Code of Practice on the Design, Manufacture and Installation of Aerial Ropeways

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Code of Practice on the Design, Manufacture and Installation of Aerial Ropeways

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1. FOREWORD

(1) This Code of Practice was issued by the Director of Electrical and Mechanical Services (hereunder abbreviated as "the Director") of the Government of the Hong Kong Special Administrative Region under section 5 of the Aerial Ropeways (Safety) Ordinance, Cap. 211 (the "Ordinance"). It is the intention of this Code of Practice to advise on the fundamental areas on the design, manufacture and installation of aerial ropeways.

(2) During the compilation of this Code of Practice reference has been made to several other national standards concerning aerial ropeways and this Code of Practice draws on extensive experience throughout the world for guidance. Much reliance has been placed on the established regulations, recommendations and codes of practice in other countries. These have been studied, adopted and amended to suit the Hong Kong situation.

(3) The electrical work shall comply with the following technical specifications and requirements:

(a) The latest edition of the Code of Practice for the Electricity (Wiring) Regulations, issued by the Electrical and Mechanical Services Department.

(b) The "Supply Rules" issued by either Hongkong Electric Company Limited or CLP Power Hong Kong Limited, as appropriate.

(4) Common terms used in this Code of Practice are defined in Appendix I. In Appendix II, definitions of parameters used in calculations on aerial ropeway systems are included.

(5) List of references relating to aerial ropeways are listed in Appendix III.

(6) It is not the intention of this Code of Practice to prohibit the inclusion of innovation and improvement in design and performance but it must be stressed that any such development should be fully supported by sound engineering principles.

2. SCOPE

(1) Definition

An aerial ropeway is defined as:

"Any apparatus for the overhead transport of passengers or goods in carriers running along or drawn by overhead cables supported by towers, pylons or other similar structures, together with any machinery, equipment or plant connected therewith."

(Note: This Code of Practice will not deal with ropeways or lifts used for industrial purposes.)

(2) There are many different types of aerial ropeway and they may be broadly categorised into two basic groups, i.e. "monocable" and "bi-cable".

(a) Monocable ropeways, as the name suggests, consists of a single steel wire rope arranged either in the form of a continuous loop to which carriers are attached, or in the form of an open loop providing a reversible carrier motion. Again there are variations in monocable systems and these are further subdivided into two types, i.e. fixed and detachable grips.

(b) Bi-cable or tri-cable (or 3S) ropeways make use of more than one steel wire ropes to perform the supporting and hauling functions of carriers. They can also be divided into fixed and detachable grip types as in the monocable design. Also, the motion of the carriers can be arranged in a continuous loop or in reversible travelling mode.

For monocable, bi-cable and tri-cable ropeways, tension is normally maintained by a rope tensioning system, e.g. by using a hydraulic system, or other means such as a free hanging mass known as counterweight. In this manner the nominal tension is kept irrespective of rope loading and elongation.

(3) Limitations

This Code of Practice is intended to give guidelines on the design, manufacture and installation of the above mentioned two basic groups of aerial ropeway but nothing herein contained shall replace the provisions of any standard in force in Hong Kong.

(4) Planning

When planning the location and route of an aerial ropeway the following factors must be carefully considered.

(a) Amenity Value

The aerial ropeway including any further extension shall be so located that adequate facilities for inter-connecting public transport are available at the terminal stations.

(b) Route

An aerial ropeway including any future extension shall be routed so that its effect on the environment is minimal; this involves consideration of noise pollution, unsightly construction and any detrimental visual impact on the local environment. In the design of the routing of the aerial ropeway or its extension, due regard shall be given to the effect on/from existing neighbouring built-up areas or natural habitat, such as vegetation, roads, railways, aircraft flight paths, electric power lines, streams, buildings, bridges and slope stability. An environmental impact assessment shall be carried out to address this subject in accordance with any other legislative requirement in force in Hong Kong.

Adequate consultation on various details of the project shall be conducted with relevant organisations and the local community. If land resumption is a related issue on the project, all necessary procedures as required by any other legislative requirement in force in Hong Kong shall be followed.

(c) Emergency Access

Adequate access to terminal stations by emergency vehicles as may be required by the Director of Fire Services (abbreviated to "DFS") shall be provided. A rescue plan shall also be drawn up in consultation with DFS and the Director to deal with emergencies during operation.

(d) Maintenance Access

A vehicular access road covering the remote towers and angle stations shall be built while adequate access for routine maintenance, splicing, rope connection and rope replacement shall be provided. A maintenance access plan shall also be worked out to address any inaccessible points with possible solutions during the planning stage.

3. OTHER LEGAL REQUIREMENTS

(1) The design, manufacture and installation of an aerial ropeway system shall comply with the requirements as stipulated in the following legislation:

(a) Factories and Industrial Undertakings Ordinance (Cap. 59) and Construction Site (Safety) Regulations
(b) Fire Services Ordinance (Cap. 95)
(c) Codes of Practice for Minimum Fire Service Installations and Equipment and Inspection, Testing and Maintenance of Installations and Equipment issued by Fire Services Department
(d) Buildings Ordinance (Cap. 123), Building Construction Regulations (Cap. 123 Sub. Leg.) and Code of Practice on Wind Effects in Hong Kong
(e) Electricity Ordinance (Cap. 406)
(f) Occupational Safety and Health Ordinance (Cap. 509)

(2) The above list is not exhaustive. Reference shall be made to other legislation wherever applicable.

4. GENERAL DESIGN

(1) Every part of an aerial ropeway system and its associated equipment shall be designed with consideration given to the safety of the passengers, general public and operating staff, and shall be designed in compliance with this Code of Practice.

(2) All systems must be designed, operated and maintained in accordance with the following principles of safety, which are to be applied in the order given:

(a) Eliminate or, if that is not possible, reduce risks by means of design and construction features;

(b) Define and implement all necessary measures to protect against risks which cannot be eliminated by the design and construction features;

(c) Define and state the precautions which should be taken to avoid the risks which it has not been possible to eliminate completely by means of the provisions and measures referred to in (a) and (b) above.

(3) Because of the high probability of any structure in Hong Kong being subject to severe winds and very heavy rainfall, the design of any exposed equipment and the selection of any materials used in the construction of an aerial ropeway shall give due regard to these factors.

(4) Prior to the construction of an aerial ropeway, the manufacturer shall furnish a full set of engineering drawings, in duplicate, together with the designs and specifications of the machinery, equipment and plant relating to the aerial ropeway to the Director in accordance with section 7 of the Ordinance.

(5) A general layout and an extract from the Survey and Mapping Office map to a scale of 1:1000 showing the line and plan (to scale) and any topographical features are required. Accompanying this, a written description indicating the size and capacity of the installation, the operational philosophy together with an assessment of the likely usage is required to assist in determining if inter-connecting public transport will need to be arranged.

(6) During the construction and installation of the aerial ropeway, details of the construction and installation procedure shall be submitted to the Director. All test certificates, surveyor reports, etc. shall also be submitted to the Director once available.

(7) The plans, designs, specifications, calculations and the method and programme of installation shall be submitted to the Director for approval prior to the commencement of any part of the installation works.

(8) The design calculations and method of installation shall be counter-checked by independent ropeway experts / consultants / surveyors / notified bodies as appropriate before submission to the Director.

(9) The parts related to civil foundation and tower structure should be separately submitted to Buildings Department for approval.

5. SYSTEM CONDITIONS

(1) Route

(a) In Hong Kong, the probability of having strong prevailing wind at the site where the aerial ropeway is going to be installed is high. To determine the wind effect on the aerial ropeway, a full scale in-situ investigation

shall be conducted prior to the detailed design of the aerial ropeway (see section 13 of this Code of Practice). The duration of the investigation shall be sufficient to determine the seasonal fluctuation of the wind direction and magnitude. The design of the aerial ropeway shall cater for the wind effect obtained in the full scale in-situ investigation and take into account possible jet wind effect arising from topographical features nearby.

(b) A geotechnical assessment of the proposed route should be carried out, based on which a site investigation programme should be designed and implemented. The design of aerial ropeway foundations shall be in accordance with the requirements of the Geotechnical Manual for Slopes (item 20 in Appendix III) and shall be submitted for approval to the appropriate government department or office as required by legislation or the design brief.

(c) The aerial view route of an aerial ropeway should be straight and the maximum allowable deviation from this requirement shall be 0.0087 rad (0.5°) for the track rope on a rope saddle or carrying-hauling rope on sheaves at each trestle. If larger angles of deviation are required then suitably designed angle stations shall be installed. In any case the trestle and its associated tower components, such as saddles, guides, sheaves etc., shall be designed to accommodate any side thrust.

(2) Profile

(a) The profile of the aerial ropeway (longitudinal side elevation) shall take into account the requirements specified in sections 6 and 7 of this Code of Practice, regarding clearance of the rope and the rescue facilities respectively.

(b) At the worst possible loading condition the maximum gradient of the rope shall not exceed 1.0 (45°) except in the case of aerial ropeway of fixed grip type, or braking facilities are provided at each carrier.

(c) The constraints above shall be moderated by the requirements of minimum sheave pressure (see section 14 of this Code of Practice) and rope stability.

(3) Integrity of the installation

(a) All components shall be suitably designed and constructed to ensure their own operational integrity and the safety of the installation. Suitable safety factors shall be adopted in the design of the components.

(b) The aerial ropeway shall be designed and constructed in such a way that, during the operation, any failure of any component will not affect the safe operation of the aerial ropeway and will not cause other components to fail.

(c) The design of the aerial ropeway shall take into account fire happening in any part of the installation, or at close proximity of the installation such

that the occurrence of fire will not endanger the passengers carried in the carriers.

(d) All components of the aerial ropeway shall be properly designed to facilitate routine monitoring and maintenance in order to avoid failure.

(e) The operation of the aerial ropeway shall be able to be manually stopped at any time.

