Session (2)

Road Design Factors and Procedures

Axle Load Control System

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Road vehicles today occupy a wide range of function from private usage by individuals to industrial utilization. One of the most important expenses in highway transportation is the very expensive cost of pavement maintenance. Different studies were carried out with the aim to eliminate pavement premature severe damages caused mainly by axle loads imposed by heavy commercial vehicles. Reliable information about the distribution of axle loads on existing traffic is required. Such information can be collected by using permanent or portable wheel-weighting devices.

A big reason for road structures deterioration is over-loaded trucks. For example a truck overloaded by 40 percent causes about 300 percent increase in flexible pavement damage when compared to a truck at the load limit.

Overloading in certain African and Middle East countries has contributed to serve deterioration of pavements and bridge decks, with failure taking place, in some cases, in less than two years.

The effect of axle loading on flexible road pavements can be quantified by using concept of equivalent standard axles (E.S.A.'s). Each truck loading, and thus its damaging or destructive effect, can be related to a number of repetitions of standard axle load, which is commonly taken to be a single axle with dual tyres with a load of 8.2 tons.

Truck weight control is influenced by two competing interests, the desire of road agencies to minimize the cost of road construction and maintenance and the desire of road haulers to minimize the cost per ton-kilometer of haulage.

Effective truck weight control in developing countries is rare. There has been little or no enforcement of regulation concerning weight, dimensions and operating characteristics of vehicles.

Review of Existing Legislation for Vehicle Weight:

As mentioned above, in many developing countries there has been little or no enforcement of regulations concerning weight, dimensions and operation of vehicles.

In Sudan, vehicle weight is governed by the Road Traffic Act (1983) and Highway Traffic Regulations (1975) Section 27/B of the Road Traffic Act states that "No person shall drive and no owner or hirer shall willfully or negligently drive any motor car which is liable by reason of its conditions or its loading to endanger the motor car itself or the passengers therein or other persons on the road or other traffic or to damage the road.

This section does not specify a certain load to be observed and so it is a discretional provision.

Section (16) of the Highway Traffic Regulations provides that " No person shall drive vehicle which exceeds 9 tons on the highway. It does not mention if it means axle load.

NHA's Axle Load Limitations:

The allowable National Highway Authority of Sudan axle loads are10, 16 and 22 tons for single, double and triple axles respectively, and 46 tons as maximum trains load. However, these standards must be checked, as the standards recommended by the survey carried by the Preferential Trade Area (PTA), in which Sudan is a member, are 10, 16 and 24 tons.

Previous Axle Load Studies in Sudan:

Road pavements are generally designed to carry a certain number of Equivalent Standard Axles (ESA) of 8.2 tons during the road's design life. If the traffic forecasts are too low, or the axle loads on the road too high, the service life of the road will be reduced. The result will be premature deterioration of the pavement, higher vehicle operating costs, more expensive road maintenance work; thus the need for costly rehabilitation or reconstruction of the road earlier than expected.

Two relevant previous studies, namely the Highway Organization and Investment Study (HOIS) 1987 and the Pavement Management System of Sudan (PMS) in 1994 had pointed out the fact and problem of overloading.

In the HOIS, on the critical sections of the Port-Sudan Khartoum Road, about 50% of the heavy vehicle axle loads were above the present legal limit of 10 tons, according to surveys conducted on the road.

The average number of ESA's for a heavy vehicle varied around 50, while several vehicles of ESA values between 200 and 250 were observed daily. ESA values from 6 – 14 millions had been carried by the various sections, with the overage loading about 8 millions since construction was completed.

In 1994 the PMS study confirmed the existence of overloading problem on all paved roads in Sudan. It was realized that it was vitally important to establish a system of monitoring performance of paved roads in Sudan to detect early warning signs of pavement failure and to prepare optimal plans for routine and periodic maintenance. This is done through establishment of an adequate system for axle load control on road network; or a tremendous cost of rehabilitation and maintenance will be needed together with higher vehicle operation costs. Without an effective overloading control regime in place, there will be dramatic consequences for the wear in new roads that are constructed to carry up to only legal axle loads. The life of existing roads will also be cut short.

The P.M.S. project provided for the design and implementation of the axle load control system, including the construction of weight bridge stations.

Implementation of Axle Load Control:

Training Programs:

A Control system should be agreed upon. This system will be operated by the Concerned Government Unit (The National Highway Authority) with the assistance of the police to enforce the law. It is very important to have office and on site training programs regarding operation, maintenance and follow up to be prepared for appointees from the two sectors.

