THE NEW MEXICO BRIDGE INSPECTION PROGRAM

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The New Mexico bridge inspection program is reviewed for its uniqueness as well as the use of the resulting data. Annual training sessions and field work with college professors has kept the program viable and continuing. Close cooperation with the Civil Engineering Department, New Mexico State University, has led to utilization of bridge capacity data developed within the program into a statewide overload routing and permit system. The system takes an overload wheel configuration and load distribution and computes an equivalent HS loading which is compared to the capacity of each bridge along a given route.

Congress in the 1968 Federal Highway Act called for national bridge inspections. National standards based generally upon the contents of the "Manual of Maintenance Inspection of Bridges 1970" (2) were issued in 1971 (1).

This paper describes how New Mexico not only established a viable bridge inspection program meeting all Federal requirements but utilizes the accumulated data in routine checks resulting from requests for permits for overweight vehicles. New Mexico has 3,000 bridges on the federal-aid highway system, with about 2,000 over geographical barriers and the remainder being over highways and railroads. All of these bridges had received their initial inspection and inventory by July of 1973.

History of the Inspection Program

The New Mexico State Highway Department initially established its bridge inspection program in November 1970. Bridge inspection crews were selected in each of the five districts. The Assistant District Highway Engineer of Maintenance, under the general direction of the District Engineer, was placed in direct charge of the district bridge inspection crews and made responsible for the prompt and proper reporting of information gathered. The District Bridge Inspection Crews were directed to make the required inspections and to place the information in reports so that it could be checked and forwarded to the general office. Consultation and general guidance was available to the districts on all technical data regarding the inspections from the Bridge Maintenance Engineer and the Bridge Engineer in the general office.

It was realized early that such a bridge inspection program would be only as good as its field inspectors - i.e. the District Bridge Inspection Crew. Although it would have been desirable to place an experienced professional engineer in each field crew and staff the crews with experienced bridge inspectors, this was not possible. However, a registered engineer was placed in charge of each crew.

In order to have trained, qualified inspectors for the program, the New Mexico State Highway Department in conjunction with the Federal Highway Administration, conducted a three week training program in January 1971. In the program the need for the importance of bridge inspection was emphasized along with inspection techniques and proper use of newly printed forms. It was decided that as much of the capacity ratings and computer coding as possible would be done at the district level. Since most bridges in New Mexico are of relatively simple design, much of the load computation could be accomplished at the district level with guidelines furnished from the general office.

A booklet, "New Mexico Bridge Inspection and Evaluation Guide," (3) was published by the Maintenance Division which covered all aspects of the Program. This booklet plus the AASHO "Manual for Maintenance Inspection of Bridges, 1970" and the FHWA "Bridge Inspectors Training Manual, 1970" (4) provided written guidance for the inspection teams. Guidance for coding data was provided by "Bridge Maintenance Inventory System" (5) published by the Engineering Computer Unit of the general office.

Implementation of Present Program

Due to the turnover of personnel and the introduction of new techniques and requirements, plus a better understanding of the scope of the project, additional training at periodic intervals was considered necessary. A staff member of the Civil Engineering Department of New Mexico State University was employed at the time with the New Mexico State Highway Department. Upon discussion of the problem, it was felt that the Department of Civil Engineering, with assistance from the experienced general office state highway department personnel, was well qualified to do the additional training. The University had the necessary facilities in terms of classrooms, training aids, and laboratory space for the efficient and economical instruction of bridge inspectors. The faculty was uniquely qualified to instruct the trainees because they were experienced professional engineers as well as professionals in the instruction of students.

In January 1972 a bridge inspection short course was initiated at New Mexico State University sponsored jointly by NMSU and the New Mexico State Highway Department. Instructors included staff members from both NMSU and NMSHD. The Federal Highway Administration also furnished assistance. Participants in the course included the highway department bridge crews, the assistant district engineers of maintenance, representatives from the general office and, as guests of the highway department, several members of the Bureau of Indian Affairs. In all, thirty-two people attended the two week course and received certificates of completion of the course. The course was based on the "Training Manual for Bridge Inspectors, 1970;" however, only sections pertinent to New Mexico were covered.

