Proposed Changes/Modifications in Draft Model Design Basis Report (DBR) for Construction of Underground Structures by Cut & Cover Method

Reasoned Document

S No	Clause No.	Existing Clause	Proposed Clause by UPMRCL	Justification by UPMRCL	DMRC remarks	Remarks from Committee members
1	2.0 (Scope of DBR)	The structural elements connected to the member on which metro live loads are supported may also be designed with taking loads and load combination, as specified in "Model Design Basis Report (DBR) for Viaduct of Metro System". Other structural elements such as secondary beams, stub columns etc., may be designed as per IS: 456.	~~The structural elements connected to the member on which metro live loads are supported may also be designed with taking loads and load combination, as specified in "Model Design Basis Report (DBR) for Viaduct of Metro System". Other structural elements such as secondary beams, stub columns etc., may be designed as per IS: 456~~.	The Para is not relevant, as this deals with viaduct elements. Hence, proposed for deletion.	We agree with the justification by UPMRCL and the clause may be deleted.	Committee has agreed on the remarks given by UPMRCL and hence the para may be deleted.
2	2.0 (Scope of DBR)	Structures, where Metro Live loads are not applicable, the design of Plain and Reinforced Concrete structures will generally be governed by IS:456, pre-stressed concrete structures shall generally be governed by IS:1343, Steel structures design shall generally be governed by IS:800. Seismic design shall be governed by IS: 1893.	Structures, where Metro Live loads are not applicable, the design of Plain and Reinforced Concrete structures will generally be governed by IS:456, pre-stressed concrete structures shall generally be governed by IS:1343, Steel structures design shall generally be governed by IS:800.~~ Seismic design shall be governed by IS: 1893.~~	In the Draft DBR, seismic design is already proposed to be done using Free Field Racking method in Para no. 7.5 which is governing.	Applicability of IS:1893 & 13920 is relevant for elevated structures where Force Based Analogy is the basis. However, the UG structures are designed on the basis of Strain based analogy as referred from "Seismic Design and Analysis of Underground Structures" by Youssef M.A Hashash,	Committee agrees with the explanation given by DMRC in support of UPMRCL remarks. Hence the following sentence may be deleted. "Seismic design shall be governed by IS:1893."

					Jeffrey J. Hook, B Schmidt, J.C Yao." That considers the Free Field Racking without any seismic response reduction. Therefore, Ductile detailing is not required for the underground structures and clauses 5.4.1 and 7.5 may also be corrected accordingly.	
3	3.0 (VIII) (Design Principles)	For excavation support, following design parameters shall be taken into account: vi) Temperature loads	For excavation support, following design parameters shall be taken into account: ~~vi) Temperature loads~~	In U/G structures temperature effects are not critical. Therefore, may be deleted.	We agree with the justification by UPMRCL and the clause may be deleted.	In most cases, top- down construction methodology is used. The duration of construction is not long enough to have significant temperature variation. After casting of the top slab, the remaining part of the structure is not exposed to the atmosphere. Hence, committee members are of the view that the temperature loads are insignificant. Committee agrees on the suggestion.
4	5.2(6) Materials (Concrete)	Where the concrete is to be placed under the slurry or water, such as diaphragm wall and barrettes, the design compressive strength and shear strength of structural concrete shall be reduced. The characteristic strength of the compression and shear stress shall be taken 80% of	~~Where the concrete is to be placed under the slurry or water, such as diaphragm wall and barrettes, the design compressive strength and shear strength of structural concrete shall be reduced. The characteristic strength of the compression and shear stress shall be taken 80% of the~~	There is not a requirement in Indian/International Codes. Therefore, can be deleted.	We agree with the justification by UPMRCL and the clause may be deleted.	As remarked by UPMRCL, no codal provision/literature found to support this para. Therefore, Committee is of the view that remark of UPMRCL is **reasonable and may be adopted.**

