METHOD OF ASSESSING HIGHWAY BRIDGES FOR SUPERLOADS

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Technological progress has made it economically beneficial to use larger and heavier industrial components termed "Superloads". These generally involve equipment for electric power and very heavy chemical plants located on coal fields. Because of the absence of inland waterways and the limited capacity of railways in Southern Africa, these loads must travel along the highway network. A current project involves the movement of payloads of up to 400,000 kg (440 tons) over some 500 km (310 miles) of road. In this instance a total of 60 under-bridges of various sizes must be crossed. In order to meet pavement loading restrictions, the transporters carrying these loads may have as many as 288 wheels distributed on 5 m (16 ft) wide axles. The four haulers used to draw these vehicles may give total combination masses of up to 800,000 kg (880 tons) and overall lengths of about 120 m (385 ft). Accurate analytical techniques are required to optimize the effects of these load trains on bridges so that every reserve of strength may be utilised. The multiplicity of structural configurations, construction materials, and original design specifications requires that each structure be assessed individually. Moreover, the variety of vehicle combinations is practically endless. For these reasons the method adopted to make such assessments relies on a load independent computerized influence surface technique involving stresses at critical points. A research program to develop a system termed "Generate-Simulate-Compare" (GSC) is now well advanced and initial analytical results show good correlation with parallel studies on monitoring techniques in the field. The paper describes the package of analytical programs and field observation methods.

In many parts of the world modern technology is making increasing demands for the use of larger and heavier industrial components. These generally comprise equipment for electric power stations and chemical plants and their movement presents transport operators and public authorities with tremendous problems. Although demand for these components is economically justified because the savings over a quarter of a century are vast, the associated repercussions and hidden costs of moving these loads are so extensive that the wisdom of permitting them to increase indefinitely is questionable.

Whereas many countries possess inland waterways, the absence of these in Southern Africa, coupled with a limited railroad carrying capacity, requires that they move along highways. Such loads are therefore of paramount interest to highway officials responsible for preserving the road network and minimizing traffic congestion.

Superload movements are limited by the height and width of the loads as well as by the forces they exert on pavements and bridges. In order to satisfy pavement loading regulations they are often supported on hundreds of wheels and are therefore very long and wide.

Although new bridges in South Africa will be designed to carry Superload transporters with a gross mass of 610,000 kg (670 tons), it is possible that many existing structures could support or be strengthened to carry these or lesser loads. As a result, the safety and stability of components in highway structures, such as bridge decks, must be carefully investigated.

National Policy

The Committee of State Road Authorities is responsible for general policy on Abnormal Loads and Superloads in South Africa. Its responsibilities include:

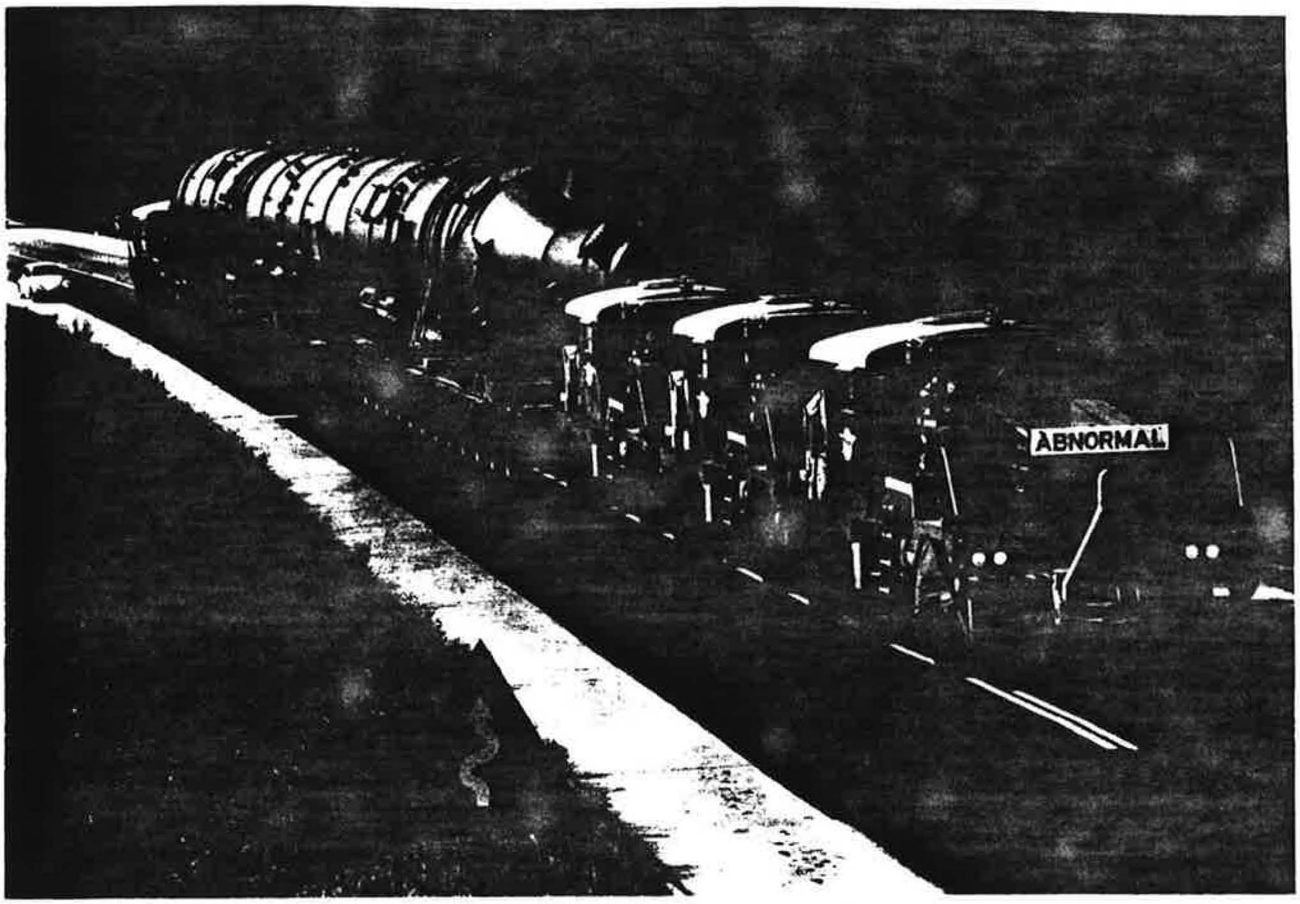
(a) preparation of regulations governing load movements
(b) selection of special routes
(c) preparation of design standards for highway structures.