Plans for Advertisement of Publicity Campaigns:

Introduction of Axle Load Control in the country will form a new culture to the concerned sectors. It is therefore, expected to have great resistance and violations to the new system. Therefore all efforts should be integrated to achieve success through the following:

1- Publicity Campaigns: to Highlight the benefits of the axle load control (good pavement performance, low vehicle operation costs, time saving, traffic safety, ..etc.). These campaigns can be organized on the basis of experience from other countries.

2- Voluntary activities to support the initiation and application of the system.

3- Distribution among transport companies and transporters unions of brochures including full information about the legal axle load.

4- Coordination with:

   a) Investment Authorities

   b) Companies and Government Authority working in relevant fields to decide on specification of imported vehicle. This is very important so as not to allow any person to import the vehicle he wants without giving attention to axle load control.

Overloading Versus Road Maintenance:

It cannot be over emphasized that if road authorities in the country fail in their obligations to maintain properly road networks, the main reason for premature failure of the roads may then not be due to only overloading poor design or construction is often a more frequent cause or premature failure than is overloading. Improper road maintenance plays a significant role in deteriorating road conditions, same times more than does the lack of enforcement of load control. The combined effects of improper road maintenance and overloading interact destructively and magnify the impact of excess axle loading. This means both bad road maintenance and overloading have adverse effect on the road condition through time.

Axle Load Control Equipment Recommendations:

Immediate efforts have to be focussed on the recommendation of suitable weighing equipment, which can best deal with the tasks of reliable axle load measurement. In Sudan such equipment must be simple. It is not advisable to use sophisticated equipment e.g. automated weigh-stations, which maybe considered too expensive for

the additional benefits they provide. Also in Sudan the heavy dust during most of the year causes problems to the sophisticated weigh-station.

Portable weigh-bridge systems are needed in order to effect a surprise element in the axle weight control system. It also helps in quick checks of overloaded vehicles.

Allowing for a margin of error it is recommended to set any axle weighing capacity for the permanent weigh-bridges and portable system as 30 tons plus an allowance of 50% for dynamic overload effects. Effectively, this means that the permanent and portable systems shall be capable of accepting axle loads up to 45 tons without damage.

Permanent Axle Weigh-bridges:

Since it is generally accepted that the axle loads are responsible for the road damage, axle-weighing system should be the ones that are recommended and so axle weigh-beams should be installed at the permanent sites. A weigh-beam of size 3m x0.75m capable of weighing a single axle at a time should be installed in specially prepared weigh lanes. The vehicles should be weighed as they travel in-motion in the weighing lane at speeds up to 10 kph maximum (better accuracy will be obtained if the speeds are kept below 5 kph). The down side of the weighing technology is that a smooth weighing site is needed in the vicinity of the weigh-bridge. The signal waveforms recorded by axle weigh-beams are sensitive to the adjacent site levels.

Individual axle weights are recorded as the axle pass over the weigh-beams and the gross weight of the vehicle is calculated as the sum of all the individual axle weights. This technique provided a reliable, sufficiently accurate, known and workable solution. Full size weigh-bridge capable of weighing vehicles in a single draft are not needed.

Portable Axle Weigh-bridge:

Portable vehicle weighing systems are required for the following reasons:

- To enable spot checks to be made on vehicles which are suspected of being overloaded.
- To check that the axle load control is being effect at the weigh-sites.

The wheel weighing capacity of each weigh-pad should be a minimum of 22.5 tons. Each weigh-pad should measure not less than 700 x 500 mm in area and not exceed 45mm in height and weigh less than 45 kg.

The portable system should have the facility to weigh vehicles both statically whereby each axle is stopped on the weigh-pads or dynamically. whereby the vehicle is weighed without stopping at speeds up to 4 kph.

Fees, Not Fines:

Very important to the operating success of an axle load control is the sanction level put against vehicle operators and the policy at the weigh-station when overloading is detected. First it is important and fair to call monies collected at weigh-stations "fees" rather than "fines". The difference whilst initially seeming to be no more than an alternative definition relates to the organization who will operate and run the weigh-stations. Fines are collected by a jurisdiction body while fees are collected by an administrative body. The same administrative body will be responsible for the weigh-bridge sites. The same body will be responsible for the maintenance of these sites.

The monies collected at the weigh-stations are therefore referred to as fees. The structure and level of fees to be paid are to be decided by the concerned authorities.