		the characteristic strength of the concrete grade	~~characteristic strength of the concrete grade~~			
5	7.0 (Loads)	The structures shall be designed for the most onerous combinations of loads using relevant safety factors. For the purpose of computing stresses and deformations, the following minimum load types and consequential effects shall be taken into account as applicable • Temperature loads TL	The structures shall be designed for the most onerous combinations of loads using relevant safety factors. For the purpose of computing stresses and deformations, the following minimum load types and consequential effects shall be taken into account as applicable ~~•Temperature loads TL~~	In U/G structures temperature effects are not critical. Therefore, may be deleted.	We agree with the justification by UPMRCL and the clause may be deleted.	Committee agrees on the suggestion as discussed above in item no 3.
6	7.2 (Superimposed Dead Loads)	Note: The SIDL can be of two types: Fixed or non-variable, and variable. In case Metro certifies that a portion of SIDL is of fixed or non-variable type and is not likely to vary significantly during the life of the structure and a special clause for ensuring the same is incorporated in the Metro's maintenance manual, the load factors applicable for dead load may be considered for this component of SIDL.	~~Note: The SIDL can be of two types: Fixed or non-variable, and variable. In case Metro certifies that a portion mil of SIDL is of fixed or non-variable type and is not likely to vary significantly during the life of the structure and a special clause for ensuring the same is incorporated in the Metro's maintenance manual, the load factors applicable for dead load may be considered for this component of SIDL.~~	This is relevant for Elevated Corridor, where the Load Combinations and Load Factors are as per IRS: Concrete Bridge Code.	We agree with the justification by UPMRCL and the clause may be deleted.	Design member from DMRC has elaborated that In case of underground structure, the SIDL acts as a beneficial load for consideration during floatation. Hence, committee members agree with UPMRCL and DMRC and therefore, the para may be deleted.

7	7.7 (Collision/Impact Loads)	7.7 Collision/Impact Loads Collision/Impact Loads For road traffic as per IRC: 6.	~~7.7 Collision/Impact Loads~~ ~~Collision/Impact Loads~~ ~~For road traffic as per IRC: 6.~~	It is primarily for Elevated Viaducts.	This has very minor effect. The clause from draft DBR may be retained.	Road traffic may hit the parapet wall of the ramp of underground structures. During discussion Metros have agreed to this para and hence the para is to be retained.
8	7.8 (Derailment Loads)	Derailment load shall be considered according to IRS Bridge Rule Appendix XXV, with relevant gauge. For ULS and stability check, loading shall be proportioned as per maximum axle load and gauge.	~~Derailment load shall be considered according to IRS Bridge Rule Appendix XXV, with relevant gauge. For ULS and stability check, loading shall be proportioned as per maximum axle load and gauge.~~ **As per latest Design Code ACI 358.1 (latest revision), for derailment check, derailment load corresponds to the application of 50% of one coach weight, applied horizontally as a 5m long uniform impact load. This "DR" load corresponds to an ULS load. For SLS Combinations (Group V), a 1/1.75 coefficient will be applied to the DR load.**	As per codal provision.	The Derailment load as per IRS Bridge Rule is of vertical nature having more relevance for the design of deck structure of elevated viaducts. In DMRC Phase-III projects, the derailment load were considered as per ACI code as also mentioned by UPMRCL. In phase-IV projects, modifications in DMRC's DBR has been done in consultation with DDC and the following clause is being considered- "The structural elements within 10m of the centre line of track, which are at risk from collision loads shall be considered at ultimate limit state only: i. For station platform edges a nominal load of 1000 kN acting horizontally and	Comparison among IRS bride rule appendix XXV, ACI 358.1 and EN:1991-2 is given below in table-1. As stated by UPMRCL & DMRC, the derailment load as per IRS Bridge rule is of vertical nature, while in Underground structure derailment loads are of horizontal nature. It has been agreed with consensus that ACI 358.1 (latest revision) seems more appropriate to design underground structure for derailment load. Hence the para is modified as "Derailment load shall be considered according to ACI 358.1 (with latest revision). "

					normal to the platform slab edge over a length of 2.2 m, shall be considered. ii. For all structural elements (columns in cross over structure) other than platform edges a nominal point load of 1250 kN acting horizontally in any direction at the top of the element level, or 1.2 m above the adjacent rail level, whichever is less, shall be considered. Where the soffit of the structural element occurs between 1.2 m and 4.0 m above adjacent rail level, the load shall be applied at soffit level." The mentioned clause of DMRC phase-IV DBR has also been considered in Mumbai Metro underground Packages of Line-3.	
9	7.13 (Earth Pressure & Water	If any of the structure supporting Metro loading is subjected to earth pressure, the loads and effects shall be calculated in accordance with Cl. 5.7 of IRS-Substructure Code.	If any of the structure supporting Metro loading is subjected to earth pressure, the loads and effects shall be calculated in accordance with Cl. 5.7 of IRS-Substructure Code. **<u>Calculation of Delta:</u>** **<u>Delta = K x Phi(cv)</u>**	As per CIRIA 760 Code.	In Delhi Metro, the IRS-Substructre Code is being considered for calculation of Earth Pressure.	Since there is IRS –Substructure code to follow upon for design of structure supporting Metro loading subjected to earth pressure.**The majority of members are of the opinion to add the following:**