(f) After the operation of the aerial ropeway has been stopped by a safety device, the system must not be possible to restart automatically unless appropriate manual reset actions have been taken.

(4) Reliability of the installation

To achieve the necessary level of system safety and reliability, the installation of a new aerial ropeway shall consider all possible hazards in the system by conducting hazard analyses such as Process Hazard Analysis, Failure Modes, Effects and Criticality Analysis (FMECA), under all operation, maintenance and environment modes throughout the design, installation, commissioning, and testing phases of the development.

(a) The manufacturer shall conduct an FMECA on the products to be supplied with reference to the design operating hours and local environmental factors.

(b) To evaluate the operational safety and reliability of an aerial ropeway after commissioning, a comprehensive assessment shall be performed prior to the commencement of installation. The assessment shall cover the analysis on all possible modes of failure of the aerial ropeway during operation. The analysis shall be based on the ropeway design, operation and maintenance regime, environmental and meteorological conditions, emergency and rescue provisions, station foundation and tower structure.

(c) The operation and maintenance manual shall be cross-checked by an independent ropeway consultant or notified bodies.

(d) The assessment report shall include but not limited to the scope, methodology, analysis result and mitigation measures.

(e) The assessment shall be re-conducted together with those experience feedback and incident happened at intervals of not more than every five years after the commencement of operation of the aerial ropeway.

(f) The hazard analyses should contain contingency plans, including but not limited to the passenger evacuation, rescue operation, arrangement of alternative transportation and co-ordination with government departments.

6. CLEARANCE

During the operation of any aerial ropeway in fully or partly loading conditions, and in any condition due to static or dynamic load, for example the wind or braking effect, the minimum clearances as detailed below must be maintained.

(1) No part of any structure or moving part shall be within reach of passengers in transit through windows or any other openings in the carriers. In the stations, passengers (including the passengers queuing for boarding) shall be kept clear from all moving machinery.

(2) In order to ensure the free passage of passengers and personnel in the station, the side clearance between the space occupied by a carrier and stationary obstacles belonging to the installation shall be at least 1.0 m. When there are no guiding devices for the carrier, such clearance shall be ensured even when the carrier is transversally swung basically by 0.34 rad (19.5°). In the station areas intended for the loading and unloading of carriers, the space reserved to the public shall be of sufficient size to ensure the free passage of passengers.

(3) Minimum clearance between the ground and the lower extremity of any carrier when outside of the stations shall be not less than 2.5 m under the most unfavourable operating conditions.

(4) For transverse movement of the carrier away from the station or trestle structures, the following will be considered as a basis for calculation:

The transverse movement of the rope due to wind pressure is to be calculated on the basis of a dynamic pressure of at least 0.2 kN/m^2 in operation and at least 1.2 kN/m^2 out of operation being exerted on the inclined length of the span in question. For spans greater than 400 m, the dynamic pressure may be reduced as stated in BS EN 12929-1. In this condition of maximum transverse movement together with any carriers inclined towards each other from the vertical at an inclination of 0.26 rad (15°), there shall be at least 1 m clearance remaining between the innermost extremity of each carrier. This clearance shall be maintained in any direction towards other stationary or moving equipment (except for the station and trestle guide rails).

(5) Wherever possible the maximum height of a stationary ropeway with closed carriers above the ground whether partially or fully loaded or bare rope shall, generally, not exceed 60 m.

(6) Wherever possible the maximum height of a stationary ropeway with open carriers above the ground whether partially or fully loaded or bare rope shall, generally, not exceed 15 m. Exceptions may be granted up to 20 m for single parts of the line as stated in BS EN 12929-1.

(7) Wherever the ropeway passes over mature forestry, a minimum clearance of 15 m should be maintained on either side of the route as a firebreak to avoid danger to carriers from fires in densely wooded areas.

Subject to the approval of the Director, the owner of the aerial ropeway may provide an alternative arrangement to ensure safety of passengers in the event

of hill fire. The alternative arrangement should be supported by:

(a) an assessment of hill fire impact on the aerial ropeway, including assessment of local conditions, height and types of vegetation in the vicinity of the route and their susceptibility to fire, identification of fire-prone sites, estimation of the speed of fire spread, effect of fire on the structural integrity of the pylons, effect of the fire on the moving carriers, etc.; and

(b) sound engineering and/or management proposals on the precautionary and preventive measures in reducing fire risk in the vicinity of the route, including planting of firebreaks, provision of firefighting equipment at pylons and towers along the rescue trail and the corresponding rescue plan(s) under identified scenarios.

7. RESCUE

(1) General

(a) All aerial ropeways shall be equipped with adequate and sufficient facilities which shall be readily available to clear the line of passengers and return them within a reasonable time to a terminal station, or location, where access for emergency services is available. The time will depend very much on the size and type of ropeways but a rescue operation shall under the worst possible conditions be able to be completed nominally within reasonable time. The method of the rescue of passengers shall be approved by the Director. Preferable is a rescue system that makes possible in any rescue situation to return the passengers within the carriers they are situated in, known as "integrated rescue system" or "recovery system".

(b) Sufficient numbers of trained persons for carrying out the rescue operation (the rescue crew) shall be on duty when the aerial ropeway is in operation. The rescue crew shall carry out rescue practice at an interval approved by the Director.

(c) Although passengers will be assisted by the rescue crew to use any rescue equipment specially provided for use under specific conditions, the rescue equipment shall be designed for easy use by the passengers without much difficulty and discomfort.

(d) Breaking strength of the nonmetallic rope for rescue operation, when new, shall be at least 15 times the maximum expected operating load. The thermic stress of the rope during rescue operation shall be taken into consideration.

(2) Permitted Forms of Rescue

(a) In order that the passengers, after rescue, may be returned to any terminal station, or location with emergency services, the terrain shall be so

prepared as to provide safe passage on foot.

(b) For night rescue, adequate lighting shall be available (see section 8 of this Code of Practice).

(c) Vertical rescue may be carried out using any combination of ropes, ladders or suitably designed equipment providing that they are safe to use and do not cause unnecessary distress to the passengers.

(d) Rescue from heights in excess of 60 m, or at places on the rope passing over difficult terrain or watercourses etc., vertical rescue will not usually be permitted. Alternative means of rescue should be provided to the satisfaction of the Director. For example, a separate rescue carrier, independently propelled, which will be available to traverse the line at any time under any breakdown conditions of the aerial ropeway, assuming the ropes are intact, shall be provided. The rescue carrier shall have facility to transfer the passengers from the line to the nearest station or trestle. The method of evacuating the passengers after being rescued from the line shall also be approved by the Director. All necessary equipment and transportation for rescuing and evacuating passengers shall be provided.

(e) Attended carriers must carry adequate rescue equipment for the passengers together with portable lights, first-aid kit and means for communicating with the terminal stations (i.e. radio or telephone).

(f) No point on any line shall be inaccessible to rescue crew and there shall be no point on any line from which it is impossible to rescue the passengers.

(g) Before a rescue operation or rescue practice is to commence, means to lock off the main drive to the ropeway shall be provided.

8. LINE LIGHTING

Line lighting, for night operation of the ropeway, shall be at two levels, namely general lighting and emergency lighting.

(1) General lighting at each trestle to give overall impression of the line shall be provided. The light intensity of the general lighting shall be at low level.

(2) Emergency lighting shall be able to illuminate the whole course of the line to facilitate rescue operation. For the vertical rescue operation at the carrier with the rope at a height not exceeding 60m above the ground, the emergency lighting shall be able to illuminate down to ground. Emergency lighting of portable type shall also be provided at the rescue carrier. Exact lighting levels will depend on the topography of the area but it is recommended that 10-20 lux would be adequate.

(3) There shall be two independent supplies of electricity for the general lighting and emergency lighting.

(4) In the course of a night rescue operation, any inadequacy of the line light (as revealed by the rescue drill) shall be supplemented by emergency lighting of a portable nature that can be easily transported to the area of the rescue operation.

9. AERIAL NAVIGATION

(1) Approval of the location of the aerial ropeway must be obtained from the Director-General of Civil Aviation. The provisions of the Hong Kong Airport (Control of Obstructions) Ordinance (Cap. 301) must also be complied with.

(2) The aerial ropeway shall be in compliance with all requirements for day or night markings for the line as specified by the Director-General of Civil Aviation. The electricity power supply for all obstruction lights, or indication lights, if installed, shall be from two independent supplies.

10. DANGEROUS AREAS

Areas that are potentially unstable and are under the risk of landslide or rockfall will not be considered suitable as the locations for an aerial ropeway unless, substantiated by using appropriate factual data obtained from the geotechnical assessment referred to in section 5 of this Code of Practice, it can be demonstrated beyond doubt that any such instability will neither have effect on any equipment/structures associated with the aerial ropeway nor on the rescue operation. The methods and standards set out in the Geotechnical Manual for Slopes (item 20 in Appendix III) should be used to determine the slope stability.

For any aerial ropeway in Hong Kong, the factors in this section require special consideration.

11. CROSSINGS

(1) The design of the line of an aerial ropeway should take into consideration the effect of the aerial ropeway on all other public and private services which include roads, railways, transmission lines and watercourses, etc. as these services may affect, or be affected by, a rescue operation or rescue practice. The installation of an aerial ropeway should not affect any public utilities and the design shall maintain suitable clearances to ensure the safety and integrity of both the ropeway and the utility as well as adequate access for maintenance and operational purposes.

(2) If a crossing of a road or railway is unavoidable this should then be so arranged as to make the crossing as near perpendicular as possible and, if necessary, protection in the way of netting or bridge works shall be installed.

(3) To protect the users of public or private services, e.g. road, railways, etc.,

against any falling objects from the carriers, risk assessment should be carried out and proper safety measures provided to the satisfaction of the Commissioner for Transport.

(4) Parallelism with overhead transmission lines is to be avoided if possible to reduce to the risk of induction or similar effect.

