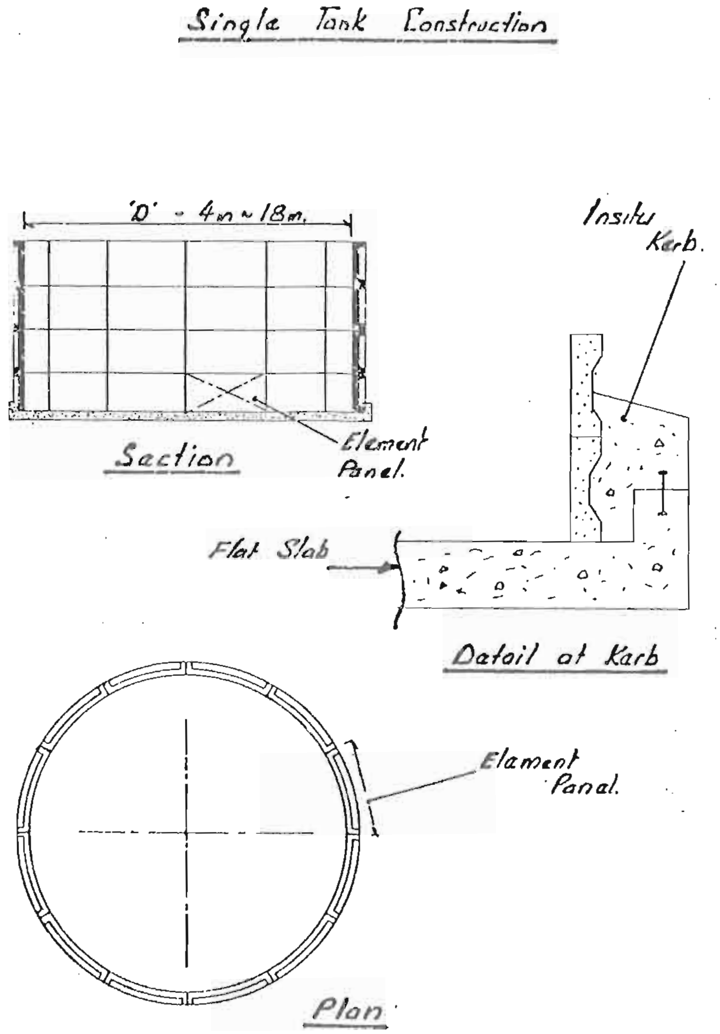
FIGURE 1:



The elements are cast in steel moulds which have been manufactured to accurate radii, each mould having a detachable timber base upon which the element is cast and initially cured. A combination of aggregates are used in the element manufacture to give a high strength dense concrete mix with a low water:cement ratio to ensure minimal cracking during curing. As outlined on figure 1, each element has a 'tongue and groove formation' such that the element top has a channel groove running throughout its length. At the casting stage, frame bar reinforcement is placed within each element to provide inherent structural rigidity.

INKA tanks are designed as circular reinforced concrete tanks subject to hoop tension conditions and capable of withstanding passive earth pressure, either as backfill or embankment, with the tanks empty. The tank wall tension reinforcement is placed in the preformed element grooves and grouted into position on site as normal reinforced concrete. No form of prestressing or post-tensioning is used, thus avoiding the consequential problems of end block stresses and anchorage sheer cracks associated with prestress works. The tension stresses in the reinforcement and the concrete are designed within the relevant code limits equivalent to the tank diameters and heights required. The tanks are constructed on a simple flat slab foundation and following the tank construction, a cast insitu concrete kerb beam is placed around the elements at the base level, as described in figure 2.

FIGURE 2:



When compared to insitu concrete tank construction, INKA tanks show considerable cost savings on an equivalent diameter basis, as the use of the precast concrete element system dispenses with the need for complicated site shuttering, special bar reinforcement and involved insitu concrete pours. Each individual element may be considered as containing its own framing mechanism in the form of a concrete column and beam construction, with a flat slab spanning between the beams and columns of the element. Such a construction ensures that load transfer takes place into the specially formed element grooves and cores, which contain the horizontal tension reinforcement and the vertical dowel bar tie reinforcement.