	Pressure)		**<u>Where, K depends upon the type of wall under consideration i.e. Wall Cast Against a Shuttering or Wall Cast against Soil like a D Wall, whose surface is adequately rough.</u>**			**For calculation of Delta (i.e Angle of friction between soil and wall), CIRIA 760 code may also be referred.** The modified para is as "If any of the structure supporting Metro loading is subjected to earth pressure, the loads and effects shall be calculated in accordance with Cl. 5.7 of IRS-Substructure Code. **For calculation of Angle of friction between soil and wall, CIRIA 760 code may be referred**."
10	7.22 (Incremental Dynamic Loads On Buried Structures)	Wood ("Earthquake Induced Soil Pressures on Structures") proposed elastic dynamic solutions for above ground ring degrees of flexibility. Based in this work it has been shown that for very flexible walls where the deflection exceeds approximately 0.5 % of the height of the wall the solution of dynamic pressures tends towards those suggested by Mononobe and Okabe which were based on the assumption that a full active wedge develops behind the wall. For buried structures it is unlikely that such an active wedge will form and it is therefore recommended that solutions based on rigid	Wood ("Earthquake Induced Soil Pressures on Structures") proposed elastic dynamic solutions for above ground ring degrees of flexibility. Based in this work it has been shown that for very flexible walls where the deflection exceeds approximately 0.5 % of the height of the wall the solution of dynamic pressures tends towards those suggested by Mononobe and Okabe which were based on the assumption that a full active wedge develops behind the wall. For buried structures it is unlikely that such an active wedge will form and it is therefore recommended that solutions based on rigid retaining walls as developed by Wood are used. The dynamic	It is essential to define C_o.	Wood's theory may be applied only to retaining walls of open Ramp. For closed box, Hashash theory is more relevant and conservative.	**The majority of committee members agree with the suggestion given by DMRC and hence the para may be removed.**

		retaining walls as developed by Wood are used. The dynamic increment should be added to static earth pressure loads based on at-rest soil pressures in addition to water pressures and other imposed loads using appropriate load combinations.	increment should be added to static earth pressure loads based on at-rest soil pressures in addition to water pressures and other imposed loads using appropriate load combinations. **Calculation of Seismic Coefficient:** **Given that IS 1893 permits reduction of the seismic coefficient with depth with the values 30m depth being half the value at the surface level it is considered appropriate to adopt an average seismic coefficient, Co, for calculating the dynamic incremental load. This average value should be based on the value at a level H/3 from the top of the tunnel where H = Depth of tunnel. Thus, if the tunnel is 6m high with 5m of soil cover then the appropriate seismic coefficient used in calculating the dynamic earth pressure increment is the value corresponding to 5+6/3 = 7m below the ground level. Interpolating between the value of 0.1125 at the ground level and 0.056 at 30m depth results in an average seismic coefficient in this case, C_o= 0.099.**			
1 1	8.1	(v) Load combinations as per IRS CBC and IRS Seismic code	The Load Combinations in UG should be from IS 456 and		The preferred code for UG is IS: 456, as primary loads on	Load combination as per IS:456 has been covered vide para 8.1-(i).

	(Ultimate Load Combinations)	for Seismic design of Railway Bridges where Metro live loads are applicable.	modified up to an extent to produce Max H and Min V, Max V and Min H.		UG structure are Earth Pressure, water Pressure and Dead loads and combinations of IS codes may therefore are more applicable. IRS code may not be relevant as the train loads are secondary loading on UG structures.	Therefore,Committee members agree with the suggestion of DMRC and the para may be deleted.
12	9.0 (Desired Ground Water Table)	Ground water level to be assumed in design for the various stages shall commensurate the ground water fluctuation in area of construction. Following values are indicated for guidance only. "Service/Operation" and "Extreme" stages or conditions may be as follows. **"Construction"** - groundwater level at measured maximum elevation. **"Service/Operation"** - groundwater level at ground level. **"Extreme"** - groundwater level at 1 in 20 years maximum (plus 0.5m allowance for sea level rise for coastal conditions).	Ground water level to be assumed in design for the various stages shall commensurate the ground water fluctuation in area of construction. Following values are indicated for guidance only. "Service/Operation" and ~~"Extreme"~~ **"Accidental"** stages or conditions may be as follows. **"Construction"** - groundwater level at measured maximum elevation. ~~**"Service/Operation"** - groundwater level at ground level.~~ ~~**"Extreme"** - groundwater level at 1 in 20 years maximum (plus 0.5m allowance for sea level rise for coastal conditions).~~ **"Service/Operation"-** Maximum Water Table in last 20 Years + 4 mts. **"Accidental"** – During Service GWT at Ground Level and		We agree with the justification by UPMRCL. Only 3 conditions as defined by UPMRCL are practically applicable. Considering water table at Ground level may be highly uneconomical in many cases. And, in 10.2 (d), the factor of safety of 1.1 shall be considered for service stage only.	**During discussion DMRC opined that the case with water level at ground level will be highly uneconomical in many areas such as Rajasthan, Gujarat etc.** **The majority of members are of the opinion that remark by UPMRCL for this para may be adopted with slight modification as under-** Ground water level to be assumed in design for the various stages shall commensurate the ground water fluctuation in the area of construction. Following values are indicated for guidance only. **"Construction"** - groundwater level at measured maximum elevation. **"Service/Operation"-** Maximum Water Table in last 20 Years + 4 mts.