Load categories

The four load categories shown in Table 1 have been tentatively adopted for the purpose of issuing permits and checking highway structures (1).

Abnormal loads. Since this category is intended to provide blanket coverage for all structures, including the weakest, with minimum structural investigation, the allowable loads are of necessity conservative. It applies to two bogie transporters drawn

Figure 1. Class B Superload of 495,000 kg (544 tons) gross mass comprising two Nicolas hydraulic suspension trailers and four haulers.



by one hauler. The permissible load is also governed by the width and inter-axle distance of two-, three- and four-axle bogies. Restrictions are also placed on the minimum distances between hauler and leading bogie and the centers of bogies. The allowable loads have been approximated by comparing bending moments and shear forces produced by 80 per cent of British Standard 153 HA loading (2) and axle group loadings on both simple and continuous decks. Overstress amounting to 25 per cent is permitted. The 125,000 kg (140 tons) gross load limitation may be revised upwards once the computerized system described in this paper becomes fully operational.

Broadly speaking, vehicles in this category may travel anywhere on bridges unless the payload exceeds 100,000 kg (110 tons).

Table 1. Load classification.

CATEGORY	GROSS VEHICLE COMBINATION MASS kg*	TRANSPORTER AND PAYLOAD MASS kg*
Abnormal loads	above legal but less than 125,000	less than 100,000
Class A Superloads	126,000 - 250,000	101,000 - 200,000
Class B Superloads	251,000 - 800,000	201,000 - 610,000
Class C Superloads	over 800,000	---

*1,000 kg = 1.102 tons

Class A Superloads. Permits for this category are issued after all structures on the proposed route have been individually checked. Transporters are generally escorted and restrictions are placed on the speed at which they traverse bridges as well as their location on the structure. Although structural investigations have hitherto relied on approximate analytical techniques (3,4), it is generally accepted that the system given below will find its greatest application to this load category.

Class B Superloads. This category is exemplified by the Nicolas trailer shown in Figure 1. Each of the two bogies of the transporter has a mass of 55,000 kg (60 tons) which bears on twelve 12-wheel axles. The 4.34 m (14 ft) wide transporter is drawn by four 40,000 kg (44 tons) haulers. With the 225,000 kg (248 tons) self-supporting payload the combined mass is 495,000 kg (544 tons). The overall length of the 36-axle load train is approximately 117 m (375 ft).

Such vehicles may only travel after each structure to be crossed has been rigorously analysed and thoroughly inspected. Structures are temporarily closed to other traffic and speeds reduced below 10 km per hour (6 mph). No braking or acceleration is permitted whilst the vehicle is on the structure and crossings may only occur in the presence of a professional engineer. Structural deflections are frequently monitored before, during and after the passage of these loads.

Precise knowledge of the masses, geometrics and position on the structure enable reductions in load factors to be made; these may be further reduced depending on the accuracy of the analysis. Typical load factors are given later in this paper. In extreme cases the haulers may be disconnected and the transporter winched across the structure.

Class C Superloads. It is anticipated that these will only be required to move short distances along coastal roads.

Routes

The majority of Superloads originate from ocean terminals and travel to destinations located within industrial complexes or mining areas near the interior of the subcontinent. Less frequent movements also originate from inland complexes.