(5) An aerial ropeway will not be permitted to pass over an overhead transmission line. If an aerial ropeway is to pass over a transmission line, the electrical supply shall be routed underground by electrical cable; this shall be done with the agreement of the appropriate power company.

(6) The location of an aerial ropeway and an existing electrical supply system shall be so arranged that there is no disturbance or interference to the operation of the aerial ropeway, its electricity supplies or telecommunications by the existing electrical supply system.

(7) Conversely, any new electrical supply system to be installed near an existing aerial ropeway should take these considerations into account.

12. LINE GUIDANCE

It is necessary to ensure that on an aerial ropeway the rope will remain in contact with the rope guidance devices and supports under any condition of operational speed or load and, in addition, under the influence of any external factor such as wind effects.

13. WIND AND EARTHQUAKE CONSIDERATIONS

(1) Methods of assessing the parameters by which the secure stability of the line is ensured in strong wind conditions vary from country to country and each is obviously suitable to that locale. In Hong Kong a factor for prime consideration is the effect of very strong or sudden winds. Wind may be considered to act in any direction, including upwards. As a general rule the pressure of the wind P_w (kN/m^2), on the ropeway and all exposed equipment may be calculated by the empirical formula v_w^2 / 160 (kN/m^2) where v_w is the maximum expected wind velocity in m/s in the vicinity of the line. This empirical formula may be adjusted proportionately by any variation in temperature or density of the air from, nominally, 15^{o}C and 1.25 kg/m^3. However, even without any adjustment, this value is considered appropriate as a first approximation.

(2) The earthquake loading referred in this Code of Practice shall be assumed to be equivalent to a ground horizontal force of 0.08 times the total weight of the building, structure or trestle.

14. TRESTLE SHEAVE AND SADDLE LOADING

(1) Assuming these values of wind loading every carrier shall under any operating condition maintain positive pressure between the ropes and the sheave batteries or saddle even if the tension in any rope varies by 50%. Except monocable ropeways, the carrier shall not leave the track rope if the haul rope tension is increased by 50% or decreased by 33%.

(2) The pressure of such ropes on the trestle shall be at least 1.7 times the required pressure for ensuring the contact, on the supposition that the wind is blowing upwards in a direction parallel to that of the support reaction and with a force equal to 300 kN/m^2.

(3) In any case, the minimum load on any sheave wheel shall be 500 kN.

15. ROPE DEFLECTION AT TRESTLES

(1) For hauling or carrying-hauling ropes the deflection of a rope ($\angle_H - \angle_L$) over the sheave wheels shall be so arranged that the deflection at each wheel will not exceed 0.04 rad (2.5°) and 0.08 rad (4.5°) for hard and soft lines sheave wheels respectively. In addition it is recommended that the minimum trestle load perpendicular to the mean of the rope tangents at the trestle is maintained at 8 - 10% of the rope tension.

(2) Track ropes may be accommodated in saddles which are grooved to hold the rope. The track rope shall be free to slide in the axial direction. As with sheave rollers the groove must be shaped so that the transition from the saddles from one span to the next is as smooth as possible. To this end, the saddle radius (R) shall be not less than 250 d (mm) and the acceleration V_r^2 / R (m/s^2) imparted to the carriers as they pass the trestle should be arranged to be less than 2.5 m/s^2 where:

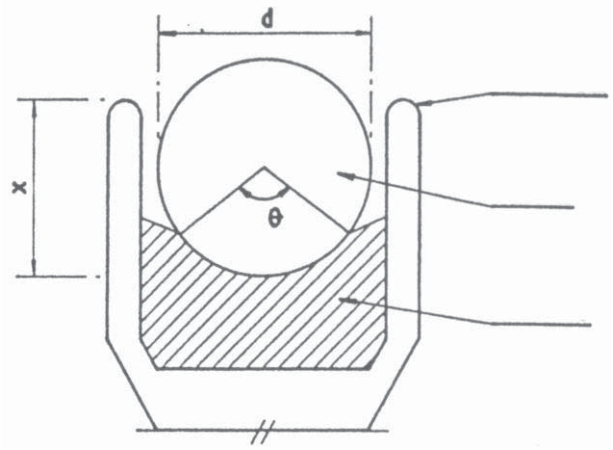
d = rope diameter (mm)
V_r = rope velocity (m/s)
R = saddle radius (mm)

(3) Hold down trestles are not permitted for aerial ropeway with track rope(s).

16. ROPE ALIGNMENT

In case of a derailment of rope(s), it is necessary to ensure that this risk is reduced to the minimum by the use of various devices to prevent injury or damage to either passengers or equipment. These devices which are detailed in section 19 of this Code of Practice will hold the rope(s) in the event of derailment to prevent the aerial ropeway from continuing the operation until the derailment is rectified.

17. SHEAVE WHEEL FLANGES



Details of sheave wheel lining

θ: Contact Angle

For a typical sheave wheel flange which is subject to wind effects, the following parameters are recommended:

θ: 120° (Hard linings)
θ: 90° (Soft linings)

With hard linings the radius of the line groove should be 5 - 10% greater than the rope radius. To ensure sufficient lateral support it is also recommended that the sheave wheel rims cover at least 75% of the rope diameter when viewed from the side i.e. x/d = 75% (where x refers to overall groove depth).

18. TRACK ROPE SADDLE GROOVES

The depth of the saddle grooves should be at least 50% of the rope diameter. The groove shall be circular and have a radius approximately 10% greater than the rope radius. These parameters are a guide only; the exact geometry will depend on the design of the carrier wheels etc. The smoothness of the passage of the carrier over the saddle must also be considered (see section 15 of this Code of Practice).

19. ROPE GUIDES AND CATCHERS

(1) The geometry of the rope guides, catchers (e.g. a set of rollers to hold the rope in the event of derailment) and saddle grooves shall be so designed as to prevent derailment on any predictable occurrence. In case of derailment, the operation of the aerial ropeway shall be stopped immediately through the intervention of a safety circuitry.

(2) The diameter and the number of the guide rollers of the hauling rope or

carrying-hauling rope shall be suitably designed for the static and dynamic force act on the rollers. In addition to this, there shall have brackets or lugs attached to the guides to ensure that, in the event of a derailment, the rope(s) will not become free from the trestle.

(3) Mechanical clamps shall be provided to hold the rope(s) to the trestles under high winds condition. Operation of an aerial ropeway is not permitted in this condition.

20. PROTECTION DEVICES ON TRESTLES

(1) A device shall be provided at each trestle to stop the operation of the aerial ropeway immediately when there is derailment at the trestle. The same device shall also be able to prevent the resumption of operation of the aerial ropeway unless the derailment is rectified. Any roller, which is used to activate the tripping device upon derailment and having a different weight from the other roller with the same appearance, shall have a clear indication.

(2) In addition, a similar device shall also be provided at each trestle to stop the operation of the aerial ropeway immediately when the trestle sheave train (a set of sheave rollers) becomes misaligned for any reason. The device shall also be able to prevent the resumption of operation of the aerial ropeway unless the misalignment is rectified.

21. DRIVING AND BRAKING REQUIREMENTS

(1) Driving

(a) The main drive of an aerial ropeway shall be able to operate under any condition of loading. The main drive shall be able to start the aerial ropeway from rest to any selected rope speed within the design range. All power units shall have the capacity to handle the most unfavourable design loading conditions, including the starting of the aerial ropeway under an overload situation of 110% of design load.

(b) The main drive shall also be able to drive the aerial ropeway at a rope speed of not exceeding 0.3m/s for the inspection of ropes as specified in the regulation 22(3) of the Aerial Ropeways (Operation and Maintenance) Regulations, Cap. 211A.

(c) Manual speed control shall be provided even the aerial ropeway is designed for automatic control. As far as practicable, the speed selected by the manual speed control shall be constant (Variations of up to ± 5% will be tolerable).

(d) The rope speed shall be monitored and recorded. In addition, a visual and audible alarm shall be activated when the rope speed is at + 5% of the maximum rope speed. The operation of the aerial ropeway shall be

automatically stopped when the rope speed is + 10% of the maximum rope speed. (Subject to the decision of the owner of the aerial ropeway, lower values for the above settings may be used. The owner shall submit the settings to the Director.)

(e) The preferred source of power for the main drive for any ropeway will be by electric motor with its electrical power derived either from a main supply or an independent auxiliary supply (e.g. diesel generator). Both sources of electrical power supply shall be readily available at the same time. Electrical interlock shall be provided to prevent the electrical motor from deriving its power from both sources at the same time. Manual selection switch shall also be provided for manually selecting the power source.

(f) An auxiliary driving unit independent of the motor drive mentioned above shall be provided. This auxiliary drive shall be powered either by the main electricity supply or an internal combustion engine. This unit shall be capable of starting and driving the aerial ropeway under an overload situation of 110% of design load at a rope speed not less than 0.5 m/s.

(g) Since an aerial ropeway has a high probability of being subject to heavy loading, e.g. for public use, an additional rescue drive used specifically for the rescue of passengers in the event of a main drive and auxiliary drive failure is required.

(h) The auxiliary drive shall drive on the driving sheave or the gearbox of the main drive. The rescue drive shall drive directly on the driving sheave and shall by-pass the main drive equipment. There shall be adequate mechanical and electrical interlocks to prevent more than one drives being parallelled together.

(i) The exact driving arrangements for different types of ropeway will depend on the design and loading pattern of the aerial ropeway and many other factors that are peculiar to a particular installation. If the main drive is carried out with a low-speed electric motor without main gearbox, known as "direct drive", the above-mentioned requirements should be followed as far as practicable...

(2) Braking

(a) The aerial ropeway shall have three types of braking systems, if applicable.

(i) Service Brake

The electrical service brake (electrical stop function) is processed by the main drive motor. The mechanical service brake may operate on any point of power transmission from motor to driving sheave.