			adequacy of structural members to be checked with ULS Load Factor as 1.0			**“Extreme”-**Ground water level shall be decided by Metro considering the site location and design life of structure**.**
13	10.0 (Flotation)	1. The minimum depth of cover to underground structures shall be 2.3 metres or depth to the underside of major utilities (eg, sewer mains, storm water mains and the like) whichever is the greater.	The minimum depth of cover to underground structures shall be ~~2.3~~ **1.5-2** metres or depth to the underside of major utilities (eg, sewer mains, storm water mains and the like) whichever is the greater.	As per design requirement.	This may not be fixed and should be dependent on guidelines of the local authority.	**The majority of members are of the opinion to modify this para as under:-** The minimum depth of cover to underground structures shall be decided by Metro authority according to design requirements and bye-laws.
		2. (c) The skin friction between the concrete surface and the soil may be assumed below the concourse.	2. (c) The skin friction between concrete surface and the soil may be assumed ~~below the concourse~~ **as per the method of construction of station i.e. Top Down or Bottom Up.** **FOS to be applied for Skin Friction of D Wall and Tension Pile are 2 & 3 respectively.**		For 2.(c) - The original clause of draft DBR is sufficient and the same may be retained and with the following modifications- In 10.2(a) & (b) Load Factor of 0.9 in place of 1.0 i.e for self weight and backfill may be considered.	Committee members agree to modify para 2(c) as suggested by UPMRCL. Further, the load factor in a) and b) statements is to be changed to 0.9 as suggested by DMRC during discussions. Statement d is to be modified as “The overall factor of safety against floatation shall not be less than **1.1 for service stage only**.

Additional Comments by DMRC

S. N	**Clause no.**	**Existing Clause**	**DMRC observations**	**RDSO remarks**

A.	5.4.1	Reinforcement Detailing "Ductile detailing of seismic resisting RC elements, shall comply with ductile requirements of IS:13920".	The line may be deleted based on our remarks at S.No. 2 above. The remarks is reproduced here: Applicability of IS:1893 & 13920 is relevant for elevated structures where Force Based Analogy is the basis. However, the UG structures are designed on the basis of Strain based analogy as referred from "Seismic Design and Analysis of Underground Structures" by Youssef M.A Hashash, Jeffrey J. Hook, B Schmidt, J.C Yao." That considers the Free Field Racking without any seismic response reduction. Therefore, Ductile detailing is not required for the underground structures and clauses 5.4.1 and 7.5 may also be corrected accordingly.	Committee members agree with observations of DMRC and hence the suggested para may be deleted.
B.	6.3.1.2	All the elements of the station structures shall be designed for a minimum fire resistance period of 4 hours.	The line may be replaced by: "All the main elements of the station structures (Roof Slab, concourse Slab, Base Slab, Outer wall, Columns & any load bearing RCC Walls, ASS-TSS room RCC walls) and including firemen staircase & Public fire escape underground structures shall be designed for a minimum fire resistance period of 4 hours. All other element like Platform slab, vent shafts, UPE Walls OTE Ducts, Stub Columns, other non load bearing RCC walls etc. shall be designed for 2-hour fire rating.	Committee members agree to modify the para as follows: 6.3.1 (1) All structures shall be designed for fire protection as specified by the applicable standards, codes **and as approved by concerned fire safety authority.** Materials specified for the Works shall be non-combustible and should not emit toxic fumes when subjected to heat or fire, except where specifically permitted. In all cases where there is significant fire risk, materials shall be self-extinguishing, low flammability, low smoke and low toxicity. 6.3.2 All the structural elements **other than main structural elements as stated in para 6.3.1** shall be designed for a minimum fire resistance period of 2 hours **or as approved by local fire safety authority.** The minimum element thickness for this fire resistance shall be as per clause 21 of IS: 456.
C.	7.5	Ductile detailing shall be according to IS:13920.	The line may be deleted based on our remarks for S.No. 2 observation.	Committee members agree with observations of DMRC and hence the suggested para may be deleted.