Routes connecting major cities are usually dictated by factors such as load width and height, highway geometrics, pavement strength and the carrying capacity of bridges. Whilst each province within the Republic is responsible for the selection of routes within its area of jurisdiction, it is necessary that these routes connect with neighbouring provinces. With this in mind, the tentative route map shown in Figure 2 has been prepared. Structures along these routes will be strengthened, where necessary, to support Class A Superloads. In some instances they will also be capable of carrying Class B Superloads. Many of these routes are intended for use in the future and the requirements in terms of numbers and frequency of Superload movements along them is not known at present.

An example of a designated Class B Superload route in operation is that between Richards Bay Harbour, on the Natal coast, and Trichardt in the important industrial and coal mining area of the Eastern Transvaal. This route is approximately 500 km (310 miles) in length and includes around 60 under-bridges. It has been carrying loads in excess of 250,000 kg (275 tons) gross since September 1977 and is expected to do so for some years to come. Over the next two years alone, a total of 700 loads in the category of Abnormal Loads and Class A and B Superloads is scheduled to be moved along this route. Of these, approximately 100 will exceed 250,000 kg (275 tons) gross, and 12 will be heavier than 600,000 kg (660 tons) gross.

Design loads

Specifications are at present being prepared for the design of future bridges in South Africa. Figure 3 shows two proposed classes of design loading: type NB and type NC.

Figure 2. Provisional Superload routes in the Republic of South Africa.

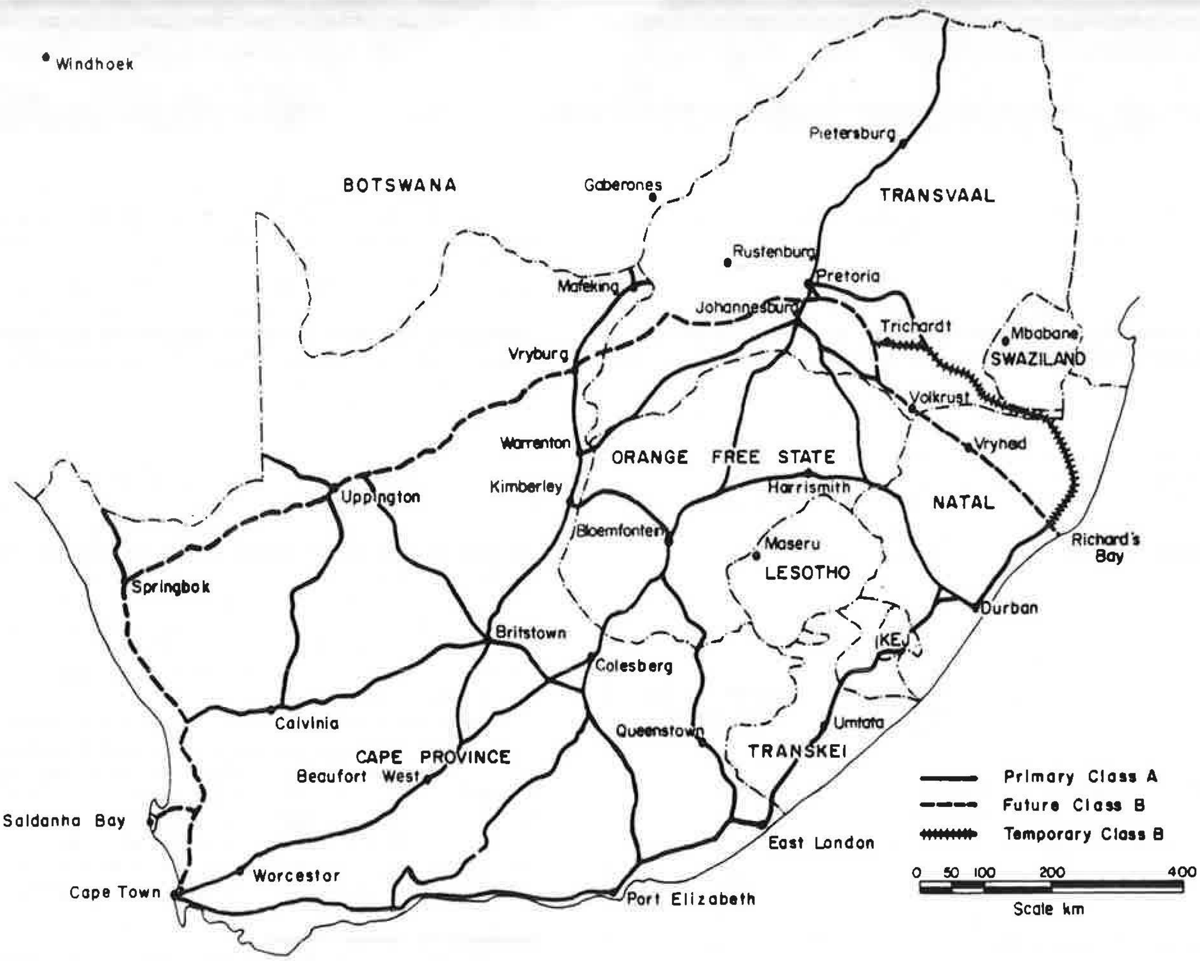
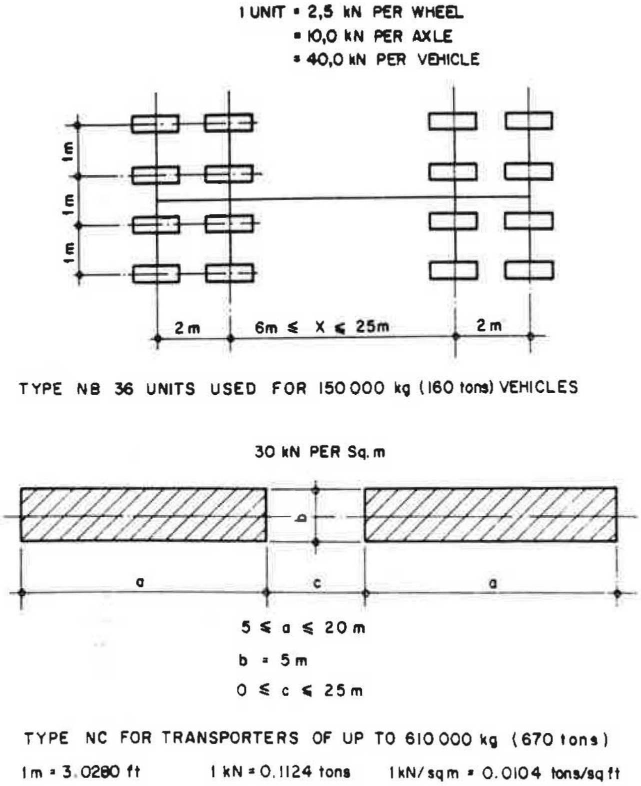