(ii) Emergency Brake

The emergency brake shall operate directly on the rim of the driving sheave.

(iii) Braking on the line (only for reversible ropeways that are designed with carriers equipped with track rope emergency brakes).

(b) The action of these brakes shall be by means of springs or dead weights which will keep the brake normally closed. During the operation of the aerial ropeway, the brakes shall be held open by hydraulic cylinders with the hydraulic power supplied by a suitably designed hydraulic power pack. When the hydraulic system (i.e. hydraulic cylinders, hydraulic power pack or associated pipework) fails, the brakes shall apply immediately to stop the operation of the aerial ropeway.

(c) The operation of the braking systems shall be arranged to work proportionately with the loading condition and rope speed such that excessive swing of the carriers could be avoided. The braking systems may be used individually or in combination to give progressive braking effects.

(d) The minimum braking effect shall generally be in excess of 0.5 m/s^2 (0.05 g) and the maximum shall be less than 2 m/s^2 (0.2 g).

(e) Any safety device or electrical trip shall turn off the supply to the drive and at the same time, apply the brake. The resumption of the operation of the aerial ropeway shall be prohibited unless the cause for the operation of any safety device or electrical trip is cleared.

(f) The components of any braking system shall be designed and constructed for easy inspection and maintenance. All components shall be designed with a safety factor of 5. Each brake shall be capable of stopping the operation of the aerial ropeway under all loading condition at maximum rope speed.

(g) The brakes shall be automatically applied if the aerial ropeway tends to run in the reverse direction unintentionally.

22. ROPES

(1) The following are the terms used when dealing with ropes:

(a) Wire

The wires for steel wire ropes are the filaments from which a rope is wound. They are normally drawn down from larger diameter steel rods. The specification for the wire is given in British Standard BS EN10264 (Parts 1 to 3). The drawing of steel wire is carried out through a series of dies which progressively reduce the diameter and if necessary transform the shape to that required. The wire may be galvanised.

(b) Strand

A strand is produced by twisting a bundle of wires together in a particular configuration. The number of wires and the number of layers in a strand depend on the use of the rope.

(c) Stranded Ropes

Stranded ropes are manufactured from a number of strands according to the application and are twisted or "closed" round a central strand; this central strand is known as the core. The core may be manufactured from a fibrous material or from a polypropylene rod. The fibres may be sisal or manila (natural fibres) or polypropylene (synthetic fibres).

(d) Spiral Ropes

Ropes manufactured of a single strand are known as spiral or helically wound ropes. These are usually multilayer ropes manufactured from a combination of round and shaped wires. The shaped wires that normally form the outer layer (and others) are designed to interlock with the adjacent wire and are known as locked coil ropes.

(e) Track Ropes

Track ropes mean ropes that are designed, manufactured or used solely for supporting carriers on an aerial ropeway. They are those ropes upon which the carrier travels on wheels as in bi-cable uni-directional or reversible ropeways. Locked coil ropes are always used as track ropes, carriers travelling on track ropes give a very smooth ride due to the locked surface wires..

(f) Hauling Ropes

Hauling ropes mean ropes that are powered by a drive system and are designed, manufactured or used solely for drawing carriers on an aerial ropeway. They are those which provide the traction force and haul the carriers on the track rope. Stranded ropes are always used as hauling ropes.

(g) Carrying-hauling Ropes

Carrying-hauling ropes mean ropes that are powered by a drive system and are designed, manufactured or used to perform both the functions of hauling ropes and track ropes. This type of rope is generally used in monocable ropeway and double monocable ropeway where the carrier is attached (either permanently or temporarily) to carrying-hauling rope(s) which continuously circulate between two terminal stations. Stranded ropes are always used as carrying-hauling ropes.

(h) Lay

The lay of a rope is the configuration of the wires in the rope. For example, for stranded ropes, the individual strands may have the wires

spun in the same sense as the helix of the rope (Lang's or parallel lay) or spun in contra-rotation (cross or ordinary lay). The exact lay of a rope depends on the application, loading and location.

(i) Pre-forming

Pre-forming is a technique used during the production of a rope so that the individual strand is set into a helical form to ensure that it will lie in the rope without tending to unwind.

(j) Post-forming

Post-forming is a similar technique used after the manufacture of a rope to eliminate the tendency of the rope to twist and kink when not under tension.

23. GENERAL REQUIREMENTS OF ROPES

(1) General

(a) As far as possible the ropes shall be made in a single length. During the threading of the rope, and when it is in normal operation, any twisting or "kinks" shall be avoided as far as possible.

(b) Welding points in the wires shall be spaced at least six times the pitch of the wire. The number of welds in a length of 500 m shall not exceed the number of the wires in the rope.

(c) Before the commencement of operation, and to provide a datum for comparison with the inspection of ropes during operation, it is recommended that the new ropes are examined by means of an electromagnetic testing instrument (defectograph), or by another non-destructive testing system which can locate defects in the wires.

(2) Lubrication

Lubricants must be applied to the wires at the manufacturing stage and any fibre core shall be similarly impregnated. After the aerial ropeway is put into operation, the rope shall be, wherever required, lubricated in accordance with the methodology and intervals recommended by the original wire rope manufacturer. The lubricants (preferably the same) shall have no chemical or corrosive action on any part of a ropeway with which it may have contact, especially rubber liners on sheaves and rollers.

24. PARTICULAR REQUIREMENTS OF ROPES

(1) Track Ropes

(a) Locked coil ropes shall be used. Stranded spiral ropes with round outer wires ("Hercules" ropes) are not allowed except for replacement of "Hercules" ropes of existing installations.

(b) The track ropes are kept under constant tension by means of a rope tensioning system, and both ends of the track rope may be anchored. In the latter case, the maximum tensile stress of the ropes is variable and shall be determined by means of calculations which take into account the influence of the temperature and load variation and shall be verified by means of measurement carried out during operation. In such cases, the necessary equipment shall be provided for measuring and regulating the tension of the ropes.

(c) When laying the track ropes, their actual breaking load in tension shall be at least 3.3 times the maximum designed axial load which takes place during operation.

(d) The calculation of the maximum axial stress shall take into account the tension in the track rope due to the rope tensioning system, the weight of the rope (component of the weight in relation to the difference in level), the resistance of the rope to sliding on the saddles and the resistance to motion of the tensioning devices. The coefficient of friction between the track rope and the saddle lined with bronze or other similar material may be assumed as being 0.10 for locked coil ropes and 0.15 for stranded spiral ropes. For steel saddles, those coefficients shall be increased by 20%.

(e) As regards transverse loads acting on the track ropes, it is necessary to similarly consider the actual maximum values of the wheels of the carriers which limit the effects due to bending, taking into account the actual minimum tensile stress in the track rope.

(2) Hauling Ropes and Carrying-hauling Ropes

(a) Stranded ropes shall be used. Hauling ropes or carrying-hauling ropes shall generally be kept under constant nominal tension by means of rope tensioning system.

(b) A safety factor of 4.5 must be used with respect to the maximum axial load of the rope compared to the calculated breaking load; but in such a case, allowance for the line friction shall be taken into account when determining the maximum axial load.

(c) In calculating the maximum axial stress of the hauling rope or carrying-hauling rope, it is necessary to take into account the most unfavourable conditions which result from the combined action of:

(i) the rope tensioning system;

(ii) the component of the weight of the rope and that of the loaded carriers, considering the carrier weight as distributed uniformly along the rope or as single loads;

(iii) the frictional resistance of the tensioning device; and

(iv) the running resistance of the line rollers to be usually calculated, for the rollers with flexible lining, as 3% of the load exerted on each roller and the inertia forces during acceleration and braking.

(3) Tensioning Ropes

(a) The tensioning ropes are generally of the ordinary lay construction stranded type with one single layer of strands or of the flexible full-locked coil type. Other ropes of different construction are not recommended.

(b) Generally a safety factor of 5.5 must be used with respect to the maximum axial load of the rope compared to the minimal breaking load.

(4) Telephone and Signalling Cables

(a) Stranded ropes with galvanised steel wires are recommended. Other types of ropes may be used only if their strength and suitability have been proved in operation.

(b) For telephone and signalling cables, the safety factor shall be at least 3.3 times the maximum designed axial stress. Cables used for telephone and signalling purposes shall not come into contact with carriers or the track/hauling/carrying-hauling ropes under the worst operating conditions. To attain this situation, the design of the supports, trestles and anchorage points shall be arranged so that the safety and operation of the aerial ropeway is not jeopardised.

25. DIMENSIONS

(1) Summary of Values for Factors of Safety for Ropes

The factors of safety, conventionally defined as the ratio between the actual tension breaking strength of the rope and the maximum axial stress which arises during operation, shall when laying the ropes not be less than the following values:

(a)	track ropes	3.3
(b)	hauling ropes	4.5
(c)	carrying-hauling ropes	4.5
(d)	tensioning ropes	5.5
(e)	telephone and signalling cables	3.3

(2) Transverse Loads

(a) The number of carrier wheels shall be such that the maximum transverse load transmitted by each shall not be more than 1.25% of the minimum axial tensile stress of the track rope at the considered point; if the wheels groove is lined with flexible material, such ratio may be increased to 1.67%. The pressure of the rope on the sheave liner shall also be limited to a maximum of 5 x 10^5 N/m^2 (0.5 kg/mm^2). As for transverse loads exerted by trestle sheaves on the track rope, provisions of section 14 of this Code of Practice shall be applied. For maximum transverse load exerted by grips on hauling ropes and carrying-hauling ropes, see EN 12927-2.

(b) When several carriers are in the same span, the angles formed by the rope at both ends of the span with respect to the horizontal shall be taken into account in the following conditions:

(i) loaded carriers
(ii) empty carriers

(c) The difference between the tangents of the angles at each end of the span shall not exceed 0.15.