D.	8.1 & 8.2	8.1 (v) "Load Combinations as per IRS CBC and IRS Seismic code for Seismic design of Railway Bridges where Metro live loads are applicable" & 8.2 (iv) "Load Combinations as per IRS CBC where Metro live loads are applicable"	The mentioned clauses may be deleted as relevant and sufficient load combinations have already been covered in the remaining other clauses.	Committee members agree with the remarks given by DMRC and hence the para may be deleted.
E.	8.3	"The design shall also include provisions to limit angular distortions to 1:2000 maximum."	The clause is quite stringent and is used for conducting detailed analysis of induced effect on existing buildings structures (EBS). The line may be replaced by: "The design shall also include provisions to limit angular distortions to 1:500 maximum."	Committee members agree with remarks given by DMRC. The para is to be modified as suggested.
F.	11.3	"IS:2911 shall be followed for design of pile, load capacity etc."	The line may be replaced by : "For design of pile, load capacity etc. for piles resting on soil, IS:2911 shall be followed. And, for piles resting on rock, IS:14593 shall be followed."	Committee members agree with the suggestion of DMRC and hence the para is to be modified as suggested.
G.	13.3	13.3(3) "An external membrane shall be provided above roof of the structure so that the roof of permanent underground structure is completely watertight."	The clause 13.3 (3) may be deleted as this comes under the construction specifications and has no effect on with design considerations/specifications. The necessary waterproofing measure may be decided based on the construction specifications by the executing agency.	Committee members agree with the suggestion of DMRC and hence the para is to be deleted.
H.	15.0	15.(c) "Temporary dewatering methods (including recharging methods, if required) and system operations, along with the other required temporary works shall neither lower the groundwater outside the walls supporting excavations, nor result in settlement, distortion or loss of ground at adjacent EBS."	The clause 15.2 (c) may be replaced by: "Drawdown of the groundwater levels outside the UG station and cut and cover tunnel walls shall be limited to not more than 2 metres from the existing average groundwater level in the zone of construction. Recharging pits shall be provided in case there is a danger of reduction in water table outside area of construction. This is necessary to prevent settlement of ground outside area of construction. In general, groundwater levels interior to construction excavations shall not be depressed more than 1.0 m below final base slab level."	Committee members agree with the suggestion of DMRC and hence the para is to be modified as suggested.

Table 1: Derailment Loads

IRS Bridge Rule (Appendix XXV)	ACI 358.1	EN 1991-2

APPENDIX-XXV

DERAILMENT LOADS FOR BALLASTED DECK BRIDGES
(25t Loading-2008)

S.N.	Condition and approach	Bridges with guard rails	Bridges without guard rails
1.	**Ultimate –** The load at which a derailed vehicle shall not cause collapse of any major element.	a) Two vertical line loads of 75 kN/m each 1.6m* apart parallel to the track in the most unfavorable position inside an area of 1.3m on either side of track centre line. b) A single load of 200 kN acting on an area of 1.3m on either side of track centre line in the most unfavorable position.	a) Two vertical line loads of 75 kN/m each 1.6m* apart parallel to the track in the most unfavorable position inside an area of 2.25m on either side of track centre line. b) A single line load of 200 kN acting on an area of 2.25m on either side of track centre line in the most unfavorable position.
2.	**Stability –** The structure shall not overturn.	A vertical line load of 94 kN/m with a total length of 20m acting on the edge of the structure under consideration.	A vertical line load of 94 kN/m with a total length of 20m acting on the edge of the structure under consideration

** The distance 1.6m is based on Broad Gauge distance 1.676m as adopted for derailment loads for MBG-1987 loading and HM loading.*

3.5.2 -Derailment Load, DR

Derailment may occur when the vehicle steering mechanism fails to respond on curves or when the wheels jump the rails at too large a pull-apart gap, which may be the result of a break in a continuously welded rail. Derailment may also be caused by inter vehicle collision. For the design of the top slab and the barrier wall of the guideway, both the vertical and horizontal derailment loads may be considered to act simultaneously.