Figure 3. Design loads for structures on Superload routes.



Type NB loading. This comprises an abnormal vehicle with a heavy load concentration on two bogies each having two 4-wheeled axles. Although this does not represent a realistic vehicle it is intended to ensure the adequate design of structures against possible rogue overloads of up to 150,000 kg (165 tons) gross. In order to provide for continuous spans the distance between the innermost axles varies from 6 to 25 m (19 to 82 ft).

Type NC loading. This is a special vehicle loading representative of multi-wheeled transporters with controlled hydraulic suspension and steering or self-propelled multi-wheeled vehicles with a gross mass of 610,000 kg (670 tons). Depending on whether or not the load is self-supporting, these vehicles can carry payloads of between 320,000 and 400,000 kg (350 and 440 tons). It is based on a wheel configuration typical of existing Class B Superloads. Although the haulers, which may each have a mass of 45,000 kg (50 tons), have been omitted for simplicity, these should be included where the load effects on a structure become critical. It is intended that all bridges on Class B Superload routes will be capable of supporting this load whilst closed to other traffic.

Safety factors for Superload analysis

The calculations involved in checking the capacity of bridge decks to carry Superloads are based on limit state theories. At present, the values ascribed to the various partial safety factors are similar, with certain modifications, to those proposed in the draft British limit state code for bridges, B/116 (5). Equivalent South African codes are being prepared, and research is being directed towards deriving the values for the partial safety factors most suited to local conditions.

From the point of view of the safety factors employed, the major difference between designing a bridge deck for everyday traffic loading and checking for a Superload is that the loading imposed by a Superload is known with a much higher reliability than in the case of normal traffic. A major advantage of the limit state philosophy is that it allows the adjustment of the values of individual partial safety factors to provide for such differing situations.

In the case of one important Superload route, in use at present, the Road Authorities concerned have agreed upon a system of partial safety factors for checking purposes, in which a value of 1.10 has been ascribed to the factor γ_{f1}* for the ultimate limit state. The value of the factor γ_{f2}* has been set at 1.00 since no other vehicles are allowed on a bridge during the crossing of a Superload. The values ascribed to the factor γ_{f3}* vary between 1.10 and 1.20, depending on the method of analysis employed.

Implicit in the above system is the assumption that the actual mass of each Superload is checked before departure (by means of individual axle "weighbridges") to ensure that both overall mass and individual axle masses do not exceed certain predetermined limits.

Capacity of existing bridges

The load capacity of bridges reflects the traffic of their time. Whereas the oldest local bridges were designed to support a laden wagen and 16 oxen, some future structures will be designed to carry 800,000 kg (880 tons) gross.

Evolutionary changes in design loads as well as increases in permissible working stresses prevent generalized attempts to assess the effects of Superloads on highway structures. The situation is aggravated by past use of inconsistent design standards within the subcontinent (7).

An earlier study (8) suggested that typical two-lane rural road bridges designed for BS 153 HA loading (2) could support Nicolas type transporters with a gross vehicle combination mass of 430,000 kg (475 tons) providing some overstress was allowed. However, it was evident that problems would be encountered with the 610,000 kg (670 tons) transporter on spans exceeding 15 m (48 ft). Although the situation improves as the number of lanes increases, the capacity of a bridge inevitably depends on its ability to distribute loads laterally.

Unfortunately, before the introduction of rational analytical techniques (9,10) in the late 30's, short and medium span bridge decks were designed as a series of independent components supporting a portion of the imposed lane load. The nominal cross beams that were provided frequently have inherent strength deficiencies which now render many older structures inadequate because of poor transverse stiffness.