26. SPLICING AND ROPE CONNECTIONS

(1) Splicing

Whenever splices in hauling or carrying-hauling ropes are required, they shall only be carried out by artisans of proven ability. The dimension of the splice may be in accordance with the recommendations of the rope manufacturers as long as the requirements of BS EN 12927-3 are met. The main requirements and other recommendations are:

(a) The total length of a long splice shall not be less than 1,200 x rope diameter.

(b) The minimum distance between two splices shall not be less than 3,000 x rope diameter.

(c) The length of the tails shall be not less than 60 x rope diameter.

(d) The loop for a carrying-hauling rope or hauling rope should not have more than two splices.

(e) A single damaged strand may be replaced as long as the damage is limited to that strand only. The length of the replaced strand shall be at least 300 x rope diameter long or 25% of total new splice length, whichever is the greater.

(f) At any splice or replaced strand, the rope diameter shall not vary more

than ± 10% of nominal diameter.

(g) Any splice or replaced strand shall not significantly affect the strength of the rope.

(2) Sockets

(a) Rope sockets are formed at the end of a track rope by casting the splayed ends of the wires (a sheaf) into an alloy of white metal. The finished socket is in the form of a cone which acts as a wedge in an appropriate conical socket (or sleeve). Other material suitable for the application may be used subject to the approval of the Director.

(b) If end sockets are to be used, they must be fitted with care. For this purpose, only firms which specialise in this technique and can prove their experience, both as regards the making of the sockets and the choice of correct materials, shall be employed, unless the ropeway company has its own qualified personnel who have proper experience in this work. During service, the rope ends shall be easily accessible for inspection. The sockets shall be filled with a white metal that may be applied at a temperature below any critical temperature which will alter the metallurgical or mechanical properties of the wire.

(c) The wires in the cap shall be spread to evenly distribute the load and arranged that no bending moment is applied to the rope as it leaves the socket.

(d) On installation of an end socket, a transverse reference mark shall be made so that any displacement can be readily seen.

(e) The end socket shall have a strength at least the same as that of the rope.

(f) The end socket shall be protected from the ingress of water or any other substance that may be corrosive or may affect the integrity of the end socket.

27. TESTING AND CERTIFICATION OF ROPES

(1) Testing

(a) The testing and acceptance (or rejection) of ropes is fully documented in BS EN 12385 or ANSI B77.1. The British Standard does not deal specifically with stranded ropes for aerial ropeways and does not include half or fully locked ropes at all, but the procedures laid out therein are totally suitable for this application and shall be applied.

(b) The test reports shall include the following items:

(i) complete description of wire rope furnished for the test, including number and arrangement of wires, grade, type of core, and

nominal breaking strength;

(ii) actual rope diameter;

(iii) measured breaking strength;

(iv) theoretical breaking strength and size of wires tested; and

(v) actual torsion of wires tested.

(2) Certification

After the testing and acceptance of a rope, in addition to the EU-Declaration of Conformity for Safety Components and the Inspection Certificates EN 10204-3.1 with standard EN 12385-9 or equivalent applied, the Director may require an independent organisation to conduct individual wire testing inspection in order to make out Inspection Certificates EN 10204-3.2 for cross-checking purpose.

28. ROPE REPLACEMENT

(1) The rope on an aerial ropeway should be replaced when any of the following conditions are present:

(a) The diameter of the rope has been reduced by 10% or more of its diameter at the time it was first installed;

(b) The number of broken wires in any length equal to 30 times the diameter of the rope exceeds 10% of the total number of wires;

(c) Estimate of loss of strength is 10% for whatever reason where the estimation method should be submitted to the Director for reference;

(d) Excessive wear on outer wires which has reduced their diameters (in radial direction) by approximately 25 – 30%;

(e) Wires becoming loose (loose wires are to be counted as broken);

(f) Distortion of the rope;

(g) Corrosion;

(h) The condition of the rope or its performance leaves any doubt as to its integrity and safety in operation.

Note: The conditions (a) and (b) are the requirements stipulated in regulation 21 of the Aerial Ropeways (Operation and Maintenance) Regulations, Cap. 211A (abbreviated as "the Regulations"). Reference shall be made to the Regulations for the exact details of the conditions (a) and (b).

29. RECOMMENDATIONS ON THE SIZING OF SHEAVES, STORAGE DRUMS AND REELS

(1) General

(a) Whenever a wire rope is flexed or wound on a sheave, wheel or storage reel, the constituent wires are bent and it is necessary to ensure that any such movement does not overstress the rope. At the point of flexure, it is the outer wires that receive the larger proportion of the combination of tension (or compression) and bending stresses. It is the objective of this section to give guidelines on the minimum permissible bending radii so that the durability of the wires is ensured.

(b) The rope, being a very complex shape to analyse fully, has several limitations as to minimum bending radii, and these are based on empirical assumptions and practical experience. Because of inter-wire and strand friction, the ropes have assumed characteristics which effectively limit the performance with regard to bending and flexing. In addition to the bending stresses, there is friction between the wires and/or strands and it is for this reason that the regular lubrication of the rope is important to minimise this effect.

(c) The limitations described below are to be considered in conjunction with sections 14 and 15 of this Code of Practice concerning the trestle rollers loading and rope deflection at the trestles.

(2) Hauling Ropes and Carrying-hauling Ropes

The following dimensions are recommended:

	Type	Dimensions (the larger value to be used in all cases)
(a)	The diameter of sheaves with movement of the rope	x 80 rope diameter

(3) Track Ropes

The following dimensions are recommended:

	Type	Dimensions (the larger value to be used in all cases)
(a)	Radius of saddles with movement of the rope	x 250 rope diameter
(b)	The diameter of the fixed drum for friction anchorage (the rope shall pass round the drum at least three times) and saddles without movement of the rope	x 65 rope diameter
(c)	Radius of roller chain diverting the rope from the line to the rope tensioning device	x 150 rope diameter

(4) Anchor Points

(a) The drum around which the track rope is anchored shall be supplied with two fixing arrangements:

(i) Fixed anchorage

(ii) Control anchorage which may adjust the rope

Facilities to inspect the rope anchorage are required.

(b) The anchor point must be adjustable so that the track rope can be moved longitudinally. In this manner the contact areas where the rope bears on the saddles may be changed.

(5) Tensioning Ropes

(a)	The deflection sheaves for tensioning ropes (The grooves of these sheaves shall be of the flexible type)	x 40 rope diameter
(b)	If these sheaves are not subject to movement, the dimension may be reduced.	x 20 rope diameter

(6) Storage Drum and Reels

For transport and storage of a rope on a drum, the barrel diameters should not be less than the following:

(a)	Track ropes	x 40 rope diameter
(b)	Stranded e.g. Lang's lay	x 25 rope diameter
(c)	Stranded e.g. flexible (multistrand)	x 19 rope diameter

During storage, the drums should be supported above the ground with the axis horizontal. There should be facility to rotate the drum periodically and the rope shall be fully protected from the weather, ingress of water and contamination from dust and debris of any kind.

30. ROPE TENSIONING SYSTEM

(1) Counterweights, hydraulic systems, or other suitable devices shall be used to keep the ropes of an aerial ropeway in tension under all modes of operation. All devices used to provide the tension shall have sufficient travel to cater all normal operating conditions including changes in loading pattern and ambient temperature.

(2) The rope tensioning system shall have monitoring equipment that will automatically prevent operation outside the design limits.

(3) Hydraulic Tensioning System

(a) The travel of the hydraulic cylinders shall be sufficient to accommodate all normal operating changes in loading and temperature.

(b) The pumps of the hydraulic tensioning system shall have a minimum safety factor of 5, unless a high velocity control valve or flow control device is used in the pipeline connecting the cylinders to the pumps. The control valve shall be rated to hold twice the normal operating pressure.

(c) The hydraulic pressure of each hydraulic cylinder shall be monitored and maintained within the design pressure limits, i.e. upper design limit and lower design limit. When the hydraulic pressure falls below the lower design limit, the pumps for the hydraulic tensioning system shall operate automatically to charge up the hydraulic cylinder. The pumps shall stop automatically when the hydraulic pressure reaches the upper design limit. Visual and audio warning signals shall be given when the hydraulic pressure falls below the lower design limit.

(d) A pressure gauge shall be provided for each hydraulic cylinder.

(e) All pipes and hoses shall be properly mounted.

(4) Counterweight

The exact configuration of the counterweight and tensioning rope (i.e. double sheaving, chains, etc.) shall be a design consideration for the particular location. If several tensioning ropes are arranged in parallel, all the precautions should be taken to ensure that the tension is uniformly distributed among them. The following, however, are the requirements for a rope tensioning system of counterweight type:

(a) The area (counterweight pit) in which the counterweight travels shall be fully enclosed and protected from the elements, and be free from the ingress of water or any debris.

(b) The counterweight pit shall be designed to accommodate the counterweight in any position (including elongation of the ropes) under all operating and weather conditions.

(c) At the upper and lower extremities of the counterweight pit, shock absorbing devices shall be installed to smoothly bring the counterweight to rest without damage. The counterweight shall not touch or rest on the bottom of the counterweight pit under the worst operational conditions and that sufficient clearance shall be provided and maintained at all times.

(d) Damping arrangements may be installed to reduce rapid or damaging oscillations of the counterweight, if required; these shall not induce significantly high tensions in the rope having due regard for the factors of safety specified in relevant sections in this Code of Practice.

(e) The counterweight shall have clear and unobstructed travel. A remote indication of counterweight movement and travel shall be installed for monitoring the position of the counterweight. This indication shall be suitably positioned so that its displayed reading can easily be seen from outside the counterweight pit.

(f) Electric switches at the acceptable limits of travel of the counterweight shall be provided; these shall initiate a trip at the appropriate levels of the counterweight.

(g) Counterweight pits shall be adequately guarded to prevent the entrance of unauthorised personnel.

(h) All components of the counterweight shall be easily accessible for inspection.