The force effects caused by a single derailed standard vehicle should be considered in the design of the guideway structure components. These effects, whether local or global, should include flexure, shear, torsion, axial tension or compression, and punching shear through the deck. The derailed vehicle should be assumed to come to rest as close to the barrier wall as physically possible to produce the largest force effect. In the design of the deck slab, a dynamic load allowance of 1.0 should be included in the wheel loads.

The magnitude and line of action of a horizontal derailment load on a barrier wall is a function of a number

6.7 Derailment and other actions for railway bridges

(l)P Railway structures shall be designed in such a way that, in the event of a derailment, the resulting damage to the bridge (in particular overturning or the collapse of the structure as a whole) is limited to a minimum.

6.7.1 Derailment actions from rail traffic on a railway bridge

(1)P Derailment of rail traffic on a railway bridge shall be considered as an Accidental Design Situation.

(2)P Two design situations shall be considered:

-**Design Situation I**: Derailment of railway vehicles, with the derailed vehicles remaining in the track area on the bridge deck with vehicles retained by the adjacent rail or an upstand wall.

- **Design Situation II:** Derailment of railway vehicles, with the derailed vehicles balanced on the edge of the bridge and loading the edge of the superstructure (excluding non- structural elements such as walkways).

NOTE The National Annex or individual project may specify additional requirements and alternative loading.

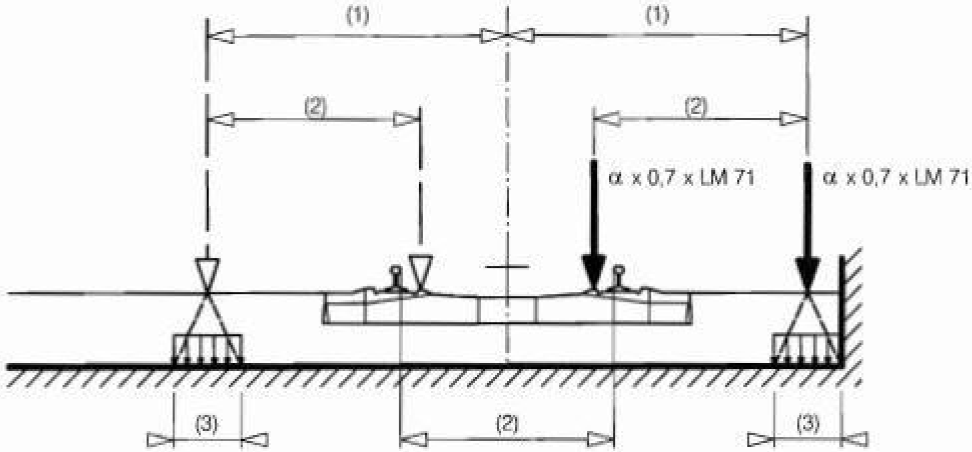
(3)P For Design Situation I, collapse of a major part of the structure shall be avoided. Local damage, however, may be

	of variables. These include the distance of the tracks from the barrier wall, the vehicle weight and speed at derailment, the flexibility of the wall, and the frictional resistance between the vehicle and the wall. In lieu of a detailed analysis, the barrier wall should be designed to resist a lateral force equivalent to 50 percent of a standard vehicle weight distributed over a length of 15 ft (5 m) along the wall and acting at the axle height. This force is equivalent to a deceleration rate of 0.5 g. Collision forces between vehicles result from the derailment of a vehicle and its subsequent resting position against the guideway sidewall. This eccentric load on the guideway causes torsional effects, which should be accounted for in the design. The magnitude and eccentricity of this vertical collision load is a function of the distance of the guideway center line from the side wall, the axle width and the relative position of the center lines of the car body and the truck after the collision.	tolerated. The parts of the structure concerned shall be designed for the following design loads in the Accidental Design Situation: α x 1,4 x LM 71 (both point loads and uniformly distributed loading, Q_{Ald} and q_{Ald}) parallel to the track in the most unfavourable position inside an area of width 1.5 times the track gauge on either side of the centre-line of the track: *Figure Given below as 6.26 (4)P For Design Situation II, the bridge should not overturn or collapse. For the determination of overall stability a maximum total length of 20 m of q_{A2d} = α x 1,4 x LM71 shall be taken as a uniformly distributed vertical line load acting on the edge of the structure under consideration. *Figure Given below as 6.27 (5)P Design Situations I and II shall be examined separately. A combination of these loads need not be considered. (6) For Design Situations I and II other rail traffic actions should be neglected for the track subjected to derailment actions. NOTE: See EN 1990 A2 for the requirements for application of traffic actions to other tracks. (7) No dynamic factor needs to be applied