Casting/manufacture

As stated, the elements are cast in specially developed moulds to the required tank diameters. This operation takes place within factory controlled conditions in a specially developed factory unit within our casting facilities here in the UK. In developing countries, the elements may be manufactured locally on site on a simple flat slab foundation under a sunshade roof shelter. Curing would then take place utilising a dished slab with water recirculation from curing sprays. Due to the use of the low water:cement ratio and special high-frequency vibrators attached to the moulds, the mould units may be stripped from the elements immediately after removal to the curing bay. We have found that virtually no deformation of element shape occurs due to the dense highly compacted concrete mix. The element normally spends about 24 hours on the timber base before removal and further curing. A range of special handling equipment has been developed to facilitate element handling and dispersal at the manufacture/casting stage, and transport to site.

Construction

Following the requisite curing, the elements are delivered to site essentially as pre-shrunk units. This means that the shrinkage of the structure as a whole at the final construction stage is considerably reduced - a factor which can have considerable benefit in hot countries where the control of regulated curing of relatively thin concrete wall structures can be both difficult and expensive. In the UK we have found that comparison of equivalent tank diameters between INKA tanks and insitu concrete tanks can show cost savings in the range of 30/40% of the tank construction where INKA tank units are used. Additionally, in the UK the availability of skilled and semi-skilled labour is readily available at a reasonable cost, although the differential that exists between skilled / unskilled labour in the construction industry is vague. In developing countries the cost of indigenous skilled labour, where available, is high, and the cost of importing such labour extremely so. Generally, construction work involving concrete tank constructions has been estimated to require a ratio of skilled to completely unskilled labour in the order of 1:3.5, and in certain instances dropping to 1:2. This therefore means that the vast majority of skilled labour required on construction projects in developing countries has to be imported at high cost. Figure 3 shows some relative figures relating to the cost of labour and materials in the construction industry, comparing UK and Middle East costs, although it must be pointed out these are given as indicative measurements only, local conditions readily determining the market value appropriate to the project in question. I have also outlined within this table relative geographical distances between regional centres of population in Saudi as a demonstration of the physical difficulties encountered in obtaining labour from local centres. Even in the UK we have some experience of regional cost differences when we consider the relevant costs for construction workers on oil rig sites compared to 'normal' construction sites, in spite of the fact that such undertakings may be geographically close.

Figure 2 shows the general construction of an INKA tank built as a single wall applicable in the diameter range of 4 metres to 18 metres. Figure 4 describes the layout and location of the reinforcement which is applied on site in the form of horizontal circular tension reinforcement and vertical dowel location reinforcement. As described, each element has a top level groove to allow the placing and location of the hoop tension reinforcement as a continuous spiral in one plane around the tank, grouted into position on site as each element lift occurs. The vertical groove in the element end corresponds to a central core hole in the centre of each element, as described in figure 1, such that the vertical dowel reinforcement may be passed continuously through each element lift, tying the horizontal rings together. Normally, 6 mm indented steel reinforcement is used as the horizontal tension reinforcement, the number of loops being determined to suit the structural requirements of the tank under consideration relating to tank depth and diameter. Successive elements are grouted in position using a mix consistency similar to that of the original casting mix of the fine aggregate grading range, a paint-on bond being applied to the element surfaces before the grout, with bond additive, is placed. Where pipes are required to pass through walls, the typical construction is as outlined in figure 8.