The first week curriculum was primarily basic mechanics such as strength of materials and statics, nomenclature, and laboratory demonstrations. Laboratory demonstrations included the destructive testing of materials and some structural elements. Also included were demonstrations of the proper use of equipment such as torque wrenches and the corrosion detector.

The second week leaned more toward application of techniques which included the proper description of bridges and defects. Field trips were conducted to various types of bridges common to New Mexico. The local bridges had sufficient defects to promote many lively discussions about how to best describe and assign a rating. The question of load reduction and posting was also extensively discussed. A complete inspection was conducted of a bridge with known defects. Color slides of the bridges and defects were available for the post field trip discussions. In all, much information was gained and exchanged during and after the trips--thus complementing the classroom instruction.

Although the school was well received, it was apparent that much improvement could be accomplished in several areas for future short courses. Areas of improvement included the following. First, additional visual aids could be related directly to New Mexico's needs. For instance, the attention of the trainees could have been greater with discussion of a particular structure native to New Mexico. Secondly, the instructors felt a need to be better acquainted with the New Mexico inspection techniques and problems. These improvements could be accomplished only by working closely with the inspection teams in the field and with the general office in Santa Fe.

Consequently, an annual training school for bridge inspectors was proposed with the recommendation that two instructors from the university work with the Highway Department and its inspectors for the summer. The Highway Department and the University agreed on an annual program plus a summer background study for the program. The background study called for a research team consisting of two staff members of NMSU to spend seven weeks in the field with the inspectors, one week in the general office and two weeks for course preparation.

The research team divided the seven week period with the various NMSHD districts. During this time various phases of the program were reviewed with the bridge inspection crews. Filing systems and data storage techniques were checked. Field inspections with crews were undertaken. Field reports were taken, placed into final form, and coded for the data bank at the general office. Special inspection equipment such as the snooper, torque wrench, and corrosion detector were utilized during the inspections.

Many color slides for later use in the short course were taken. These pictures included all phases of inspection including proper use of safety cones, utilization of flagmen, and proper use of equipment. All types of bridges were photographed including many unique and unusual bridges. Close up, detailed photographs were made of both the usual and the unusual defects. Common type of defects included salt deterioration of concrete, hazardous approaches, outdated bridge railing and inadequate deck geometry.

A general survey of "interesting" bridges gave the research inspectors much insight into the problems of a bridge and how to inspect it. A rapport was established with all of the inspection crews which helped immeasurably in training and updating.

Particular subjects and ideas suggested by the inspectors were put into the course. A more detailed explanation of the appraisal and condition rating evaluation was requested. Careful review was necessary to establish exactly what was meant by such things as minimum tolerable condition or present minimum criteria. How to incorporate certain defects into capacity ratings was a common question. In New Mexico capacity ratings were initially computed by the actual inspector, if at all possible, and reviewed by the district office and the general office.

A week in the general office was of great benefit to the NMSU group. Coordination in establishing guidelines with the FHWA was discussed. Much of the criteria for ratings was clarified. Coordination with other sections, particularly the roles of the bridge design and engineering computer section were discussed and evaluated.

An overall understanding was developed by the NMSU team in how bridge inspection data was collected, where it went and for what purpose. The fact that actual field operation is only an initial step in bridge inspection was made evident. Reports, computer code forms, filing and capacity ratings take an appreciable amount of time and effort. This understanding helped immensely with course preparation and evaluation for the annual training program.

New Mexico now has a viable and continuing program for bridge inspection. The inventory has been completed for several years and a process has been established for reinspection of bridges as required. Also, a continuing training program for inspectors has been established.

Uniqueness of the New Mexico Program

The fact that NMSHD and NMSU have put together a cooperative annual training program is probably not unique. However, the manner in which the course directors from the university involved themselves with the program probably is unique. These professors not only worked with the field inspectors in establishing a training program, but have continued to assist in various ways. The Rio Grande Gorge bridge, a 366m (1200 ft) deck truss with a 183m (600 ft) main span and 200m (650 ft) clearance, has been inspected three times since the New Mexico bridge inspection program began. Each time the NMSU professors were two of the members of the inspection crew. Techniques and procedures were developed which were unique to this size and type structure. A similar case involves the 122m (400 ft) steel arch at Los Alamos. In both situations the college professors worked hand in hand with the field crews providing training and experience for both groups. A continuing rapport has been established.