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*In the limit state nomenclature (6):
γ_{f1} is a factor to allow for possible unusual increases in load.
γ_{f2} is a factor to allow for the reduced probability of load combinations.
γ_{f3} is a factor to allow for inaccurate assessment of load effects.

Assessment factors

A number of factors are involved in the assessment of the load capacity of a bridge.

Structural and materials variations

Forms of construction commonly encountered in Southern Africa include simply supported, continuous, and articulated spans as well as frames and filled spandrel arches. About 250 box girders are located on primary routes, a figure which is increasing annually by 8.0 per cent. Trusses and cable systems are rare.

Decking arrangements include solid slabs, voided slabs, and beam and slab systems. Orthotropic steel plates and battle decks seldom occur.

Whereas steel and timber are scarcely used, reinforced concrete, prestressed concrete and steel-concrete composite construction appear regularly.

Such a multiplicity of configurations and materials frustrate generalized methods of assessing the Superload capacity of bridges. Assessment techniques have to compromise between precise analyses of the majority of structural types, with a view to reducing the margin of safety, and approximate methods, entailing more conservative safety margins. The latter will temporarily suffice for the minority of bridges, such as frames and arches.

Load configuration

The practically endless number of combinations of axle loads and spacings encountered in Class A Superload vehicles again thwarts attempts to generalize.

Lateral distribution

The ability of a bridge deck to distribute loads across its width depends on the relative flexural and torsional stiffnesses in the longitudinal and transverse directions. The load position is also important and optimum distribution generally occurs when the load is symmetrical about the longitudinal center-line. However, as transverse systems are never infinitely stiff, longitudinal members located directly beneath the vehicle carry a greater proportion of the load than edge members. In this context, local bridge engineers follow European practice and analyse decks as integral units in preference to North American practice where distribution factors are used (11).

Assessment technique

The primary reason for analysing an existing structure under passage of a live load is to predict the maximum forces in its component parts and ascertain if such movement will be safe. Investigations of serviceability, fatigue life and deflections may be equally important. It is usual, but not necessarily reliable, to assume that the capacity of structural components reflects the information shown on completion drawings and contained in the original specification.

The assessment technique should enable highway authorities to process permit application rapidly. Besides being accurate, to allow use of reduced load factors, it should also be simple, economical, and sufficiently flexible to handle any practical load configuration. Some compromise is necessary to meet these differing requirements.

As it would be impractical to assess every bridge element, investigations are restricted to critical sections where the combined dead- and live-load forces tend to maximize. The strength over the remainder of the member should be consistent with that at the critical section. Theoretical strengths at critical sections are reduced proportionally where weaknesses are detected. The more important critical forces encountered in common structures are listed in Table 2(8).

Engineers recognise that bridges may be analysed by any of the following methods: plastic, nonlinear elastic and elastic.

Plastic analysis

Collapse methods based on Johansen's yield line theory depend on the load configuration, its position on the structure and the arrangement of reinforcement. Although computer programs have been developed to determine which of several possible collapse patterns is the most critical, this method is not ideally suited to routine assessments since a complete analysis must be performed for each load position.

Nonlinear elastic analysis

Although the true behavior of most bridge materials is nonlinear, an elasto-plastic method is not favored because of the lengthy analytical process. The technique is relatively new and a computer is essential. The load is applied incrementally beginning at the

Table 2. Critical forces associated with various materials and forms of bridge construction.

CONSTRUCTION	COMPONENT	MATERIAL	CRITICAL FORCES
Multiple beam and slab	Main beams	All	Midspan bending, support shear, reactions
		Reinforced concrete	Steel-concrete bond
		Prestressed concrete	Principal stresses
		Steel	Bearing stiffeners
		Composite	Interface shear
	Cross beams	All	Bending and possibly shear
	Deck slabs	All	Bending, shear, and punching shear
	Bearings	All	Crushing and longitudinal forces
Slab decks	Slab	All	Midspan bending as well as compound moments in skew decks
	Bearings		Uplift at corners of skew decks
Continuous	Main beams	All	Besides those listed above, hogging moments in spans straddled by bogies
	Bearings	All	Uplift at discontinuous ends

fully elastic condition. At each stage the tangent modulus is used to describe the behavior of individual elements. However, because this is only an approximation, the system must be equilibriated by a series of iterations each of which involves a complete elastic analysis. Despite the development of techniques for increasing the rate of convergence, the method remains excessively expensive for routine assessments.

Elastic analysis

Elastic methods may be efficiently employed to obtain information under service conditions. Stresses, cracking, deflections and fatigue life may be readily investigated and the capacity of a structure determined using established margins of strength. Since the law of superposition applies, influence coefficients may be employed with considerable advantage for routine assessments.

Influence coefficients

Influence coefficients describe the variation of structural actions, such as moment, shear, reaction, and deflection, at a particular point for unit load applied anywhere on a structure.

Influence lines

Coefficients are grouped together as influence lines in the case of one- or two-dimensional structures, such as beams or frames. Although engineers have long used these lines to investigate the behavior of bridges, they are unsuitable for accurate assessments because of assumptions regarding transverse distribution.