FIGURE 3: Relative cost ratios - labour costs

	U.K. Rate 44 Hour Week	M.E. Rate* 60 Hour Week
Labourer/Helper	1.05	0.60
Welder	1.60	3.40
Carpenter	1.30	2.90
Electrician	1.50	3.10
Erector	1.25	3.20

* Excludes leave allowances, accommodation allowances and travel

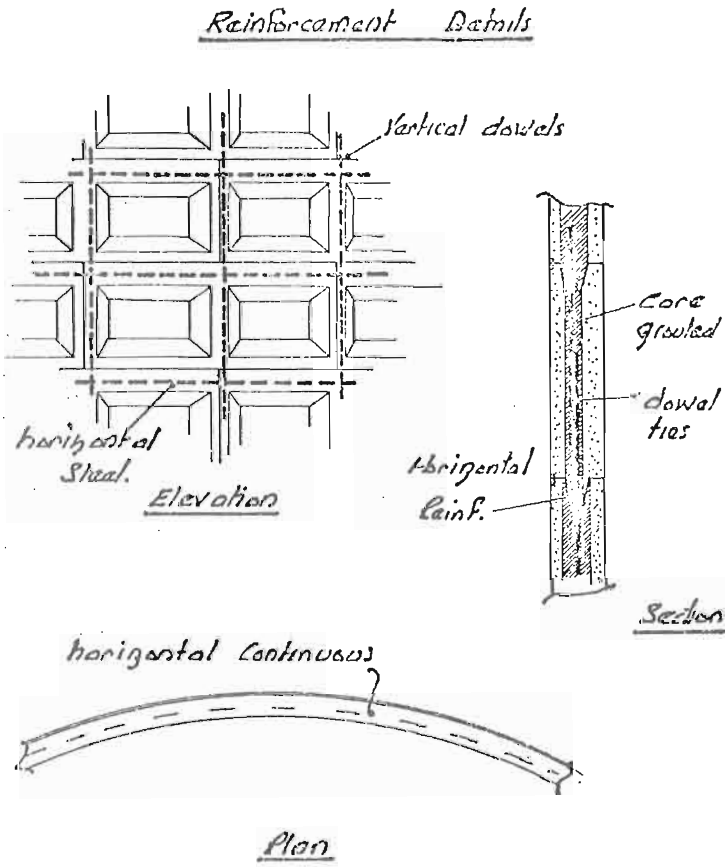
Plant Costs (Top Line Equipment)

	U.K. Rate Per Week	M.E. Rate Per Week
Crane (15 Tonne)	480	750
Crane (25 Tonne)	600	950
Welding M/C (400 amp)	50	68
Compressor (600 c.f.m.)	60	90
Mixer (5/7) Portable	20	31
½ Tonne Pickup	150	220

Approx. Distances Between Population Centres - Kilometres

	Damman	Hofuf	Mecca	Riyadh	Jeddah	Dhahran
Damman	0	170	500	460	1550	15
Hofuf	170	0	1300	330	1400	150
Mecca	1500	1300	0	1000	70	1450
Riyadh	460	330	1000	0	1050	450
Jeddah	1500	1400	70	1050	0	1500
Dhahran	15	150	1450	450	1500	0

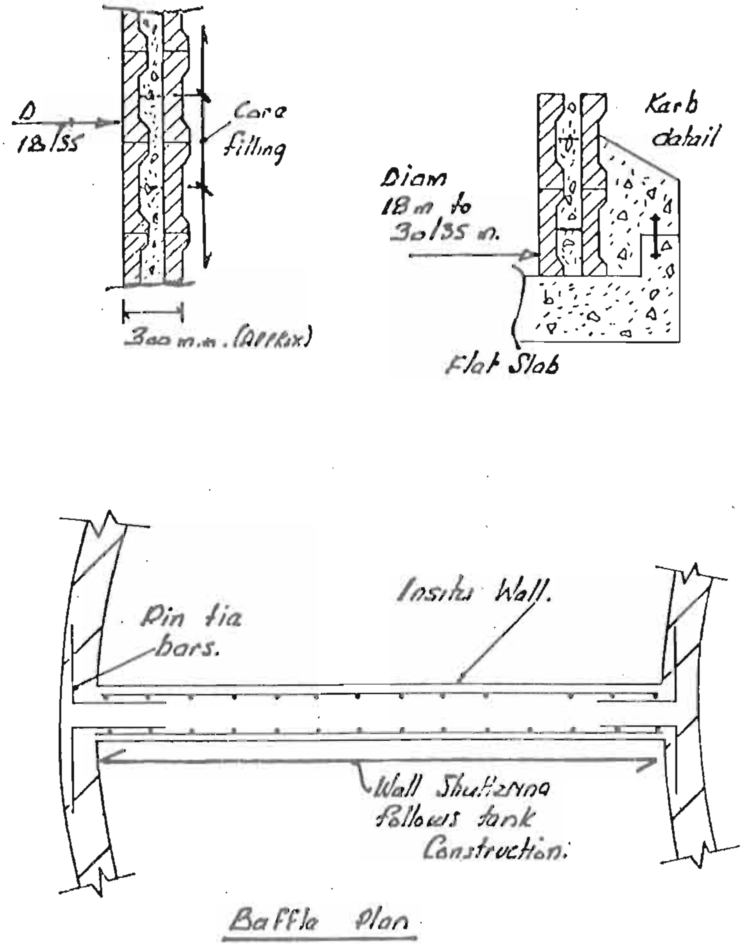
FIGURE 4:



INKA tanks are normally constructed on a flat base, although where required tank construction can take place on sloping bases.

Figure 5 describes the construction requirements where a double tank wall is required for larger diameters, between 18 metres and 30 metres diameter. Under such circumstances each wall leaf is 120 mm thick, with an overall wall construction of some 300 mm. Consideration could be given to larger tank diameters by increasing the distance between the wall elements, thus increasing the overall wall thickness. The construction of a double wall tank would be carried out in alternate lifts, and the core grout being placed to a half-element depth as each lift proceeds. The location of the external kerb arrangement for the double tank wall is also indicated in figure 5, as is the arrangement of the insitu baffle wall, which may be required between inner and outer tank wall constructions. Such an arrangement is necessary where INKA Bioreactor Systems are constructed, as the outer ring is used as the external wall to the aeration and sludge treatment zones, the inner tank providing the settling system. For such systems, which are suitable up to population loads of some 4000 persons, it is necessary to divide the outer ring into zones for aeration, sludge treatment, grit removal etc. The same requirement is also necessary where

FIGURE 5:



we construct an INKA Spiral 'S' System where a series of concentric rings are constructed as part of the aeration, sludge treatment etc requirements. Generally speaking, such plants are suitable up to population loads in the range of 4000/35 000 p.e. The general construction details of a division wall are as indicated in figure 5 where, at the construction of the INKA tank walls, 90^{o} 'pin bars' are built in to the horizontal element joints with a pin length projecting from the wall face for location within the division wall. Normally such division walls, designed as vertical cantilevers, are cast into position following the construction of the tank, thus only requiring relatively simple straight shuttering to effect the division wall construction.

A range of special erection equipment in the form of lifting hooks, grabs, and special crane units have been developed for use as part of the INKA tank system. With respect to the crane units, these have been designed for essentially manual operation, thus minimising maintenance and 'down time' due to failure of mechanical/electrical plant.

Application

We consider that the application and use of INKA tank systems in developing countries would result in considerable cost savings compared to insitu or prefabricated steel tank constructions. We have developed a TECHNOLOGY PACKAGE whereby we undertake to supply supervisory personnel to work with local unskilled labour for the production of the concrete tank elements and subsequent construction of tank units on site. As part of this package we supply, on a contract rental basis, the necessary special mould units, special vibration equipment, base mould equipment, handling and erection equipment etc, in order to produce, cure and construct a tank system complete. This includes the supply of a special low order mechanical/electrical cranage unit for the construction phase.

The application of INKA tanks has already in the UK demonstrated a wide range of application, and apart from their use in our own INKA aeration systems have been utilised in projects for filter tank units, balancing and settling tanks as part of ICI high rate filter schemes, bulk storage and industrial waste water use. At the present time we have under construction two major projects utilising the Spiral 'S' System with INKA tanks, where a total of some 70 tank units are under construction. We are also about to commence a further project involving the construction of some 35 tanks as part of a scheme for a trout farming project.