(i) If more than one tensioning rope is utilised, the load shall be shared equally between them.

(j) The foundations of both tensioning and anchorage equipment must have a factor of safety of not less than 1.5 with regard to moving and overturning. This factor must be calculated on the assumption that the foundations are free, that is, the effect of earth has not been taken into consideration.

31. COMMUNICATIONS

(1) There is a constant need to maintain adequate verbal contact between the terminal stations and the passengers or other operational staff on board the carriers, especially at times of emergency. Therefore, the following forms of communication equipment shall be provided to ensure an effective communication is available at all times.

(a) Telephone

All terminal stations shall be connected to the public telephone service. In addition to this requirement, an internal telephone system connected to the major sections of the ropeway is required.

(b) Wireless Communication System

A wireless communication system, approved by the Director-General of Communications, shall be provided. The system shall not interfere with other similar systems in Hong Kong. For the aerial ropeway with attended carriers, a wireless communication system shall be provided at the carriers for the communication between the carriers and terminal stations.

(c) Public Address System

The line of a multi-carrier aerial ropeway shall be provided with a public address system that is audible within the carriers from any point on the line. In addition, portable loud-hailers are recommended for "on-the-spot" communication in case of emergency. At least one of these modes of communication shall be readily available at all times. Any cables that are also used for the transmission of any electrical systems shall be suitably protected and isolated; the strength of any suspended cable shall comply with the requirements in section 25 of this Code of Practice.

32. STATIONS

(1) Structures

The building structures and facilities shall be constructed in accordance with the requirements as stipulated in the Buildings Ordinance (Cap. 123). The design of the station buildings shall take into account all the forces upon them, including rope tensions and an earthquake loading as indicated in section 13 of this Code of Practice.

(2) Access

(a) Queuing area shall be provided at each station for passenger boarding. The queuing area shall be sufficiently large to cater for the maximum passenger flow.

(b) The layout and deposition of the stations shall be such that the access and exit points are clear, even at times of maximum passenger flow. The

circulation of passengers is, as far as possible, unhindered. Sufficient covered space shall be provided, under average passenger flow conditions, for waiting passengers.

(3) Prohibited Areas

(a) Passengers shall not have access to any area housing machinery or operational equipment and shall be given access only to the boarding and alighting areas.

(b) All machinery and equipment shall be adequately guarded with noise attenuation facilities. The driving gear and the return deflection devices shall be protected against weather.

(4) Boarding Area

At boarding areas in those stations where the carriers are in constant motion, enough space to accommodate the passengers queuing up for boarding the carriers shall be available. In all cases, sufficient space shall be provided, under average passenger flow conditions, for waiting passengers under cover or shelter from the weather. Sufficient public hygiene facilities shall be available at all times.

(5) Emergency Lighting

Emergency lighting in the stations shall be available from a secure supply. Such supply should conform to the Codes of Practice for Minimum Fire Service Installations and Equipment and Inspection, Testing and Maintenance of Installations and Equipment issued by the Fire Services Department.

(6) Prevention of Fire

Upon receipt of building plans, the Director of Fire Services will be responsible for formulating requirements/recommendations for the intended use of such stations. In addition, proper management of stations with specific reference to good housekeeping, effective control of passengers, unobstructed entrances/exists, etc. are essential for prevention of fire. Any such requirement of the Director of Fire Services shall be complied with.

(7) Notices

The following notices shall be posted in a conspicuous place in each station and shall be kept in good condition:

(a) Notices, in both Chinese and English, containing the messages as required in the Regulations and, in addition, giving warning of hazards related to moving machinery; and

(b) Notices, in both Chinese and English, and either with a red or yellow background, giving warning of the danger of fire in the station, as well as in the vicinity of the ropeway line.

33. CONTROL AND SAFETY CIRCUITS

(1) Annunciation

All control and safety circuits shall be monitored and annunciated by means of visual indication signals or audible alarms, and the audible alarms shall not have sounds that may be confused with any telephone ringing etc.

(2) Controllability

All control and safety circuitry shall be easily accessible in the control room. The operational controls must be positioned inside the control room such that the ropeway may be operated and controlled in any desired mode. The control room should be located in one of the stations and so positioned as to afford the best possible view of the line and shall be located close to the place where operation is normally carried out.

(3) Automatic Operation

(a) The operation of the safety circuitry shall be automatic and the safety circuitry shall be arranged so that the operation of any circuitry shall stop the operation of the aerial ropeway. After the activation of safety circuitry, resumption of the operation should not be possible unless the fault is cleared. The operation of any protective circuit shall be clearly annunciated in the control room giving information as to the type and location of the fault.

(b) Duplication of these circuits will be required at the various terminal stations.

(c) Ropeways that require a reduction in velocity for the passage of the carriers over the intermediate trestles shall be suitably equipped with control system(s) so that this may be carried out automatically.

(4) Attendant Controls

Attended carriers shall have facility to stop the operation of the aerial ropeway; this facility will be independent of the controls at the stations.

(5) Bridging Circuits

If a fault is occasioned by a breakdown or malfunction of the control circuitry, it may be permissible, under certain circumstances, to by-pass that part of the equipment with a bridging circuit. All such devices should be correctly engineered and their functions clearly described in the design documentation. It is intended that with properly designed bridging circuits misuse and further damage to the equipment will be prevented. Their use, however, must be under the supervision of responsible staff and under no circumstances must their use jeopardise safety.

(6) Tension Limits in Bi-cable or Tri-cable Systems

The operation of bi-cable or tri-cable systems shall be automatically stopped if the tension in the hauling rope exceeds 1.4 times the maximum designed

tension allowable under the worst operational load condition. Indication of derailment and/or sheave misalignment shall be activated by means of switches that require close inspection and resetting before an aerial ropeway, so tripped, can be restarted.

(7) Door Closing Interlock

A device for either stopping or preventing a carrier with an open door from leaving the station shall be provided.

(8) Emergency Stop and End Buffers

(a) Emergency stops, which allow the personnel to stop the line in case of emergency, must be provided in the stations.

(b) For reversible ropeways, the terminal stations shall be provided with end-of-travel limit switches for carriers. Other facilities including buffers and controls for the automatic stopping of the line shall also be provided.

(9) Software By-Pass

The bypass of a non-critical fault of a certain equipment/system, which has been affirmed by the Competent Person as safe and does not pose any hazard to the passengers and ropeway safety, could be achieved by means of simulation by control software (i.e. software by-pass). The function should have password protection or be activated with a by-pass key or both. The log record of the software by-pass shall be stored automatically by the ropeway monitoring system for tracking purpose.

34. TRESTLES

(1) The trestles may be constructed of either steel, prestressed or reinforced concrete. In any case they shall be designed and constructed with the following considerations:

(a) Calculations shall take into account combination of trestle and rope pressure;

(b) (i) Horizontal load due to the friction of the passage of the moving rope (normally considered to be 3.0% of total rope pressure), or

(ii) Sliding friction of track rope on saddle (normally considered to be in the range between 1.3 - 1.8%);

(c) Loading due to carriers on line. The load is to be considered static and apportioned to the trestles;

(d) Wind and earthquake loading (see section 13 of this Code of Practice);

(e) All dynamic forces acting on the trestles during ropeway operation shall be taken into account and a minimum factor of safety of 3 shall be used in

all simplifying calculations. For specific calculation, see BS EN 13107;

(f) The Geotechnical Manual for Slopes should he used in the design of the overall stability of the foundations. Where only the dead weight of the structure is considered, the factor of safety against uplift of the foundation whether in operation or not, or in the most unfavourable conditions of loading, shall be not less than 2.0. A very high standard of anchorage system, particularly with respect to corrosion protection is required. The foundation or the structural components should be designed to prevent any differential settlement occurring.

(g) While the sheave trains and rope guides must adjust themselves to the passage of the rope, the trestle must be torsionally rigid such that the maximum displacement, under the worst conditions, shall not displace the centre line of the sheave wheel or rope guide by more than 20% of the largest rope diameter, in the transverse direction, on that trestle.

(h) The trestles may be mechanically tied to prevent bending or overturning. Flexible wire ropes are not permissible for this application.

(i) Means for easily lifting the rope from the sheave wheels is required.

(j) Safety provisions shall be incorporated in the structure to facilitate maintenance and rescue operations, i.e. fixed ladders, walkways and safety rails. Permanent anchor points shall be provided at the trestle for the attachment of fall protection devices for the maintenance staff or rescue crew.

(k) The number and spacing of the trestles shall be such that the necessary clearances are maintained (see section 6 of this Code of Practice) in conjunction with the limitations of maximum gradients and rope deflections).

(l) The materials of which the trestles are constructed shall be adequately protected on all surfaces from corrosion, including the inside of tubes and hollow sections.

(m) The trestles shall be numbered sequentially from the lower station. These numbers must be clearly visible and legible from a distance of 200 m.

35. CARRIER CONSIDERATIONS

(1) Carrier Parameters

Carriers are the vehicles suspended from the rope in which the passengers are carried. There are many varied types of carrier but all must comply with some basic design requirements which are detailed below:

(a) With regard to carrier speed and spacing, it is necessary to ensure that the natural frequencies of a ropeway shall have no relationship to the induced vibration frequencies by the weather elements or any external force at any speed or loading condition.

(b) Each person shall be in general assumed to be equivalent to a 75 kg mass.

(c) Standing passengers are allowed if the carrier is suitably designed for that purpose.

(d) The boarding time for each carrier shall be configured for safe and easy boarding, depending on boarding situation and the kind of carrier.

(e) The safety factor of the structure, hanger and all load bearing components shall be at least 4 for simplifying calculations. For specific calculation, see BS EN 13796-1.

(f) The design calculations shall take into account all probable static and dynamic forces that will be encountered in operation (including fatigue loading), such as vehicle weight itself, passenger load, wind force, inertia forces at trestles, starting acceleration and braking.