Influence surfaces

Influence surfaces relate to coefficients extending in two directions across an area, such as a flat plate or bridge deck. They may take the form of either contour diagrams or digital models. Whereas the former are suitable for manual usage, the latter are almost mandatory for computerized load simulations. They are able to handle endless variations in wheel load, inter-axle distance, transverse wheel spacing and vehicle path.

Mesh size

The selection of mesh* size and mesh points is important and a network comprising continuous straight lines with a variable inter-nodal distance is ideal. Nodes located on primary members are supplemented by intermediate points which are closely spaced in the vicinity of the critical point or center-of-interest but more widely spaced at locations remote from it. Although the original intention was to develop programs for generating influence surfaces for points located within the central loading strip, this has been rejected in favor of a more general approach which permits the evaluation of coefficients for centers-of-interest anywhere on the deck. Besides allowing for skew tracking the resulting programs provide a useful design aid.

* A grid or network of application points

The GSC system

Since 1945 the number and frequency of requests for Superload permits has increased steadily. Time limitations have forced engineers to use various shortcuts and approximations. Unfortunately, these methods are no longer satisfactory since, in the case of Class B Superloads, large numbers of axles are involved and more precise analyses are required to justify the use of higher working stresses. It is therefore necessary to adopt a method that will be consistent, accurate and rapid.

The computerized approach described below fulfils these requirements. It involves three basic steps: "Generate", "Simulate", and "Compare" (GSC). An intermediate "Synthesizer" is required between the last two where compound stresses are involved. The system was originally conceived by the Ministry of Roads and Road Traffic, Rhodesia, for investigating Class A Superloads. It is currently being improved and extended for general use in South Africa.

Generate

Initially, the characteristics of a given structure or series of identical structures are established by means of influence surfaces for moments, shears, reactions, and deflections at preselected critical points. Whereas influence lines will be temporarily used for arches, frames and related structures, influence surfaces will be used for slab and multibeam bridges. These data are generated by a suite of computer programs. It is also necessary at this stage to determine the dead-load forces, thermal effects, member strengths, load factors and permissible working stresses. This information need only be evaluated once for permanent storage within a computer installation.

It is anticipated that this aspect will be undertaken by consultants appointed by the provincial authorities and that the results will be stored in computers owned by the provinces for the subsequent processing of loads, using the programs described below.

Simulate

Movements of load trains are simulated to evaluate critical forces. Such simulations are ideally suited to digital computers.

Load train descriptions involve wheel loads, longitudinal axle spacing, and inter-wheel distances as well as the location of the travel path on a given structure. The simulation program seeks the worst sum of the products of wheel loads and coefficients at their point of application. A second order interpolation formula is used to evaluate coefficients at points located between influence surface or influence line nodes.

Optimization efficiency is frustrated by variations in the shapes of influence surfaces or lines as well as by the relative location and magnitude of wheel loads. In order to overcome this difficulty, the load train is advanced across the structure in suitably small increments. Studies have shown that the error involved in using point loads rather than patch (tire contact areas) loads is insignificant where large numbers of wheels are involved.

Compare

Following simulation, the dead-, thermal-, and live-load forces are multiplied by their respective load factors and the resulting stresses at critical points combined and compared with the allowable stresses. Comparisons with the ultimate moment are also used. The computer prints out a message stating whether the proposed movement is SAFE or UNSAFE along with the stress data upon which this conclusion is based.

Synthesize

In some instances, such as prestressed construction and slab decks, principal stresses and compound moments are required. When this is necessary the computer will complete the simulation process for each force involved and store the results for successive load positions. It will then return to combine these forces, and if necessary, determine their direction prior to evaluating stresses and establishing the optimum value.

Computer programs

Programs are being developed on an in-house CDC Cyber 174. They are written in standard FORTRAN and will eventually be tested on several leading computers.

The "simulate" programs have been completed. The "generate" programs listed below will produce influence surfaces for right angled and skew decks that may be either simply supported or continuous. Types of construction will include beam and slab, solid slab and some voided slabs. An influence line program capable of handling 11 spans of variable section has also been prepared.

1. Grillage beam elements for beam and slab decks.
2. Variable mesh finite differences for either isotropic slabs or "substitute" orthotropic slabs.
3. Quadrilateral plate, membrane and beam elements for beam and slab decks.
4. Hybrid stress plate, membrane and beam elements for beam and slab decks.
5. Hybrid stress plate elements for either isotropic slabs or "substitute" orthotropic slabs.

The apparent duplication is deliberate and is intended to enable users to verify results using another method prior to placing them in permanent storage. The quadrilateral plate in the third program uses a previously developed SAP element (12) which, although generally satisfactory, yields neither shear forces in the plates nor an influence coefficient at the center-of-interest should this lie within the plate. This version will therefore be superseded by the hybrid stress plate and membrane elements (13) mentioned in the fourth program. However, the matrix solution subroutine, USOL (12), has been retained in all the finite element programs. Eventually the finite element programs will be extended to evaluate thermal effects.