These professors have also worked in the NMSHD bridge design section in evaluating capacities of existing bridges. This opportunity gave not only insight to evaluating defects as reported from the field but also a working knowledge of establishing inventory and operating capacity ratings.

This unusual position of the engineering professors of not only observing but also participating in inspection, capacity evaluation, and data recording has yielded some unique benefits to the NMSHD. Among these benefits was the coupling of the data on bridge capacities from the inspection to the reoccurring problem of overweight or "permit" vehicles. This coupling which is discussed in some detail below has made the New Mexico bridge inspection program unique. In addition this data base provided by the bridge inspection program is utilized to establish posted capacity limits. Height and width restrictions are also evaluated along any particular route with this data.

Coupling Bridge Inspection and Overload Permits

In New Mexico a permit is necessary if, among other criteria such as length and width, the gross weight of any vehicle exceeds 384kN (86,400 lbs). Any truck requiring a permit because of gross weight is referred to the New Mexico State Highway Department for evaluation of the effects on the highway and bridge structures. Permits for overweight vehicles have been requested for vehicles with gross weights over 3.56MN (800,000 lbs). Unexpected requests to check the adequacy of structures for a particular route for an overweight truck with odd axle spacing were becoming more and more numerous. Previously these requests required engineers to be removed from their normal duties to pinpoint potential problem bridges and reanalyze them for the particular overload vehicle. The procedure was not only time consuming with valuable engineering man hours, but the potential for serious error existed.

First, it was possible that a potentially dangerous structure could be overlooked. Second, there was a chance for error in a rush analysis. Also, the data available in the bridge section did not always reflect the current condition of a bridge. The problem seemed to be becoming worse as more heavy industry was being located in areas where no railhead existed.

To alleviate the problem the New Mexico State Highway Department considered a more automated method of operation. Two facts stood out. First, a computerized technique of locating bridges along a proposed route as well as performing a structural analysis of the bridges would certainly speed up the operation and allow the bridge engineer to make a decision on each new overload configuration. Second, the latest information concerning any modifications and structural conditions of all bridges within the State was already available through the bridge maintenance inspection program.

The inventory and operating ratings, as well as other pertinent data such as bridge type and location, were stored on magnetic tape (4). Since the Civil Engineering Department, New Mexico State University, had helped in creating the data by assisting in the training of the inspectors and in some cases actually inspecting bridges and calculating the load ratings, they were not only aware of the data tapes but also the quantity and quality of the data. Computer programs to check capacities of bridges had been proposed by consultants and agencies but no one before had proposed utilizing directly the data accumulated by the bridge maintenance program.

In a cooperative agreement the Civil Engineering Department, New Mexico State University, was charged with developing a computer system that would meet the criteria of the NMSHD to streamline the operation and use the bridge maintenance inspection information already collected and stored on magnetic tapes. This data bank included the results of a complete analysis of every bridge in New Mexico. The load capacity rating was recorded as a HS loading for both the inventory and operating rating.

A new analysis of each structure along each route was rejected as impractical. First, too much input data for each structure would be required to perform such an analysis. Second, this detailed structural data was not available from the bridge inspection inventory system. Also, large quantities of computer time would be required to check out a proposed route, and finally, a detailed analysis would be repetitious. Each bridge was already analyzed and given a safe load capacity rating as a part of the bridge inspection program and this rating was stored as a part of the bridge inspection inventory data. With this in mind, the following approach was used to develop ØVLØAD, a computer program to automatically check bridge structure capacity with a given overweight vehicle.

Method of Equivalent Loading

For several years the New Mexico State Highway Department has been determining the overload capacity of bridges by comparing the moments used by the overloading vehicle to the designed moments produced by the standard AASHTO truck. Therefore, the operating capacity of bridges was designated the standard HS truck configuration which produced the over-stresses permitted in the Manual for Maintenance Inspection of Bridges published by the American Association of State Highway Officials. (2)

Within ØVLØAD a method of equivalent loads is established which simulates the actual overload truck passing over each and every bridge on the proposed route. The overload truck is converted into an equivalent HS truck for each particular bridge based on maximum bending moments or other criteria. This equivalent HS truck is then compared with either the operating rating or inventory rating as stored within the computer. Any time the equivalent HS load exceeds the stored value, the computer program automatically prints out the bridge number, location, equivalent load capacity required, and the rated safe load capacity. This printout is available for evaluation by the bridge engineer. The engineer may, at his option, prohibit the overload, reroute the overload, or do a more detailed analysis of the particular bridge or bridges.