(g) The enclosure of the carrier shall be so designed as to prevent the passengers from being thrown out in case of accident and must have facility to prevent passengers from getting out of a closed carrier. Also, all doors should be closed, either manually or automatically, from the outside and shall not be opened from inside the carrier except by the attendant in the case of an attended carrier.

(h) All carriers shall have adequate natural ventilation. Any window opening shall be suitably guarded to prevent passengers from either falling from the carrier or touching any other part of the ropeway. The transparent material for the window opening shall be shatter-proof.

(i) Minimum sizes for carriers

(i) For standing passengers:

Floor area A = N/6 m^2

(N = number of passengers)

Height H = 2.20 m

(ii) For seated passengers:

Seat width W = 0.5 m
Floor area A = 0.33 m^2 (per passenger)

(j) Carriers that designed to accommodate standing passengers shall be provided with adequate handrails etc. For reversible ropeways, each carrier shall be equipped with a device to indicate audibly any overload situation; the operation of the ropeway shall be automatically stopped wherever there is an overload situation in any carrier.

(k) All components of a carrier shall be easily accessible for inspection and maintenance. All internal and external surfaces shall be protected to prevent corrosion.

(l) The hanger of a carrier shall be articulated in the longitudinal direction and shall be damped to prevent excessive swinging.

(m) For carriers that run on rollers, the number of rollers shall be such that the loading on each shall comply with those limitations as laid down in section 25(2) of this Code of Practice.

(n) For carriers that have facility to provide braking on the rope, such a brake, other brakes at the stations shall be arranged to operate to eliminate abrupt changes in velocity. Any such brake shall not cause damage to the ropes.

(o) As far as possible, carriers shall be made of materials that are not easy to ignite.

(2) Capacity

(a) The carrier (including the hanger) shall be suitably designed for the rated passenger carrying capacity. The design calculation of the carrier (including the hanger) for substantiating the design capacity shall be submitted to the Director. When designing the carrying capacity, the loading and unloading of passengers should be taken into consideration.

(b) The rated passenger carrying capacity shall be displayed for every carrier. All information shall be written in both Chinese and English.

(3) Speed

(a) As the ropeway technology develops, there will be a natural increase to the maximum permissible speeds. The variation of speed of vehicles due to either acceleration or deceleration shall not cause disagreeable sensation to passengers. This development will not be discouraged although the recommended safe maximum speeds at the present time will be:

(i) Gondola (uni-directional, closed carriers)	
monocable	6.0 m/s
double monocable	7.0 m/s
(ii) Chairlift (uni-directional, open carriers) (see BS EN 12929-1 for details)	5.0 m/s
(iii) Uni-directional bi-cable,	
with one track rope	7.0 m/s
with two track ropes	8.0 m/s
(iv) Reversible bi-cable	12.0 m/s
(v) Reversible bi-cable above towers	
attended, with one track rope	10.0 m/s
attended, with two track ropes	12.0 m/s
unattended, with one track rope	7.0 m/s
unattended, with two track ropes	8.0 m/s

Information (including design calculation, job reference, local wind condition, etc.) for substantiating that the aerial ropeway could be operated at the design speed under the permitted wind condition (in terms of wind speed and wind direction) shall be submitted to the Director for approving the design speed of the aerial ropeway. The Director may grant an approval to the design speed of the aerial ropeway at a value lower than the above list.

(b) When carriers are in constant motion for loading and unloading passengers, the maximum speed shall not be greater than 0.25 m/s.

(c) It should be re-emphasised that the maximum speed of any system must be designed with safety in mind. The difficulty of designing, operating and maintaining a ropeway is compounded, to a first order approximation, by a direct proportion to the square of the speed. Comfort of the ride is also a significant consideration for the design of an aerial ropeway.

(4) Spacing

The minimum distance between two successive carriers shall not be less than 1.5 times the stopping distance under the most unfavourable load conditions.

36. ATTACHMENT OF CARRIERS TO THE ROPE

(1) Reversible Aerial Ropeways

The reversible aerial ropeways usually have two large carriers travelling in opposite direction on a single loop of hauling rope and are suspended on one or more track ropes. Instead of a splice, the loop may be formed by two lengths of rope. The ends of the two half loops are usually connected directly to the carrier wheel bogie by means of "Muff" couplings. In essence, the coupling consists of sockets, where the individual wires are spread and clamped mechanically, or by casting into a white metal matrix. These fixings are permanent and shall have a pull out strength equal to the strength of the hauling rope(s).

(2) Uni-directional Aerial Ropeways - Permanent or Fixed Grips

(a) There are several grips that can be used for this duty but the one most commonly used is the type that may be clamped to the rope by means of a screw adjustment. The grip pressure on the rope is ensured by means of a spring (disc springs). The grip is designed to be able to pass round the driving and return sheaves.

(b) The device for attachment of the carrier to the carrying-hauling or hauling rope shall resist the tendency to slide along the rope when subject to a force of not less than three times the force component of the carrier under on-load condition along the axis of the rope at the maximum gradient, with the understanding that, however, such a resistance must not be less than the weight of the loaded carrier.

(3) Uni-directional Aerial Ropeways - Detachable Grips

(a) This type of grip is detachable from the carrying-hauling or hauling rope during operation and there are devices in the stations which automatically clamp and unclamp the grip to and from the rope.

(b) The device for attachment of the carrier to the carrying-hauling or hauling rope shall be of such a construction that any danger of accidental opening (unlocking) must be prevented, and that the gripping force does not decrease below the required minimum pressure necessary to avoid sliding. The conditions may be fulfilled by providing the gripping devices by means of springs (spiral or disc springs).

(c) The device for attachment of the carrier to the carrying-hauling or hauling rope shall resist the tendency to slide along the rope when subject to a force of not less than three times the force component of the carrier under on-load condition along the axis of the rope at the maximum gradient, with the understanding that, however, such a resistance must not be less than the weight of the loaded cabin.

(d) The required resistance to sliding shall be automatically kept even on the assumption that the rope diameter is reduced by 10% of the nominal diameter and taking into consideration, for the calculation, a coefficient of adherence between the jaws and the lubricated rope at a value of 0.13. If jaws used are of particular shape, then the value of the coefficient adopted in the calculations shall be determined by tests.

(e) The value of resistance to sliding of the clamps shall be checked periodically by means of a proper apparatus with which such values can be ascertained quickly.

(f) The shape of grips and the profile of the groove shall adapt themselves, taking into account the maximum lateral swinging permitted for the carriers.

(g) Facility to synchronise the rope and the carrier speed at the point of attachment is necessary.

(h) When the clamps grip the carrying-hauling rope or hauling rope, the speed of the carrier shall not be deviated more than 20% of the speed of the rope.

(4) Checking the Clamping Efficiency

(a) Ropeways that have the carriers automatically attached and detached from the hauling rope or carrying-hauling rope shall have a device that can automatically check the integrity of the grip(s) on the rope and the resistance to sliding.

(b) Due to the possibility of the clamp sliding on the rope, the following conditions are recommended for safe operation:

(i) A device in the station that will check that the grip is fully engaged and locked to the rope shall be provided.

(ii) A device shall be provided to test the gripping efficiency by measuring a relevant parameter for the gripping force. This will be an automatic device which will check each carrier on launching.

(iii) A device shall be provided to check that the carrier is physically separated from the moving rope. In cases where a carrier is not detached correctly, facilities will be available for stopping the line and safely bringing the carrier to rest.

37. LIGHTNING PROTECTION, EARTHING AND WIND SPEED INDICATORS

(1) Lightning Protection

An aerial ropeway shall be adequately protected from lightning by means of a suitably proven device. Each trestle shall be suitably earthed to give a maximum earth resistance of 10 ohms as laid down in British Standard BS EN 62305: 2011 or equivalent Code of Practice for Protection of Structures against Lightning. It will be permissible to electrically connect two or more trestles together to fulfill this requirement.

(2) Earthing

All electrical equipment shall be connected to earth according to Code of Practice for the Electricity (Wiring) Regulations.

(3) Wind Speed Indicators

Instruments giving indication and warning of high wind speed are required. Because of the possibility of localised wind conditions, it is recommended that the indicators that give the alarms and/or trip functions of wind speed be duplicated.

(4) Weather Monitoring System

(a) The weather monitoring system shall provide real-time weather conditions to the operating personnel during operation, which include the measurements of all the wind speed indicators installed along the route of the ropeway, as well as the readings and warning signals of lightning, rainfall and strong wind issued by the Hong Kong Observatory in the vicinity of the ropeway area. In addition, audio signal shall be given to alert the personnel when any of the preset warning limits for ropeway operation are reached.

(b) The operational personnel shall be equipped with updated information on the weather condition within the vicinity of the ropeway during the operation of the ropeway.

38. INFORMATION TO BE SUBMITTED

(1) The Director will require a full set of engineering drawings to be submitted together with sufficient information and calculations to justify the design and the additional information and documents referred to in section 4 of this Code of Practice.

(2) Information will also be required by the Director in accordance with sections 7 and 8 of the Ordinance and the Regulations made thereunder on the following points:

(a) That the design is safe;

(b) That the calculations have ample margin for error (any error must be evaluated and justified);

(c) That eccentric and fatigue loads are considered;

(d) That weather, topographical and geotechnical aspects are considered;

(e) That there can be no ambiguity in the calculations and the procedures must be self-explanatory;

(f) That all safety factors are clearly established and justified;

(g) As to rope profile (static and dynamic) at the best and worst conditions;

(h) As to rope performance at sheaves, trestles, drive wheel and return sheaves;

(i) As to movement of rope tensioning system (predicted) in operation and extended service;

(j) As to strength and stability of all fixings and anchorages;

(k) As to compliance with the respective recommendations either given or referred to in this Code of Practice, or a justification as to the reason for non-compliance;

(l) The ropeway operation is highly reliable with adequate emergency and rescue equipment provided;

(m) As to quality assurance of the aerial ropeway equipment and installation works;

(n) As to method of installation of the aerial ropeway including a comprehensive job hazard, risk assessment and contingency plan; and

(o) As to the organisation chart of the project team, installation programme, qualifications of project team members and manpower plan.