		to the design loads in 6.7.1(3) and 6.7.1(4). (8)P For structural elements which are situated above the level of the rails, measures to Mitigate the consequences of a derailment shall be in accordance with the specified requirements. NOTE 1 The requirements may be specified in the National Annex or for the individual project. NOTE 2 The National Annex or individual project may also specify requirements to retain a derailed train on the structure. **6.7.2 Derailment under or adjacent to a structure and other actions for Accidental Design Situations** (1) When a derailment occurs, there is a risk of collision between derailed vehicles and structures over or adjacent to the track. The requirements for collision loading and other design requirements are specified in EN 1991-1-7. (2) Other actions for Accidental Design Situations are given in EN 1991 be taken into account. **6.7.3 Other actions** (l)P The following actions shall also be

		taken into account in the design of the structure: -effects due to inclined decks or inclined bearing surfaces, -longitudinal anchorage forces from stressing or de-stressing rails in accordance with the specified requirements. -longitudinal forces due to the accidental breakage of rails in accordance with the specified requirements. -actions from catenaries and other overhead line equipment attached to the structure in accordance with the specified requirements. -actions from other railway infrastructure and equipment in accordance with the specified requirements. NOTE: The specified requirements including actions for any Accidental Design Situation to be taken into account may be specified in the National Annex or for the individual project.

*Figure Given below



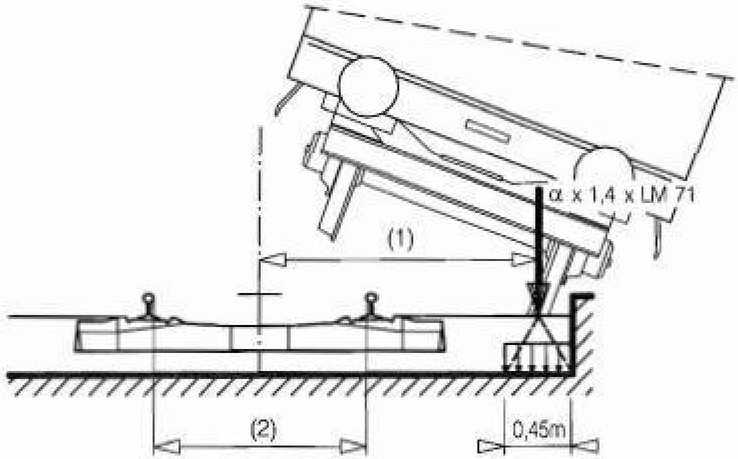
Key

(1) max. 1,5*s* or less if against wall

(2) Track gauge *s*

(3) For ballasted decks the point forces may be assumed to be distributed on a square of side 450mm at the top of the deck.

Figure 6.26 - Design Situation I - equivalent load Q_{A1d} and q_{A1d}



Key

(1) Load acting on edge of structure

(2) Track gauge *s*

Figure 6.27 - Design Situation II - equivalent load q_{A2d}

NOTE The above-mentioned equivalent load is only to be considered for determining the ultimate strength or the stability of the structure as a whole. Minor structural elements need not be designed for this load.

Clause 5.7 of IRS Sub Structure Code

5.7 EARTH PRESSURE (EP)

5.7.1 All earth retaining structures shall be designed for the active pressure due to earth fill behind the structure. The general condition encountered is illustrated in (Fig.2)