The time required to generate influence surfaces has been greatly reduced through use of the Muller-Breslau principle reported by Newmark (14). Descriptions of this technique and the method of handling non-prismatic sections have been given elsewhere (15,16). Running times are very short. For example, it cost about $6.00 to generate five deflection influence surfaces for a simply supported span with eight main beams which reduced to 99 nodes having 114 beam elements and 80 plate elements. The simulation of a 21-axle Class A Superload across these five surfaces cost only 55 cents on the CDC Cyber 174.

Inspection and monitoring of bridges

Inspection prior to load movements

Before a route can be designated as suitable for Superloads, each structure on it is subjected to a detailed visual inspection. Any factor which may affect the structural performance of a bridge is noted, particular attention being paid to such aspects as deterioration of concrete, rusting of reinforcement, cracking of concrete in both super- and sub-structures and settlement or deterioration of bearings.

Evidently, such inspections must go hand in hand with the structural analysis carried out for each bridge to assess its ability to carry the required loads, and it is vital that the present condition of the structure is reflected in the data used in the analysis. For example, if extensive cracking is observed in a reinforced concrete cross-beam, the transverse stiffness of the deck will be adversely affected, and the analysis must be adjusted accordingly. Again, especially with multi-span, continuous structures, the effect of any settlement of the bearings must be taken into account.

This stage of inspection and structural checking is carried out some months before a route is scheduled to carry Superloads, in order to allow time for any remedial or strengthening work which may be necessary.

Strengthening methods are dictated by the structural configuration, material, location and ground-soffit clearance. Methods used in South Africa have included the reinforcement of longitudinal members by coverplating or prestress, increasing the prestress of transverse members and propping from the ground. This last method is generally considered undesirable. Other methods which have received consideration include the insertion of additional longitudinal or transverse beams, the provision of outrider beams or trusses, and the use of towers and stayed cables.

Inspection and monitoring during load movements

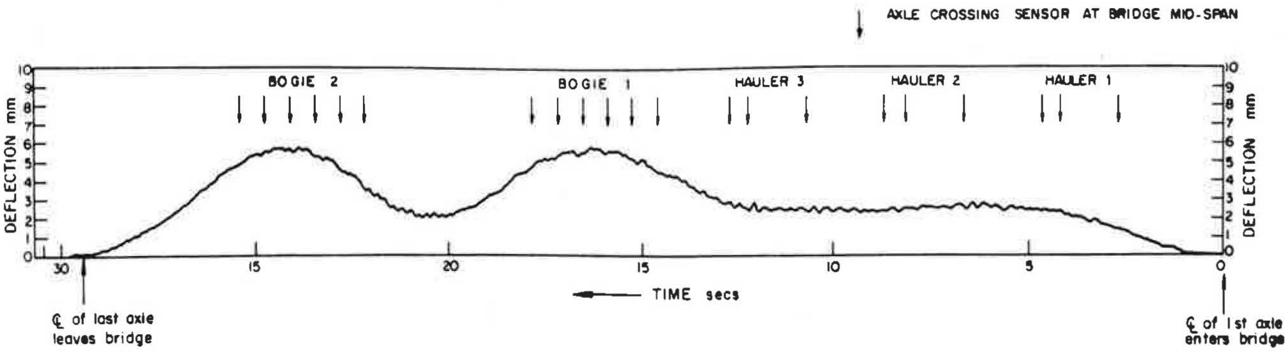
The frequency of inspection of the structures on a Superload route over the period of use of the route is greater than that applicable to bridges which have only to carry normal traffic. In addition, the performance of selected bridges during the passage of certain loads is monitored in some detail. Such monitoring is conducted for two reasons. Firstly, the performance of suspect bridges on a route is observed, in order to obtain advance warning of any deterioration or damage caused by the loads, and to generally confirm any assumptions which may have been made in the structural checks. Observations consist primarily of recording maximum vertical deflections in decks, and monitoring the width of cracks in concrete members, together with the development of cracks under load.

Secondly, the National Institute for Transport and Road Research is making use of Superload movements over bridges to further its research in the field of bridge deck analysis. A number of structurally sound bridges have been selected for observation along the Superloads route from Richards Bay to Trichardt*. The observations are at present restricted to monitoring the vertical deflection of the decks, at a number of positions, during the passage of a load. The results will be of use in checking deck analysis programs currently being developed and generally in establishing criteria regarding the behavior of such structures under loads of this magnitude.

An apparatus has been developed specifically for these observations which produces a continuous trace of the deflection at any number of chosen points on

*The following consulting engineers have been appointed to check the safety of structures along this route:
Drennan, Maud and Partners; D.L. Webb and Associates; Van Niekerk, Kleyn and Edwards.

Figure 4. Deflection trace from Bridge 2783.



the soffit of the deck, as the load crosses the bridge (17). The deflection is measured by recording the movement of a weight suspended, at ground level, by a wire attached to the deck at the required point. The weight forms part of a mechanism, termed a deflectometer, in which its vertical movement is detected by an LVDT and recorded on a UV recorder. The number of LVDT channels, and hence measurement points, is at present limited to ten. A switch sensor, placed on the deck surface near mid-span, registers a mark on the UV recorder trace as each axle in the load train passes over it.