Description of Program

The program, ØVLØAD, consists of the main program and three subroutines. The main program receives input data, reads stored data on bridges, determines whether or not a bridge is on the requested route, makes a comparison between safe load capacity and the required capacity, and prints information on inadequate bridges. The subroutines compute the required capacity for a given overload vehicle on each particular bridge. A simplified flow chart of the program is shown in Figure 1.

The process is initiated by the input of the route numbers and Department of Defense, DOD, section numbers over which the proposed overloaded truck is to take. The axle spacings and axle loads of the truck are inputted for use in the computation of an equivalent HS truck. Finally, whether the comparison will be with inventory rating or operating rating is entered.

All bridge data are stored in numerical order by bridge number on a magnetic tape or disk. All data for a particular bridge are read and evaluated and any bridges not on the route are rejected before any equivalent load computations are made. If the bridge is on the desired route and within the desired DOD sections, the structure is classified into one of four types and an equivalent loading determined.

The structures in New Mexico can be divided into four general categories: Simple span bridges, continuous span bridges, truss type bridges, and concrete box culverts. Although other types of bridges exist, such as rigid frame structures, each can be classified into one of the above categories for determination of the equivalent HS truck rating of an overweight vehicle.

For structures classified as simple span bridges, the subroutine SIMSP is called. The SIMSP subroutine utilizes the span lengths of the bridge to be checked and the axle spacing and axle loads of the overloaded vehicle. The first axle of the vehicle is placed at mid span of the first span and the criticial bending moments are determined by a standard matrix method of structural analysis. This moment is retained for later comparison. The next axle is moved to mid span and a new bending moment is calculated. The bending moment is compared to the previous bending moment and the larger value is retained. This procedure is continued until bending moments for all positions of the vehicle have been compared. The bending moments produced by a standard HS 20 truck is computed in a similar manner for the same span. An equivalent HS rating is assigned to the overloaded truck by the ratio of bending moments produced by the two trucks times twenty. This equivalent HS value is stored for later comparison. The overloaded vehicle is then moved to the next span. The entire procedure is repeated for this span. The new equivalent HS rating is compared to the old rating and the larger value retained. This procedure is continued until all spans have been checked. The largest equivalent HS rating is then returned to the main program for comparison with either the operating or inventory rating as requested.

For structures classified as continuous span bridges, the subroutine CØNTU is called. The CØNTU subroutine has a general procedure similar to that of SIMSP. The computation of bending moments by matrix methods is made on the basis of a continuous prismatic structure with actual span lengths. Both positive and negative bending moments are determined. The maximum values for each span is saved and the equivalent HS ratings are returned to the main program.

Structures classified as trusses are subjected to the computations of the subroutine TRBM. The subroutine TRBM proceeds in a manner similar to SIMSP except that three equivalent HS ratings are computed. These three equivalent HS ratings are necessary because the data bank does not indicate in what manner an excess load would cause the truss to fail. The overload vehicle is moved across the truss and the maximum equivalent HS ratings are computed based on stringer moments, floor beam reactions, and span length moments. All three HS ratings are returned to the main program and if any exceed the safe capacity, the bridge is considered inadequate.

Once a structure has been classified and the equivalent HS rating has been assigned for the overload vehicle by one of the three subroutines, the equivalent HS rating is compared to the safe loading capacity that has been previously determined for that structure by a complete analysis. If the equivalent HS rating is less than the safe load capacity assigned the bridge, the program goes to the next bridge. If the equivalent HS rating is greater than the stored operating capacity, the bridge is considered inadequate and pertinent information about the bridge is printed. The information gives the user a quick identification of the critical bridges, possible need for reanalysis or whether detours might be necessary and available. This procedure is repeated until every bridge on the designated route has been checked and every inadequate bridge listed.