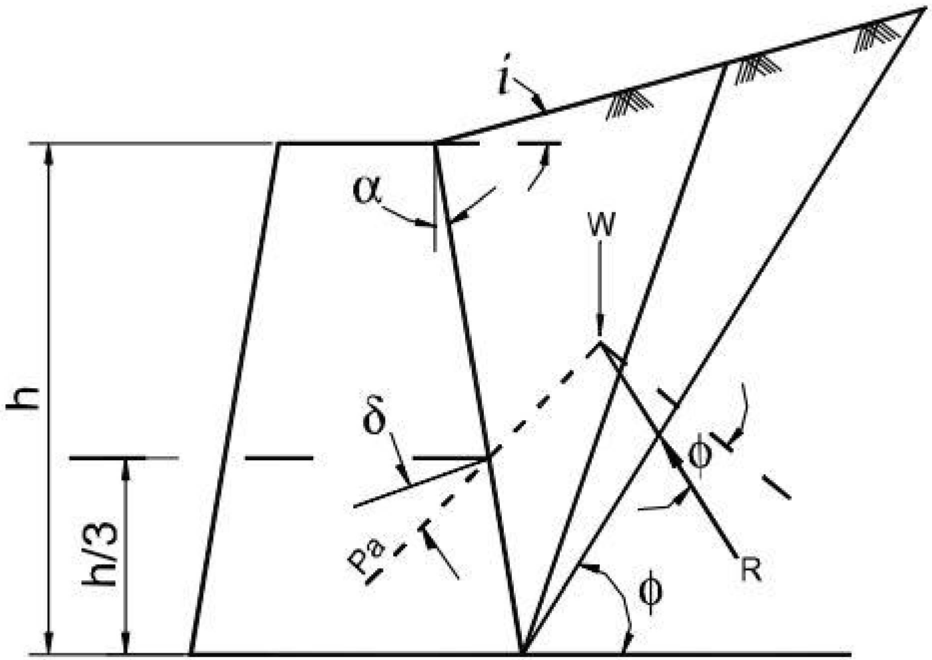


Fig -2

The active pressure due to earth fill shall be calculated by the formula, based on Coulomb's theory for active earth pressure given below:-
Pa = ½ Wh2 Ka
where :-
Pa = Active earth pressure per unit length of wall.

W = Unit weight of soil.
h = height of wall.
ϕ = angle of internal friction of back fill soil.
δ= angle of friction between wall and earth fill where value of is not determined by actual tests, the following values may be assumed. (i) = 1/3 ϕ for concrete structures. (ii) = 2/3 ϕ for masonry structures.
i = angle which the earth surface makes with horizontal behind the earth retaining structure.
α= angle which the back surface of earth retaining structure makes with vertical.

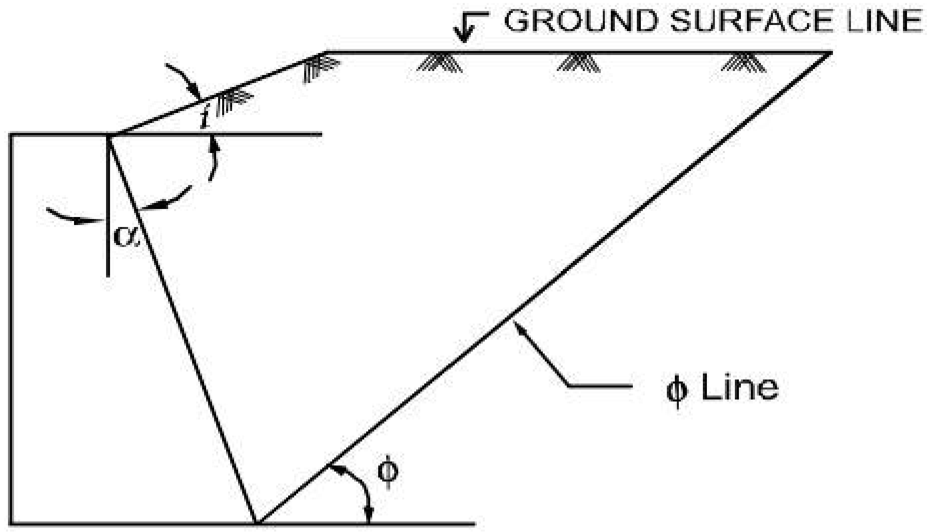
Ka = Coefficient of static active earth pressure condition.

$$K_a = \frac{\cos^2(\phi-\alpha)}{\cos^2\alpha \cos(\alpha+\delta)\left[1+\sqrt{\frac{\sin(\phi+\delta)\sin(\phi-i)}{\cos(\alpha+\delta)\cos(\alpha-i)}}\right]^2}$$

5.7.1.1 The point of application of the active earth pressure due to earth fill shall be assumed to be at a point on the earth face of the structure at a height of h/3 above the section where stresses are being investigated.

5.7.1.2 The direction of the active earth pressure shall be assumed to be inclined at an angle to the normal to the back face of the structure.

5.7.1.3 The magnitude of active earth pressure can also be determined graphically by well known graphical constructions such as Rebhann’s or Culmann’s construction particularly in case of wing walls, where the profile of earthwork to be supported is not easily susceptible to analysis. (Fig.3)



5.7.1.4 These formulae for active earth pressures are based on the supposition that backfill behind the structure is granular and there is effective drainage. These conditions shall be ensured by providing filter media and backfill behind the structure as shown in Fig.2 and as described in clause 5.7.1 and 5.7.2

5.7.1.5 In testing the stability of section of abutments below the ground level, 1/3rd of the passive pressure of the earth in front of the abutment may be allowed for upto the level below which the soil is not likely to be scoured.