With the development of the INKA Spiral 'S' generally described in figure 6, the application and range of use of the tank units for waste water treatment has been considerably expanded. We are already at an advanced stage of discussion for the use of the Spiral 'S' system, utilising the tank units, for projects in the Middle East and Africa. INKA tanks are essentially a self-help operation, the tanks being manufactured locally to site with local labour, although we do not consider at this time that the method is applicable for projects having flows lower than 1000 m^3/day. The system has not yet been used as part of water supply treatment, although we have already constructed tank units complete with roofs as part of an industrial treatment process, and such an application could be readily adopted for water storage.

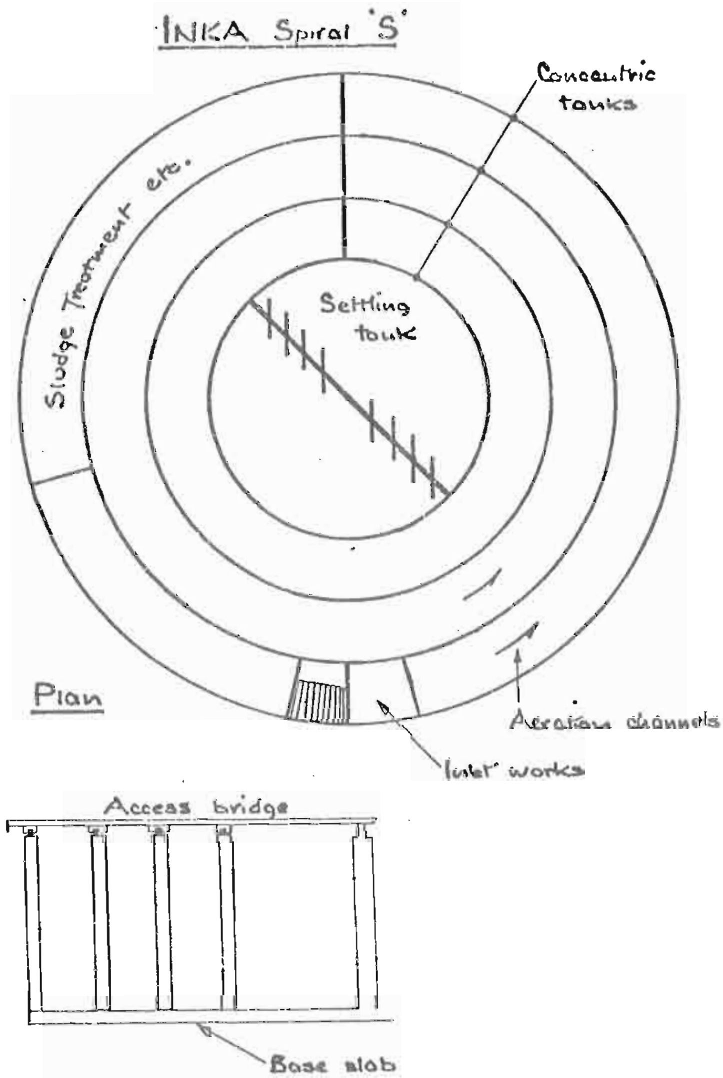
STEEL TANKS

We have been, and are involved, in the supply of small range package sewage treatment plants to developing countries, utilising steel tanks. One of the many problems associated with steel tanks is the lack of structural rigidity of tanks constructed into the ground under earth backfill pressure with the tanks empty. Such conditions usually result in tank buckling with consequential plant failure.

Figure 7 shows a system of steel tank design/construction we have developed utilising a close bolting technique for construction on site, and incorporating horizontal and vertical tank stiffening to provide structural rigidity. Such a construction, which is designed as a shell unit, subject to vertical compressive loading and end thrust, has been found to withstand full earth backfill conditions to a diameter of some 15 metres, constructed 3 metres into the ground.