(3) All the submissions as specified in this Code of Practice could be made in either hardcopy or electronic form. The formats of electronic submissions shall be commonly used and shall be specified by the Director from time to time through circular letters.

39. VARIATION OF REQUIREMENTS

For the avoidance of any doubt, it is stated here that the Director may, in his discretion, in any particular case vary any of the requirements stipulated in this Code of Practice.

TERMINOLOGY AND DEFINITIONS

The field of aerial ropeways is highly specialised and, as such, has its own terminology and definitions which may be considered unusual. In order to simplify matters, this section is added to provide a basic list of terms used in aerial ropeway engineering. In some cases, common alternatives are also included.

Rope	:	A rope in an aerial ropeway always refers to a wire rope consisting of several strands of steel wires and/or spiral ropes (see text). The rope may have a fibre core strand in some cases. The configuration of the wires (or strand) in the rope depends on its duty.
Trestle	:	(or tower; pylon) A trestle is a structure of steel or concrete spaced along the line of an aerial ropeway in order to either support or depress the rope to maintain the correct profile and tension characteristics.
Line	:	The axis of the ropeway viewed in plan.
Stations	:	Buildings at the line of ropeways. Passengers may embark, transfer or alight only at stations.
Angle Station	:	A structure at which the lateral direction of the path of the ropeway changes.
Carrier	:	(or cabin; car; gondola; chair) The carrier is the vehicle which carries the passengers.
Hanger	:	The hanger is the load bearing structure from the rope to the carrier.
Grip	:	(or clamp) The grip is the device which attaches the hanger to the rope.
Transverse	:	The direction perpendicular to the line.
Sheaves/Rollers	:	(or wheels) Rotating supports which deflect and guide the direction of the rope.
Sheave trains	:	(or roller batteries) A set of rollers on their supporting structure, with the rollers arranged one after the other so as to change the direction of a moving rope.
Defectograph	:	A defectograph is a device for surveying the section of the rope for broken or damaged wires. This instrument normally works on an electromagnetic principle; any broken or damaged wire will cause a disturbance to the sensor of the instrument. The disturbances are recorded continuously and can be shown on a screen.
Bi-cable or tri-cable	:	Bi-cable or tri-cable ropeways are those that allow the carriers to

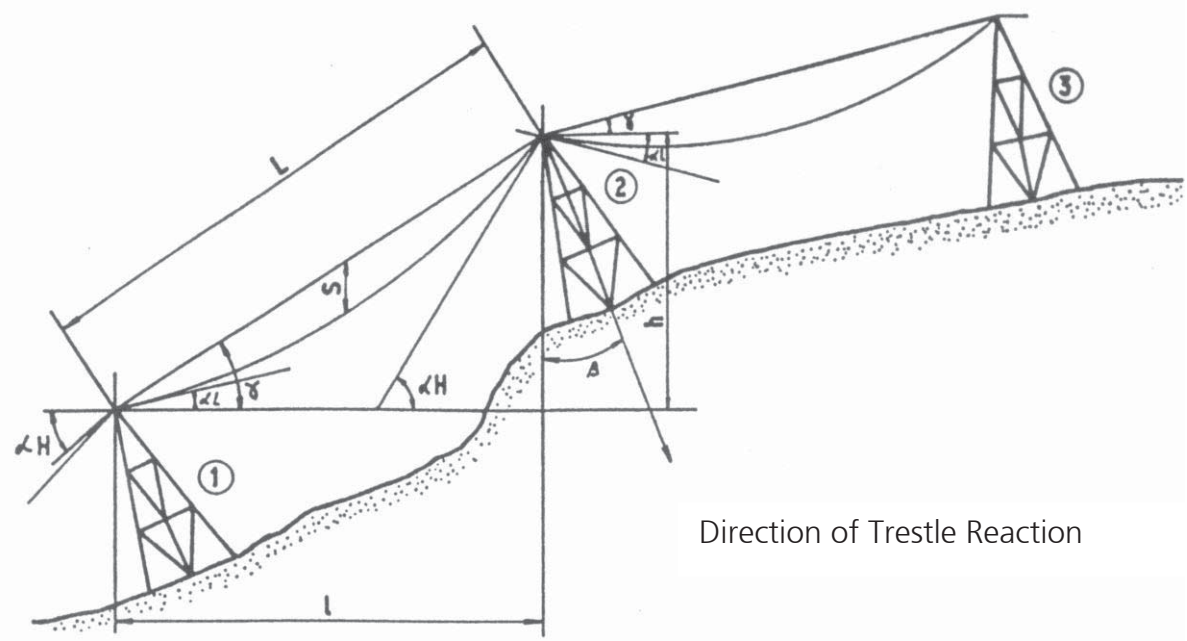
run on rollers on one or two stationary rope(s) called the track rope(s). The motive effort is supplied by a hauling rope which is attached to the bogie of the supporting rollers.

Monocable : A monocable ropeway is one where the carrier is attached directly to a single rope. This rope performs both the carrying and the hauling functions. In case of double monocable ropeway, the carrier is attached directly to two carrying-hauling ropes.

Counterweight: The counterweight is a large mass of steel or concrete which is freely suspended, by various means, to the ropes of a ropeway. In this manner a constant and steady tension is maintained in the ropes.

Additional terms and definitions can be found in the BS EN 12385-2:2002 + AI: 2008 Steel Wire Ropes – Safety – Part2: Definitions, designation and classification.

Definitions of Parameters



Direction of Trestle Reaction

(1), (2) etc.: Trestle number

l: Horizontal component of span (m)

h: Vertical rise of span (m)

L: Chord length of span (m)

β : Angle of trestle reaction (∠H + ∠L)/2 (°)

∠L: Rope outlet angle (°)

∠H: Rope inlet angle (°)

γ : Chord angle (°)

T: Rope tension (kN)

n: No. of sheave wheels

P: Rope reaction at trestle (kN)

D: Diameter of rope (mm)

d: Diameter of wire (mm)

S: Sag (m)

(Note: For normal rope calculation, the profile of the rope may be considered to be parabolic.)

REFERENCES

1. Technical Recommendations, Studies and Statistics for Aerial Ropeways. International Organisation for Transportation by Rope (O.I.T.A.F.).

2. Indian Standard. Codes of Practice for the Construction of various types of Aerial Ropeways: IS 5228:2003; IS: 5229:1998; IS 5230:2003.

3. American National Standard Institute (ANSI). ANSI B77.1 –2011. For Passenger Tramways – Aerial Tramways, Aerial Lifts, Surface Lifts and Tows:- Safety Requirements

4. British Standard BS EN 10264:2012 - Steel wire and wire products – Steel wire for ropes Part 1, 2 & 3.

5. British Standard BS EN ISO 80000-1:2013 - Quantities and units Part 1 – General.

6. Outdoor Lighting Handbook Lumsden. et al.

7. British Standard BS 5266: Part 1:2011. Code of Practice for the Emergency Escape Lighting of Premises.

8. Redgraves Health and Safety in Factories. Fife and Machin.

9. British Standard BS EN 1991-1-4:2005+AI: 2010 - Eurocode 1: Actions on structure Part 1-4: General actions – Wind actions.

10. Typhoons in Hong Kong and Building Design. Faber and Bell.

11. British Standard BS EN 62305:2011 - Protection against Lightning.

12. Regulations for the Electrical Equipment of Buildings (Institute of Electrical Engineers Regulations).

13. Geotechnical Manual for Slopes, 2nd Edition (1997) Geotechnical Engineering Office of Civil Engineering Department

14. Commission of the European Communities (EC), Regulation of the European Parliament and of the Council, relating to cableway installations designed to carry persons.

15. British Standard BS EN 12385-1-2-8-9: 2002+AI: 2008 – Steel wire ropes – Safety – Part 1: General requirements; Part 2: Definitions, designation and classification; Part 8: Stranded hauling and carrying-hauling ropes for cableway installations designed to carry persons; Part 9: Locked coil carrying ropes for cableway installations designed to carry persons.

16. British Standard BS EN 12929-1-2: 2015 – Safety requirements for cableway installations designed to carry persons – General requirements.

17. British Standard BS EN 12930: 2015 – Safety requirements for cableway installations designed to carry persons – Calculations.

18. British Standard BS EN 12927-5-6: 2004 - Safety requirements for cableway installations designed to carry persons - Ropes Part 5 - Storage, transportation,

installation and tensioning; Part 6 – Discard criteria.

19. British Standard BS EN 1909:2004 - Safety requirements for cableway installations designed to carry persons — Recovery and evacuation.

20. British Standard BS EN 1709:2004 - Safety requirements for cableway installations designed to carry persons — Pre-commissioning inspection, maintenance, operational inspection and checks.

21. British Standard BS EN 13796:2005 - Safety requirements for cableway installations designed to carry persons — Carriers.

22. British Standards EN Series concerning safety requirements for cableway installations designed to carry persons comprising the following parts:
    EN 1907 – Terminology
    EN 12929 – General requirements
    EN 12930 – Calculations
    EN 12927 (all parts) – Ropes
    EN 1908 – Tensioning devices
    EN 13223 – Drive systems and other mechanical equipment
    EN 13796 (all parts) – Carriers
    EN 13243 – Electrical equipment other than for drive systems
    EN 13107 – Civil engineering works
    EN 1709 – Precommissioning inspection, maintenance and operational inspection and checks
    EN 1909 – Recovery and evacuation
    EN 12397 – Operation
    EN 12408 – Quality assurance
    This series of Standards forms a complete set with regard to the design, manufacture, erection, maintenance and operation of all cableway installations designed to carry persons.

General Legislation EMSD

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