Example of an Alternative Weight Enforcement Policy and Fee Structure:

The weight levels that are used to decide the fee to be paid are based upon the following vehicle parameters:

1- That no separate axle with twin single tyres exceeds 8,000 kg

2- That no separate axle with twin double tyres exceeds 10,000 kg

3- That the Gross Vehicle Weight (GVW) does not exceed the sum allowed single axle loads and the maximum allowable group axle weight

Example of total GVW (in tons) for different configurations.

The simple:

O Represents a two wheel axle and the symbol

◎ Represents a four-wheel axle.

In each case the steering axle is shown on the left

Axle Configuration on Vehicle		Max Axle weight Distribution (Tons)		Maximum permitted GVW (Tons)
O---◎◎¬--------◎◎◎	=	8+16+24	=	48
O--------O	=	8+8	=	16
O------◎ + ◎------◎◎	=	8+10+10+16	=	44
O------◎ + O------O	=	8+10+8+8	=	34
O---◎¬--------OO	=	8+10+16	=	34
O---◎◎¬--------O◎◎	=	8+16+24	=	48

The above examples show how the gross vehicle weight (GVW) limit is set by the sum of the individual axle weight limits plus any group axle weight limit present.

The last example in the above table shows that an axle combination with a two wheel axle in a group of two off four wheeled axle in Sudan, is dealt with in exactly the same way as the first example.

Details of Suggested Fee Structure:

The fee structure detailed here is based upon the implementation of the alternative weight enforcement policy given above.

The basis for calculation of a fee structure should contain the effects of increased damage to the road and also the increased revenue to the transport from higher load factor. The fees collected at the weigh-stations should seek to table the bulk of any additional net revenue accruing to the transporter through loading beyond the official limit. The transporter will then see the benefit of his increased loading diminish.

An equation is to be sought which encompasses road damage costs and increased transporter revenue. The out-put from the equation should be a fee level that should be used to calculate a fee structure to be paid versus overload.

Hereunder are some definitions to be used in the equation:

D = Damage costs per ESA – km

R = Transporters increased revenue from overloading in units of per ton kilometer

O = Operator Costs incurred by the transporter when he carries excess load (e.g. additional, diesel, etc....) This value is expressed as a percentage.

E = ESA per additional ton load carried

S = Distance traveled by the truck in Kilometer

P = Probability of truck interception by the enforcement scheme.

A sample of equation incorporating the above variables with typical values is as follows:

The net additional revenue to the transporter per ESA carried by the road is:

$$\frac{R \times (1-O) \times S}{E \times S} = \frac{R(1-O)}{E}$$

Fee to be paid by the transporter $= \frac{R \times (1-O) - D}{E}$

A table can be formed showing the suggested fees versus Axle Overload

Note: the authority can form its own equation from experience or from the experience of a neighbouring country.

Off Loading Mandate and Special Exemptions:

It is recommended an off-loading mandate at the weigh-stations so that when an overloading is detected the excess weight for the particular axle is redistributed to ensure legal axle loads or removed if the excesses are too severe.

In the event of the detection of overloading on a vehicle carrying perishable goods, medicines or livestock the off loading mandate would not apply. Instead a special fee would be collected in recognition of the importance of the cargo and the road damage which would be caused by the axle load excess. The level of this special fee will have to be the outcome of a study.

Off-Loading mandate should only be in cases of gross overloading – perhaps when a 25% or 30% overload is reached. Off-loading is a very powerful deterrent sanction if rigorously applied.

Conclusion:

The requirement of axle load controls in Sudan is without doubt. Previous axle load studies carried out in the region and in neighbouring countries demonstrate high ESA truck loading exists. Without an effective control system in operation the life of new roads will be cut short.

This report has introduced in brief the idea of an axle load control consisting of the initial installation of simple weigh-beams and the use of portable weigh-bridges used for spot checks.

The structure of the fees to be paid by truck drivers is to be the outcome of a separate study. However, an equation was developed in this report, although it is very rough and based on assumptions.

Public awareness of the axle load limits and simple explanations why axle loads damage highways in the form of publicity campaigns will help with the control of excessive overloading.

References:

1- The Highway Organization and Investment Study" Final Report of The Republic of Sudan

2- "Pavement Management System for Sudan" Final Report of The Republic of Sudan

3- "Axle Load Control Study" Ashraf & Salah Consulting Engineers