As described in figure 7, horizontal stiffening is provided to counteract the ring compression due to the earth backfill, and the vertical break bank stiffeners are provided to reduce the l/r ratio of the horizontal stiffening to accord with design requirements. Such tanks are usually produced in a height range of 2.5 to 4.5 metres depending upon requirements and diameter. The circumference panel lengths are normally about 5.5 metres, the individual panels being joined together using a close bolting technique, the jointing flanges being rolled steel angles. Such

FIGURE 6:



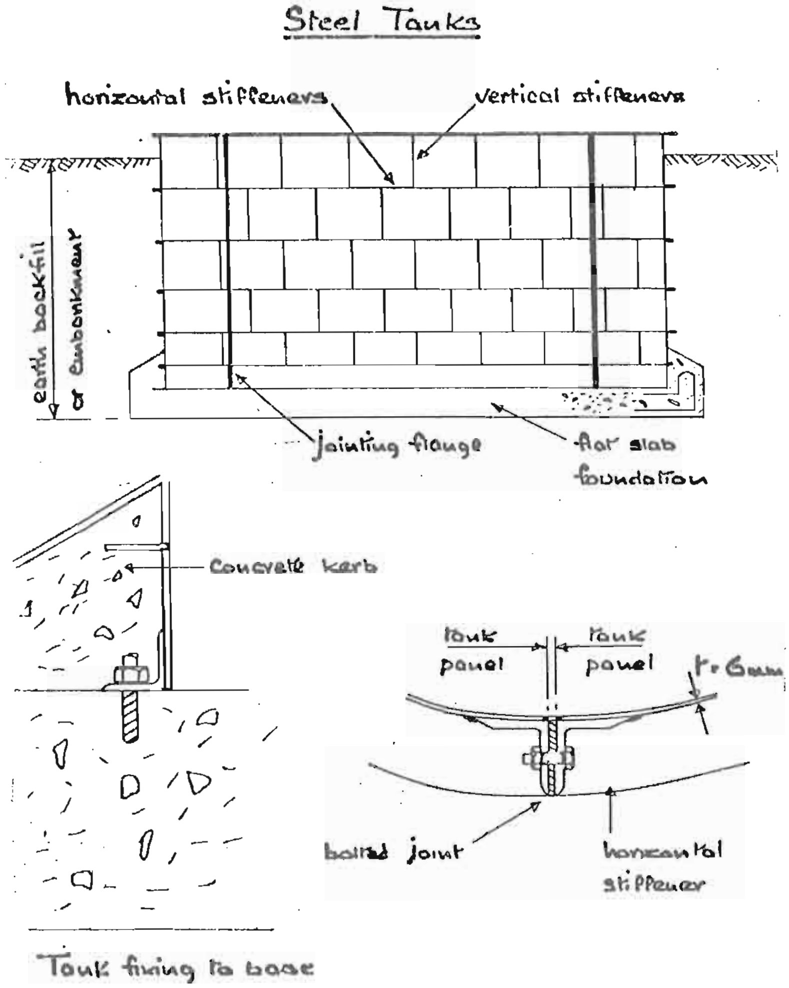
tank units when constructed on site have a very high inherent strength, and due to the construction techniques employed have the added bonus that they resist even the most adverse handling and shipping conditions!

Under most circumstances we have found that such steel tanks incorporating stiffening are cheaper than insitu concrete tanks of equivalent diameters, as essentially only unskilled labour is required on site in order to erect the tanks under our supervision. Such tanks have been utilised as part of wastewater treatment projects both in the UK and in developing countries. We have, however, found that the overall costs of such steel tanks are greater than equivalent concrete INKA tanks.