Output Information

Figure 2 is a typical output which lists all inadequate bridges on the route. Each bridge number, route, and DOD section is listed. This information is followed by the type of bridge, a description of the location of the bridge, the critical span length, the equivalent HS load capacity required and the rated HS load capacity. The equivalent load is divided by the rated operating load to give a ratio to assist in evaluating the bridge. Trusses have three equivalent HS truck printouts. The first indicates an equivalent truck based on floorbeam reaction loadings, the second indicates the stringer moments and the third indicates an equivalent truck based on overall moment.

This output pinpoints all potentially critical bridges and prints a comparison of the capacity based on allowable criteria set by AASHTO (4) as analyzed in the bridge inspection program and the equivalent capacity computed by the program. These critical bridges, capacities, and required equivalent capacities are reviewed by an engineer before any decision is made on the issuance of a permit.

In some cases a requirement for adjustment of axles or axle spacing, restrictions on speed, or re-evaluation of bridge capacity is all that is required to approve a permit. In other cases the vehicle may not be allowed to use one or more structures and the construction of a detour may be necessary. In all cases the engineer has the confidence that all bridges on a route have been considered and critical bridges with essential data have been referred to him.

Present Operation

The program ØVLØAD has the capability to pick out all bridges which do not meet the equivalent load criteria along a proposed route and print the pertinent data within minutes. In New Mexico an engineering technician inputs the necessary information via a remote terminal and the results are available within minutes. If the proposed route is inadequate, an engineer can either choose an alternate route which can be checked by the same system