Despite, or perhaps because of, its simplicity, this system has performed well in the field, producing accurate traces of deflection at relatively low capital and running cost. Traces obtained during tests conducted on two bridges are shown in Figures 4 and 5. Figure 4 shows the mid-span deflection (at the bridge centerline) of a prestressed concrete deck of 21 m (67 ft) span. The total mass of the payload and transporter (excluding haulers) was 174,000 kg (192 tons). In the test shown in Figure 5 the deflection was monitored at five points on the deck. The bridge consisted of a prestressed concrete deck, of 31 m (100 ft) span, and the total mass of the payload and transporter (excluding haulers) was 190,000 kg (210 tons).

So far, the level of agreement between the observed deflections and those predicted by the analysis programs being developed has been encouraging. It is considered that, in the future, monitoring the performance of bridge decks by such methods will play an important part in the assessment of these structures for carrying Superloads.

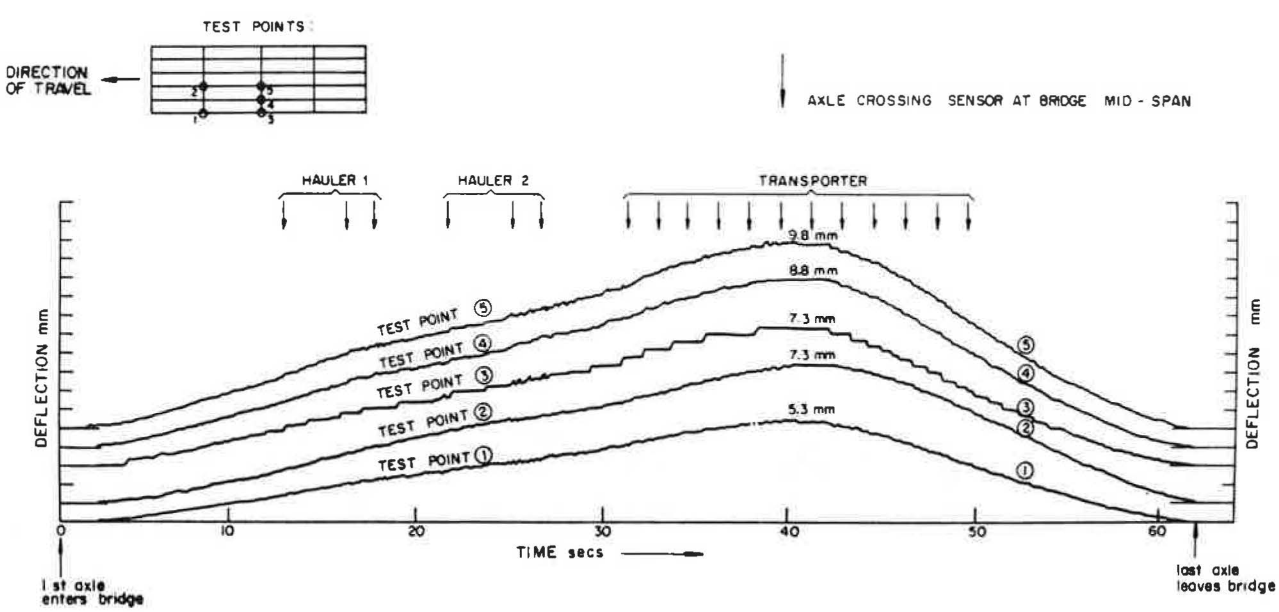
Summary

Following recognition of the fact that the movement of essential Superloads is necessary for the industrial development of South Africa, national policy has been directed towards the development of systems and techniques required to assess the effects of these loads.

This policy includes the coordination of interprovincial routes, the development of design load specifications for future bridges, load classification, analytical techniques, and methods of inspecting structures and monitoring their behavior during the passage of Superloads.

Attempts to produce generalized methods of assessing the strength of various bridges are frustrated by the multiplicity of materials, decking systems, and architectural styles as well as a variety of axle and wheel load configurations.

Figure 5. Deflection trace from Bridge 1168.



Since structures cannot be completely analysed for every heavy vehicle movement, critical points are selected where forces tend to maximize. The computerized GSC system, which assumes elastic behavior, is being extended to process the large number of Superload movements rapidly, consistently and accurately.

Bridge characteristics, in the form of influence coefficients, sectional properties, load factors, and permissible working stresses, are evaluated once and permanently stored within a computer system. Subsequent load simulations and stress comparisons may then be undertaken quickly and at short notice. This system should enable 80 per cent of the structures located on primary rural routes to be readily investigated.

Importance is attached to the inspection of structures before, during and after the movement of the heavier Superloads. This aspect includes the preparation of an inspection manual and the development of simple equipment for monitoring the deflections of structures during transient loads. Observed deflections are used to check analytical assumptions and verify the GSC system. The results to date show satisfactory agreement.

Acknowledgements

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