Equipment

Where we are responsible for the supply of a small package type unit or 'turn-key' contract we have developed a range of equipment which is equally

FIGURE 7:

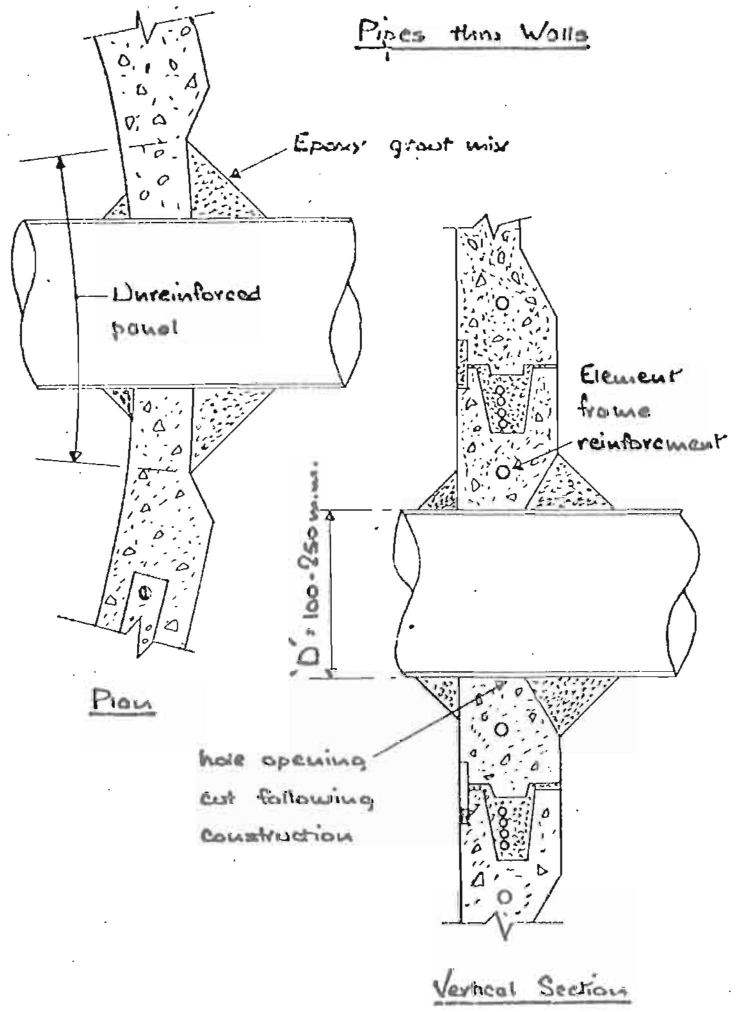


applicable to both the concrete INKA tank or prefabricated steel tank systems. The range of equipment operation is similar to that of established practice - what we try to ensure is that the location and fixing of the same has a higher degree of flexibility in relation to overseas works as opposed to UK installation, where access to the site during tank construction is not readily available.

Flexibility can be achieved by utilising such items as stainless steel/ mild steel suspended weirs with adjustable wall brackets as opposed to cast insitu units, and the inclusion of floating joints on scraper assemblies etc.

Where possible pre-assembly of equipment should be carried out in the UK before dispatch, and where steel tank units are employed we carry out complete trial erection. In spite of such precautions it will, however, be found necesaary to increase the structural dimension of equipment being sent to developing countries in order to prevent damage occurring during transit. Where possible containerisation is worth consideration. Some 'flexible' support systems are shown in figure 9.

FIGURE 8:

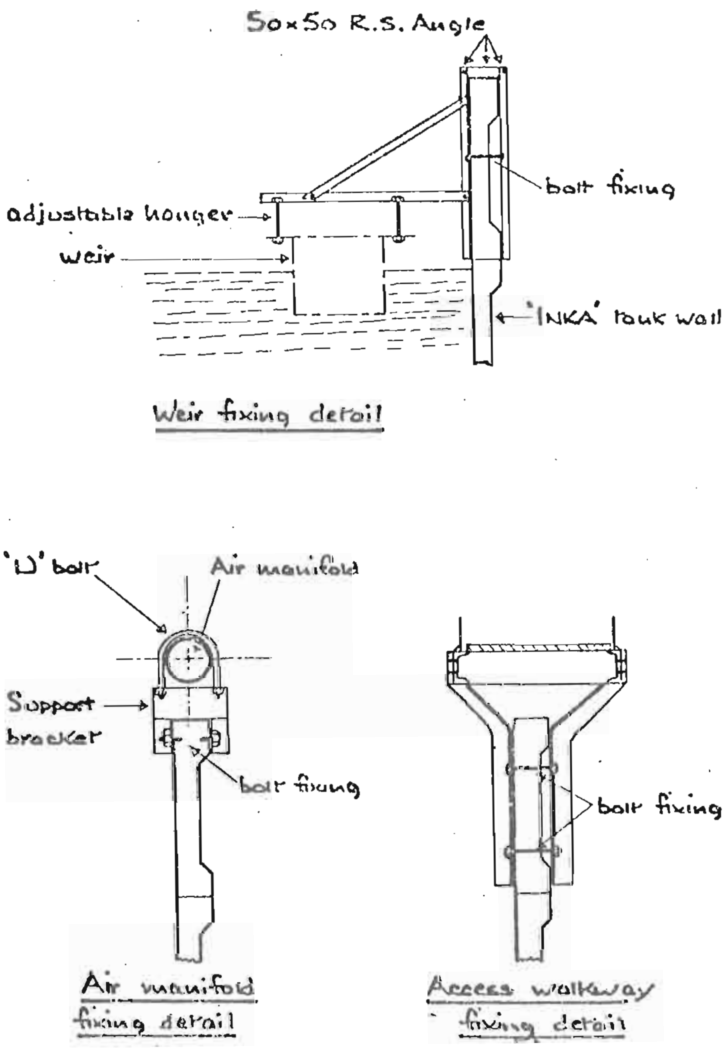


Normally the type of system we supply to developing countries involves a diffused aeration system utilising air blowers for medium pressure, high volume air production. We have found that if the blower speed does not exceed 1200 rpm, taking due account of temperature rise across the machine, the blower life will be extended due to the low wear on bearings and blower vanes etc. Consideration should always be given to providing as much protection as possible against dust intrusion, especially in the case of mechanical plant and electric motors. Whilst such protection may seem obvious, a further stage of protection is to provide a greater depth between top water level and the top of the tank wall. We have found that a distance of 500 mm gives a reasonable degree of protection against dust intrusion into the plant.

Whenever considering equipment for construction/installation for projects abroad, there are four essential points we consider:

a) Consideration of total prefabrication/partial fabrication to size of unit and structural rigidity of same. At all costs avoid site welding unless on very large projects.

FIGURE 9:



b) Availability and quality of labour and erection plant locally to site.

c) Costs of shipping and transportation of items, as very often shipping is a 'Catch 22' situation - if you don't pay for low bulk high dead weight, then you pay for low weight high cubic capacity. At the equipment design stage a break down of items of plant such as scraper shafts/scraper arms, screen units etc, to simply assembled site units can often considerably reduce bulk shipping charges. In spite of additional cost, the use of containers can prove worthwhile.

d) The overall maintenance of the plant in terms of spares required, plant finish and general running considerations. It will often be found much more convenient to supply spare fractional horse power motors for units such as scrapers and screens, as opposed to supplying motor internals. Consideration of simple automation in terms of plant running experience is always worthwhile for simple operations such as intermittent descumming, sludge transfers, sludge thickening, aerobic digestion etc.

When specifying a paint finish it must be remembered that the high quality temperature controlled pitch epoxy paint applied at works cannot readily be repeated in overseas countries, nor indeed in the UK. I would suggest that following shot blasting, primer painting and undercoating is sufficient for most equipment, with supply of adequate touch-up paint, the finishing coats of paint to be applied on site. We have found that chlorinated rubber provides a satisfactory paint finish and protection, and one that can be readily maintained in the years ahead.

Finally, whenever designing, supplying or constructing equipment for treatment plants in developing countries, the greatest requirement I feel is to equate all such considerations to common sense.

ACKNOWLEDGEMENTS

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