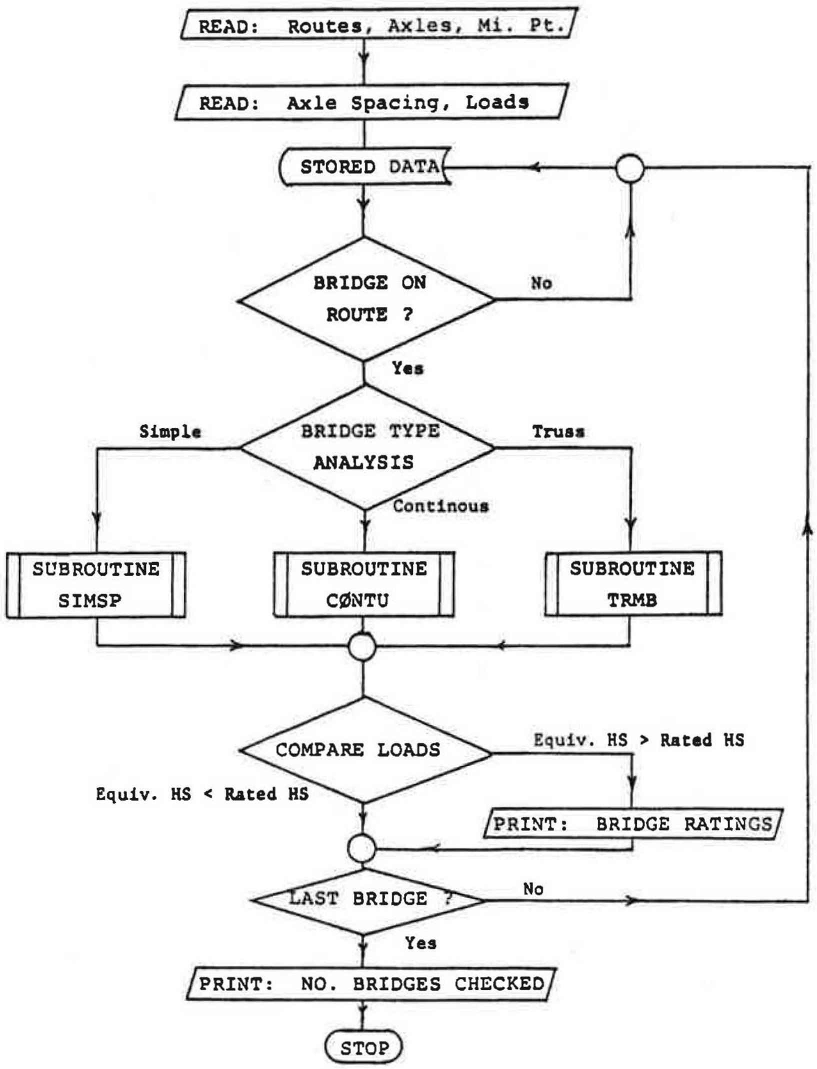

Figure 1. MAIN PROGRAM ØVLØAD

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OUTPUT DATA

THE BRIDGE OVERLOAD PROGRAM DEVELOPED BY
WHITE-MINOR, NMSU 1973-74 AND SPONSORED BY THE NEW MEXICO STATE
HIGHWAY DEPT. LATEST UPDATE AUGUST, 1977.
ROUTE DIRECTION CODE EXPLAINED IN NMSHD BRIDGE INSPECTION MANUAL, ARTICLE 14.10.8
NOTE:  THE FOLLOWING IS COMPARED WITH OPERATING RATING

BRIDGE NO.1744 ROUTE NO. 44 DOD SECT NO. 430 ROUTE DIRECTION 1
DOD MILEPOINT IS 21.15
TIMBER SIMPLE SPAN BRIDGE
21.1NM W OF JCT SR126&44
SPAN LENGTHS   25.00
EQ HS =102.0 RATED HS = 19.0 RATIO =5.4

BRIDGE NO. 1780 ROUTE NO. 44 DOD SECT NO. 425 ROUTE DIRECTION 1
DOD MILEPOINT IS .23
STEEL CONTINUOUS BRIDGE
STRINGER TYPE
0.4ME OF US 85, BERNALILLO
SPAN LENGTHS 28.00   42.00   28.00
POS HS = 99.5 RATED HS = 30.0 RATIO = 3.3

BRIDGE NO. 3107 ROUTE NO. 44 DOD SECT NO. 425 ROUTE DIRECTION 0
DOD MILEPOINT IS 18.10
17.7 M NW JCT I-25 & SR 44
SPAN LENGTHS      10.00
CONCRETE BOX CULVERT RATED CAPACITY = 23.0

BRIDGE NO. 6946 ROUTE NO. 44 DOD SECTION NO. 425 ROUTE DIRECTION 1
DOD MILEPOINT IS 9.08
PRESTRESSED CONCRETE SIMPLE SPAN BRIDGE
8.7 M NWEST JCT I-25 & SR 44
SPAN LENGTHS    51.00
EQU HS = 101.8 RATED HS = 45.0 RATIO = 2.3

BRIDGE NO. 1521 ROUTE NO. 90 DOD SECT NO. 999 ROUTE DIRECTION 1
DOD MILEPOINT IS 0
92.3 MI NE OF US70/SR90
TRUSS LENGTH = 100.00 SPAN LENGTHS = 17.00
EQ DECK HS = 31.3 EQ FLBM HS = 32.2 EQ TRUSS HS = 38.5 RATED HS = 22.0
RATIO-1 = 1.4 RATIO-2 = 1.5 RATIO-3 = 1.7

57 BRIDGES HAVE BEEN CHECKED
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Figure 2. SAMPLE OUTPUT FROM ØVLØAD

or take a detailed look at the inadequate structures.

Although the analytical procedures used are relatively simple and contain approximations such as assuming prismatic members and no lateral distribution of load, these simplifications and assumptions were essential to the successful mating of ØVLØAD to the bridge inspection program data. This was accomplished only through thorough understanding of the field operation, data collection, safe load rating techniques, and data record keeping of the bridge inspection program.

Many requests each week for permits based on weight are received by the New Mexico State Highway Department. All such requests are evaluated with the system. The majority of the requests are evaluated with the system. The majority of the requests indicate no inadequate bridges along their proposed route. Only those overloads indicating inadequate bridges are referred to engineers for further evaluation. The system has reduced engineering manpower requirements for checking structures for an overweight vehicle permit, yet has reduced the potential for error without sacrificing engineering evaluation.

A similar computer program has simplified the posting of inadequate bridges. The specified legal loads are passed over all bridges within the state via the computer and compared with the inventory capacity. Those bridges where the equivalent legal load exceeds the inventory rating were posted at the inventory capacity. The system also provides a quick method for listing posted bridges.

Conclusions

The New Mexico State Highway Department has a viable and continuing program for bridge inspection. This program was developed in close cooperation with New Mexico State University. Data developed within the program is utilized on a continuing basis in a statewide overload routing and permit system as well as in other routing operations.

References

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